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CLEO®/Europe 2007

CA - Solid-state Lasers

Advances in solid-state lasers sources and systems provide powerful tools for an increasingly broad range of applications including high-resolution spectroscopy, trace-gas and remote sensing, communications, material processing, medicine, biology and entertainment. This year, the Solid-State Laser Section of CLEO/Europe has extended its scope to include such nonlinear frequency conversion techniques as continuous-wave intracavity self-Raman generation, which is particularly important for producing visible output at various wavelengths, as required e.g. for displays. CLEO/Europe also remains the meeting of choice for new developments in laser and nonlinear materials, high-power/high-energy lasers, and ultrafast laser sources for many applications in a broad spectral domain, from the ultraviolet to the mid-infrared region. The meeting is continuing its expansion to include anything that could impact the development of solid-state laser sources and systems, from concepts and basic material research, to new emerging devices and novel applications that drive the development of the solid-state laser technology. For example:

- new artificial laser materials, based on crystalline fibers and hybrid ceramics and crystals hold promise for future extremely compact, versatile and high-power laser devices,
- significant progress can be seen in the area of visible laser sources pumped with original blue and frequency-doubled infrared semiconductor lasers
- a new conduction-cooled compact laser is used for laser breakdown spectroscopy on Mars, and
- compact microchip lasers appear to be suitable for laser ignition in car engines, etc.

The present meeting will highlight a number of recent breakthroughs, among which, for example, is the achievement of the ~10 kW power levels by thin-disk solid-state lasers, the invited talk presented by A. Giesen from the Institut für Strahlwerkzeuge in Stuttgart, or the generation of 100-W all-solid-state UV lasers using improved quality nonlinear crystals, the talk given by T. Katsura from Mitsubishi Company in Hyogo, Japan. Last but not least, the progress in the all-ceramic Yb:YAG composite microchip lasers, exceeding 500 W output power, deserves mentioning, as presented in an invited talk given by T. Taira from the Institute for Molecular Science in Okazaki, Japan.

CB - Semiconductor Lasers

45 years after their invention, semiconductor lasers are ubiquitous. They have revolutionized optical communication, and optical storage devices, and find many further applications ranging from spectroscopy, via material processing to medical applications. They also represent one of the most active and progressing research fields in optics. This is reflected by 167 submissions to this conference, out of which 6 invited talks, more than 80 oral and about 40 poster contributions have been **selected by an highly qualified, motivated and well-supported world-experts committee**. Due to

advances in material technology, novel laser concepts and designs and, in addition, insights into nonlinear properties, new spectral regions and novel applications can be obtained or come in view.
At this conference, two communities have been joined for the first time: the laser technology and applications community and the nonlinear laser dynamics community. By the experiment bringing these communities together, it is intended to demonstrate that also nonlinear laser dynamics – so far rather considered a nuisance to applications - might be utilized and lead to novel applications.
The conference illustrates the huge bandwidth of achievable wavelengths, ranging in the presented contributions from 600nm up to 100µm, the latter being the so called Terahertz regime. Novel lasers have been designed to directly generate such 'Terawaves': the 'Quantum Cascade Lasers'. Recent advances and progress of these lasers will be presented on this conference. They might boost novel imaging applications comprising medical and security applications, and trace gas sensing.
Another hot trend represented on the conference is the realization of so-called micro- and nanolasers. The possibility to minimize and integrate lasers in arrays opens new perspectives to study and modify fundamental quantum optical properties of light. Moreover, they offer a huge variety of novel applications ranging from scaling the output power, up to integrated photonic circuits.

CC - Holography, adaptive optics, optical storage and photorefractives

Nanoparticles, nanorods, photoinduced lattices… are the new keywords reflecting the dynamism of the session on holography, adaptive optics, optical storage and photorefractives.
Mastering materials at the nanometer scale indeed considerably improves the performances of data storage recording materials and makes holographic memories always closer to reality. Nanoparticles dispersed in polymers increase the dynamic holographic range and simultaneously reduce the shrinkage. Similarly, polymer dispersed liquid crystals also presents low shrinkage and, moreover, an improved sensitivity in the blue part of the spectrum. After the large storage density allowed by the access to the 3D storage volume by holography, further boost of the capacity is now anticipated by accessing the spectral dimension. This dimension may become available by addition of metallic nanorods of various sizes and shapes, and thus of different sensitivity ranges, inside the same host matrix. Beside these new holographic materials, other point storage materials are still on the deck as shown by the papers on advanced chalcogenide materials and two-photon quantum dot photorefractive polymers.
Behind the presentations of the fascinating dynamics patterns produced by photonic lattices, and more generally by solitonic propagation and interaction, one can easily foresee and dream about new bricks for future flexible optical networks. The papers reveal a better understanding and control of light localization, of self trapped and self organized states and of light diffraction in photonic lattices.
Adaptive cavities and mirrors involved in the composition of original and smart laser systems appear to be closer to applications. Better control and better design of adaptive mirrors drastically improve the laser beam quality and brightness. Another approach is to design self-organized systems evolving spontaneously to the optimum emission regime. The different self-adaptive loop resonator and phase conjugate mirror setups presented here, demonstrate their ability to enhance the short pulse and high energy operations.
All these novelties should not hinder the constant ameliorations of the dynamic holographic interferometers involving photorefractives and laser gain materials as well

as the novel applications of stacked computer generated holograms for restitution of colored images.
We are convinced that all these exciting results will provide you with a very enjoyable and productive session.

CD - Applications of Nonlinear Optics

In recent years nonlinear optics has progressed from being a laboratory curