БЪЛГАРСКА АКАДЕМИЯ НА НАУКИТЕ ИНСТИТУТ ПО ЕЛЕКТРОНИКА “АКАДЕМИК ЕМИЛ ДЖАКОВ”

BULGARIAN ACADEMY OF SCIENCES INSTITUTE OF ELECTRONICS “ACADEMICIAN EMIL DJAKOV”

SIXTEENTH INTERNATIONAL SCHOOL ON QUANTUM ELECTRONICS

“LASER PHYSICS AND APPLICATIONS”

20-24 September, 2010, Nessebar, Bulgaria

BOOK OF ABSTRACTS

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SCHOOL TOPICS

A. Laser - matter interactions
B. Laser spectroscopy and metrology
C. Laser remote sensing and ecology
D. Lasers in biology and medicine
E. Laser systems and nonlinear optics

The organizers are very pleased to acknowledge the co-operating organizations for their support of the school organization.
Special acknowledgments we address also to the industrial partners for their participation in the scientific exhibition.

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SCIENTIFIC EXHIBITION

INDUSTRIAL PRESENTATIONS

IP1

INTEGRATED SOLUTIONS FOR STATE-OF-THE-ART BIOMEDICAL IMAGING: FROM OCT TO ADAPTIVE OPTICS

Julien Vigroux

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e-mail: jvigroux@thorlabs.com

For several years now, Thorlabs has gone beyond its role as a supplier in traditional photonics equipment and started developing both, integrated solutions and single components ranging from industrial to biomedical research applications. A particularly strong emphasis has been put on state-of-the-art imaging techniques like optical coherence tomography (OCT), confocal microscopy, or adaptive optics based methods. The ongoing collaborations with world leading laboratories has led to numerous new product developments, e.g. in the fields of developmental biology, vascular imaging, or ophthalmology, just to name a few.

A brief overview on the Thorlabs portfolio with a focus on those imaging techniques will be given. Some of the key experimental challenges will be discussed from the viewpoint of an equipment manufacturer, and the solutions offered by Thorlabs will be presented together with some of the experimental achievements they enabled.

IP2

LASERS FOR SCIENTIFIC CHALLENGES

Jan Schaefer

TOPTICA Photonics AG, Lochhamer Schlag 1, 82166 Graefelfing (Munich), Germany
e-mail: jan.schaefer@toptica.com

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The talk gives an overview over TOPTICA's research grade diode laser systems emphasizing how TOPTICA's "pro" technology leads to outstanding performance, stability and ease of use. Examples of standard and customized TOPTICA solutions are given for various cold atom and trapped ion experiments. Many such lasers are successfully used in laboratories worldwide.

IP3

SPECTRAL METHODS FOR ANALYSIS OF BIOLOGICAL SAMPLES

Nikolay Georgiev

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IP4

NEW DPSS INDUSTRIAL AND SCIENTIFIC LASERS

Plamen Yankov

Coherent - Bulgaria,"Nadejda" bl.636 B, 1231 Sofia, Bulgaria
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The presentation covers the new high power visible and UV DPSS lasers. The new approach is towards higher reliability and performance of the laser with extended warranty and life time. Several new features for "hands free" operation are shown.

SCIENTIFIC EXHIBITION

PRODUCTS PRESENTATIONS

PRODUCTS PRESENTATIONS

PP1

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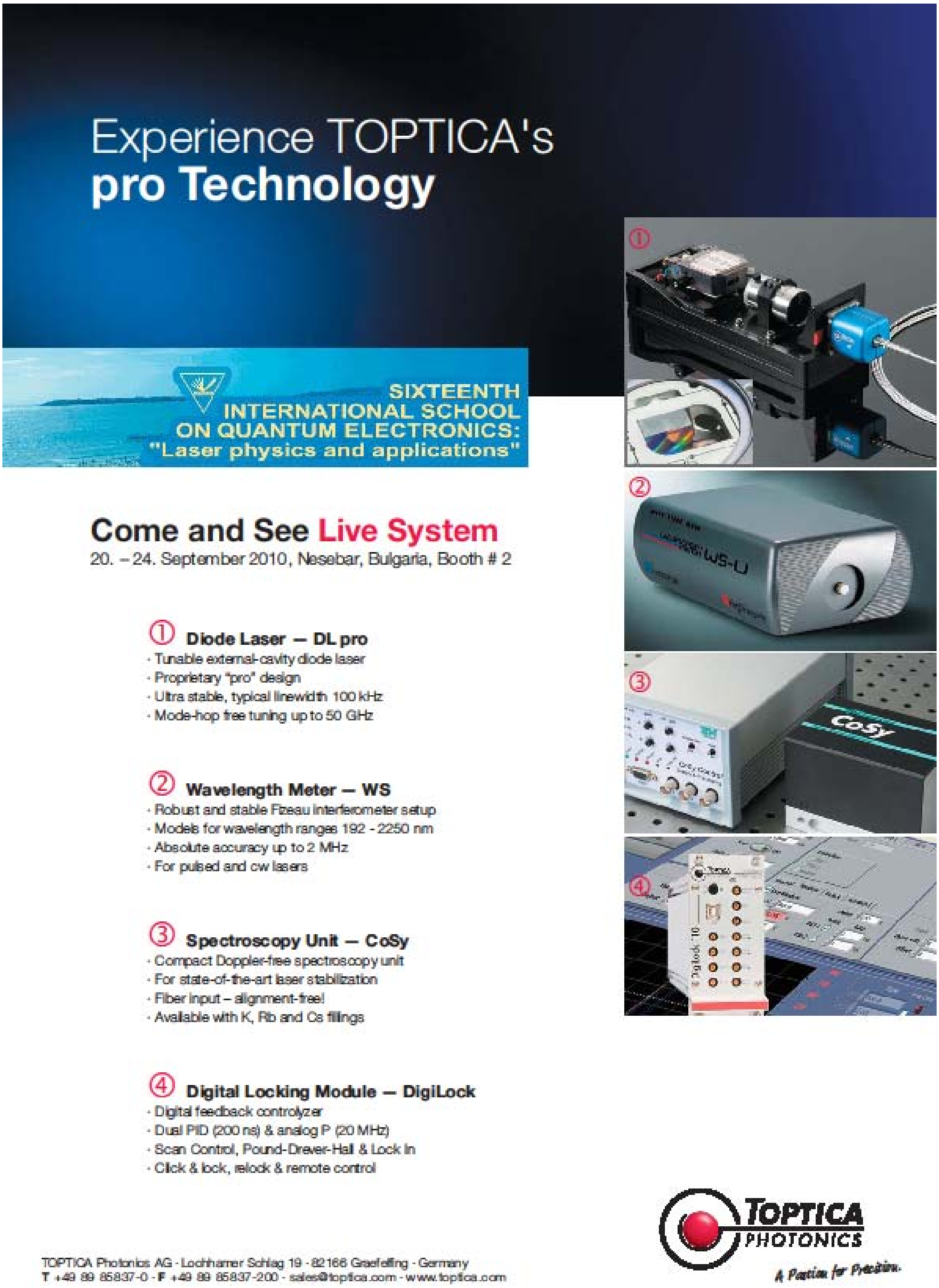
PP2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PRODUCTS PRESENTATIONS

PP3

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PP4

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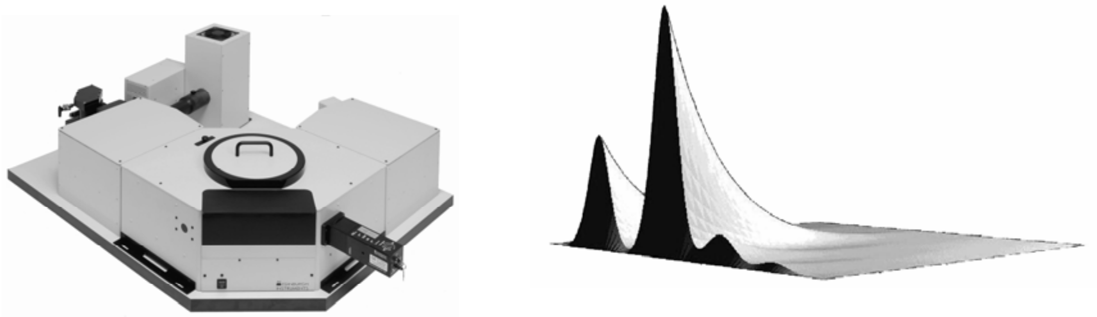

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PLENARY SESSION

INVITED LECTURES

LASER REMOTE SENSING AND ECOLOGY

L1

RAMAN-SHIFTED EYE-SAFE AEROSOL LIDAR (REAL)

Shane Mayor

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This seminar will describe the critical hardware requirements of the Raman-shifted Eye-safe Aerosol Lidar (REAL, http://www.phys.csuchico.edu/lidar/) and recent advances in extracting two-component wind vector fields from the images it produces.

The REAL [1, 2] is an eye-safe, ground-based, scanning, elastic aerosol backscatter lidar operating at 1.54 microns wavelength. Operation at this wavelength offers several advantages compared to other laser wavelengths including: (1) maximum eye-safety, (2) invisible beam, (3) superior performance photodetectors compared with those used at longer wavelengths, (4) low atmospheric molecular scattering when compared with operation at shorter wavelengths, (5) good aerosol backscattering, (6) atmospheric transparency, and (7) availability of optical and photonic components used in the modern telecommunations industry. A key issue for creating a high-performance direct-detection lidar at 1.5 microns is the use of InGaAs avalanche photodetectors that have active areas of at most 200 microns in diameter. The small active area imposes a maximum limitation on the lidar receiver's field-of-view (about 0.54 mrad for REAL). As a result, a key requirement is creating a transmitter subsystem that can produce a pulsed ($\geq$ 10 Hz) beam with low divergence ($\leq$ 0.25 mrad full-angle), high pulse-energy ($\geq$ 150 mJ), and short pulse-duration ($\leq$ 10 ns). The REAL achieves this by use of a commercially-available flashlamp-pumped Nd:YAG laser and a custom high-pressure methane gas cell for wavelength shifting via stimulated Raman scattering. Optical engineering details of the lidar system will be presented in the talk.

The atmospheric aerosol features in the images that REAL produces can be tracked to infer wind vectors. The method of tracking macroscopic aerosol features has an advantage over Doppler lidars in that two components of motion can be sensed. (Doppler lidars can only sense the radial component of flow). In the past, tracking aerosol features was typically done by computing two-dimensional cross-correlation functions (CCFs) and noting the displacement of the peak of the CCF with respect to the origin. Recently, the author has been collaborating with French colleagues to apply an entirely new algorithm to extract motion vectors. The new approach is called "dense estimation" and it has its origin in the field of computer vision. Vectors from both approaches [3, 4] will be presented in this seminar and compared with coincident sonic anemometer measurements collected at 1.6 km range.

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Acknowledgements: U.S. National Science Foundation (NSF) Award 0924407.

LASER SPECTROSCOPY AND METROLOGY

L2

COHERENT LASER SPECTROSCOPY OF RUBIDIUM ATOM

S. Mitra[1], M. M. Hossain[1], B. Ray[1], P. N. Ghosh[2], S. Cartaleva[3], D. Slavov[3]

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Line shape of Electromagnetically Induced Transparency (EIT) in a multilevel atomic system has been studied experimentally and theoretically. We have studied EIT resonance in five level hyperfine transitions of ^{85}Rb D_2 spectra. Numerical solutions based on density matrix equations are used to account for the non-linear transitions. We show that the Doppler averaging process in a multi-level system produces sharp and symmetric EIT profile. Introduction of buffer gas in the sample cell changes the ground state decay rates thus resulting in variation in the EIT line width. EIT peak becomes sharp and narrow with reduction of these decay rates. Pump power dependence of the EIT spectrum has also been studied. Experiments were also carried out with buffer gas like nitrogen in order to find the effect on the line width of the EIT resonance. The observed width of the EIT spectrum depends strongly on pump and probe power densities, incoherent decay rates from the levels, beam diameter, relative phase sensitivity of the pump and probe lasers etc. Comparison of the simulated and experimental spectra leads to information on the level decay rates.

L3

LASER SPECTROSCOPY WITH NANOMETRIC CELLS CONTAINING ATOMIC VAPOR OF METAL: INFLUENCE OF BUFFER GAS

D. Sarkisyan[1], G. Hakhumyan[1,2], A. Sargsyan[1], C. Leroy[2], Y. Pashayan-Leroy[2]

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[2]*Laboratoire Interdisciplinaire Carnot de Bourgogne, UMR CNRS 5209 - Université de Bourgogne, F-21078 Dijon Cedex, France*

Comparison of resonant absorption and fluorescence in a nano-metric thin cell containing Rubidium atomic vapor with other Rubidium nano-metric thin cells where additional neon gas is added under 6 Torr and 20 Torr pressure will be presented.
The effect of collapse and revival of Dicke-type narrowing [1-6] is still observable for the Rb nano-metric thin cells where Ne gas is added under 6 and 20 Torr pressure for the thickness $L=\lambda/2$ and $L=\lambda$, where λ is a resonant laser wavelength 794 nm (D_1 line). Particularly for 6

Torr of Ne the line-width of the transmission spectrum for the thickness $L=\lambda/2$ is 2 times narrower than that for $L=\lambda$, while in the case of pure Rb vapor the line-width of the transmission spectrum for the thickness $L=\lambda/2$ is 4 times narrower than that for $L=\lambda$.

For an ordinary Rb cell with L = 0.1 - 10 cm with addition of buffer gas, the velocity selective optical pumping/saturation (VSOP) resonances in saturated absorption spectra are fully suppressed when the buffer gas pressure > 0.5 Torr. A spectacular difference is that for $L=\lambda$, VSOP resonances located at the atomic transition are still observable even when neon gas pressure is ≥ 6 Torr, and they wash out only for pressure ~ 20 Torr.

Narrowband fluorescence spectra of the STC with $L=\lambda/2$ can be used as a convenient tool for online buffer gas pressure monitoring for the conditions when ordinary pressure gauges are unusable [7].
A good agreement of the experimental results with theoretical model is observed.

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L4

ATOMIC SOURCES CONTROLLED BY LIGHT: MAIN FEATURES AND APPLICATIONS

A. Bogi, A. Burchianti, C. Marinelli, E. Mariotti, **L. Moi**

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LIAD is a non-thermal process in which atoms adsorbed on a surface are released into the vapour phase under illumination. LIAD of alkali metal atoms has been observed from several materials: a few milliwatts of even non coherent and non resonant light may increase the alkali-atomic density in coated-glass cells more than one order of magnitude. Photoatomic sources can be made also using bare glass, even if the photodesorption efficiency per unit area is lower. This limit can be overcome using nanoporous glass with an inner surface of 100 m2/g.

LIAD is widely used as loading technique for magneto-optical traps, atom chips, and photonic bandgap fibers. There is also the possibility to use LIAD, in sealed glass cells, to generate and stabilize in a controlled way large alkali-metal vapour densities. The method requires low or moderate desorbing light intensities; furthermore it can be easily extended to all photonic devices in which LIAD is used to deliver atoms in vapour phase.

L5

RAMAN-RAMSEY SPECTROSCOPY IN RUBIDIUM VAPOR CELL

B. Jelenković, Z. Grujic, M. Mijailović, M. Radonjić, A. Krmpot,
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Effects of Ramsey method of separated oscillatory fields on electromagnetically induced transparency (EIT) and on non-linear magneto optical rotation of laser polarization (NMOR) in hot alkali vapors will be presented. Here, unlike in the original Ramsey method, oscillatory fields consist of pair of laser beams in Raman resonance with the atomic levels of Λ scheme. It was shown that presence of a dark region between two interaction regions considerable changes shapes and line-widths of these coherent resonances.

We will give an overview of results with different Ramsey methods applied to narrower EIT and NMOR resonances in gas cells with alkali atoms with buffer gas [1,2] or with special wall coatings [3]. Effects of Raman-Ramsey methods on EIT and NMOR have been investigated in vacuum cells only briefly [4].

We will show probe EIT [5] and probe NMOR [6] obtained with spatially separated pump and probe beams in Rb vacuum cell. Special configuration of pump and probe beams enabled Raman-Ramsey method to be effectively applied in vacuum cells on narrowing EIT and NMOR. Narrowing and Ramsey fringes, observed in probe EIE and NMOR, are due to temporal evolution of the pump induced alignment, evident from changes of the these resonances with the angle between linear polarizations of pump and probe beams, and with length of the dark region. Experimental results are in agreement with the results of the theoretical model which calculates probe fluorescence and polarization rotation by solving time dependent optical Bloch equations, from the time when atom enters the pump beam to the time when it leaves the probe beam. Calculated density matrix elements were averaged over atomic velocities distribution.

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LASER-MATTER INTERACTION

L6

ULTRAFAST DYNAMICS IN STRONG-FIELD INTERACTIONS WITH MOLECULES AND SOLID SURFACES - High-harmonic generation and nanostructuring -

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Development of high-intensity, ultrashort-pulse lasers has opened new fields of laser - matter interaction in the ultrafast, strong field regime. Our interest has been focused on nonperturbative nonlinear phenomena in atoms, molecules and solid surfaces that are induced with the intense fs laser pulses. Here we present two topics in our study using intense fs laser pulses: one is the formation of periodic nanostructures on solid surfaces, and the other is the high-order harmonic generation from coherently rotating molecules.

Despite the diffraction limit of light, intense fs laser pulses are able to form periodic nanostructures on dielectric materials [1]. To understand the ultrafast interaction process on the surface, characteristic properties of nanostructure formation on hard thin films have been studied in detail for different laser parameters such as polarization, fluence, wavelength, and superimposed pulse number. The experimental results have shown that nanoscale *nearfield* is induced on the corrugated surface area much smaller than the laser wavelength [2]. The enhanced local field is able to initiate nanometer-size ablation, when the laser fluence is lower than the threshold of ablation. Based on the observed initial stage in the nanoscale ablation, the origin of nanoscale periodicity has been attributed to the excitation of *surface plasmon polaritons* (SPPs) due to ionization in the surface layer [2]. The estimated period in nanostructures is in good agreement with the observed size, and the observed properties of nanostructuring reconcile with the excitation of SPPs. This model is being applied to understand nanostrocturing of semiconductor surfaces.

Intense fs laser pulses are able to induce a variety of nonperturbative nonlinear phenomena in gaseous molecules, allowing us to see ultrafast dynamics of molecules. Using a pump and probe technique, we have studied high-order harmonic generation (HHG) from nonadiabatically aligned molecules, while a theoretical model has been developed for the correct description of the HHG from coherently rotating molecules [3-5]. The time-dependent harmonic signal and its frequency spectrum observed provide us with a new way to probe structures and dynamics of molecular systems. The experimental technique using HHG from aligned molecules was applied to the sensitive measurement of molecular rotational temperature, and its validity was tested for a pulsed supersonic N_2 flow with a rapid temperature decrease [5].

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L7

ULTRAFAST LASER ABLATION: LASER-MATTER INTERACTION, PLASMA CHARACTERIZATION AND NANOPARTICLES GENERATION

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Laser ablation with nanosecond and femtosecond pulses is involved in a number of techniques, such as pulsed laser deposition (PLD), laser-induced breakdown spectroscopy, nanoparticle synthesis and laser machining.

In this lecture we report on the more recent experimental results on the characterization of the laser ablation process with nanosecond (ns) and femtosecond (fs) laser pulses. As key application of ns laser ablation we will focus on PLD addressing the various aspects of the technique and emphasizing the propagation dynamics of a laser ablated plasma plume into a background gas. As for the fs laser ablation we will discuss the process resulting in a plume formed by atoms and nanoparticles, addressing the current understanding of the various mechanisms involved in the phenomenon and the possibilities offered for the elaboration of nanoparticle-assembled films of different materials. Finally, very recent results on fs laser ablation with double pulses will be also given.

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L8

LASER DEPOSITION OF TiO_2 FOR URETHRAL CATETHER

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Catheters and medicals tubes are widely used to introduce pharmaceuticals and nutrients into arteries and veins, and to drain fluids or urine from urethra or the digestive organs. Nevertheless, catheter- associated infections are common, accounting for 40% of all nosocomial infections. Several types of catheters with antibacterial effects has been developed [1]. Also photocatalytic effect of TiO_2 was extensively studied in this relation [1-2]. It is well known that illuminated TiO_2 photocatalysts can decompose most noxious or toxic organic compounds.

We studied the properties of titanium dioxide layers created by pulsed laser deposition from pure titanium and titanium dioxide targets. To reach crystalline structure at low substrate temperatures the radio-frequency (RF) discharge between the target and the substrate was implemented. The crystalline structure of layers was determined by X-ray diffraction and morphology by atomic force microscopy. Using RF discharge, mixture of anatase and rutile was reached at substrate temperature of 85°C, which was reached only by discharge itself. The antibacterial test was performed against Escherichia coli cells.

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LASER SYSTEMS AND NONLINEAR OPTICS

L9

NANOPHONONICS: A NONLINEAR BATTLEGROUND *PAR EXCELLENCE*

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Sound propagation is by essence nonlinear as nature has been far more generous with acoustic anharmonicities than optical ones; in fact the study of acoustic nonlinearities by far predates and strongly influenced that of the optical ones[1]. Still the subsequent development of the latter, favoured by the advent of the laser, outpaced that of the former. This trend is changing as judicious exploitation of photo-thermal and stimulated opto-acoustic effects led

to an impressive development of intense coherent acoustic pulses possessing features comparable to those of the optical ones [2,3]; their operation can be additionally enhanced by the implementation of different confinement schemes as has been the case with photonic devices and cavities.

Here we briefly review the passive photothermal schemes [4-7] and the underlying physical processes in metal and semiconductor nanostructures for generation of coherent optically driven sources of large amplitude acoustic pulses and large acoustic phonon populations down to the picosecond and submicron spatiotemporal scales; their beam directivity and monochromaticity can be comparable to that of optical pulses delivered by lasers and other intense coherent optical sources and are being exploited in a number of powerful diagnostic techniques and *phononic* devices where in addition confinement can substantially improve their performances [2,3].

We illustrate the present state of art with some examples from recent studies for acoustic *soliton* propagation [8,9] and attempts for *saser* (sound amplification by stimulated emission of radiation) operation [10,11], phononic gratings and microcavities[12] and older ones [13]on parametric phonon breakdown. We also briefly touch [14] the issue of the *quantum acoustic* phonon limit and noise and the problematic that arises in the transition from the quantum to the classical mechanical levels

We also discuss the acoustoelectric amplification [15] and the issue of photoinduced phonon transport in polar semiconductor nanostructures and its coupling with charge transport through the photogalvanic effect. The later can only take place[16], without the application of external fields, in media lacking spatial inversion symmetry brought off equilibrium by photoabsorption of coherent light such as from a laser and can be view as a photodriven ratchet and pawl effect.

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L10

3D SOLITONLIKE BULLETS IN NONLINEAR OPTICS AND BOSE-EINSTEIN CONDENSATES

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Mathematical similarities and parallels between two different physical objects, optical solitons and matter-wave solitons, both described by similar mathematical models: the nonlinear Schrodinger equation (NLSE) and the Gross-Pitaevskii equation (GPE) model, open the possibility to study both systems in parallel and because of the obvious complexity of experiments with matter-wave solitons, offer outstanding possibilities in studies of BEC system by performing experiments in the nonlinear optical system and vise versa.

Three dimensional (3D) spatiotemporal solitones that are self-localized in two transverse dimensions and one longitudinal dimension were predicted by Silberberg in 1990 and termed *light bullets.* Spatiotemporal soliton bullets are among the most intriguing and challenging entities. There has been an extensive field of research in the past 10 years in the areas of light bullets and the imitations of the standard NLSE. In this report we briefly overview recent theoretical studies of the existence and stability of 3D solitons. We provide a theoretical presentation of the main concepts underlying the physics of soliton bullets in conditions of extremely low transverse and longitudinal sizes when the so-called non-paraxial effects play a crucial role. The main effort is devoted to discussion of the relevant theoretical aspects when the equations governing the propagation of soliton-like bullets should be different from the well-known paraxial approximation. Thus, we have considered alternative models that should (and do) permit the propagation of stable soliton bullets. With contributions from major groups who have pioneered research in this field, the report describes the historical development of the subject, provides a background to the associated nonlinear optical processes, the generation mechanisms of femtosecond soliton bullets. In principle, soliton bullets may be supported by a variety of nonlinear mechanisms. These include quadratic nonlinear media that support solitones for all physical dimensions and where two dimensional bullet formation was achieved, saturable and nonlocal media; materials with competing nonlinearities where higher-order effects such as fourth-order dispersion may play a stabilizing role, propagation in optical lattices and filamentation, the concept of three-dimensional light bullet formation in tandem structures where nonlinearity and dispersion are contributed by different materials, just to name a few. Experimentally, however, only 2D spatiotemporal solitons have been demonstrated.

Based on the generalized nonlinear Schrödinger equation model with sign-reversal varying-in-time harmonic oscillator potential, we show that conditions of its exact integrability in one-dimensional case (1D) indicate conclusively the way for solitonlike bullets generation in 3D nonautonomous nonlinear and dispersive systems during reversal periodic transformation from cigar-shaped to ball-shaped trapping potential. It turns out that the generation of matter-wave soliton bullets can be realized if periodic variations of nonlinearity and confining potential are opposite in phases so that the peaks of nonlinearity inside the atomic cloud coincide in time with repulsive character of trapping potential. In nonlinear optical applications, this kind of periodic graded-index nonlinear structure with alternating waveguiding and antiwaveguiding segments can be used to simulate different and complicated processes in the total scenario of matter-wave soliton bullets generation.

L11

SOLITON DYNAMICS IN SUPERCONTINUUM GENERATION

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Continuous-wave (CW) and long pulse duration fiber lasers have proved to be ideal sources for high average power and spectrally flat supercontinuum generation in optical fibres [1,2]. In the CW case continua over 1000 nm broad with up to 100 mW/nm spectral power have been generated [2], whereas in the long pulse case the full silica transparency region between 320 nm and 2400 nm can be covered [1]. The foundation of these supercontinua has been the efficient generation of high peak power solitons through modulation instability, followed by what have now been identified as the key processes in supercontinuum formation [3]: dispersive wave excitation, soliton self frequency shift, soliton collisions, and trapping of dispersive waves by the solitons. However, there are a range of more subtle nonlinear dynamics involved in the supercontinuum formation process: the extended set of soliton-dispersive wave four wave mixing processes, and polarization effects.

Four waves mixing of dispersive waves with solitons has been explained in some detail, and observed experimentally in some isolated ultra-short pumping scenarios [4]. We will look at how these processes occur in the context of long duration pump pulses where modulation instability gives rise to very large numbers of solitons and dispersive waves, undergoing regular collisions. In this case, four wave mixing processes can significantly alter the supercontinuum development, beyond the normal analysis.

In contrast to the case of ultra-short pumped supercontinuum, long pulse and CW supercontinuum generation tends to be pumped with randomly polarized sources. This leads to a range of cross-polarization nonlinear dynamics, such as the creation of vector solitons and soliton shadows [5]. We will analyze how these affect the supercontinuum in comparison to the linearly polarized case.

Finally we will conclude with a review of the state of the art high average power supercontinuum sources and describe ongoing developments and future prospects.

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L12

FUNCTIONAL NONLINEAR PHOTONIC CRYSTALS

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The second-order nonlinear coefficient of ferroelectric nonlinear materials can be modulated nowadays with micron-scale, or even sub-micron-scale resolution [1]. This modulation enables to efficiently convert the frequency of optical waves, but in addition it allows new applications, based on all-optical control of the phase, amplitude and polarization of the nonlinearly generated waves. In this talk I will review the realization of functional nonlinear optical devices, such as nonlinear lenses, switches, polarization rotators, deflectors and beam shapers.

As a specific example, I will concentrate on nonlinear photonic crystals that convert a Gaussian fundamental beam into an accelerating Airy beam at the second harmonic frequency. Airy beams are beams whose transverse amplitude dependence at origin is defined by the Airy function. These beams have generated significant interest recently owing to their unique properties: They are termed *"non-diffracting"* since the infinite Airy wavepacket does not spread as it propagates, and *"accelerating"*, since these wavepacets are centered around a parabolic trajectory in space.

For generating an Airy beam, it is useful to manipulate first the Fourier transform of the beam, which in the case of the Airy function is characterized by cubic phase dependence. For this purpose we have designed and fabricated a special asymmetric nonlinear photonic crystal [2] which converts the frequency of an input pump beam, and simultaneously adds a cubic phase to the harmonically generated wave.

In addition to frequency conversion, the nonlinear interaction provides new possibilities for manipulating and controlling Airy beams, that cannot be achieved using linear optics. One option that was experimentally demonstrated in [3] is all-optical shaping of the caustic of the Airy beam. By changing the quasi-phase matching conditions, e.g., the crystal temperature or pump wavelength, one can alter the location of the Airy beam peak intensity along the same curved trajectory. Another possibility is to all-optically control the acceleration direction of the beam [4] by relying on the opposite signs of phase mismatch values for up-conversion and down-conversion processes. Switching from one process to the other will therefore generate Airy beams that accelerate to opposite directions.

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LASERS IN BIOLOGY AND MEDICINE

L13

PHOTODYNAMIC THERAPY: BACKGROUND, CLINICAL APPLICATIONS AND NEW DEVELOPMENTS

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Photodynamic Therapy (PDT) is a treatment modality that uses the combination of light and a photosensitive drug to induce a therapeutic effect. The first written references to PDT date from 40 centuries ago. Yet its name has been given and its basic concepts have been described roughly 100 years ago. In spite of this long history, only in the last 2 decades it has started to gain acceptance in a number of specific clinical fields. This is related to the invention of the laser and fiber optics and their technical maturing.

Current application fields range from pre malignant skin diseases and macula degeneration to palliative cancer treatment. Although many drugs with photosensitizing properties are available in nature, the photosensitizers used for clinical PDT are carefully constructed to induce minimum side effects in the patients. As the photosensitizers only accumulate slightly in diseased tissue, large amounts of the drugs are also present in the skin, where it can induce side effects when exposed to daylight.

Penetration of light is often seen as a serious limitation of PDT. Using red light therapeutic working depths of up to 1 cm are reached. With blue and green it is no more than a few mm. This indeed is al lot less than for instance with radiotherapy. This limited penetration, however, is often a benefit rather than a limitation. For instance in treatment of skin cancer with PDT the limited penetration of the light prevents damage to deeper layers and hence can produce scar free removal of the cancer. Using fiber optics inserted through endoscopes we can reach many surfaces deep inside the body such as the colon, the esophagus, the stomach, the nasopharynx and the lungs. Here too, early cancers are usually less than 1 mm thick and can be excellently treated with PDT. For large bulky tumors such as in the base of the tongue or the prostate we developed an approach using insertion of multiple optical fibers into the tissue. With this approach volumes up to 100 cc have been treated deep inside the base of the tongue with excellent results.

Future developments are aimed at making the photosensitizer more selective for cancer cells. This can be done by engineering the molecule in such a way that it selectively couples to cancer specific proteins. Results so far have not been encouraging. This is related to the fact that photosensitizer molecules are often very lipophyllic and bind aspecifically to any lipid structure available. Hence we are now investigating the use of nano particles to pack the photosensitizer. These nanoparticles are then functionalized so that targeted delivery can take place. Using this approach we were able to reach a highly selective cell kill in very specific cells in vitro. If this approach can be employed for human disease we can treat cancer very selectively without damage to functional surrounding tissue.

L14

OPTICAL BIOPSY FOR STRUCTURE, FUNCTION AND BIOCHEMISTRY – A CONTINUING CHALLENGE

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In recent years the ability to capture high resolution images with excellent biochemical specificity has become widely available in research labs and to some extent as support in hospitals. However, these facilities are largely confined to thin samples, usually of single cell thickness. Many methods have been developed to provide planar 2D images of molecular concentration (e.g. see figure 1). Meanwhile, physicists have developed techniques which produce exquisite 3D images of the human tissue including microvascular architecture using techniques based on low coherence, photo-acoustic, multi-photon and even stimulated-emission microscopy. However, despite the extraordinary impact photonics has had on the life sciences where almost every fluorescing molecule in biology can be imaged in high resolution, biophotonics is not making a significant clinical or commercial impact.

Over the past decade substantial advances have been made in tomography including Doppler OCT [1] and photoacoustic tomography. We discuss major developments in imaging and the need to merge structure, function and biochemistry into one composite image for clinical research and practice.

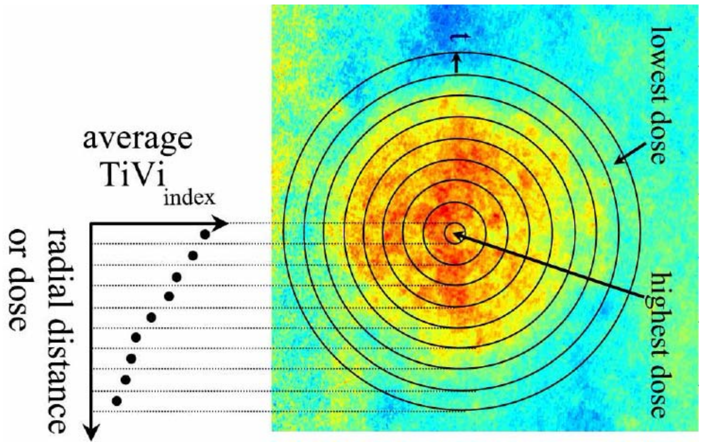

Fig. 1. Radial analysis of UVB Provocations.

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L15

LASER ABLATION AND HIGH PRECISION PATTERING OF BIOMATERIALS AND INTRAOCULAR LENSES

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The use of intraocular lenses (IOL) is the most promising method for restoring excellent vision in cataract surgery. In addition, multifocal intraocular lenses for good distant and near vision are investigated. Several new materials, techniques and patterns are studied for the formation and etching of intraocular lenses in order to improve their optical properties and reduce the diffractive aberrations. As pulsed laser ablation is well established as a universal tool for surface processing of organic polymer materials, this study was focused in using laser ablation with short and ultrashort laser pulses for surface modification of PMMA and intraocular lenses, instead of using other conventional techniques. The main advantage of using very short laser pulses, e.g. ps or fs pulses is that heat diffusion into the polymer material is negligible. As a result high precision patterning of the sample, without thermal damage of the surroundings, becomes possible.

In this study, laser ablation was performed using commercially available hydrophobic acrylic IOLs, hydrophilic acrylic IOLs, and PMMA IOLs, with various diopters. We investigated the ablation efficiency and the phenomenology of the etched patterns by testing the ablation rate, versus laser energy fluence, at several wavelengths and the surface modification with atomic force microscopy (AFM) or scanning electron microscopy (SEM). The irradiated polymers have different optical properties, at the applied wavelengths, and therefore, present different ablation behaviour and morphology of the laser ablated crater walls and surrounding surfaces. The experimental results, the theoretical assumptions and some mathematical modeling of the relevant ablation mechanisms are discussed.

L16

GAINING AN UNDERSTANDING OF ULTRA-SHORT LASER ABLATION BY VARIOUS EXPERIMENTAL EVIDENCE AND SELECTED APPLICATIONS

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Ultra fast laser interaction with surfaces results in fast electronic and thermal ablation processes. The way, how the energy is deposited, determines to a large extent, how efficiently the different processes contribute to laser-matter interaction. We have shown how laser analytical techniques can help to identify the time behavior of the energy deposition, the composition and energy of the emitted particles. Atomic Force Microscopy (AFM) allows determining the surface topography after different stages of ultra-short laser-matter interaction [1, 2]. Both techniques combined can yield substantial information for better understanding the physics involved. E.g. the appearance of so-called nano-hillocks on the surface can be regarded as a typical topographic feature associated with fast electronic processes (correlated with the existence of hot electrons), in particular, demonstrating the efficient localization of energy in small volumes.

A very promising aspect of the various surface structures is their application in several areas, such as optics, photonics, magneto - optics etc., in particular the correlated nonlinear properties of the materials modified by the laser.

The Z-scan technique [2] is well suited for measuring TPA (two photon absorption) cross sections. This technique relies on the transformation of phase distortion to amplitude distortion during beam propagation through a nonlinear medium.

On behalf of some representative examples we will demonstrate these new aspects of ultra short laser material modification [3].

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L17

WILL ANYONE REMEMBER US?
THOUGHTS ON INFORMATION LOSS CAUSED BY PROGRES

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Technological developments are driven by commercial competition, and surprisingly examples as diverse as computer speed, fiber optic communication or cost per pixel on a CCD camera often follow a relatively smooth logarithmic improvement per year. The normal assumption is that this is desirable, but such progress is frequently only achievable by the introduction of new software, different types of storage media or new operating conditions. Consequently existing technologies become outdated. For transient information this is unimportant, but for long term storage and archiving of information, images, photographs, film or video, there is an inevitable loss of earlier records. This is not a new phenomenon as even information on stone or clay tablets has decayed or been lost. Losses are not just physical decay of storage materials, but are equally problematic in terms of our understanding because of changing language and cultural nuances of the text.

Examples are given to emphasize how technological progress has speeded up information decay and loss. Since logarithmic "laws" have been proposed to describe the trends for electronic and other scientific improvements, one may speculate if equivalent trends apply to information loss. It appears that one may propose that the product of three factors is roughly constant. These are the time needed to write the new information; the quantity of information stored, and the average survival time of the information before the storage medium has decayed or is obsolete. The reality of such a "law" is that, whereas we may currently have records and photographs from many earlier generations, our rapidly stored electronic data may be lost within a few years, and certainly will have vanished in a readable form for the next generation.

L18

ADVANCES IN PHOTONICS DESIGN AND MODELING FOR NANO- AND BIOPHOTONICS APPLICATIONS

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The formulation of the Finite-Difference Time-Domain (FDTD) approach will be presented in the framework of its potential applications to both nano- and biophotonics. The unifying principle of this combination is the common dimension scale of the scattering objects as well as the common nature of the scattering phenomena. After a rigorous introduction to the FDTD approach the presentation will focus on recent unique design and simulation examples of sub-wavelength silicon nanophotonic structures including gratings, couplers, multiplexers etc. The examples of biophotonics applications will focus on two different configurations: i) light scattering from single biological cells alone in controlled refractive index matching conditions and ii) Optical Phase Contrast Microscope (OPCM) imaging of cells containing gold nanoparticles. The discussion includes the case of OPCM microscopy as a prospective modality for *in vivo* flow cytometry. The application of the FDTD approach for the simulation of OPCM and flow cytometry imaging opens a new application area with a significant research potential – the design and modeling of advanced nanobioimaging instrumentation.

L19

RAMAN SPECTROSCOPY: A PROSPECTIVE TOOL IN LIFE SCIENCES

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Raman spectroscopy as a label-free, non-invasive and non-destructive, but very specific technique down to the molecular level offers a huge potential for solving biomedical problems. Advances in the field of laser sources, filters and detectors enabled the development of specialized Raman techniques, such as micro-Raman, resonance Raman, surface enhanced Raman spectroscopy (SERS), tip enhanced Raman spectroscopy (TERS), and coherent anti-Stokes Raman scattering (CARS). In this contribution we report how the power of Raman spectroscopy can be utilized to obtained detailed spectral information of microorganisms, single cells, and tissues. These insights help to identify pathogens, understand the structure and function of biological material and systems as well as metabolic processes, unravel the mode of action of drugs and assist in early stage cancer diagnosis.

L20

NEW METHOD FOR CONTROL OF THE THERAPEUTIC EFFECT EFFICIENCY OF COLD LASER RADIATION

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In modern laser therapy "the dosimetry" is based on the empirical effect of the power density of laser radiation on the tissue. The power density of 4 J/cm^2 is accepted as an extreme level for reaching the therapeutic effect. Nevertheless this method ignores an individual biological response to the laser radiation and does not provide correct determination of therapeutic effect.

In this report new method of "dosimetry" for phototherapy based on controlling the level of tissue oxygenation is presented. The level of tissue oxygenation is an important indicator of cell metabolism efficiency and energy production in tissue. Controlling this mechanism gives unique possibility of biological stimulation to reach therapeutic effect.

Laser induced photodissociation of oxyhemoglobin (HbO_2) allows to extract an additional amount of oxygen locally at irradiating zone. This phenomenon provides unique possibility using optical methods to regulate the local oxygen tissue saturation. An additional oxygen release rate can be directly measured through the value of oxyhemoglobin arterial blood saturation (ΔSaO_2).

The amount of oxygen released into tissue also depends on the capacity of circulatory system to carry oxygen. This capacity mainly defined by contribution of two parameters: hemoglobin concentration in blood [Hb] and its circulation speed. The impact of the actual Hb concentration is described by the ratio of $[Hb]/[Hb]_n$, were $[Hb]_n$ is standard concentration that is normal for particular sex and age. The impact of the blood circulation speed is taken into account through the heart pulse rate P_r.

Finally, therapeutic "dose" can be determine by the value of $\Delta SaO_2 = SaO_2 - SaO_2^{h\nu}$, were SaO_2 is saturation without and $SaO_2^{h\ h\nu}$ with laser irradiation, heart pulse rate P_r, time of exposure T, ratio of actual and standard hemoglobin concentrations $[Hb]/[Hb]_n$.

$$D(O_2) = \frac{[Hb]}{[Hb]_n} \cdot \left(\frac{\Delta SaO_2}{100} \right) \cdot P_r \cdot T$$

It should be noted that involved parameters are objective and could be measured by well-known clinical routine. The suggested new method of "dosimetry" based on the key biological parameters and connected with aerobic cell metabolism provides the possibility of precise determination of the therapeutic effect of low level laser radiation.

POSTER SESSIONS

PRESENTED CONTRIBUTIONS

A - *LASER –MATTER INTERACTIONS*

PA1

MICROPROCESSING OF THIN COLLAGEN FILMS BY ULTRASHORT LASER ABLATION

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This preliminary work explores a technique for processing collagen thin films by femtosecond Ti:Sapphire laser ablation in order to provide a structured matrix support for cell growth and other tissue engineering applications [1,2]. The laser-induced structuring of collagen easily yields an expanded micro foam material with interconnected pores and properties that mimics the native collagen-based extracellular matrix [3]. The obtained structured matrix is formed by a cavitation and bubble growth mechanism. The surface properties of collagen thin films before and after Ti-sapphire irradiation with 800 nm were investigated by means of the technique Field Emission Scanning Electron Microscope (FESEM). FESEM analysis showed that with a single pulse of ultra-short laser radiation is capable of inducing morphological changes in the irradiated collagen films. The size of the observed features can be controlled by selection of laser fluence and pulse duration.

Collagen is the most widely distributed class of proteins in the human body. Collagen-based biomaterials were developed and explored for the purposes of tissue engineering. Biomaterials are expected to function as cell scaffolds to replace native collagen. The ultra-short laser ablation induced nanofoaming of biomaterials will improve currently available techniques. Artificial collagen nanofibers are increasingly significant in numerous tissue engineering applications and seem to be ideal scaffolds for cell growth and proliferation.

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PA2

CuBr LASER BEAM TRANSFORMATIONS

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CuBr laser beam transformations are studied in a beam focusing experiment. A modelling via Fourier transform is also performed with annular beams of simplified flat two-level geometry of near field: bright outer ring with a darker core. The pattern of focal beam profile i.e. far field is calculated and characterized with respect of its intensity structure. As found beam annularity has small effect on far-field intensity pattern.

PA3

PAPER SURFACE MODIFICATION BY LASERS

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Cleaning of paper is necessary due to the fact that contamination has to be removed and the fragile organic substrate should be preserved. The conventional cleaning methods are mechanical or by the application of chemicals. These methods can lead to partial damage of the print layers or brittle the original paper substrate. Lasers are a sufficient tool for cleaning as the dose of energy delivered can be controlled as well as the penetration depth to a specific contaminated point, therefore suitable for accurate, efficient and safe cleaning. Excimer laser at 308 nm and Nd:YAG laser at 532 nm with fluences below 0.86 Jcm^{-2} were used for cleaning of cellulose and paper materials [1], leading to no detrimental effects of Nd:YAG laser radiation. Further experimental investigation of historical paper samples cleaned by Nd:YAG laser pulses were presented [2]. The experimental results obtained by using photometry, laser induced fluorescence (LIF) and plasma spectroscopy (LIPS). The same wavelength and type of laser was applied for cleaning of artificially soiled paper [3]. High laser fluences of about 2 Jcm^{-2} were applied and the laser cleaning efficiency was superior to that obtained by eraser cleaning. In addition, Nd:YAG was experimentally used operating at 1064 nm, 532 nm, 355 nm and excimer laser at 248 nm for cleaning of paper models and original objects [4]. It was observed that the green laser has the highest cleaning efficiency whereas the UV laser was the most effective tool in the removal of homogenous layers of adhesive from original objects.

The current experiment concerns laser cleaning of paper, initially of test papers mechanically soiled and then of an original book of the early 20th Century. The test objects are newspaper, A4 paper, glossy paper, cardboard and paper whatman No.1056. During the experiments undertaken so far ink of a pen, pencil or ink from a stamp was mechanically employed on the

paper surface. Laser cleaning was applied using Nd:YAG operating at 532 nm and CO_2 laser at 10.6 μm for various fluencies. An example of cleaning using a pulsed Nd:YAG laser emitting at 532 nm with pulse duration at 7 ns is shown in Fig. 1. Subsequently Nd:YAG at 1.06 μm and 266 nm will be used thus making a comparison for the best type of wavelength and fluence required. In addition, laser radiation at 2.94 μm will be applied to the paper samples. Eventually, laser cleaning will be performed to a book of 20th Century, by choosing the best experimental condition and parameters derived from the test sample cleaning.

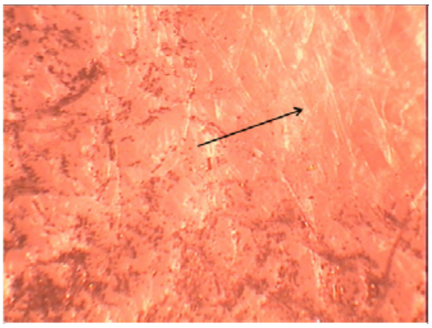

Fig. 1. Laser cleaning results after irradiation by Nd:YAG laser emitting at 532 nm. The arrow indicates the cleaning area. The fluence was 1.55 J/cm^2

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PA4

THIN FILM HOMOGENIZATION BY INVERSE PULSED LASER DEPOSITION

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Recently we proposed a novel PLD arrangement, termed inverse pulsed laser deposition (IPLD) that can represent an alternative to the traditional PLD technique by preserving its versatility, while producing thin films of better surface morphology without any complex instrumentation [1, 2]. Two configurations of this new target-substrate arrangement, namely static and co-rotating IPLD were developed. In the *static IPLD configuration*, the substrate is stationary with respect to the ablated spot; while in the *co-rotating IPLD configuration* the substrate is fixed to the target surface and rotates simultaneously with the target [3]. Co-rotating IPLD proved to be capable of homogenizing the film thickness [4].

Here we report a model calculation supported by experimental results to describe the radial growth rate variation of co-rotating IPLD films. To characterize the homogeneity of CN_x, TiO_x, and Ti co-rotating IPLD films, a thickness inhomogeneity index (*TII*) is introduced, which allows the comparison of films of different lateral dimensions. The semi-analytical, semi-numerical model derives the radial variation of the growth rate of co-rotating IPLD films from the lateral growth rate distributions measured along the symmetry axes of the static IPLD films. The laterally averaged growth rate (*LAGR*) is used to describe how the ambient pressure affects thin film growth in the 0.5–50 Pa domain. As an example, the absolute error between the measured and calculated radial growth rate variation of CN_x layers grown by co-rotating IPLD at 5 Pa, was less than 3%, while the *LAGR* was predicted with 20% accuracy.

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PA5

FLUORESCENCE FROM $Pb_{1-X}Cd_XSe$ POLYCRYSTALLINE FILMS ECXITED BY NON-MONOCHROMATIC LIGHT AT $\lambda_{max}\approx 0.9$ μm

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The spontaneous fluorescence from vacuum-seeded thin films of solid Pb Cd Se solutions is well known [1, 2]. It has been verified that the fluorescence can be observed after optical excitation in films thermally treated by heating in an oxygen atmosphere conditions.

The increased interest to the structure of the chalcogenide lead films is based on the fact that their quantum transitions lie in the near infrared spectrum (2 - 5 μm) that allows one to develop a set of light sources with controlled bandwidth.

The $Pb_{1-X}Cd_XSe$ polycrystalline films with thickness of 0.2 mm deposited on a 20x20 mm glass plate and treated in the oxygen atmosphere at temperature of ~400^0C have been investigated. The typical spectrum of the fluorescence of the $Pb_{1-x}Cd_xSe$ polycrystalline film excited by a Ga-photodiode radiation with $\lambda_{max} \approx 0.9$ μm is presented in fig. 1. The spectra obtained can be roughly approximated by the Rosberg-Shockley formula [3] that describes the interband recombination. It was found that the positions of the fluorescence peaks depend on the Cd concentration in the PbCdSe solid solution demonstrating a blue shift of the fluorescence peak with Cd concentration growth.

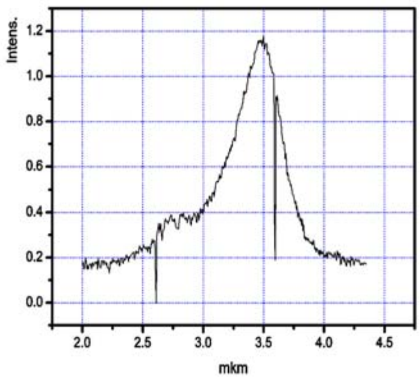

Fig.1

The temperature dependence of the fluorescence peak in the range from -20 to $+40^0$C was found to be linear with slope coefficient $p \sim -4.48.10^{-3}$ μm/ºK and, most probably, is related to the temperature dependence of the PbSe forbidden band width.

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PA6

MANUFACTURE OF MICROSTRUCTURED GLASS-CARBON SURFACE USING LASER TECHNOLOGIES

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In many scientific centers all over the world including Russia development of autoemissive cathodes is being actively carried out [1]. The main purpose of these researches is a study of cathodes performed on the basis of carbon microstructures with high density of the emissive current. Such cathodes (in comparison to a match head) can be applied in any electrovacuum devices with the high density of electronic streams and a microsecond available time.

Paper describes a complex of laser technologies for glass-carbon plate processing. The range of laser technologies for glass-carbon plate processing is applied: scribing, milling, cleaning and structuring.

Scribing of a 2 mm monolithic glass-carbon plate allows breaking the carbon preforms. Laser milling is applied both for cutting of cathodes themselves and for micropeaks formation. Cleaning of the cathode surface after laser milling (soot sedimentations removal) is carried out on the same equipment with changing mode. Laser structuring of the micropeaks surface is carried out by laser micrograving.

Also the process of impurity migration on a surface of plates is considered. The elemental composition of glass-carbon plates is controlled by LIBS-method.

The produced structure represents a field of micropeaks of the dome-shaped form with the sizes of the basis of one point 10×10 μm micron and from 15 μm height. On the tops of micropeaks chaotically located groups of nanopeaks [2] are formed, improving emitting ability of structure and the cathode as a whole. The structure provides the average density of the current emission 1 A/cm^2.

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PA7

PREPARATION OF GOLD AND SILVER NANOPARTICLES BY PULSED LASER ABLATION OF SOLID TARGET IN WATER

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Colloidal solutions of gold and silver nanoparticles (NPs) were prepared using a method pulsed laser ablation of target in liquid media. A gold and silver targets immersed in double distilled water are irradiated for 20 min by laser pulses with duration of 15 ns and repetition rate of 10 Hz. In order to investigate influences of laser wavelength and fluence on the particle size, shape and optical properties the experiments were preformed by using two different wavelength – the fundamental and the second harmonic (SH) (λ = 1064 and 532 nm, respectively) of a Nd:YAG laser system. Two different values of the laser fluence for each wavelength at the experimental conditions chosen were used and thus it was changed from several J/cm^2 to tens of J/cm^2. For characterization of the NPs shape and size distribution were used transmission electron microscope (TEM) and optical transmission spectroscopy in the near UV and in the visible region. Spherical shape of the nanoparticles at the low laser fluence and appearance of aggregation and building of nanowires at the SH and high laser fluence is seen. Dependence of the mean particle size at the SH on the laser fluence was established. The mean diameter of gold NPs became smaller with decrease in laser wavelength.

PA8

PULSED LASER NANOSTRUCTURING OF THIN AU AND AG FILMS FOR APPLICATION IN SURFACE ENHANCED RAMAN SPECTROSCOPY

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Metal nanostructuring surfaces are produced by Nd: YAG laser nanomodification of thin gold and silver films. Gold and silver films with different thicknesses and deposition conditions are produced on SiO_2 substrate by pulsed laser deposition technique. After laser annealing of the deposited thin films the metal surfaces were nanostructured as the film is decomposed into nanoparticles with diameters in the range of few tens of nanometers. Post-annealing the structure of the films was investigated with scanning electron microscope (SEM).

The produced nanostructured surfaces are covered with Rodamine 6G and tested as active substrates for Surface Enhanced Raman Spectroscopy (SERS). The SERS enhancement factor is estimated as high as 10^7.

PA9

CONTROL OF MOLECULAR SINGLET-TRIPLET STATE CHARACTER USING AUTLER-TOWNES EFFECT

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The Autler-Townes (AT) effect [1] (also known as ac, optical or dynamic Stark splitting) has been extensively studied in atoms, while high-resolution molecular data is still scarce [2-4]. It has potential for new applications to molecular spectroscopy, e. g. obtaining transition dipole moment matrix elements [2-4] or lifetimes and branching ratios of highly excited molecular states [4]. The AT effect and its dependence on the molecular magnetic quantum number (M_J) has also been shown as an all-optical method for aligning non-polar molecules for chemical reactions [3]. We present here the use of AT effect to control the singlet-triplet state character in molecules. In a three-laser excitation scheme in $^7Li_2$ we have demonstrated that application of a strong coupling field to the singlet component of a singlet-triplet mixed pair leads to significant enhancement in the mixing coefficients and therefore the amount of singlet or triplet character in the pair of states which are initially mixed by the spin-orbit interaction. When the coupling field is absent, the fluorescence spectrum of the system as a function of the probe laser detuning shows the usual double resonance peaks. When the coupling field is turned on, a definite change in the fluorescence spectrum is observed. First, the "main" singlet peak is split into two components, and second, the intensity of the predominantly triplet peak is increased. The coupling laser causes AT splitting of the singlet state of the mixed pair, giving rise to the two components in the fluorescence spectrum. As the coupling field strength increases, the lower component of the AT pair is brought closer to the nominal triplet state. Due to the spin-orbit interaction, these two states are further mixed, as a result of which the nominal triplet state acquires more singlet character and the AT component of the singlet state acquires more triplet character. To understand the above effects we have currently developed a theoretical model based on solving the density matrix equations of motion. The total Hamiltonian of the system is written in the unperturbed basis of molecular states, while the spin-orbit interaction between the unperturbed singlet and triplet states is added as a perturbation. Our preliminary simulations are in good agreement with the experimental data even though future work is needed.

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PA10

THE FÖSTER RESONANCE AND STOCHASTIC DYNAMICS OF AN ALKALI ATOM IN MICROWAVE FIELD

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A highly excited hydrogen-like atom in an electric microwave field of frequency ω and intensity F exhibits an example of a physical system with distinct properties of trajectory instability [1]. The extensive studies of time evolution of Rydberg electron (RE) moving in a Coulomb potential in presence of a microwave field have demonstrated that onset of the global dynamic chaos in semi-classical trajectories exhibits a threshold, which depends on the intensity F. For the given value of n_0, this threshold value F_c satisfies the relation $F_c n_0^5 = n_0/(49 n_0 \omega^{1/3})$ provided $s = \omega n_0^3 >> 1$. For RE in an alkali atom [2] the important modification of $F_c(n_0)$ was obtained and it was shown that the expression $F_c(n_0)$ involves the dipole matrix elements $S_\pm(\varepsilon_0 l_0) = S(\varepsilon_0, l_0 \to \varepsilon_0 + \omega, l_0 \pm 1)$ between the current RE state q_0 ($q = \{\varepsilon = 1/(2n^{*2}), l\}$) and states from the nearest *(l-1)*, *(l+1)* series. If $F > F_c$, the evolution of RE acquires the character of strongly locally unstable Hamiltonian system (K-systems) with intense trajectory mixing in phase space [1]. Or else, for a fixed field intensity $F = F_c$ there exists a well-defined boundary n_0 that separates the region $n > n_0$ of chaotic motion from the region $n<n_0$ of regular motion. Importantly, in alkali atoms the diffusion coefficient D_ε describing stochastic migration of RE through energy levels in the region $n^* > n_0^*$ is expressed via the elements $S_\pm(\varepsilon, l)$ [2]. Due to such migration, the so called RE diffusion ionization in the microwave field can take place [1].

One should expect interesting manifestation of the Föster resonance (FR) in the RE dynamics. Under FR, some Rydberg *l*-state is situated exactly in the middle between two *l'*-states (*l'=l+1*, or *l'=l-1*). The latter implies that the difference $\Delta\mu = \mu_l - \mu_{l'}$ between quantum defects has a half-integer value and, in accordance with Seaton criteria, means vanishing of the dipole matrix element: $S_\pm(l \to l') \approx 0$. Such situation is an analog of the Cooper minimum phenomena in the discrete spectrum of RE energies. In other words, FR may strongly modify both the stochastic region boundary n_0^* and the diffusion coefficient D_ε. We demonstrated some blocking of the dynamic chaos regime by FR for the model one-electron atom with the atomic potential $U_s(r) = -1/r + \alpha/(2r^2)$. The diffusion ionization time was calculated with the classical trajectory technique. A special numerical code based on Split Propagation Technique [3] was adopted to provide reliable stable results for calculations involving a large number of RE evolutions along the atomic orbits.

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PA11

INVESTIGATION OF FERROMAGNETIC PROPERTIES OF LSMO NANOLAYERS BY LASER MODULATED REFLECTANCE PROBE

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Modulated optical reflectance (MOR) technique is reported, implemented to magnetoresistive $La_{2/3}Sr_{1/3}MnO_3$ (LSMO) thin films. Measurement of the variations of optical reflectance of a sample subjected to periodic photothermal modulation is proportional to the variations of the charge carrier concentration. Therefore, MOR signal at certain conditions is correlated to a quasi-Drude model. While the purpose of this paper is to develop the noncontact, nondestructive MOR principle, the magnetoresistance of these compound manganites exhibit strong MOR effect and may find important applications in magnetoresistive devices

The measurement scheme uses a flexible laser microscope based on elements of integral and fibre optics. Two laser beams of different wavelengths are precisely aligned in the focal spot (determining spatial resolution of 5 μm) onto the sample. The pump laser diode is square-wave modulated at set frequency and its purpose is to modulate locally the temperature of the sample film. Successively, the heating and the probe laser beams are selectively separated via a fibre-optics monochromator and high-finesse interference- filter in the detector tract. The probe beam is modulated solely by reflection and is detected by a high impedance photodiode and a lock-in amplifier synchronized by the heating laser, to provide an electrical signal proportional to the modulated reflectance at each point of the sample. The advantage of the nondestructive principle with rapid measurement time, as well, selective response by the magnetoresistive film without interference by the substrate properties are particularly useful for experimental conditions unaffected by the probe beam or external fields. The results of experiments are presented, where the modulated surface is scanned for studying the sample properties around the temperatures of phase transitions, as well as, where magnetic field is applied. A further development could be the application of a similar scheme to read information from magnetically recorded media, where magnetization of the media will be sensed by the local change in the magnetoresistance.

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PA12

LASER FORMING OF CIRCULAR STEEL PLATES WITH VARIABLE ENERGY DENSITY SCANNING

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Laser forming is a flexible forming process accomplished by introducing thermal stresses in the material, to yield elasto-plastic bending or buckling of the sheet metal.

In the present work, attempt is made to reduce the undesired waviness that results from uniform energy density scanning, by applying variable scanning speed, keeping power and spot diameter constant. To simulate the coupled thermo mechanical phenomena involved in this problem, an appropriate finite element model is developed. The simulation predicts the thermal and the stress fields as well as the deformation of circular plate subjected to laser irradiation, with uniform as well as variable energy density, along a circular path.

It is observed that laser scanning of a circular plate, with uniform energy density, introduces significant waviness in the final deformed shape. A plot of the peak temperature attained at the points on the circular path of scanning shows a startup zone with increasing peak temperature, a steady zone with uniform maximum temperature and a tail part with a very high peak temperature. The waviness in the circular plate more or less follows the trend of peak temperature variation along the scanning path.

Simulation is further carried out with variable energy density by adjusting the scanning speeds in the three zones, keeping the power and spot diameter constant, so as to generate a uniform peak temperature along the scanning path. It is observed that this scheme with variable energy density results in a final deformation with reduced waviness.

PA13

LOW COST ENHANCEMENTS OF PHOTOMULTIPLIER SENSITIVITY

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Photomultiplier tubes are widely used detectors of low level light signals; however their performance is often limited, especially at long wavelengths. Input signals are reduced both by surface reflection and by transmission through the photocathode layer. Earlier methods of overcoming these weaknesses are summarized. New predictive modeling of the reflectivity and absorption reveals dependencies that are a function of angle of incidence, cathode thickness and polarization. Improvements on normal usage using extremely simple and low cost techniques are effective. These are demonstrated using retrofits that can improve the overall sensitivity of many types of photomultiplier. Examples include a simple external conical torch reflector, which has raised the efficiency of an S20 multialkali photocathode by between 20 to 10% across the blue to red spectral range. A second example, of a semi-cylindrical glass coupler, improved the absorption efficiency by exploiting 60 degree, rather than normal incidence of the light. Enhancements are up to 500% at longer wavelengths. Such gains are particularly valuable as this is the region of lowest quantum efficiency for the standard operation of the tubes.

B - *LASER SPECTROSCOPY AND METROLOGY*

PB1

INFLUENCE OF RADIAL LASER BEAM PROFILE ON HANLE ELECTROMAGNETICALLY INDUCED TRANSPARENCY IN Rb VAPOR

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In this paper we investigated the influence of two different laser beam profiles, the Gaussian and the Π-shaped profile, on the Hanle electromagnetically induced transparency (EIT) resonance lineshapes. The influence of radial intensity distribution of the laser beam on coherent effects was previously studied in [1, 2]. Our studies were done in the vacuum Rb gas cell with the laser resonant to the open $F_g=2\rightarrow F_e=1$ transition at D_1 line in ^{87}Rb. Hanle EIT resonances were measured and calculated for two different beam profiles of the same beam diameter. Experiments showed that the Gaussian and the Π-shaped profile give different amplitudes and linewidths of the Hanle EIT resonances for the same total power. Resonances induced by the Gaussian laser beam profile are narrower and have lower amplitudes when compared to the case of Π-shaped profile.

We also presented the Hanle resonances obtained from the various segments of the laser beam cross-section, selected by moving the small aperture, placed in front of the detector, along the laser beam diameter. Significant differences in the Hanle lineshapes are observed depending on whether the central or outer parts of the laser beam are detected. The line narrowing and two counter-sign peaks occur at outer, less intense parts of the Gaussian laser beam, while in the case of a Π-shaped profile these effects were observed in central segments of the beam. Excitation in the wings of the Gaussian beam profile produces narrower lines compared to the central part of the beam due to repeated interaction of atom and photons. Atoms are first coherently prepared in the intense central region of Gaussian beam, and afterwards "probed" in the laser wings [3]. On the other hand, atoms entering Π-shaped beam become coherently prepared into the stationary dark state. Average time spent by atom inside the beam increases with approaching the beam center, so that resonance narrowing in central segments is due to the time of flight.

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PB2

EFFECTS OF LASER BEAM PROFILE ON THE ELECTROMAGNETICALLY INDUCED ABSORPTION IN Rb VAPOR

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We present experimental and theoretical study of the Hanle electromagnetically induced absorption (EIA) resonances obtained using Gaussian and Π-shaped laser beam profiles. The two beams have the same total power and beam diameter. The laser beam propagates through the vacuum Rb gas cell and couples the closed $F_g = 2 \rightarrow F_e = 3$ transition of D2 line in ^{87}Rb. The influence of radial intensity distribution of the laser beam on coherent population trapping and electromagnetically induced transparency was previously studied in [1, 2], but to the best of our knowledge, there is no such study for the case of EIA transition. Comparison of linewidth and amplitude dependencies on laser intensity is presented. Experiment and theoretical model show that Gaussian and the Π-shaped beam profile yield different amplitudes and linewidths of the Hanle EIA resonances. Amplitudes change in a qualitatively similar manner for both profiles. With respect to the Gaussian beam, Π-shaped beam yields larger amplitudes at lower laser intensities, but lower amplitudes at higher intensities. Linewidths behave quite differently for the two profiles. There is very rapid increase at low intensities for both profiles. However, Π-shaped profile gives pronounced maximum at about 1 mW/cm^2 with consequent intensity narrowing, as noted earlier in [3], while Gaussian profile provides almost flat linewidth dependence at higher intensities.

In addition, we studied Hanle EIA resonances from selected small areas of the cross section of laser beam (Gaussian or Π-shaped), after the entire laser beam passes through the Rb vapor cell. In the case of Gaussian beam linewidths increase if the small area is closer to the beam center, while in a Π-shaped beam the resonances become gradually narrower as getting closer to the beam center. The increase of linewidths with approaching the beam center in the case of a Gaussian beam is dominated by power broadening, while the decrease of linewidths for Π-shaped beam is typical time of flight narrowing.

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PB3

COMPARISON OF BRIGHT RESONANCES IN MICROMETRIC AND CENTIMETER CELLS FILLED WITH Cs VAPOR

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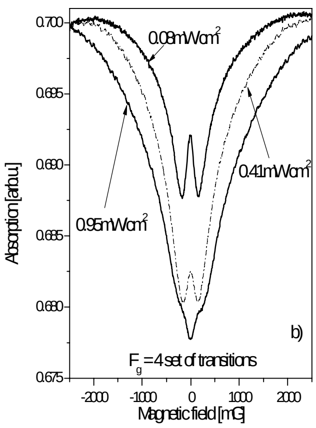

Fig.1 Bright resonance sign reversal observed at the F_g = 4 set of transitions. L=700mkm and T_{cell} = 34°C.

Hanle type resonances are mainly studied for alkali atoms in optical cells with centimeter dimensions. In absence of depolarizing collisions of the excited state, depending on the ratio of the degeneracy of the two states involved in the optical transition, sub-natural width resonance of both Electromagnetically Induced Transparency (EIT, dark resonance), and Electromagnetically Induced Absorption (EIA, bright resonance) can be observed [1].

Here we report on the EIA resonance study on the D_2 line of Cs atoms, confined in a cell with micrometric thickness (L=700μm, thin cell) and cell window diameter of about 1cm. This is of interest for miniaturization of practical optical sensors, which are involved in precise frequency standards/magnetometers [2,3]. In our experiment, the beam of a narrow-band diode laser, operating at λ = 852 nm is directed at the thin cell in orthogonal to its windows direction. In addition, a cell with L = 2.5cm is used, for comparison of the bright resonance behavior in both types of cells. Cs atom absorption is measured versus a magnetic field varied around zero value. For the L=700μm cell, a narrow EIA resonance is observed, superimposed on the bottom of a broader EIT resonance. With the enhancement of laser intensity, the bright resonance amplitude suffers fast reduction and even at very low intensity ($W < 1mW/cm^2$), the resonance sign reversal takes place (Fig.1). However, previous experiments in cm-cells have shown that the bright resonance is observed to higher than $200mW/cm^2$ intensities [1]. To test those results, the resonance profile was measured for the L = 2.5cm cell, under the same conditions as for the L=700μm cell. As seen from (Fig.2), no bright resonance sign reversal occurs for the cm-thickness cell. Further theoretical study is in progress to analyze

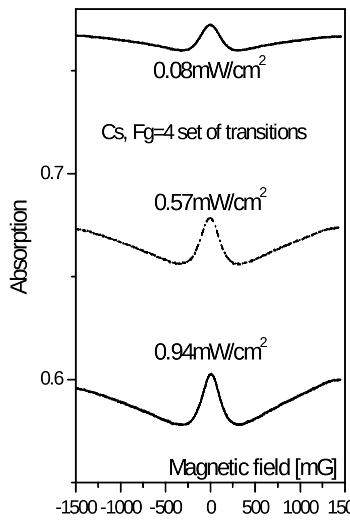

Fig.2 The bright resonance is stable with intensity; F_g = 4 set of transitions. L = 2.5cm, T_{cell} = 22°C.

the physical processes behind the bright resonance sign reversal with light intensity, which is observed for the L=700μm cell.

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PB4

POPULATION CONTROL OF Na EXCITED STATES BY MEANS OF INTERFERENCE DUE TO AUTLER-TOWNS EFFECT

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We will present our results on the application of Ramsey-type interference effects for population switching of excited states. Our calculations show that spatial distribution of the atomic excitation can be created and controlled by employing reversed Autler-Townes excitation scheme. Interference fringes in such Autler-Townes spectra have been reported in [1] for the case of a closed three-level system coupled by a resonant pulsed pump laser in the first excitation step, creating time-varying dressed states, excited by a probe pulse in the second excitation step. In our experiment, the dressed states are spatially varying – the two lasers are *cw* and cross a supersonic sodium, coupling an open three-level ladder system. The lasers are focused in such a way that a strong and short (tightly focused) pump laser couples the two lower levels $|g\rangle$ and $|e\rangle$, and weak and long (less tightly focused) probe laser couples the intermediate $|e\rangle$ and the upper level $|f\rangle$. The energy difference between the dressed states is determined by the pump field Rabi frequency and its detuning from resonance.

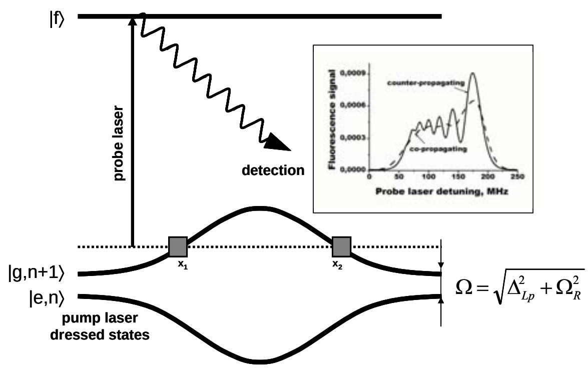

Fig.1. Interaction scheme

Our numerical calculations of the density matrix equations of motion using the split propagation technique show that with this arrangement the spatial distribution of the atomic or molecular excited state populations can be precisely controlled by varying the laser frequencies and intensities. When the frequencies of both laser are fixed, the excitation of the upper level can take place at two spatial locations (Fig.1). This leads to two possible pathways for level |f> excitation, where the probability amplitude of this level after the second crossing point is determined by the constructive or destructive interference of both excitation pathways. Our simulations show [2] that interference fringes in the excitation spectrum of the upper level can be resolved when counter-propagating laser beams are used to avoid residual Doppler broadening. We show that such Ramsey-type interferences of dressed states can be used for fast population control and switching. The experiment has been performed when the pump laser is tuned near the D_1 line of Na, and the final state is the $8S_{1/2}$. Possible applications will be discussed.

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PB5

EFFECT OF THE TRANSIT TIME ON THE TRANSITION BROADENING

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Transit-time effects are well-known phenomena, which manifest when the interaction time *T* of atoms or molecules with the laser radiation field is limited. The effects caused by finite *T* emerge in a vast number of applications. The finite time of flight τ_{tr} of the particles crossing the laser beam, as well as their velocity distribution introduce an additional inhomogeneous broadening mechanism, which leads to increase in the width of the spectral line profile. Thus the observed lineshape can be significantly larger than the natural width $\Delta\omega_{sp}$ of the optical transition, determined by the spontaneous lifetime of the excited state τ_{sp} [1].

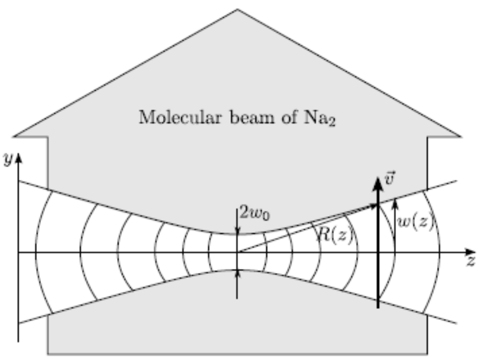

Fig.1 A molecule passing through a steady-state laser beam of Gaussian space intensity distribution

In the present work we analyze experimentally and theoretically the absorption line shapes $P(\Delta)$ of molecular optical transitions, resulting from the molecule-laser interaction in a supersonic beam (Fig. 1). We consider an isolated two-level system, excited with a weak laser beam of Gaussian intensity distribution, when the transit times τ_{tr} are comparable to the spontaneous lifetime τ_{sp} of the excited level.

In order to avoid residual Doppler broadening, our experiment is performed by measuring laser-induced excitation spectra of a three-level molecular ladder in a supersonic beam of Na_2 molecules. Two counterpropagating laser beams are focused onto the molecular beam and the fluorescence is detected. The first-stage laser field *P* couples the populated ground electronic level *g* with a lower excited level *e*. The second-stage laser field *S* couples both excited levels *e* and *f*, and is scanned across the resonant frequency of *e-f* transition. In order to model a two-level system, we exclude the intermediate state *e* with the help of large detuning from the one-photon resonance, making the *e*-level virtual.

We find analytical description of the fluorescence profile $P(\Delta)$ and show that it has a Voigt shape for an arbitrary ratio between τ_{tr} and τ_{sp}. We show that the spectral line broadening of the transition driven by focused Gaussian laser beam is a result of combined broadening mechanisms, arising from the curved electromagnetic field wave fronts and the increase in transit time along the laser beam propagation axis. We show that the spectral linewidth does not change along the propagation axis of the laser beam and it is a function of only one parameter – the laser beam waist size (when other broadening mechanisms like reabsorption, saturation and collisions are negligible). The theoretical predictions agree well with the experimental results.

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PB6

EFFECTS OF THE OPTICAL PUMPING IN NONLINEAR SPECTROSCOPY OF A Cs COLD BEAM

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We present the results of measurements of excitation spectra of cold Cesium atomic beam produced out of a pyramidal-MOT [1]. The beam features a flux density of about 10^{11} atoms/(cm^2s), with a longitudinal velocity around 10 m/s. Using transverse optical molasses, the residual beam divergence is reduced to below 5 mrad, corresponding to an average transverse atom velocity below 1 cm/s. The atomic beam was excited by a probe laser beam (∅ ≈ 1 mm) sent along a transverse direction, and the fluorescence detected at right angles by a photomultiplier. The probe laser frequency was scanned across the $F''=4 \rightarrow F'=5$ hyperfine

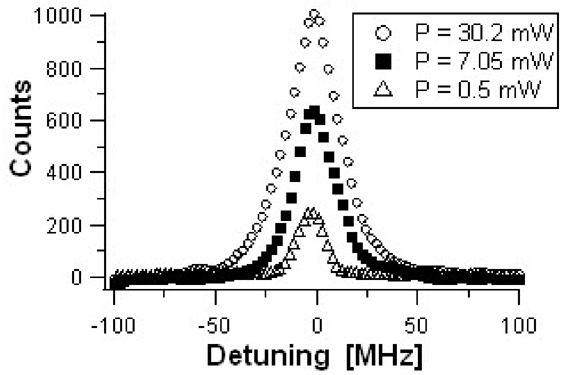

Fig.1. Emission spectra from the Cs laser-cooled atomic beam at three different values of the probe power: 0.5 mW, 7.05 mW and 30.2 mW

transition of the D_2 line of Cs atoms. Figure 1 shows examples of the probe excitation spectra acquired at different probe laser powers corresponding to intensity variations in the range 10^2-10^4 mW/cm^2, which is well above the respective saturation intensity (1.1 mW/cm^2). The observed power broadening of the spectra follows a strongly sub-linear behavior. Moreover, the simultaneous acquisition of the fluorescence image through a calibrated CCD, allowing us to determine the size and shape of the fluorescent spot, shows that the emitted photons stem from a larger volume at larger probe intensity.

We attribute the experimental finding to two factors: (i) Gaussian spatial intensity distribution of the probe laser field and (ii) optical pumping due to mixing between *F'* = 5 and *F'* = 4 HF components of the $6P_{3/2}$ state by the relatively strong probe field. The effect of the first factor is well known and leads to spatial expansion of the glowing zone. The second factor turns out to be more important under our unique experimental situation when the transit time ~10^{-4} s exceeds the natural lifetime τ=30.5 ns in ~$3{\cdot}10^3$ times. The strong coupling between the ground *F"* = 4 and the excited *F'* = 5 HF levels creates two dressed states ($d_{+,-}$), which share the population of both initial HF levels. The probe field mixes the *F'* = 4 HF of $6P_{3/2}$ into the dressed states, thus opening a channel for optical pumping and resulting in depletion broadening of the excitation spectra. Adopting the treatment of optical pumping [2] for our inhomogeneous spatial conditions we obtained a qualitative explanation of the observed broadenings.

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PB7

SPECTROSCOPY OF MICRO-FABRICATED Cs VAPOURS CELLS FOR MINIATURE ATOMIC CLOCKS

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We present our spectroscopic studies on Coherent Population Trapping (CPT) in micro-fabricated Caesium cells and our evaluation of its application in miniature atomic frequency standards. In an atomic clock, the frequency of a quartz oscillator is stabilized to the ground-state hyperfine transition F=3, m_F=0 → F=4, m_F=0 of Cs atom. Probing this transition by CPT spectroscopy overcomes the traditional need for a microwave cavity, and in combination with micro-fabricated Cs cells allows a strong miniaturization of the clock. The Cs vapour cells were realised using anodic bonding and different techniques for Cs dispensing [1]. A DFB laser diode [2] emitting around 894nm and an Electro-Optical Modulator (driven at 4.6 GHz) were used to create the coherent two-colour optical source for exciting the CPT resonance.

In a recent work, we have shown that it is possible to obtain a quadratic temperature dependence of the CPT central frequency with a single buffer gas [3] and reported on our preliminary frequency stability measurements [4]. Here, we present our analysis of the CPT resonance as a function of the main laser-related parameters, such as light-shift and light broadening effects, and with different buffer gases in order to optimise the short, medium and long-term frequency stability of the atomic clock.

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PB8

COMPARISON OF DARK RESONANCES FOR Cs VAPOR CONTAINED IN OPTICAL CELLS OF DIFFERENT THICKNESSES

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Recently significant effort has been devoted to the development of miniaturized atomic clocks and magnetometers based on dark resonances (DR). DRs have been prepared in Cs atoms confined in submillimeter-thickness (thin) cell with high pressure buffer gas added to prevent frequent collisions of alkali atoms with the cell walls [1]. The DR contrast measured in the thin cells is similar in magnitude to that obtained in centimeter-sized cells, but substantially more laser intensity is needed when sufficient buffer-gas pressure is used. The buffer gas broadens the excited states of the alkali atoms, which limits the pumping efficiency and compromises the performance of vapor cell clock and magnetometer. A promising strategy for increasing atom interaction time consists in the use of antirelaxation-wall coated cells; however, high atomic-vapor densities are limited owing to coating degradation with temperature [2].

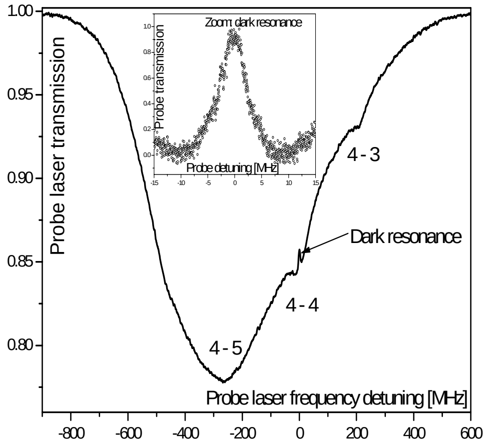

Fig.1: DR observed in the probe laser transmission spectrum.

We present our study concerning the comparison of DR parameters, prepared on the D_2 line in pure Cs vapor, for two cell thicknesses: (i) several centimeters (conventional cell) and (ii) 700μm (thin cell). In a thin cell, the atomic interaction time with a laser beam (propagating perpendicular to the cell windows) is highly anisotropic. Atoms moving nearly parallel to the cell windows have long interaction times compared to atoms moving in the direction perpendicular to the windows. The advantage of such approach is that mainly the first group of atoms contributes to a narrow DR signal [3]. The bichromatic light field for the DR spectroscopy was provided by two independent narrow-band DFB diode lasers: pump (with frequency fixed at the $F_g = 3 \rightarrow F_e = 4$ transition) and probe (scanned around the $F_g = 4$ set of transitions). No magnetic field shield was used. A sub-natural width DR is observed for the conventional cell (Fig.1). No significant broadening occurs for the DR prepared in the thin cell. Moreover, our experiments have shown that the thin-cell case is much less sensitive to the magnetic field gradients, laser beam overlapping and the mutual coherence of the two independent lasers. The development is in progress of a theoretical model to analyze quantitatively the potential for application of thin cells without buffer gas filling in miniaturized atomic clocks and magnetometers.

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Acknowledgements: The work is partially supported by the Bulgarian NCSR (grant No: DO 02-108/22.05.2009) and Indian -Bulgarian (BIn-2/07) bilateral contract**.**

PB9

ELECTROMAGNETICALLY INDUCED TRANSPARENCY AND DICKE NARROWING RESONANCES IN NANOMETRIC Cs-VAPOR LAYERS

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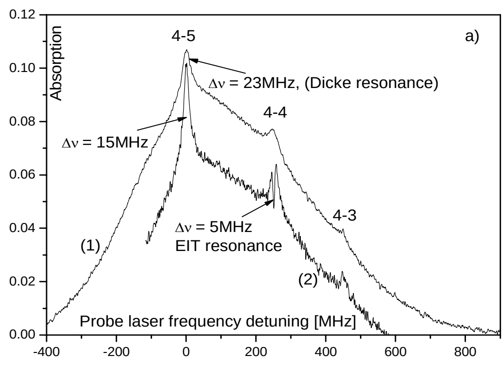

Fig.1 EIT and Dicke resonance: (1) probe laser is scanning on the F_g = 4 set; (2) coupling laser is fixed at 3 - 4 transition. The curve (2) is shifted for convenience.

Electromagnetically Induced Transparency (EIT) has found many applications. A significant effort has been recently oriented to the development of miniaturized atomic clocks and magnetometers, based on sub-millimeter-thickness cell filled with alkali vapor and high-pressure buffer gas. Only few works are devoted to EIT study in Extremely thin cells (ETC) with nanometric thickness [1,2].

Here we present the first results related to EIT preparation in ETC with thickness L = 1.5λ, where λ = 852nm is the wavelength of the laser light resonant with Cs D_2 line. The ETC is an atomic-vapor container where the distance L between two cell windows is much smaller than the other dimensions, and the time of atom-light interaction is highly anisotropic. Atoms moving nearly parallel to the cell windows have long interaction times compared to atoms moving orthogonal to the windows. This property of ETC could make possible the cell miniaturization without buffer gas using. In addition, the L = 1.5 λ case provides the possibility to study the EIT jointly with the Dicke-type coherent narrowing of optical transition [3]. We illustrate our results related to the ETC spectrum on the set of transition starting from the ground hyperfine (hf) level F_g = 4, obtained by scanning a narrow-band (2MHz) probe laser (Fig.1). If the probe laser is of low intensity (0.3mW/cm^2), narrow Dicke resonances occur, centered at the 4 → 3,4,5 hf transitions - curve (1). Of highest amplitude is the resonance at the closed 4 → 5 transition. To obtain an EIT resonance, a coupling laser (35mW/cm^2) is involved, fixed at the 3 → 4 transition, staring from F_g = 3. The EIT resonance, centered at 4 → 4 transition - curve (2), is of sub-natural width, proving that it is based mainly on atoms flying parallel to cell windows. Note that in the ETC, the dephasing rate of ground levels for the atoms moving orthogonal to the windows is ~ 70 MHz. While is clear that the centered at the 3 → 4 transition laser causes accumulation on the F_g = 4 level of Cs atoms with small velocity projection on the laser beam direction, it should be stressed that the Dicke resonance amplitude at the 4 → 5 transition is strongly enhanced by the coupling laser. Moreover, some narrowing of Dicke resonance is observed. Beside for optical cell miniaturization, the proposed two-laser approach could be advantageous for further Dicke effect study in ETC, because still it is not experimentally clarified what are the contributions of different-velocity-class atoms to the Dicke narrowing.

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Acknowledgements: The work is partially supported by the Bulgarian NCSR (grant No: DO 02-108/22.05.2009) and Indian -Bulgarian (BIn-2/07) bilateral contract**.**

PB10

COHERENT POPULATION TRAPPING RESONANCE STRUCTURE IN PARAFFIN-COATED Rb VAPOR CELLS

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The increase of the interest in the Coherent Population Trapping (CPT) resonances and processes which determine their shape is result of the fast development of their applications and the need of good magnetooptical sensors [1]. In this work the shape and width of the CPT resonances are investigated in different paraffin-coated Rb vapor cells from point of view of building of miniature and sensitive detector.

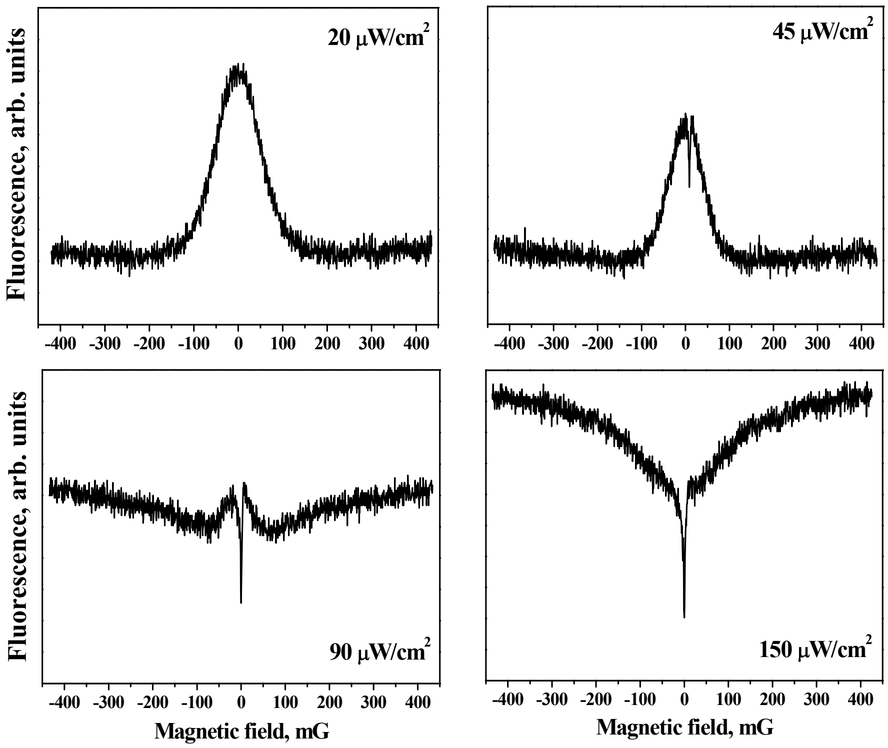

Fig.1. Shape of the CPT resonance registered in fluorescence on laser power density in paraffin-coated Rb vapor cell on the D_1 ^{87}Rb line (F_g=2→F_e=1 transition).

It is known that the resonances have complex shape [2]. In Fig. 1 the development of the resonance shape with the laser power in paraffin-coated Rb cell is presented. The influence of different processes on the shape of the resonances is analyzed and their contribution to the resonance width is evaluated.

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Acknowledgements: The work was supported by the Bulgarian National Science Fund (Grant No: DO-02-108/2009).

PB11

CHARACTERIZATION OF A Rb MAGNETO-OPTICAL TRAP

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The physics with ultra-cold atoms and its application attract the attention of the scientists. The production of ensembles of cold atoms in magneto-optical traps has become a routine task in the last years. We are going to report on the characterization of the first Magneto-optical trap in Bulgaria, which has been settled in the Institute of Solid State Physics, Bulgarian Academy of Sciences.

A glass cell with anti-reflection coating on the windows is used. The vacuum in the cell is in the order of 10^{-10} Torr. Rubidium vapour is introduced to the vacuum cell and is controlled by heating of a commercial vapour source (Alrasource) with natural abundance of ^{87}Rb and ^{85}Rb isotopes. The cloud of cold rubidium atoms is produced by usage of home-made diode lasers in Littrow scheme stabilized by DAVLL. A retro-reflected optical configuration has helped to assure enough power in the laser beams for the efficient optical trapping of the Rb atoms. Diagnostics of the Magneto-Optical trap is made by observation of the fluorescent signal.

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PB12

EXPERIMENTAL SET-UP FOR LASER-INDUCED BREAKDOWN SPECTROSCOPY (LIBS) ANALYSIS AND APPLICATION IN ARCHAEOLOGY

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In the last years Laser-induced breakdown spectroscopy (LIBS) is a promising technique for diagnostic and elemental analysis of the material composition, identification and classification of objects of cultural heritage [1].

The method using LIBS analysis of archaeological artifacts and modern technique is used for the first time in Bulgaria. LIBS analysis gave possibility to distinguish groups of objects on the base of composition of the alloys which will gave the archaeologists possibility to interpret better the artifacts not only stylistically.

The experimental set-up arranged in our laboratory consists a pulsed Q-switched Nd:YAG laser, operating at the fundamental frequency, wavelength λ=1064 nm. The duration of the laser pulses is $t \approx 10$ ns and repetition rate 10 Hz. The laser beam is guided toward sample by set of mirrors (type LASEROPTIK) and focusing lens. The energy of the laser pulses is reduced to 5-10 mJ using variable attenuator (type LASEROPTIK). The light emitted from the plasma is collected with an optical fibre and detected by Eschelle spectrometer (type Mechelle 5000) and a multichannel detector (ICCD) (type ANDOR DH 734-18F-03) having 1024 x 1024 pixels.

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Acknowledgements: This work was financially supported by the project "Laser diagnostics in archaeology", DO 02-274/2008, financed from the Bulgarian National Science Fund.

PB13

NEW NARROW RESONANCE IN THE FLUORESCENCE OF CLOSED OPTICAL TRANSITION OBSERVED IN NANOMETRIC Cs-VAPOR LAYERS

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In addition to the first observation of narrow and well resolved fluorescent spectra in Extremely Thin Cell (ETC) [1], recently it has been demonstrated [2] that even narrower dips appear in the fluorescence profiles, at ETC thickness L = λ. These saturation dips occur for open hyperfine transitions of Cs D_2 line. No dip has been observed in the fluorescence of genuinely closed 4-5 transition. For later transition and using a narrow band (few MHz) diode laser, even a tiny peak in the fluorescence has been demonstrated [3], for L = 6λ cell and very low atomic source temperature (48 °C).

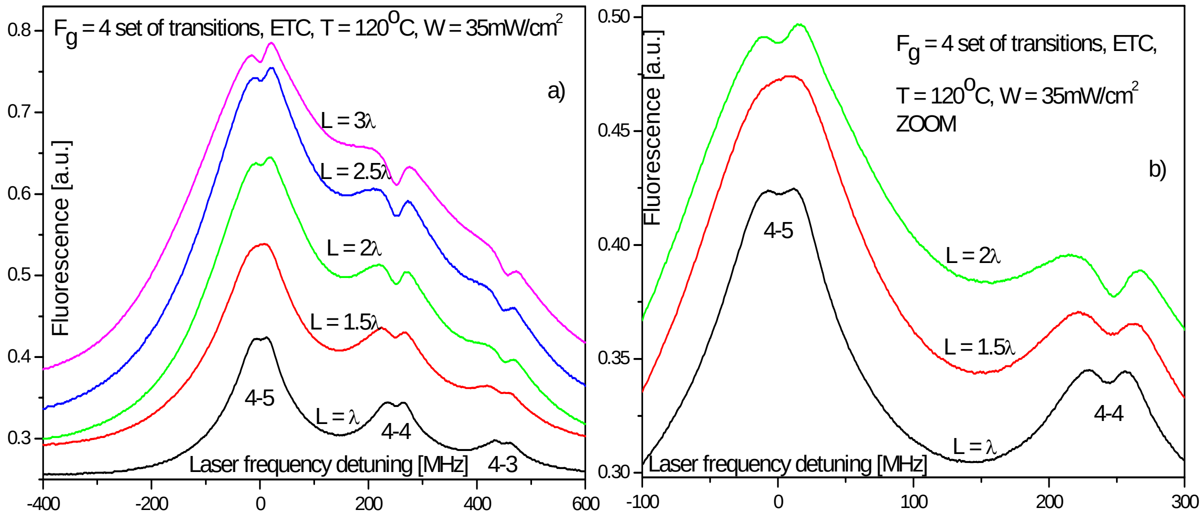

Fig.1 Fluorescence spectra (a) of the D_2 line of Cs, observed in ETC with thicknesses L = λ, 1.5λ, 2λ, 2.5λ, 3λ. Zoom (b) is showing the behavior of 4-5 closed transition fluorescence for L = 1.5λ (Dicke revival) and L = λ, 2λ (no Dicke effect).

In this communication we report the first observation of a narrow, reduced fluorescence dip also in the profile of the closed 4-5 transition, which is illustrated in Fig.1. Here, a different ETC and much more stable than in [2] laser were used. For the open 4-4 and 4-3 transitions, dips in the fluorescence occur starting from L = λ, while in [3] the start point was L = 2λ. For ETC temperature of 120^0C and higher, a dip in the 4-5 transition fluorescence is observed even for L = λ, while for lower temperature (85^0C) – only for L = 3λ. Note that no dip in the 4-5 transition fluorescence appear, where (L = 1.5λ) a well pronounced Dicke revival takes place. Theoretical modeling of the fluorescence will be presented to discuss the possible reasons for the new dip observation in the fluorescence of genuinely closed transition.

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PB14

NON-THERMAL STABILIZATION OF LARGE SODIUM VAPOUR DENSITIES

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The possibility to create and control atomic vapour densities with known precision is a key requirement for photonic applications. So far, the techniques developed to fulfill this demand have been based on heating, with three main drawbacks: thermal inertia, power consumption and potential exposure to degradation and damaging.

In this presentation, we implement a compact, cheap and fully automatic system to create and stabilize large densities of Na vapour at room temperature, based on the so-called Light-Induced Atomic Desorption, thus avoiding the drawbacks listed before [1]. LIAD is a non-thermal effect due to the photoejection of alkali atoms trapped in organic coating surfaces [2] or in porous materials such as nanoporous silica [3] or alumina [4]: under non resonant and weak illumination, a sudden release of atoms is observed, which increases the atomic density over the thermal equilibrium [2].

We show that, by shining a poly-dimethyl-siloxane (PDMS) coated glass cell containing Na by means of a cheap 435 nm LED, it is possible to increase the atom density at room temperature up to several orders of magnitude larger than the thermal equilibrium value.

By using the fluorescence signal both as a monitor and as a feedback, our system allows for automatic compensation of the progressive depletion of the coating, thus avoiding the reduction of vapour density due to adsorption/desorption rate changes. We obtain a preset Na density of 5.6×10^9 atoms/cm^3 at room temperature and keep it stable for more than 20 minutes with a precision better than 1%. Our system is suitable also for modulating the atomic density according to preset functions, such as sawtooth or sinusoidal, with the response time depending on the adsorption rate and the maximum frequency achievable limited by the amount of modulation required.

In conclusion, we demonstrate the feasibility of a compact, cheap, harmless, power-saving system based on LIAD to create and stabilize high alkali atoms vapour densities at room temperature; its characteristics and its flexibility make our system particularly appealing for photonic sensing, especially in biomedical applications, but also for more fundamental fields where a controlled atomic density is required, such as in CPT-related experiments [5].

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PB15

MULTIPLE PEAKS DUE TO EIT AND AUTLER-TOWNES EFFECT IN LAMBDA-PROBING OF THE STRONGLY DRIVEN $5P_{3/2}$ MANIFOLD OF COLD ^{85}Rb ATOMS IN MOT

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Electromagnetically induced transparency (EIT) and Autler-Townes (A-T) effect in lambda configuration were studied under conditions of strong coupling of the hyperfine manifold $5P_{3/2}(F')$ with the ground state $5S_{1/2}(F=2)$ of cold ^{85}Rb atoms in magneto-optical trap (MOT). Registered spectra of absorption of a weak beam, tuned across $5S_{1/2}(F=3)\rightarrow 5P_{3/2}(F')$ transitions, were interpreted by applying a 5-level optical Bloch equations model (similar to that considered in [1]) and its modifications. See Fig. 1 for the scheme of levels and transitions.

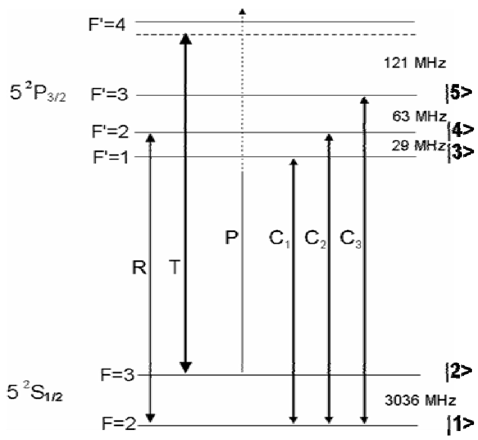

Fig. 1 Levels of ^{85}Rb atoms interacting with laser beams in the considered lambda scheme. The arrow P is for the tuned probing, and C_1, C_2, C_3 for the coupling-transitions at resonance. C_1 is not directly probed because the $F = 3 \rightarrow F' = 1$ transition is dipole-forbidden. However, the coupling C_1 was found to be imprinted into the spectra *via* multiphoton transitions. The five states |i> considered in the model are marked. The spectra were registered with the coupling beam at various detunings from C_j resonances. The trapping and repumping beams (T and R) were weak and are neglected in the model.

The spectra are dependent on mutual polarizations of the two laser beams. This indicates that transitions between magnetic states m_F *and* $m_{F'}$ have to be considered, which are not accounted for within the 5-level model. *E.g.*, with the coupling field at the C_3 (or C_2) resonance, a peak with polarization-dependent amplitude is observed at the absorption line center, where an absorption minimum due to A-T/EIT is expected. We interpret the presence of this peak as an effect of absorption to uncoupled $m_{F'}$ states [2]. To mimic other m_F- *and* $m_{F'}$-dependent characteristics, not reproduced within the 5-level approximation, we supplemented the 5-level model with two 4-level models, and a fairly good reproduction of the observed spectral features was obtained.

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PB16

ON THE USE OF EFFECTIVE RABI FREQUENCY AS A GLOBAL MOT PARAMETER DEPENDING ON THE MEAN TRAPPING BEAM POWER

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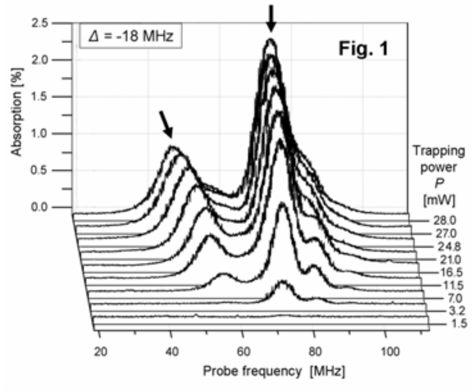
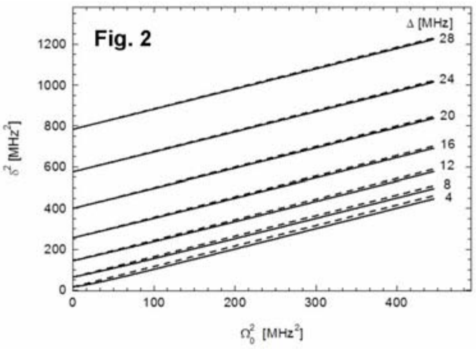
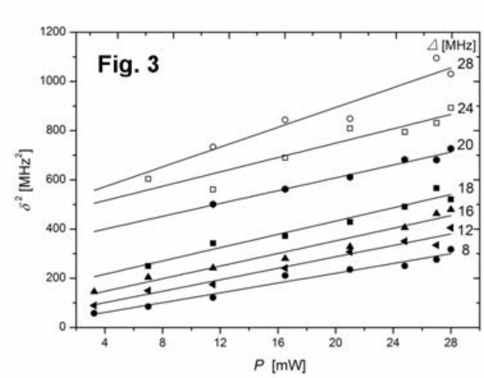
An analysis is presented of the pump-probe spectra of a weak beam absorption in our operating ^{85}Rb MOT with the trapping beam acting as a pumping beam. We have shown that, despite the complex nature of the space-dependent interactions of atoms with MOT fields [1], it is possible to determine a range of trapping beam detunings Δ (and mean intensities P), in which the probed MOT region can be characterized by an effective Rabi frequency related to the mean laser power in an analogical way as the Rabi frequency for a single atom interacting with the local field **E** is related to its power.







The experiment was performed in a standard 6-beam MOT described in [2]. The cascade scheme $5S_{1/2}(F=3) \rightarrow 5P_{3/2}(F'=4) \rightarrow 5D_{5/2}(F'')$ was studied. The trapping beam negative detunings Δ from the first-step resonance and intensity P were varied stepwise within the ranges of the possibly stable MOT operation and of detectable absorption spectra. For each given (Δ, P), the probe beam frequency was tuned and the absorption spectrum in the second step of the cascade was registered. Due to Autler-Townes (A-T) effect caused by the first-step strong field, the three *hfs* components of ... ved tr... In 85... ine 5...

Due to this and to A-T splitting and broadening, the absorption spectrum is dense with partially overlapping peaks. However, the pair of peaks, corresponding to $F'=4 \rightarrow F''=5$ transition, clearly dominates; see arrows in Fig. 1, showing an example of power-dependent spectra for Δ=18 MHz. We have taken the distance δ between such peaks for analysis.

We have used a 3-level model of optical Bloch equations. It predicts, for the parameters realistic for our experiment, a nearly linear dependence $\delta^2(\Omega_0^2)$, Ω_0 being the Rabi frequency, and the plots nearly overlap with plots of the squared generalized Rabi frequency $\Omega^2 = \Omega_0^2 + \Delta^2$, marked in Fig. 2 by dashed straight lines.

It has turned out that in the range of Δ (which is most often used in our MOT) the plots of experimental $\delta^2(P)$, drawn with full points in Fig. 3, can be fitted to almost parallel straight lines $\delta^2 = a + bP$. Therefore, we ascribe the mean $\sqrt{b}$, in this range, to the constant $\sqrt{B}$, scaling the values of the effective Rabi frequency Ω_0^{eff} with P, as $\Omega_0^{\text{eff}} = \sqrt{BP}$, in analogy to the relation used for Ω_0 for a single MOT atom in its local **E** field. The determined $\sqrt{B}$ amounts to 3.5(2) MHz/$\sqrt{\text{mW}}$. The value, as well as the limits of the method, should be checked for each new alignment, change of the magnetic field gradient, *etc*.

The term of effective Rabi frequency, as used in the literature, is defined in a similar way as here, but often without discussion of the limits of its validity.

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PB17

FOUR CHANNEL HOLOGRAPHIC INFRARED OPTICAL ELEMENT

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Holographic optical elements (HOEs) exhibit unique properties for optical metrology. The paper presents a HOE for a phase-stepping digital electronic speckle pattern interferometry. More specifically, the proposed HOE allows for simultaneous reconstruction of four virtual and parallel to the HOE surface reference planes with two pairs of wavelengths at off-axis illumination. In this way we transform a two-beam interferometer into a multiple beam interferometer (actually, four separate channels) for precision full-field displacement measurement of the object under loading. Since it is not possible to record the HOE directly in the IR region, recording should be performed in the visible part of the spectrum. After the additional chemical treatment, the spectral maximum can be shifted for correct reconstruction into the IR region. The availability of affluent options of lasers with comparatively close wavelengths in the IR region facilitates the choice of coherent light sources for reconstruction. In addition, the following obligatory requirements have to be set on the HOE: i) optimal diffraction efficiency at the working wavelength (790 nm and 830 nm); ii) minimal absorption in the IR region; iii) simultaneous reconstruction with two pairs of wavelengths.

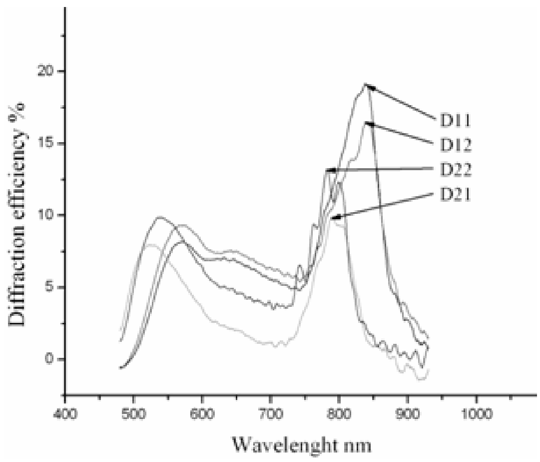

Fig.1: Spectral diffraction efficiency of four records in the optical element

The HOE was constructed as a sandwich structure of two reflection (Denisuyk type) holograms. For recording of holograms we used a silver halide emulsion with super high resolution - over 10 000 line/mm. Each of the holograms represents two records of a diffuse metal object illuminated under 30^0 to the normal. This permits observation in normal direction of four reference holographic images, which interfere with the beam reflected from the object. Both holographic reflection records were made successively on a single holographic plate. In a such way we form four independent optical channels using two laser beams at 790 nm with *S* and *P* polarizations, as well as two *S* and *P* polarized beams at 830 nm.

PB18

DYNAMIC LASER SPECKLE FOR NON-DESTRUCTIVE QUALITY EVALUATION OF BREAD

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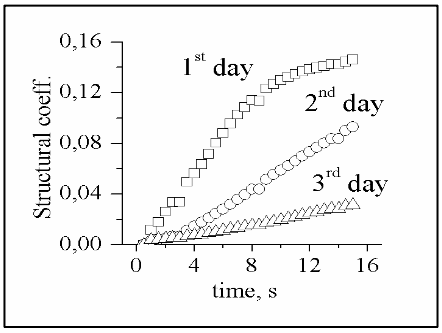
Coherent illumination of a diffuse object yields a randomly varying interference pattern, which changes over time at any modification of the object. This phenomenon can be used for detection and visualization of physical or biological activity in various objects (e.g. fruits and seeds) through statistical description of laser speckle dynamics [1]. The present report aims at nondestructive quality evaluation of bread by spatial-temporal characterization of laser speckle. In the set-up for acquisition and storage of dynamic speckle patterns an expanded beam from a DPSS laser (532 nm and 100mW) illuminated the sample through a ground glass diffuser. A CCD camera, adjusted to focus the sample, recorded regularly a sequence of images (8 bits and 780 x 582 squared pixels, sized 8.1 × 8.1 μm) at sampling frequencies 2 Hz and 0.5 Hz during a chemical and physical process of bread's staling. Several statistical approaches based on the concepts of first and second order statistics were applied to the full images in the sequence or to the time histories of single pixels. Segmentation of images into matrixes of isometric fragments was also utilized. Different algorithms were assessed for display of speckle pattern activity as speckle contrast analysis, spatial-temporal speckle correlation techniques, analysis of histograms for subtraction between successive speckle patterns, signal decomposition using Fourier and discrete wavelet transforms, determination of energy in different frequency bands.



As an example, the embedded figure shows that the speed of decrease of the mean square of the difference (the so called structural coefficient) between the first and successive images in the sequence is subject to conditions of the bread freshness, moisture and preservation for the three days of measurement.

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PB19

ABSORPTION AND NMOR RESONANCES DUE TO RAMAN RAMSEY INTERFERENCE IN DARK AND BRIGHT COHERENT STATES

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We have compared, experimentally and theoretically, absorption and nonlinear magneto optical rotation resonances for dark and bright long-lived Zeeman coherences in the D_1 and D_2 line of ^{87}Rb, for linearly polarized input laser light, by applying spatially separated laser fields. The transmission of the probe beam, placed inside the hollow pump beam, shows the narrowing of the Hanle resonance (at the external magnetic field B=0) by Raman-Ramsey effect. We observe Ramsey fringes whose separation from the central peak depends on the distance between the beams [1]. Our configuration of spatially separated hollow pump and coaxial probe beam provides sufficient flux of coherently prepared atoms in the probe beam thus enabling first observation of narrow Ramsey fringes in the probe NMOR in vacuum cells [2].

In the experiment, the extended cavity diode laser is locked to either D_1 line open transition Fg=2→Fe=1 or D_2 line closed transition Fg=2→Fe=3 in ^{87}Rb. In case of the open transition we observed Hanle EIT resonances by Ramsey interference effects between the phase-oscillating dark state and the probe beam electric filed, and in case of the closed transition we observed Hanle EIA resonances because of interference effects with bright state. The shape of the Hanle and probe NMOR resonances at different spacing between pump and probe beams and for different orientation of the polarization of the pump and the probe beam is explained through interference between the pump prepared atomic coherence and the probe laser field.

Experimental results are in agreement with the results of the model which calculates probe fluorescence and rotation of the probe polarization by solving time dependent optical Bloch equations, following the atom through three distinct regions of the Ramsey experiment: pump beam, dark region between two lasers and the probe beam. The results for total excited state populations were averaged over atomic velocities distribution.

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PB20

COUPLING-PROBE LASER SPECTRA OF Cs D_2 LINE: DEPENDENCE ON OPTICAL CELL THICKNESS

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Similar to Electromagnetically Induced Transparency (EIT) and Electromagneticaly Induced Absorption (EIA) prepared in Hanle configuration [1], the interaction of a degenerate two-level system with coupling and probe light beams gives rise to such type of resonances [2]. Most of the experiments are in alkali cells, while few utilize atomic beams.

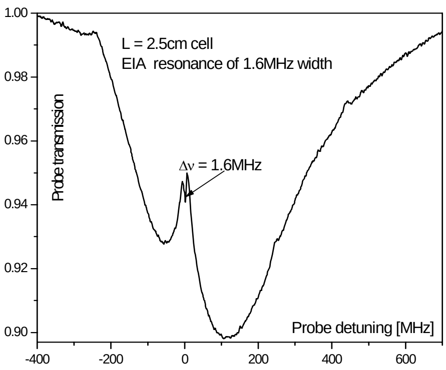

Fig.1 EIA resonance: the coupling laser (65mW/cm^2) fixed close to the 4–5 transition; probe laser (1.8mW/cm^2) scanned along the F_g=4 set of transitions.

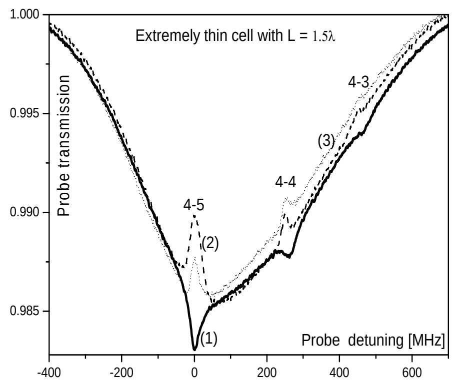

Fig.2 Probe laser (0.6mW/cm^2) spectra (F_g=4 set) in the L=1.5λ cell: (1) no coupling laser; (2) coupling (30mW/cm^2) at the 4-5 transition; (3) coupling at the 4–4 transition.

We present a comparison of coupling-probe spectra of Cs atoms (D_2 line) contained in a cell of thickness L = 2.5cm and an extremely thin cell [3] of L = 1.5λ (λ = 852nm). Two mono-mode DFB lasers were used with orthogonal linear polarizations. In the L = 2.5cm cell, a sub-natural-width EIA resonance was observed in the transmission of probe laser scanned on the F_g = 4 set (Fig. 1) with the coupling laser fixed within the 4-5 transition. The EIA resonance is on the top of a broader, enhanced transmission resonance. In addition to [2], the F_g = 3 set of transitions is also examined showing EIT resonance in the probe transmission on the F_g = 3 set with the coupling fixed within the 3-2 transition. For the L = 1.5λ cell, our experiments show no sub-natural-width resonance in the probe transmission when the coupling laser is fixed successively at 4-5, 4-4 and 4-3 transitions. Only broader velocity selective optical pumping peaks in the transmission occur (Fig.2). It should be stressed that under the same conditions, EIT resonances are easily observed when coupling the $F_g = 3$ and 4 levels to an excited level.

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PB21

PHOTOREFLECTANCE STUDY OF INDIUM SEGREGATION IN THE InGaAs QUANTUM WELL

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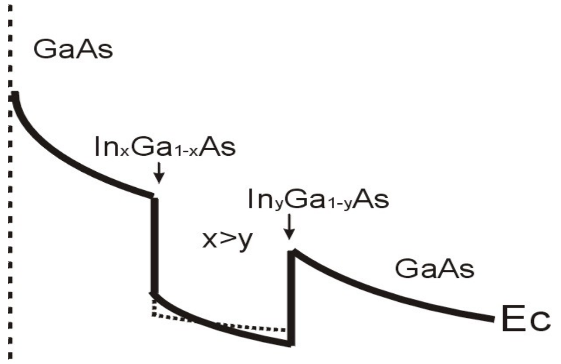

Fig.1. Indium segregation induced band shift

Realization of high-performance InGaAs/GaAs based devices requires flat and abrupt quantum well (QW) interfaces. The main reason of interface broadening in InGaAs/GaAs structures is a surface segregation of indium atoms [1]. Many experiments both in situ and ex situ were devoted to the investigation of indium profile in InGaAs layers grown by MBE and MOCVD [2 and references there]. We report the results of photoreflectance (PR) studying of the indium segregation process during the MBE growth of InGaAs QW.

The investigated sample was grown on semi-insulating GaAs (001) substrate by MBE. The $In_{0.5}Ga_{0.5}As$ QW was placed between GaAs barriers. The QW parameters are controlled by Talystep profilemeter. The sample was undoped and the QW is placed into space charge region (SCR) (20 nm far from the surface).

The PR lines were observed in the energy range from 1.32 to 1.40 eV. These lines are connected with the interband transitions in the QW. Our calculations show that observed lines are the 1e-1lh and 1e-h zone types. There is no line of 2e-2hh type, which is typical for QW placed into SCR. This fact is connected with the indium segregation in the InGaAs QW which leads to the flat bands regime in the QW (see dots at figure) and, hence, realizes the parity selection rules. The segregation parameters (segregation length and segregation ratio) have been calculated from the segregation induced bands shift.

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PB22

MINIATURIZATION OF FREQUENCY REFERENCE BASED ON MICROMETRIC VAPOR LAYER FLUORESCENCE SPECTRUM

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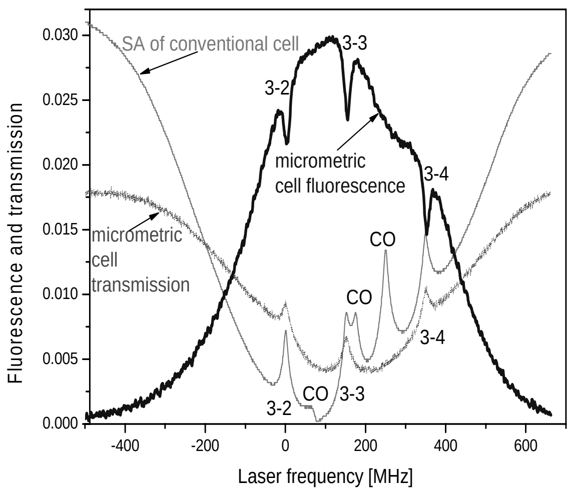

Fig.1: Fluorescence and transmission spectra, for micrometric cell with L = 6λ. SA spectrum in the probe beam transmission, for L= 2.5cm cell.

Creating frequency reference by Saturated Absorption (SA) spectroscopy of atomic transitions is well known two-light-beam technique [1]. A disadvantage could be the presence of close in frequency hyperfine atomic transitions. When the hyperfine splitting is comparable with the transition natural width the crossover (CO) resonances, which occur between the hyperfine resonances, can mask them not allowing one to obtain good frequency reference. The extreme reduction (to several microns) of the thickness L of optical cells, filled with alkali vapor, has provided a new way for suppressing the CO resonances in the transmission [2]. An advantage is taken of the short atom light interaction (i.e. low contribution) for atoms with large projection of the velocity in the direction of the laser beam, oriented orthogonally to cell window. Atoms with small velocity component over the beam (of a millimeter diameter) direction interact with the light much longer, thus, forming a narrow resonance centered at the hyperfine transition and measurable by single beam technique. It has been also shown [3] that tiny narrow dip occurs in the fluorescence observed in cell with L = λ; λ = 852nm (Cs D_2 line).

Here we present our experimental and theoretical results, demonstrating that a small increase of L results in a strong rising of the contrast of the dip occurring in the fluorescence on Cs D_2 line, still avoiding the CO resonances. Moreover, the dip is observed by single beam spectroscopy and exhibits lower width than that of the peak observed in the transmission. As radiation source, a DFB diode laser is used, operating in single-frequency mode with λ = 852 nm and line width of 2-3 MHz. For L = 6λ cell, the dip contrast improvement of more than an order of magnitude is achieved compare to the observations reported for L = λ in [3]. On the Fg = 3 set of transitions (Fig.1), only three very well resolved fluorescence dips are observed of less width than that of resonances occuring in SA and transmission spectra. Note that the SA spectrum observed in the conventional (L = 2.5cm) cell is much more complicated than the three-dip spectrum in the L = 6λ cell fluorescence. Our theoretical simulation confirms the experimental results, showing that the contrast of sub-Doppler features, observed in the fluorescence profiles, strongly increases with the micrometric cell thickness (in the region of several microns).

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PB23

ELECTROMAGNETICALLY INDUCED TRANSPARENCY OF Rb ATOMS IN TRAVELLING AND STANDING WAVE FIELDS

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Coherent spectroscopy like electromagnetically induced transparency (EIT), coherent population trapping (CPT), electromagnetically induced absorption (EIA), lasing without inversion (LWI) have been studied extensively for its potential applications in the fields of quantum information, quantum computation, atomic clock etc. EIT was investigated mostly in travelling wave though standing wave field can change its property significantly [1, 2]. We have observed EIT resonances using both travelling and standing wave laser fields in a Doppler broadened lambda (Λ) type multi-level atomic system. Utilizing the D_2 transition of Rb atoms at room temperature EIT resonances are studied. Modification of EIT peak along with other velocity selective enhanced absorption dips in presence of a strong standing wave control field are studied. The narrow resonances can be moved along the probe Doppler profile are observed with the shift of control laser frequency. The optical property of an atomic medium periodically varies owing to the interference of two strong coupling fields. The medium becomes transparent to the probe beam at the antinodes of the standing wave while at the nodes the medium is still opaque. This spatial modulation of the refractive index of the medium known as electromagnetically induced grating (EIG) can diffract the probe laser beam [3, 4]. We will observe this diffracted beam which carries the information of the induced grating. EIG signal has many advantages over the EIT signal. Recently, it is used for the storage of light pulses and construction of optical switches [5].

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PB24

MODELING OF SPECKLE NOISE IN THE INTERFEROMETRIC PHASE-STEPPING PHOTOLASTIC-COATING STRESS ANALYSIS

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An interferometric phase-stepping realization of the photolastic-coating method is an effective approach to separate the stress components over the tested specimen. For the purpose, a series of six photoelastic fringe patterns are recorded at preliminary known orientations of the polarization elements in a circular polariscope to build both isochromatic and isoclinic phase maps which give the loci of points with a constant difference of principal stresses and constant principal stress direction respectively. In addition, holographic recording of four fringe patterns is applied for retrieval of isopachic fringes which give the sum of principal stresses. The easiest way to perform a combined polariscopic and holographic measurement for full-field stress analysis is to use a laser light source. However, the speckle noise at coherent illumination violates the requirement for high signal-to-noise ratio in the recorded patterns and worsens the accurate phase estimation and unwrapping. Reliable phase retrieval of isochromatics, isoclinics and isopachics requires speckle noise reduction and normalization of the fringe patterns recorded with a laser light. The goal of the present paper is to create an adequate model of the full-field photoelastic measurement and to evaluate the quality of the phase retrieval after denoising. The developed model is based on calculation of the complex amplitudes in a Mach-Zender interferometer combined with a circular polariscope. When the shutter in the reference beam is closed, the system operates as a circular polariscope for photoelastic measurement of isochromatics and isoclinics. The signal-dependent noise model is assumed for the speckle noise. The quality of the phase retrieval after denoising is characterized by the histograms of fluctuations in the unwrapped phase maps obtained for the three photoelastic parameters as well as by one-dimensional profiles of the calculated principal stresses. Comparison of different denoising algorithms with and without normalization is made by processing experimental fringe patterns which were recorded at pure tensile load for PhotoStress coated samples with different mechanical stress concentrators.

PB25

COHERENT POPULATION TRAPPING RESONANCES IN POTASSIUM WITH AMPLITUDE-MODULATED LIGHT

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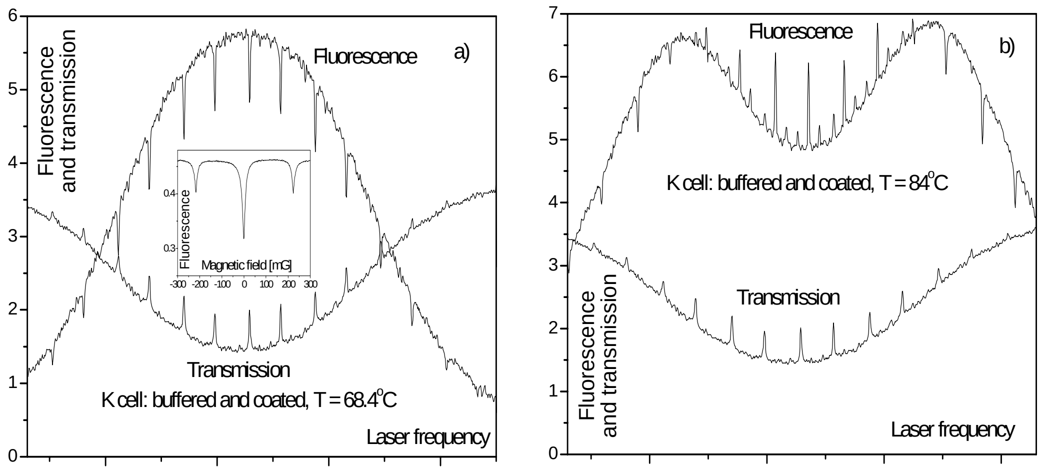

Fig.1. Illustration of dark resonance sign reversal (in the fluorescence only) with cell temperature: double scan of laser frequency and MF; the insert shows a three-ply dark resonance- a component at MF = 0 and two side components at modulation frequency. (a) dark resonances in the fluorescence and transmission, (b) three-ply bright resonances in the central region of the fluorescence profile.

Optical magnetometers based on Coherent population trapping (CPT) resonances observed in Hanle configuration allow to measure weak magnetic fields (MF) within a comparable to the resonance width range. To overcome this drawback, a frequency modulation spectroscopy of CPT resonance in Cs (D_2 line) has been applied for registration of human cardio MF in unshielded environment [1]. For further improvement, the resonance amplitude increasing is needed because in the Cs vapor it is very low due to the hyperfine optical pumping.

We present amplitude modulation spectroscopy of CPT resonance prepared in K, where it is possible to overcome the hyperfine optical pumping due to the overlapping of hyperfine transitions [2]. Because both types of laser light modulation result in similar sensitivity of MF measurement [3], the amplitude modulation was chosen as more practical one for application in K (D_1 line). Circularly polarized light is directed to a coated cell containing K vapor and buffer gas (Ne/Ar). Two different registrations of K fluorescence and transmission are performed: (i) vs. MF (orthogonal to light beam), at constant modulation frequency and (ii) vs. modulation frequency, at constant MF. Three dark resonances appear for a single MF scan (Fig.1a, insert). The applied double scan of laser frequency and MF allows the observation of resonance amplitude along the line profile (Fig.1). For low cell temperature, only dark resonances are observed (Fig.1a), while it rising leads to resonance sign reversal in the fluorescence, even with enhanced amplitude (Fig.1b). The bright resonance appearing will be discussed, as well as systematic results about the side resonance contrast (higher than 10%), width (below one kHz) and their potential for MF measurement.

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POSTER SESSION - I

C- *LASER REMOTE SENSING AND ECOLOGY*

PC1

LASER REMOTE SENSING OF TROPOSPHERIC AEROSOLS AND CLOUDS

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Aerosols and clouds have significant impact on the regional and global climate. Tropospheric aerosols are among the most uncertain elements in the estimation of Earth's radiative budget because of their highly variable characteristics and the complex phenomena in which they are involved. In present, laser remote sensing apparatus (LIDARS) are important tools for determining most of the aerosol properties. Lidar investigation methods are characterized with high spatial, temporal, and spectral resolution, as well as ability for real-time measurements and analysis of quickly changing parameters and composition of the atmosphere over long ranges and wide areas.

In this work, experimental results from regular laser remote investigations of tropospheric aerosols and clouds are presented. Examples of calculated atmospheric backscatter coefficient profiles extracted from four-year lidar dataset collected in Sofia (Bulgaria) are included and analyzed. They illustrate remote detection of aerosol fields and clouds at different altitudes including Saharan dust intrusions over the city and high-situated cirrus clouds. The mass temporal evolution and the spatial distribution of registered atmospheric layers are visualized by 2D-colormaps in height-time coordinates. Ground-based measurements are performed with a newly developed lidar at the Laser Radar Lab, Institute of Electronics, Bulgarian Academy of Sciences. The light source in the system is a Q-switched frequency-doubled Nd:YAG laser. The backscattering radiation from the atmosphere is collected by means of a Cassegrain-type telescope. The wavelength spectral separator consists of two aerosol channels and one Raman-channel. A simple, fast, and efficient receiving system is based on high sensitivity photo-receiving modules with very compact design and reliable operation. The acquisition system is provided with specialized software, well adapted to different lidar tasks, allowing for performing comfortable detection, conversion, and processing of lidar data. The good parameters of all the laser, telescope, photo-receiving modules, and software make it possible the developed lidar to be utilized for carrying out fast and accurate long-range remote atmospheric measurements with high spatial and temporal resolution. Reported results demonstrate the ability of the system for monitoring the atmosphere up to the tropopause top.

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PC2
LIDAR OBSERVATION OF VOLCANIC DUST LAYERS OVER SOFIA

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Second half of April and beginning of May 2010, were remembered by a big trouble in the airplane traffic over Europe, due to the eruption of the volcano Eyjafjallajokull in Iceland. The volcanic ash propagated quickly in the atmosphere traversing most of European countries. Its trajectories were forecasted and observed by many meteorological stations to prevent unintended consequences of the airplane transport.

The lidar stations of the European lidar network EARLYNET-ASOS [1] performed a large campaign of measurements to identify the position, the height above ground level (AGL) and the thickness of the volcanic aerosols transported in the air. It was an appreciable work to update meteorological forecasting and to study volcanic distribution directions, power and sedimentation in continental scale. As partner in EARLINET-ASOS project, Sofia lidar station performed measurements of the atmospheric aerosol profiling which results where quickly presented on the WEB-page of the Institute of Electronics – BAS [2]. A more detailed discussion and comments concerning only Sofia-lidar measurements of the volcanic dust layers observed over the town we present in this work.

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PC3

A DIFFERENTIAL DETECTION SCHEME OF SPECTRAL SHIFTS IN LONG-PERIOD FIBER GRATINGS

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In this work we present an analysis of the response of a compact, simple and inexpensive optoelectronic sensor system intended to detect spectral shifts of a long-period fiber grating (LPG). The system makes use of a diffraction grating and a couple of receiving optical fibers that pick up signals at two different wavelengths. This differential detection system provides the same useful information from an LPG-based sensor as with a conventional laboratory system using optical spectrum analyzers for monitoring the minimum offset of LPG. The design of the fiber detection pair as a function of the parameters of the dispersion grating, the pick-up fiber and the LPG parameters, is presented in detail. Simulation of the detection system responses is presented using real from spectral shifts in nano-coated LPGs caused by the evaporation of various liquids such as water, ethanol and acetone, which are examples of corrosive, flammable and hazardous substances. Fiber optic sensors with similar detection can find applications in structural health monitoring for moisture detection, monitoring the spillage of toxic and flammable substances in industry etc.

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PC4

STATISTICAL MODELING OF DECONVOLUTION PROCEDURES FOR IMPROVING THE RESOLUTION OF MEASURING ELECTRON TEMPERATURE PROFILES IN TOKAMAK PLASMAS BY THOMSON SCATTERING LIDAR

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The electron temperature T_e and density n_e profiles along a line of sight through the torus core are basic characteristics of the tokamak fusion plasma. They are conditioned by the modes of heating and confinement of the high-temperature plasma as well as by the different oscillatory movements of the plasma particles sometimes leading to the appearance of crucial instabilities. Thus, the T_e and n_e profiles are not only important factors of the development and the efficiency of the fusion process but are indicators as well of the dynamic plasma state. So far, the most appropriate approach to their simultaneous express determination in a remote contactless way is the Thomson scattering (TS) lidar approach [1]. The minimum range

resolution interval achievable by the contemporary core TS lidars is about 12-15 cm. Such a resolution is relatively good in general, but is insufficient for resolving small-scale inhomogeneities and the edge pedestal areas of T_e and n_e profiles in the so-called high-confinement mode (H-mode) of operation of the tokamak reactors.

A way of improving the range resolution of the TS lidars is based on the use of deconvolution techniques [2] for recovering the high-resolution lidar profiles. The deconvolution procedures, however, increase the influence of the noise. Therefore, to achieve acceptable recovered profiles one should apply a final filtering that lowers the sensing resolution to some compromise extent.

The main purpose of the present work is to outline by statistical modeling some optimal conditions under which the deconvolution techniques lead to satisfactory high-resolution restoration of the T_e profiles measured by the center-of-mass wavelength (CMW) method [3,4]. In the study, the sensing laser pulse shape and the receiving-system response function are assumed to be Gaussian- or exponentially-shaped. The plasma light background influence is taken into account as well as the Poisson fluctuations of the photoelectron number after the photocathode enhanced in the process of cascade multiplying in the employed microchannel photomultiplier tube.

It is shown that the deconvolution techniques ensure an accurate enhanced-resolution recovering of the T_e profiles for electron temperatures from 1 to 10 keV, sensing pulse energy $E_p \sim 1$ J, and electron concentration n_e in the range 2 - 9×10^{19} m^{-3}. Under such conditions the sensitivity of the CMW method is maximum, and the TS signal is strong enough having comparatively small relative fluctuations and exceeding essentially the plasma light background. It is also shown that an optimal final filtration of the lidar profiles is attainable by using smooth monotone sharp-cutoff digital filters.

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PC5

THREE-YEAR LIDAR INVESTIGATIONS IN THE ATMOSPHERIC BOUNDARY LAYER OVER SOFIA, BULGARIA

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The atmospheric boundary layer height might be determined with high time and spatial resolutions using lidars. That height defines the volume in which various pollutants spread, especially over an urban area in a mountain valley [1, 2]. Any particular volume of the atmosphere might be observed at the desired period of time (e.g during a period of a day, week or more) using ground based remote sensing means. This work aims at following of the seasonal variations of the mixing layer height over a mountain valley over different years.

In the present paper the quoted experimental lidar data are taken during different seasons in 2005, 2006 and the beginning of 2007.

The dynamics of the different layers heights during various seasons are determined. To determine the stable, residual and the mixing layer heights two methods are involved, namely the minimum of the second derivative of the S-function and that of the mean square deviation. The applicability of those methods in investigations performed during different seasons is determined.

On the basis of three-year lidar studies experimentally determined histograms of heights of the three main layers in the atmospheric boundary layer are presented. The time interval of the stable and residual layers destruction and the mixing layer formation are determined and their manifestation during different seasons is followed. For the purpose certain days in spring, summer, autumn and winter respectively are chosen.

The presented experimental results might be summarized as follows: (i) the two methods have different use during different seasons; (ii) the method of the second derivative of the S-function of the lidar signal is more reliable in winter and spring; (iii) the method of the mean square deviation might be used during all four seasons (excluding in the cases of very homogeneous mixing layer).

In conclusion it should be noted that during the seasons (excluding the winter) two different types of mixing layer (ML) are observed: ML with low height and gradually increase of the height and ML with high altitude and two stages of development (slow and fast). Under anticyclonic synoptical conditions the types of the mixing layer mentioned depends on the quantity of the solar radiation, the relative humidity of the air, soil moisture and the wind velocity.

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PC6

HEIGHT OF THE PLANETARY BOUNDARY LAYER, AEROSOL OPTICAL DEPTH AND WATER VAPOR CONTENT DETERMINED BY LIDAR AND SUN PHOTOMETER

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Aerosol optical depth (AOD) and precipitable water vapor amount (W) are two very important physical parameters for characterizing aerosols. Routine observation of total atmospheric column AOD and W globally is a fundamental way of determining aerosol optical characteristics and its influence in the global radiation budget and climate change. The most practical means of making these observations is by remote sensing, which can be either from the ground (by lidars or looking in the skyward direction with sun photometers) or from space (looking toward the ground through the atmosphere with imaging radiometers and lidars onboard satellites or high altitude aircraft) [1, 2, 3].

In the present investigation the results from the experimental campaign carried out in the period between 01.10.2008 and 22.10.2008 in two regions of Sofia (Institute of Electronics and Astronomical Observatory, Borisova Gradina Park) are presented. An aerosol lidar, two sun photometers Microtops II, pyranometer and automatic meteorological station were used during the experiments.

The experimental campaign was carried out in two stages. The aim of the first one was calibration of the Bulgarian sun photometer by simultaneous measurements with the Indian sun photometer, freshly calibrated in the USA. The aim of the second stage was to determine the atmospheric aerosol optical characteristics and water vapor content (WVC) in two regions of Sofia during the planetary boundary layer (PBL) development.

Few different types of AOD and WVC behavior are observed. The height of the mixing layer varied from 400m to 1600 (2000)m during the measurements. The height of the residual layer changed from 800m to 2000m. The stable boundary layer did not exceed 200-400m.

During the experiments, the AOD at wavelength $\lambda = 500$nm had values from $\tau_a = 0.025$ to $\tau_a = 0.42$. The WVC values varied in the range from 1cm to 2cm.

Joint interpretation of lidar data and sun photometers data is done under the assumption that most of the aerosol load and water vapor are located in the PBL in absence of volcanic eruption and transportation of Saharan dust.

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PC7

CASE STUDIES OF THE SURFACE OZONE AND ATMOSPHERIC BOUNDARY LAYER OVER SOFIA, BULGARIA

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Atmospheric boundary layer characteristics and ozone near the ground in considerable degree define climatic situation over locality and in connection with observed climatic changes these components are actively investigated.

Dynamics of the surface ozone and atmospheric boundary layer over Sofia has been studied at sites with different properties of the underlying surfaces. Experimental observations have been performed with *in-situ* and remote-sensing techniques. Ozone concentrations have been measured with ozone gas analyzers working on different detecting principles. The structure and temporal development of the atmospheric boundary layer have been observed with lidar and ceilometers - lidar.

Observations of the atmospheric boundary layer formation performed with remote-sensing techniques showed that in dependence upon meteorological situation and season the maximum mixing layer height is detected between about 13-15 h. The surface ozone variations demonstrated similar behaviour in some cases. Measured at different sites values of the ozone concentrations near the ground give information about local climate with respect to ozone pollution.

PC8

DYNAMICAL CHARACTERISTICS OF ATMOSPHERIC LAYERS OVER COMPLEX TERRAIN PROBED BY TWO-WAVELENGTH LIDAR

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Earth's relief can strongly influence parameters of adjoining atmospheric layers such as thermal and radiative budgets, regime of air circulations (winds, air flows), water balance and rainfalls, etc. Observations on the atmospheric dynamics over complex terrains are important for monitoring features and changes of local climate and ecology in aspect of global climatic and ecological processes.

In this work we report results of lidar measurements on the dynamics of low atmospheric layers over heterogenic orographic domain close to Sofia, Bulgaria, including a large urban area, a plain zone, and a high mountain (Vitosha mountain).

Measurements are carried out at 1064 nm and 532 nm by using two aerosol channels of a three-channel lidar based on a Q-switched Nd:YAG laser. The system provides registration and processing of lidar signals over distances of up to 30 m with a range resolution of 15 m.

Representative statistical results of lidar measurements over the zone of investigation are described, obtained on a summer day and a winter day. The standard deviation of range-corrected lidar signals, normalized to the signal's mean value, is used as a characteristic of atmospheric instabilities. Series of time-distance colormap diagrams of both the normalised standard deviation and backscattering coefficient are presented and analysed, illustrating the spatial-temporal evolution of atmospheric fluctuations and aerosol distributions at the two probing wavelengths over lidar ranges. Corresponding series of time-averaged range profiles of the normalized standard deviation and backscattering coefficient are also displayed and discussed. Specific features of the atmospheric dynamics over the studied complex orographic area are established as related to seasonal and diurnal meteorological conditions. Taking advantage of the two-wavelength lidar sounding, dynamical behaviors of the fine and coarse aerosol components are distinguished and juxtaposed in orographic aspect. In addition, dynamical as well as time-averaged range profiles of backscattering Ångström coefficient are presented, as a characteristic of the fine-to-coarse aerosol particle ratio.

Reported results reveal the strong and specific impact of the heterogenic orography on dynamical parameters of the fine and coarse components of the atmospheric layers, under distinctive seasonal conditions; especially in the interface zones connecting areas of different orographic type.

D - *LASERS IN BIOLOGY AND MEDICINE*

PD1

DEVELOPMENT OF NONINVASIVE OPTICAL METHODS FOR DETERMINATION THE LEVEL OF VENOUS BLOOD SATURATION

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The value of oxygen saturation in the venous blood has a significant role in the oxygen exchange in tissue. Reduction of the concentration of oxygen in the arterial blood causes hypoxia, which is the major problem limiting the efficiency of the medical therapy. One of the main mechanisms of the hypoxia elimination is based on compensation the deficit of oxygen by increasing direct ***extraction*** of molecular ***oxygen*** from the arterial blood that leads to reduction of oxygen in venous blood.

In this report two simple optical techniques for measurement of venous blood saturation are presented. The first one is based on the pulseoximetry with artificial mechanical modulation of tissue volume and the second one on the spectrophotometry of the human respiratory rhythm. Good correlations between the results obtained with both techniques are observed.

PD2

NEW METHOD FOR CONTROL OF TOOTH WHITENING

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New methods of control of tooth bleaching stages through simultaneous measurements of a reflected light and a fluorescence signal are proposed. It is shown that the bleaching process leads to significant changes in the intensity of a scattered signal and also in the shape and intensity of the fluorescence spectra. Experimental data illustrate that the bleaching process

causes essential changes in the teeth discoloration in short time as 8-10 min from the beginning of the application procedure. The continuation of the treatment is not necessary moreover the probability of the enamel destroy increases considerably. The proposed optical back control of tooth surface is a base for development of a practical set up to control the duration of the bleaching procedure.

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PD3

SHAPE AND DEFORMATION MEASUREMENT OF LIVING OOCYTE CELLS BY INTERFEROMETRIC FRINGE PROJECTION

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Precise automated manipulations of biologic cells are widely used in fields like medicine, biotechnology, microbiology, and pharmacology. In many cases inspecting the cell profile and its change during micro injection is very important. It allows to estimate the cell's elastic properties, membrane quality, penetration force and others [1-6].

Here we present an approach to measure the shape of living Oocytes and their deformation during injection. For that purpose an interference fringe pattern is projected on the cells at a certain angle [7-9]. The obtained fringe patterns are recorded by a high resolution digital camera. To extract the phase from the captured fringe patterns, numerical algorithms based on Windowed Fourier Transform were used [10, 11]. The experimental results for artificial polymer membrane and real Oocyre cells are presented.

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PD4

FIBER END SEALING CAP FOR Er:YAG LASER ABLATION

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A considerable interest in the mid-infrared Er:YAG laser surgery and microsurgery has been observed in recent years, especially after the development of optical fibers and waveguides for safe and efficient transmission of the ~3.0 μm wavelength beams [1]. Although a problem appears in medical applications where the fiber is used for the so called "contact mode". The irradiated substrate is melted or ablated and a part of this material usually destroys the inner surface of the fiber end. Therefore, part of the debris can enter the fiber end and discontinue the transmittance. To overcome this problem, the end of the fiber must be sealed. The advantage of sealing is not only in preventing liquid or particle penetration into fiber, but also the possibility to modify the space structure of the delivered beam [2].

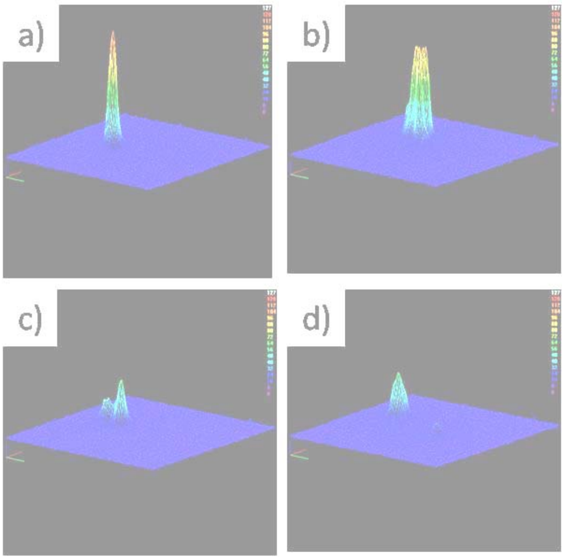

Fig.1. Shows the output beam profile after a) an optical fiber diameter 465 μm, b) a sealing cap with distal end shape ball, c) a sealing cap with distal end shape dome and d) a sealing cap with distal end shape plano convex.

In this study, we investigated the properties of three sealing caps with various distal end geometries in order to evaluate the attenuation, spatial and temporal energy distribution of the transmitted laser radiation. As a laser source we used a Q-switch and a free-running Er:YAG laser with the pulse duration of 190 ns and 80 μs respectively. As a transmission medium, three fluoride glass optical fibers were used with output end sealed. Fig. 1 shows representative results of the output beam profile after a) an optical fiber diameter 465 μm, and b-d) a sealing cap with various distal end shapes. Finally, we perform ablation experiments using a sealed optical fiber and we control the divergence of laser light for various applications.

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PD5

LASER-INDUCED BREAKDOWN SPECTROSCOPY OF DENTAL PATHOLOGIES

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One of the most exciting potential growth areas for lasers in dentistry is diagnostics. Recently optical approaches (such as laser – or light-induced fluorescence spectroscopy (LIFS), Fourier-transform infrared reflectance spectroscopy (FTIR), laser-induced break-down spectroscopy (LIBS), diffuse–reflectance spectroscopy (DRS)) to enhance the early detection of dental decay have become a "hot" topic [1, 2]. In fact carious decay usually develops as a tiny area of demineralization on the enamel, which could be detected by element analytic techniques such as LIBS. That demineralization can quickly turn into a large lesion inside the tooth, it is often discovered too late to prevent the kind of decay that leads to cavities. The same optical detection approaches could be used for monitoring of the caries removal using laser ablation or drilling techniques [3].

Therefore, the major line of our investigations is related to the development of a methodology for real-time optical feedback control during selective ablation of tooth tissues using LIBS. Tooth structures with and without pathological changes are investigated in vitro and their element analysis is compared to differentiate major changes, which occur during tooth carious process and growth. This would permit the dentist to follow normal drilling procedures while obtaining automatic, real-time information about the composition of the sample area and the status of ablation. The first comments about experimental combination of spectral detection of tooth lesions and following laser ablation appear in a form of scientific investigation [2].

Additional to the major aimed results, related to development of smart feedback spectral system during dental treatment of carious lesions, our investigations could be useful for the development of alternative to existing on the market devices for initial diagnosis of tooth pathologies, with possibility to differentiate initial demineralization from pre-carious conditions, different pre-carious and carious stages of the lesions, and to differentiate these major disorders from other tooth pathologies, such as odontolithiasis, fluorosis, etc. in measurement mode, working in real time. We expect that this system could have improved sensitivity and specificity parameters for tooth lesion type determination.

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PD6

FLUORESCENCE SPECTROSCOPY OF NON-MELANOMA CUTANEOUS TUMORS – DIAGNOSTIC FEATURES

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Optical biopsy is relatively new term used in medical practice for description of fluorescence and/or reflectance spectroscopy of human tissues in vivo. Painless, instant diagnoses from optical biopsies will soon be a reality. These forms of optical diagnoses are preferable to the removal of several square centimeters of tissue surface - common in traditional biopsies – followed by delays while samples are sent for clinical analysis. There is also possible that the optical biopsy apparatus will requires a learning curve of several practice attempts, compared to years of training needed for more conventional techniques. Fluorescence spectroscopy of human tissues is very attractive tool for early diagnosis of cancer due to its high sensitivity, easy-to-use methodology for measurements, lack of need for contrast agents application on the tissue under investigation, possibilities for real time measurements and noninvasive tumor detection. However, till our days, no reliable and universal system for fluorescence detection of skin cancer has not appeared on the medical market.

Problems for development of such diagnostic fluorescence system for skin cancer detection are related to the great variety of benign and malignant forms of skin pathologies, for example basal cell carcinoma lesions have more than 15 sub-types, squamous cell carcinoma lesions, have about 10 different subtypes, and all of them have variety of benign and dysplastic forms, as well as they are different, including by their fluorescence properties, on different stages on the lesion growth.

Our investigation is a part of a clinical trial for introduction of spectral diagnostic system for skin cancer detection in the common practice of the dermatological department of National Oncological Medical Center-Sofia. Autofluorescence spectroscopy is applied to several different classes of malignant non-melanoma cutaneous lesions. Initially, they were classified visually and dermatoscopically. Second step was detection of lesion' and surrounding normal skin autofluorescence using different excitation wavelengths, namely 365, 385, and 405 nm. In the end for every lesion histological examination is used as a "gold standard" for all our investigations.

The spectra and dermatoscopic evaluations were obtained from more than 250 patients up to now. Spectral properties of variety of benign cutaneous lesions are also evaluated for development of more precise discrimination algorithms for diagnosis of cancer lesions. The origins of diagnostically significant spectral features are evaluated and differentiation schemes will be discussed in our report.

Clinical trial is currently under implementation and with broadening of the database with fluorescence spectra of major skin benign and malignant pathologies we expect to receive objective tool for detection and evaluation of skin lesion type, which could become a basis for reliable system for fluorescence detection of non-melanoma skin cancer.

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PD7

A DUAL INTERPRETATION OF EXPERIMENTAL DATA CONCERNING THE PROPAGATION OF LASER LIGHT THROUGH TISSUE-LIKE TURBID MEDIA

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The propagation is investigated of a continuous laser beam through homogeneous tissue-like turbid media such as diluted emulsions of Intralipid or milk. The cross sectional radial distributions of the detected forward-propagating light power at different depths along the beam axis in each medium of interest are experimentally determined. The detected-power spatial distribution is also described analytically by a solution of the radiative transfer equation for the case of sharply forward directed Henyey-Greenstein indicatrices. Expectedly, as in the case of sharply forward directed Gaussian indicatrices we have considered formerly, the experimental results turn out to be consistent with the analytical expressions obtained over the corresponding ranges of validity of the latter. Moreover, it is shown that the theoretical approach employed allows one to derive simple explicit expressions for estimating, in the case of not only Gaussian but Henyey-Greenstein indicatrices as well, the extinction (μ_e), the reduced-scattering (μ_s') and absorption (μ_a) coefficients and the g-factor of the investigated media on the basis of the experimental data. On the basis of the expressions derived, μ_e, μ_s', and the g-factors are estimated of some of the dilutions of concern in the experiment. The values obtained are quite reasonable and exhibit a behavior of the optical coefficients, depending on the dilution turbidity, that has been observed formerly in similar experiments. A comparative analysis of the estimated characteristics of the dilutions shows that in the case of Henyey-Greenstein indicatrix we have a smaller value of the g-factor and larger value of μ_s' with respect to the case of Gaussian indicatrix. At equal g-factors, in the former case we shall have a narrower forward-propagating scattered-light beam with higher on-axis intensity as compared with the latter case.

The investigations performed in the work are important for the development of methods for measuring the optical characteristics of turbid media such as tissues and experimental tissue-like phantoms. They would also be especially useful in the process of establishing the laws

governing the radiative transfer inside the optically investigated (by optical tomography approaches) biological objects.

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PD8

PHOTODYNAMIC INACTIVATION WITH PHTHALOCYANINES OF SOME ORAL PATHOGEN BACTERIA: LIGHT DOSE DEPENDENCE

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The PDT is a process in which radiation with proper parameters acts on a dye that is applied to the target objects and in result of photochemical and photophysical procceses the bacterial death on target objects is significant. The aim of this study was to investigate the effects of light doses in photodynamic therapy (PDT) on endodontic pathogens by evaluating the decrease in microbial count of bacteria, sampled from root canals and caries.

The phthalocyanine complexes of silicon(IV), germanium(IV) and indium(III) with peripheral substitution of *methyl*pirydiloxy functional groups (SiPc1, GePc1 and InPc1 were chosen as a photosensitizers (PS) in accordance with their good solubility in water solutions and with a highly intensive absorption maximum in the far red region (675-685 nm), which makes them suitable as a photodynamic sensitizers. Photodynamic efficacy against *Streptococcus faecalis*, *Streptococcus mutans, MRSA, Streptococcus sangius* and fungi *Candida albicans* as planktonic samples was evaluated. The high photodynamic efficacy was shown for SiPc1 at low concentrations (0.9 μM) and light dose of 30 J cm^{-2} and fluency 60 mW cm^{-2}. The photodynamic response after irradiation with different light doses shows that with most effective PS it is possible to achieve full bacterial inactivation after 10-12 minutes of object treatment. The comparison between efficacy of phthalocyanine PS and other PS (porphyrin and methylene blue) in PDT procedures on oral pathogens was evaluated. Photodynamic therapy appears as an effective method of inactivation of bacteria involved in dental infections. The application of new phtalocyanines leads to complete microbial destruction. The proposed method could become a promising alternative treatment of infections in endodontic treatments in dental practice.

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PD9

BIOSAFETY OF SUNSCREEN NANOCOMPONENTS: AN OPTICAL STUDY

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Nowadays titanium dioxide (TiO_2) and zinc oxide (ZnO) nanoparticles (NPs) are used as ultraviolet (UV) blocking agents in modern sunscreens. Because of absorption and scattering properties, these particles prevent UV photons from reaching living skin cells. After application, NPs should remain on the skin surface or within the uppermost layer of skin, the stratum corneum. Penetration into deeper parts of the skin down to the living cells should be avoided. At the present time, an intensive discussion is in progress about the safety of mineral solid nanoparticles concerning their possibility to pass the skin barrier and to accumulate in the living tissue.

This issue converges into an investigative task to assess the ZnO and TiO_2 NP transdermal penetrability. Minimal invasive and non-destructive methods, as well as optical properties of sunscreen NPs, play an important role in this research, especially accounting for recent findings concerning ZnO high visibility on a skin autofluorescence background.

We report about study on NP penetration into human skin non-invasively *in vivo* and *in vitro* by multiphoton microscopy (MPM) employing a titanium-sapphire laser as a light source.

As intrinsic properties of the nanoparticels under study, we also discuss their light-protective properties in the UV spectral range when they are localized within the stratum corneum. Simulations with Monte Carlo method consider a model comprising two sublayers of the stratum corneum, one of which is partially filled with NPs. A hybrid phase function is applied for the NPs and skin cells (corneocytes).

Phototoxic properties of NPs administered onto porcine skin *in vitro* are evaluated with electron paramagnetic resonance (EPR) method. Contributions of skin and NPs are compared.

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PD10

He-Ne LOW LEVEL LASER THERAPEUTIC APPPLICATIONS FOR TREATMENT OF CORNEAL TRAUMA

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This investigation is carried out on two groups of patients with corpus allienum corneae. In every group are included 40 patients (40 eyes). For the first group standard treatment is applied after extraction of the corpus allienum corneae using antibiotic drugs (Aftaquix®) and epithalizing gel (Cornergel®). First group is used as a control. For the second group of patients immediately after extraction of the corpus allienum corneae, eyes are irradiated for 3 minutes with He-Ne laser (Mediray 04, Optella Ltd., Sofia, Bulgaria) at emission wavelength at 632 nm and power density 0,1 mW/cm^2. Second group of eyes is treated with the same drugs as the control group.

We observed epithelisation of the damaged cornea in the first group – after 24 hours, and in the laser-irradiated group of eyes significant epithelisation is pronounced the 10th hour after irradiation. Epithelization is proved by fluorescein reaction to detect the eye cornea recovery. The patient eyes of the both groups were investigated under bio-microscope in cobalt-blue illumination. For irradiated eyes by LLLT, we have found that the healing period is shortened significantly by 42 % ($p<0,001$).

Our results revealed that LLLT application is appropriate and perspective for recovery therapy after corpus allienum corneae extraction.

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PD11

PHOTODYNAMIC EFFICACY OF WATER SOLUBLE SILICON(IV), GERMANIUM(IV) AND INDIUM(III) PHTHALOCYANINES ON ORAL FUNGUS

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The metallophthalocyanines of silicon(IV), germanium(IV) and indium(III) with peripheral substitution of *methyl*pirydiloxy functional groups (SiPc1, GePc1 and InPc1) were synthesized by following the known chemical procedures. The phthalocyanine complexes were shown to possess a good solubility in water solutions, which makes them suitable as photodynamic sensitizers. The visible absorption properties of the complexes with a highly intensive maximum in the far red region (675-689 nm) were observed. The photochemical properties of singlet oxygen generation were investigated and were shown to increase in the order: GePc1 < SiPc1 < InPc1. Photodynamic antifungal efficacy against *Candida albicans* as planktonic and as biofilm grown on the denture acrylic resins was evaluated. The high photodynamic efficacy was shown for SiPc1 at very low concentrations (0.45 μM, 0.9 μM) and light dose of 50 J cm^{-2} and 60 mW cm^{-2}. The photodynamic response after GePc1 was slight at concentrations of 0.9 μM and 1.8 μM and increased with 1-2 log after application of higher concentrations (3.6 μM and 5.4 μM). The inactivation of the fungus cells after InPc1 was negligible even at strong treatment conditions (6.8 μM). The studied phthalocyanines were compared to the recently studied tetra-*methyl*pirydiloxy Ga(III)- and Zn(II)-phthalocyanines (GaPc1 and ZnPcMe), which were shown with a good potential for inactivation of representative pathogenic bacterial strains.

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E - *LASER SYSTEMS AND NONLINEAR OPTICS*

PE1

DIODE EDGE-PUMPED Yb:YAG DISK LASER

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Disk architecture for laser active mediums has advantages for high-average-power operation with good beam quality. Edge-pumping is very advantageous for pumping disk lasers because it provides a long absorption path for the pump compared with end-pumped one, which needs very complicated pump geometry. Moreover, edge-pumping allows reduction of disk doping level and makes it more practical to use lasants with low absorption cross-sections. The key criteria for edge-pumping architecture in any disk laser include: 1) efficient transport of pump power to the gain medium, 2) efficient absorption of pump radiation, and 3) high uniformity of absorbed pump power density [1].

In the current work, we report diode pump arrays arranged around the circumference of a disk and point toward its center. For laser operation, the disk on a heat sink was situated in the center of the pump module and four pumping and duct lens units were arranged radially and symmetrically. Pump radiation is injected into the undoped edge and is channeled into the doped portion of the disk where it is gradually absorbed. For delivering the pump light into the gain medium, lens duct has been employed. Non-imaging optic devices, which include illumination optics, transcend imaging optic ones in optimum delivery of the pump light [2]. The requirements for disk-shaped gain medium are different from those for rods. Here, the key criterion is a uniform deposition of absorbed pump power and in turn a uniform temperature distribution throughout the disk [3]. Therefore, we need to reverse the process. In other words, firstly, a uniform distribution of pump power is obtained within the active medium restrictions. Secondly, we try to meet those criteria by designing an appropriate duct.

In order to obtain laser output power, a self-consistent numerical model has been developed for simulating lasing properties of our configuration. A Monte Carlo ray tracing based code and 2D finite element analysis (FEA) with the ANSYS package have been utilized to calculate the absorption power and temperature distribution inside the crystal, respectively [4-5]. The model is used to investigate the influence of the effective parameters on the operational efficiency of the disk laser.

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PE2

CALCULATING OPTICAL PATH DIFFERENCE IN END-PUMPED Yb:YAG THIN DISK LASERS

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In real thin disk laser systems, a fraction of absorbed pump power is dissipated as heat. Consequently, the thin disk lasers experience a temperature gradient in the axial direction of the disk which produces inhomogeneous stress and strain distributions. These inhomogeneous profiles of temperature, stress and strain lead to several adverse effects on laser operation such as fracture, strain-induced birefringence and thermal lensing. These thermal effects are the main limiting factors to the laser power and beam quality [1-2]. The main contributors to the optical path difference (OPD) or the thermal lensing in thin disk lasers are the temperature gradient, axial thermal strain (bulging), thermal strain-induced birefringence and deformation of the disk [3-4].

In this paper, we present the numerical calculation of Von Mises stress and the thermal lensing due to temperature gradient, stress gradient and deformation. Based on the results of our numerical study, it was proved that the most dominant parameters, which cause optical path difference and therefore thermal lensing, are temperature-dependent refractive index and deformation of the disk. Moreover, these are both directly related to absolute temperature values within the crystal. A parametric analysis, which includes the impact of heat transfer coefficient, cooling fluid temperature, and crystal thickness, has been performed in order to get a better understanding the role of the essential parameters in controlling temperature and stress.

The most effective way to suppress thermal lensing effect is to reduce the coolant temperature and the thickness of the disk. However, the resonator design should be matched with the thermal lens value. One can also predict the maximum pump power limit for a given system beyond which the thin disk may be fractured.

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PE3

THERMAL STRESS EFFECTS IN PULSED PUMP SOLID STATE LASERS WITH SUPER-GAUSSIAN PROFILE

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The thermally induced stress in pulsed pump solid state lasers with super-Gaussian profile has been investigated. An analytical expression for thermal stress is introduced. We consider the heat deposited in the crystal due to the pump. The temperature distribution in the crystal has been calculated by solving the non-steady state heat conduction equation. A Ti:Sapphire crystal is assumed pumped by a pulse laser. All the stress components have been obtained and discussed in details. The results show that the non-homogenous temperature distribution is induced by thermal stress in the crystal.

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PE4

TEMPERATURE DISTRIBUTION AND THERMAL LENSING IN A FLASH LAMP PUMPED Nd:YAG LASER

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Keywords: Flash lamp pump; Thermal Effects; Solid State Lasers.

The effect of thermal lensing is a critical factor for resonator design and must be considered to improve the beam quality. The absorption of the pump radiation by laser material and surface cooling leads to a nonuniform temperature distribution in the rod. Temperature gradients inside the rod induce stress and thermo-optical effects such as thermal lensing effect and also affect the gain because of the temperature dependent emission wavelength of Nd:YAG crystals. Many noticeable efforts for managing and reducing thermal effects under various types of pumping geometries are found in [4-6].

In this paper the temperature distribution in a cylindrical Nd:YAG rod under repetitive flash lamp pulses is numerically simulated when pumped by flash lamp with 150 μs pulse width and 10 *Hz* repetition rate . For this purpose, we consider Gaussian pump pulse shape in time and redial absorption in laser rod. Then, the focal length of thermal lens due to the thermal dispersion is calculated. Our calculations show that the temperature converges to a finite value and doses evolve in time noticeably. Also, in contrast with single pulse shooting that the sign of thermal focal lens changes with time, the induced lens has a positive sign in all times.

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PE5

SEWING UP THREE-DIMENSIONAL SOLUTIONS OF NLS EQUATION FOR A MEDIUM WITH SPATIAL DEPENDENCE OF THE REFRACTIVE INDEX

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3D+1 non-linear equation of Schrodinger for Ker-type medium with anomalous dispersion and spatial dependence of the refractive index is examined in the present work. Accurate analytical solutions in spherical coordinates for an area near to the beginning of the examined coordinate system are found. The points, in which the solutions are sewn up, are obtained.

PE6

NONLINEAR REGIME OF PROPAGATION OF THREE-DIMENSIONAL OPTICAL PULSES WITH LARGE SPECTRAL BANDWIDTH

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In this paper, a careful analysis is provided of the nonlinear propagation of three-dimensional pulses with large spectral bandwidth in isotropic media. After applying the small parameter method to nonlinear amplitude equation, approximate analytical solutions up to first order are obtained.

PE7

THE EFFECT OF TEMPERATURE ON PREFORMANCE END-PUMPED Yb:YAG THIN DISK LASERS

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Because of many advantages such as high output power, good beam quality, high optical efficiency and finally its small dimensions, disk laser has focused many researchers interest. Furthermore Yb:YAG as a quasi-three-level active medium is quite preferable to improve thermal management originating from the considerably lower thermal loading factors.[1,2]

In this paper we investigate the performance of CW diode pumped Yb:YAG thin disk laser by considering temperature dependence of absorption cross section, stimulated emission cross section, Boltzmann occupation factors and thermal conductivity of Yb:YAG crystal. As a first step the absorbed pump power distribution into the laser active medium is simulated by Monte-Carlo ray tracing approach [3]. Employing the distribution of absorbed energy the next step is to evaluate temperature distribution by 3D finite element analyses (FEA), considering axial symmetry inside the crystal.

The crystal temperature, absorption cross section and absorbed pump power distribution is exploited to solve the rate equations and consequently the output power is achieved as well. The new set of exited population and absorption coefficient yield a new distribution of temperature which leads us to start the above steps again. This process implement iteratively until the change of temperature gets smaller than a given limit.

Consequently the output intensity is calculated by changing the input intensity in various pump spots diameter, additionally the effect of coupling mirror reflectivity is investigated on output intensity.

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PE8

A LASER SYSTEM FOR CONSTUCTION DOT MATRIX HOLOGRAMS

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The holography is the technique that enables permanent record of 3D color pictures. Due to its sub-micronic structure, holograms are remarkable safety elements which are very difficult to counterfeit. Dot-matrix technology, as one of the commonly used methods, represents substantial obstacle to all types of fraudulent activities. This kind of holograms is mainly used for the purpose of protection against forgery (checks, cards, passports) but it can also serve the function of decoration, advertizing or (simply) artistic expression. This paper describes the device that generates the hologram matrix by using the dot-matrix images whose appearance can be personalized (customized) by computer genereted.

The device consisted of mechanical, electrical and optical components which were driven via control software. As a source of coherent light emission we used DPSS laser with 473 nm wavelenght and 50 mW output power. The motorized XY table was used for positioning photosensitive material with accuracy up to 250 nm and preciseness up to 1 um. By using mirrors and prisms, we were able to introduce two parallel laser beams onto the front side of an objective and separate them to desired distance. We set photosensitive material in the objective focus in order to obtain interference pattern of laser beams. Diffraction grating obtained this way was characterized with 15 um diametar and 1 um periodicity. The hologram was recorded dot by dot by using the software for hologram calculations.

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PE9

OPTIMIZATION OF THE PETZVAL OBJECTIVE WITH THE VARIOUS EVOLUTION STRATEGIES AND DUMPED LEAST SQUARES

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Problem of optimization of optical systems is very old problem and belongs to a class of highly nonlinear optimization problems. Many researchers proposed various methods or their improvements in order to solve this problem. All those methods can be classified in two broad groups:

- Classical optimization methods based on some kind of the damped least squares (DLS) [1];
- Modern optimization methods based on analogies in nature like genetic algorithms [2] and evolution strategies [3].

In this paper authors tried to implement modern optimization techniques in the optimization of optical systems. Following evolutionary algorithms based on the genetic algorithms and evolution strategies will be presented:

- steady state genetic algorithm;
- two membered evolution strategy (1+1) ES – EVOL;
- multimebered evolution strategy in three verians:
  - with mutation as only genetic parameter (μ, λ) ES – GRUP;
  - with mutation and recombination as genetic parameters (μ, λ) ES – REKO;
  - with various genetic operators (μ, λ) ES – REKO.

Optimization of Petzval lens by all this algorithms are compared amogn themselves and with classical DLS optimization and the best evolution algorithm is selected. First results in applying evolutionary algorithms in optimization of the cemented doublet and the Cooke triplet are published in [4, 5].

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PE10

SINGULAR OPTICAL BEAMS IN SELF-FOCUSING KERR NONLINEAR MEDIA

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The phase fronts of singular optical beams contain dislocations in which the phase is indeterminate and the field intensity vanishes. Possible ways to generate singular beams in femtosecond laser fields are to use optical systems utilizing computer generated holograms or spatial light modulators aligned within optical schemes with controlled dispersion – 4*f* [1-3] or 2*f*-2*f* setups [4], double-pass grating [2] or prism compressor [5]. However, in contrast to the case in *self-defocusing* media, in which singular beams can evolve in dark solitons, their evolution in *self-focusing* nonlinear media remains relatively weakly explored [6,7].

In this work we present numerical studies on the filamentation of optical vortices and crossed one-dimensional dark beams proving that amplitude perturbations (intentionally introduced or naturally arising due to the beam diffraction) can strongly influence the initiation of the process of filament formation. The filaments (hot spots) are the sources for white light generation. The results show that by controlling the initial amplitude perturbations and/or diffraction one can rule the density and the distribution of the filaments. The numerical simulations based on the quasi-(3+1)-dimensional nonlinear Schrödinger equation accounted for the possible variable initial computer generated hologram to nonlinear medium free space propagation, for the nonlinear evolution along the Kerr medium, and for the free-space beam/pulse propagation to the far field. An important result confirming previous experimental observation is that the dark beams and their phase profiles survive the filamentation process. In case of crossed 1D odd dark beams we numerically study the influence of the initial diffraction on the generation of satellite hot-spots inside the self-focusing medium. Under certain conditions, the satellite hot spots appear comparable in intensity to the central ones.

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PE11

DIODE END PUMPED Nd:YVO_4 LASER PASSIVELY Q-SWITCHED WITH Cr^{+4}:YAG SATURABLE ABSORBER

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Through recently development in passively Q-switched laser systems and solid state laser materials, small high-power lasers have became much more practical for a variety of applications such as micromachining, ranging, remote sensing, and microsurgery. Compared with active Q-switching, passive techniques that use saturable absorbers can significantly simplify the operation, improve the efficiency, the reliability and the compactness, and reduce the costs of laser sources. Among all saturable absorbers which introduced in laser technology, Cr^{+4}:YAG has attracted great attention. Cr^{+4}:YAG crystal has been widely used as a Q-switch to achieve the giant pulse in Nd:YAG lasers [1, 2]. Also Cr^{+4}:YAG has been used successfully as a passive Q-switch for a variety of new laser media, specially Nd doped lasers such as Nd:YVO_4 [3], Nd:LSB [4], Nd:GdVO [5], Nd:S-VAP [6], etc. Nd:YVO_4 is among the most efficient laser materials suitable for diode pumping in 808 nm.

In this paper, we report our experimental study on passive Q-switching of a diode-pumped Nd:YVO_4 lasers with Cr^{+4}:YAG saturable absorber when CW pumped with a 3 W laser diode. Laser pulses as short as 37 ns with a repetition rate of 100 kHz and peak power of 140 W can be produced by using a concave mirror with 100 mm radius of curvature.

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PE12

HIDDEN FEATURES OF SOLITON ADAPTATION LAW TO EXTERNAL POTENTIALS: OPTICAL AND MATTER_WAVE SOLITON BULLETS IN NONAUTONOMOUS AND NONLINEAR SYSTEMS

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Mathematical similarities and parallels between two different physical objects, optical solitons and matter-wave solitons, both described by similar mathematical models: the nonlinear Schrodinger equation (NLSE) and the Gross-Pitaevskii equation (GPE) model, open the possibility to study both systems in parallel and because of the obvious complexity of experiments with matter-wave solitons, offer outstanding possibilities in studies of BEC system by performing experiments in the nonlinear optical system and vise versa.

Whereas in nonlinear optics, the transition from the 3D Maxwell's equations to the 1D NLSE is the well established procedure, by contrast, in the matter wave physics, the deduction of the 1D model from the 3D GPE model is not so straightforward and this procedure requires more sophisticated reasoning. The problem here is worse than it is in the case of temporal solitons in fibers and a closer look into this 3D→1D reduction procedure must be taken.

Closer inspection will show that, in general, this 3D→1D reduction is not justified for varying in time trapping potentials. In particular, we show that the assumptions made in deriving the 1D GPE break down. Conventionally, 1D NLSE model works well for cigar-shaped atom cloud when its axial width is much larger than the diameter of the "cigar". The crucial questions, though, are: what happens if both the axial width of cigar-shaped trapping potential and nonlinearity inside the atom cloud vary with time in accordance with the soliton adaptation law obtained in 1D approximation [1]? And, that is more important, what happens if parabolic potential periodically changes its sign that physically means periodic transformations from the trapping axial potential to the repulsive one.

Based on the generalized nonlinear Schrödinger equation model with sign-reversal varying-in-time harmonic oscillator potential, we show that conditions of its exact integrability in one-dimensional case (1D) indicate conclusively the way for soliton like bullets generation in 3D nonautonomous nonlinear and dispersive systems during reversal periodic transformation from cigar-shaped to ball-shaped trapping potential. It turns out that the generation of matter-wave soliton bullets can be realized if periodic variations of nonlinearity and confining potential are opposite in phases so that the peaks of nonlinearity inside the atomic cloud coincide in time with repulsive character of trapping potential. In nonlinear optical applications, this kind of periodic graded-index nonlinear structure with alternating waveguiding and antiwaveguiding segments can be used to simulate complicated processes in matter-wave soliton bullets generation.

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PE13

NUMERICAL STUDY OF THIN DISK LASER WITH AXICON-BASED BESSEL-GAUSS RESONATOR

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In this study, a detailed study of thin disk laser with axicon-based Bessel-Gauss resonator has been carried out. By using the Fox-Li method, it is possible to find the lowest mode shape and associated optical loss for an arbitrary optical resonator. This goal is achieved by iterating the laser beam back and forth inside the cavity numerically for many round trips until the mode shape and loss stabilizes asymptotically. By employing this method, one can simulate cavities with arbitrary curved surfaces, apertures, and interface roughness. Nevertheless, the mentioned routine is very time-consuming and therefore, we make use of a technique in order to convert the Huygens-Fresnel integral self-consistency equation into a matrix one and then find the eigenvalues and the eigenfields of the resonator.

In the end-pumped disk lasers, two configurations have been demonstrated so far: multi-pass (Giesen pump model) and recycling schemes. In the multi-pass configuration, which is going to be utilized in this work, the pump beam, typically from a homogenized diode-laser stack, is incident on a parabolic mirror. A paraxial ray analysis is performed to find the self-consistency condition to have stable periodic ray trajectory after one or two round trips. Here, special attention is paid to investigate the dependence of the transverse profile and the loss on the curvature of the output coupler and the cavity length.

Here, we have assumed that rear of thin disk is HR coated and has a role as the resonator back mirror. The coupler mirror with a determined curvature radius was located on the appropriate place. An axicon from of YAG material has been stuck on Yb:YAG thin disk. This axicon not only decreases the ASE and heat deformation but also causes the creation of the Bessel-Gauss mode on couple mirror.

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PE14

NEW DEVICES FOR APPLICATIONS IN LASERS AND OPTICAL COMMUNICATIONS BASED OF THE WEDGED INTERFERENCE STRUCTURES

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In the recent years we have investigated systematically (theory, experimental) the optical properties of the compact wedged interference structures of the Fizeau interferometer type for the non-studied case of illumination with a limited diameter laser beam [1-4]. The unique properties of this structure (IW-Interference Wedge),part of whichever are find by us, makes it competitive element for laser resonator design [1-4]. Here, on the base of our results, we present and discussed the new applications of an IW in realization of a new, practical useful, devices for optical communications, laser applications , metrologies and spectroscopy.

First, we present the original Wavelength-Division-Multiplexing competitive element for optical communications with the important properties of independent tuning of each input-output. We present also its practical realization. We carried out, on the base of our models, the theoretical consideration, especially for the case of work with a very short laser pulse ~ 1-0.05 ns, i.e. the pulse repetition rate of order of GHz and more, that are of interest for modern digital communications.

As a second point we present – theory, experimental, a new devices, based on the noted above wedged structure, for registration of extremely small (~ angular second) change of angle of the rigid object. We compare its action with the traditional devices and show its competitiveness.

As a third point, we show – experiment, theory, that for some cases (incident, angles, wedge thickness) the IW present a new properties of a strong optical asymmetry – i.e. the different place of resonant maximum for angular symmetrically incident beams. This property permits to use in convenient situations the IW wedge as an element, create the asymmetry, for example in ring optical laser resonators.

As a conclusion we discuss the potential of the carried out above new practical applications of the IW in noted modern and classical domains of human activity – the advantages and the limitation, the case of essentially competitive applications.

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PE15

FABRICATION, SUBSTRUCTURE AND PROPERTIES OF $LiNbO_3$ FILMS

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Fine $LiNbO_3$ films are perspective material for creation of heterostructures of acoustooptical devices, optical and acoustic wave conductors, etc. To buildup $LiNbO_3$ films, various approaches have been used. Ion sputtering methods, in particular, RF magnetron sputtering (RFMS) and ion-beam sputtering (IBS) are efficient for obtaining films of compound oxides, with preservation of their elemental composition.

In the paper fulfilled there have been studied: substructure, composition, and morphology of the films' surfaces, grown on the surface of plates (111)Si, (001)Si, heterostructure, single-crystal plate Si - amorphous film SiO_2, by methods of RFMS and IBS of single-crystal target $LiNbO_3$ of congruous composition in the medium of Ar. There have been studied structural and phase conversions in the films as a result of thermal annealing (TA). Electrophysical parameters of heterostructures Si-SiO_2-$LiNbO_3$-Al and Si-$LiNbO_3$-Al were studied by the methods of I-V characteristics, high-frequency (at 1 MHz frequency) C-V characteristics and through the frequency dependences of dielectric loss (impendence analyzer Solartron 1260).

Single phase films $LiNbO_3$with random grain orientation form on heated (550°C) substrates (111)Si-SiO_2. The element concentration in volume of the films corresponds to $LiNbO_3$. TA (700°C, 60 min) of the as-grown nanocrystalline films $LiNbO_3$ causes recrystallization, along with formation of block crystalline structure (with the size of the blocks approximately equal to 0.5 μm), consisting of subgrains $LiNbO_3$ (with average size 80 nm).The C-V analysis has revealed that the dielectric constant equals ε=27.8 (for $LiNbO_3$ as-grown films) and ε=29.7 (for $LiNbO_3$ films after TA). The I-V analisis demonstrated that, seemingly, in the studied heterostructures (100)Si-$LiNbO_3$-Al, a hopping conduction mechanism is realized along the charge localization centers (CLC) in layer $LiNbO_3$, with a variable jump distance[1]. TA entails a decrease in the bulk concentration of the traps from $N_t=1\times10^{18}cm^{-3}$ to $N_t=1\times10^{16}cm^{3}$.

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PE16

INVESTIGATION OF THE MEDIUM PARAMETERS IN STIMULATED BRILLOUIN SCATTERING PROCESS

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With the development of laser technology, laser protection is getting more attention. For this reason, one of the parameters investigated vastly in recent years is the optical limiting. The optical limiting mechanisms based on various nonlinear effects such as inverse saturated absorption [1, 2], nonlinear refraction, reflection, and diffraction [3], etc. One kind of nonlinear optical processes called Stimulated Brillouin Scattering (SBS) has the optical limiting characteristic. In SBS process, laser and Stokes wave interact with each other in a medium through the intermediary of a sound wave.

In the current research, we have considered that pump light propagates along negative z axis, while the Stokes light propagates along positive z axis as depicted in Fig. (1). By supposing slowly varying approximation, the coupling one-dimensional wave equations of transient SBS are written as follows [4]:

$$\left[\frac{n}{c}\left(\frac{\partial}{\partial t}\right)+\frac{\partial}{\partial z}\right]E_p=-\alpha E_p+ik\rho E_p \qquad (1)$$

$$\left[\frac{n}{c}\left(\frac{\partial}{\partial t}\right)-\frac{\partial}{\partial z}\right]E_s=-\alpha E_s-ik\rho^* E_p \qquad (2)$$

$$\frac{\partial}{\partial t}+\frac{\Gamma_B}{2}\rho=i\Lambda E_p E_s^*-\alpha E_s+f \qquad (3)$$

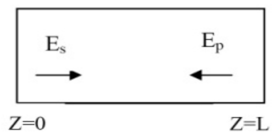

Fig.1.Geometry of the SBS interaction

where $E_p(z,t)$ and $E_s(z,t)$ are amplitudes of pump and Stokes light, respectively; α is a absorption coefficient of medium; Γ_B is Brillouin linewidth; n is refractive index; c is velocity of light in vacuum; $\rho(z,t)$ is medium density; K and Λ are Brillouin photon-phonon coupling coefficients and f(z,t) is a Gaussian random process. These equations can be solved numerically by finite difference method. In this paper, the effects of medium phonon lifetime, medium gain coefficient, focal length, and input pump power for Stokes signal initiation and development have been investigated in detail. In this respect, four different media, namely CCL_4, $GeCL_4$, CS_2, and acetone were used. The results demonstrate that different media need different noise profile for Stokes signal initiation and growing. Moreover, the result proposes a new way to investigate medium-radiation interaction via SBS process.

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PE17

INTERFEROMETRIC AUTOCORRELATION OF ULTRASHORT PULSES WITH TILTED PULSE FRONTS

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The pulse front tilt (PFT) is a specific spatio-temporal distortion of (ultra)fast optical pulses - the pulse front is tilted with respect to the direction of beam/pulse propagation, while its phase front remains perpendicular to it. The PFT is one of the major issues in chirped pulse amplification systems [1-3]. Specific diagnostic techniques for detecting and measuring PFT are available: tilted pulse front autocorrelation, spectrally resolved interferometry, and Grating-Eliminated No-nonsense Observation of Ultrashort Incident Laser Light E-fields (GRENOUILLE). The usual interferometric second-harmonic autocorrelators based on Michelson- or Mach-Zehnder-type schemes are not able to detect PFT unless one of the beams/pulses is inverted in space [4,5]. In such inverted-field autocorrelators the delay between the pulses depends also on the particular transverse coordinate across the beam and, hence, the recorded autocorrelation trace contains information on the effective broadening of the ultrashort pulse due to the PFT.

In this contribution we will present an exact analytical expression for the second-harmonic interferometric autocorrelation signal of an inverted-field autocorrelator. It confirms the intuitively expected effective broadening of the ultrashort pulses in the presence of an arbitrary PFT. Experimental data obtained with externally compressed pulses of a commercial femtosecond oscillator with intentionally and controllably introduced PFT will be discussed.

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PE18

CALCULATION OF TEMPERATURE DISTRIBUTION OF A TWO LAYER MODEL OF SKIN UNDER A PULSED LASER INTERACTION

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A comprehensive thermal model to obtain the temperature distribution in skin under a pulsed laser interaction has been presented in this article. For this reason, we consider a two layer model of skin. The exponential absorption of laser in the skin has been considered and a coupled of the non steady state and non homogenous heat conducting equation have been considered to describe the temperature distribution model. The differential equations solved analytically and the temperature distribution has been obtained in the two layer of skin by using the appropriate boundary conditions. The results then discussed finally and compared with the other models.

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PE19

THE PROPAGATION OF RAY IN THE FIBER LASERS WITH THERMAL ABBERATION CONSIDERATION

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The trajectory of ray in fiber laser according to ray equation with thermal consideration has been investigated in this paper. We considered a diode pumped fiber laser which heat deposited due to pumping. By considering exponential energy decay within the fiber, the heat conduction equation has been solved and the temperature distribution has been obtained. The nonhomogenous temperature distributions influence the refractive index and the trajectory of ray, too. The ray equation according to the temperature dependent change of refractive index has been obtained and discussed.

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PE20

ENHANSED SOLITON SPECTRAL TUNNELING EFFECT OF SELF-COMPRESSING COLORED FEMTOSECOND SOLITONS

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The discovery of stimulated Raman self-scattering (SRSS) effect of femtosecond optical solitons is acknowledged to be among the most notable achievements of nonlinear fibre optics. This effect is also often called intrapulse stimulated Raman scattering (ISRS), or soliton self-frequency shift (SSFS), thereby emphasizing the unusual regime of stimulated Raman scattering, when the spectrum of a high-power ultrashort laser pulse proves to be so broad that it covers the band of Raman resonances of the medium. In this case, the Stokes spectral component of the field shifted by the frequency of molecular vibrations is contained within the pump pulse itself. The amplification of low-frequency Stokes components in the field of high-frequency anti-Stokes spectral components of the same soliton pulse results in a continuous red shift of its spectrum. These extraordinary soliton-like wave packets travelling not only in the ordinary space and time, but also in the spectral space, are known as colored

femtosecond solitons. Colored solitons play an important role in the soliton supercontinuum generation.

The most interesting features of colored optical solitons are connected with the possibility of their tunneling in the spectral domain through a potential barrier-like spectral inhomogeneity of group velocity dispersion (GVD), including the forbidden band of positive GVD [1]. This effect is known as soliton spectral tunneling effect (SST).

In order to experimentally observe the SST effect, a fiber with a narrow normal GVD region surrounded by two regions of anomalous GVD is required. Recently, Dudley and coauthors [2] presented a numerical study of soliton spectral tunnelling in an index-guiding photonic crystal fibre with a sub-wavelength central air core defect. Poletti, Horak, and Richardson [3] designed a number of index-guiding holey fibers with relatively simple structure which possess suitable dispersive properties for the observation of soliton spectral tunneling.

In this report, we consider the influence of the soliton binding energy on dynamics of the SST effect when the amplitude and duration of the tunneling soliton vary in time when the soliton spectrum approaches a forbidden GVD barrier. We show that soliton self-compressing effect has dramatic impact on the SST through forbidden spectral region of positive GVD.

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PE21

INFLUENCE OF SOME GASEOUS ADDITIVES ON GAS-DISCHARGE PARAMETERS AND LASER PERFORMANCE OF A He-$SrBr_2$ LASER

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Recently, by means of free electron lasers (FELs) with variable wavelength between 3 and 20 μm, it has been found that the laser radiation at 6.45 μm is the most effective tool for soft tissue and bone ablation with minimal thermal damage and smear layer [1]. However, an application of the free electron laser in viable clinical systems is impeded by its size, cost and considerable overheads.

Further investigation and widespread clinical use of 6.45 μm radiation requires the development of an alternative laser source, delivering 6.45 μm radiation with output parameters capable of tissue ablation and having much greater clinical relevance. Strontium vapor laser, which operates on the 6.45 μm self-terminating atom transition [2], could be applied instead of the FEL. However, the short lifetime (several tens of hours) of the strontium laser discharge tube due to the chemical reaction between metal strontium and the discharge tube under the discharge condition of high operating temperature is a major shortcoming, limiting its further development. The difficulty of laser tube cracking could be overcome by using of strontium dibromide ($SrBr_2$) instead of pure Sr [3].

On the ground of our experience with CuBr vapor laser an increase in the output parameters could be obtained through the following methods: active volume scaling and exploring the influence of some admixtures to the buffer gas on the laser power. An active volume scaling in bore and length of a Sr atom laser excited in a nanosecond pulse longitudinal He-$SrBr_2$ discharge was carried out. The optimal temperature regime is found for laser oscillation on several different Sr atom and ion lines. The optimal discharge conditions for achieving a maximal multiline average output power are also found. At multiline operation a record average output power of 4.25 W is obtained, more than 90% of which is concentrated on the 6.45 μm Sr atom line.
A new discharge tube with furtherly increased active volume in bore is developed. The effect of different gaseous additives – neon, hydrogen, etc., to the helium buffer gas on the gas and electron temperatures, as well as on the output laser parameters is investigated.

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PE22

ENIGMAS OF OPTICAL AND MATTER-WAVE NONLINEAR SOLITON TUNNELING EFFECTS

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Recent studies have thrown doubt on the ideal treatment of soliton tunneling. The most important enigmas in this field can be formulated in the following way: As to whether nonlinear soliton tunneling effect will resemble more the point like classical particle case or the quantum mechanical behavior in which the particle itself has an internal structure? How `hidden' degrees of freedom can show up in the process of soliton tunneling?

Historically, the first demonstration that the soliton is a composite particle "possessing an inner degree of freedom" was found by Kosevich [1]. Kosevich considered the resonant and non-resonant soliton scattering by impurities in the mean field approximation and concluded that "we have to interpret the soliton as a bound state of N quasiparticles with its amplitude being proportional to N, that is why, when "the binding energy of a quasiparticle in the soliton is considerably larger that its kinetic energy it is difficult "to tear out" a free quasi-particle from the soliton" [1]. This physical mechanism of the soliton decay during its scattering by external potentials is hereafter referred to as the Kosevich mechanism of the soliton decay. To stress the complexity of the problem Kosevich concluded that "the NLSE soliton is similar to an atom but not to an elementary particle" [1]. It should be particularly emphasized that the soliton binding energy effect is most pronounced in nonlinear pairing of bright and dark NLSE solitons.

Recently, Segev and collaborators [2] discovered experimentally the nonlinear spatial soliton tunneling effects of paraxial Gaussian beam launched in a trap potential. By increasing the power levels, the dynamics transformed from linear tunneling to nonlinear tunneling, and then to a narrow spatial soliton ejection. In addition, partial trapping of the soliton was also experimentally observed. It seems very attractive to use both the spatial and temporal nonlinear optical soliton tunneling effects in the developing basically novel all-optical tera-bit-rate soliton logic and switching devices.

The question we should like to discuss in the present Report is: What happens if the amplitude and duration of the input soliton vary in time when the soliton approaches a classically forbidden barrier? In particular, what happens in the case of the nonlinear tunneling of self-compressing soliton when its binding energy is increased? As to whether this case will resemble more the classical particle case or the quantum mechanical behavior? These questions are taken up in this Report.

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PE23

DYNAMICS OF THREE-DIMENSIONAL OPTICAL PULSES IN A LINEAR MEDIUM WITH ATTENUATION

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A linear regime of propagation of short optical pulses in isotropic dispersive medium with attenuation is examined in present work. An exact analytical solution of the amplitude vector equation in k-space is found. Applying small parameter method to this equation, a solution up to first order is obtained.

PE24

SEWING UP THREE-DIMENSIONAL SOLUTIONS OF NLS EQUATION FOR A MEDIUM WITH SPATIAL DEPENDENCE OF THE REFRACTIVE INDEX

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3D+1 non-linear equation of Schrodinger for Ker-type medium with anomalous dispersion and spatial dependence of the refractive index is examined in the present work. Accurate analytical solutions in spherical coordinates for an area near to the beginning of the examined coordinate system are found. The points, in which the solutions are sewn up are obtained.

PE25

AXICON BASED RING LASER BEAM SHAPER WITH VARIABLE PARAMETERS

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We report on a flexible axicon beam shaper. Our design allows obtaining a ring shaped laser beam with variable parameter as ring diameter, ring shape, ring thickness and possibility to generate the ring with variable thickness.

A ring shaped laser beam is widely used for different physical, chemical and biomedical [1] experiments. There are a number of methods allowing a ring shaping of a laser beam. Most popular methods used to generate an annular beam can be summarized as:

- Shadowing the central part of the beam by diaphragm - the main part of the beam energy is lost and the beam profile is unsymmetrical.
- Mechanical scanning - moving part, speed limitation (especially for fast moving target), reduced average exposure time, tangential drag force introduced by scanning focus.
- Diffractive optics/Holography - lower efficiency, not suitable for power limiting system, dynamically adjustment of ring size and depth needs Spatial Light Modulator (SLM).
- Axicon - low cost, high efficiency, easy implementation. The ring size can be dynamically adjustable. The devise is practically achromatic.

Axicon is introduced by McLeod in 1954, to generate ring-shaped foci for cutting holes with great precision in various materials with CO2 lasers. Axicon is used to convert a parallel Gaussian laser beam into a ring, to create a non diffractive Bessel beam or to focus a parallel beam into long focus depth.

The main elements of the design proposed are two conical lenses – smaller and larger as is shown in Fig. 1. The smaller lens focuses the Gaussian laser beam and behind the focus the beam becames hollow conical one. The larger lens forms a cylindrical ring shaped beam. Changing the distance between two conical lenses we can change the ring diameter, maintaining the ring thickness. To change the ring thickness we should vary the input beam diameter. A prism or lens based variable beam expander can be employed for this purpose. Using a prism or cylindrical lens expander the beam can be modified to elliptical which allows obtaining a ring with unequal thickness. Finally a second variable prism beam expander can be used behind the larger conical lens allowing obtaining the elliptical ring. Optionally a hole through the conical lens can be drilled. This will allow easily obtaining a thin beam which is coaxial to the ring beam. The conical lenses are from glass (BK7) or plastic (PMMA). The plastic lenses are manufactured by diamond machining.

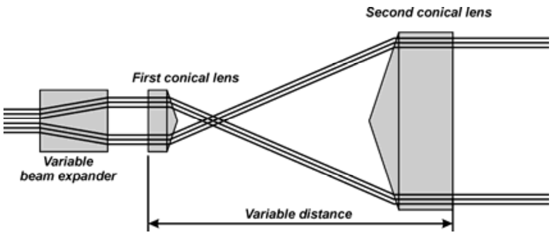

Fig. 1.Variable axicon based layout with a single beam expander.

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PE26

FRACTIONAL VORTEX DIPOLES OF EDGE-SCREW TYPE IN SELF-FOCUSING KERR NONLINEAR MEDIA

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Dark optical beams containing a mixed-type phase dislocation (a pair of π semispirals separated by a one-dimensional phase jump) have shown important potential for signal beam steering in negative nonlinear media (NLM) due to their defined spatial velocity, controlled through geometrical parameters [1-3]. Such beams, also called *fractional vortex dipoles*, were proven to create steering satellite peaks thus forming optically-induced curved waveguides in self-focusing (photorefractive) NLM [4].

In this work we study the evolution of dark beams of finite length carrying edge-screw phase dislocations (Fig. 1) in self-focusing Kerr nonlinear media aiming to find appropriate conditions to control the process of filamentation of the background beam. The initial stage of such self-focusing is shown in Fig. 2. In the case of a single fractional vortex dipole, geometry-controlled conditions for changing the left-to-right ratio of the peak are found. Depending on their orientation, two parallel or in-line mixed phase dislocations carried by a common background beam are predicted to perturb it and to initiate filamentation of a different number of peaks with different spatial distribution.

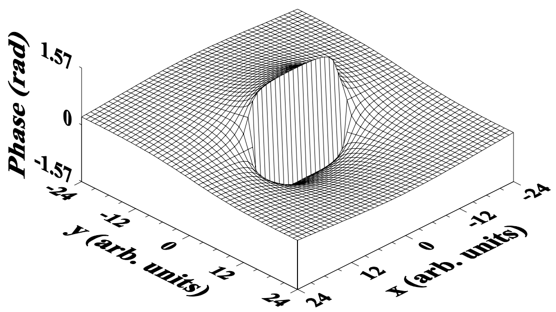

Fig. 1. The edge-screw mixed phase dislocation of a fractional vortex dipole.

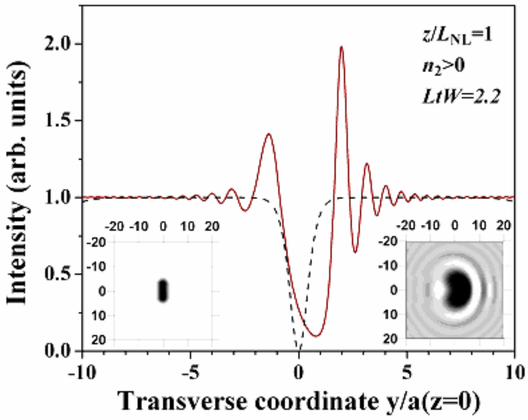

Fig. 2. Input (dashed curve and left inset) and deflected odd dark beam (solid curve, right inset) at a nonlinear propagation distance $z/L_{NL}=1$ for positive nonlinearity.

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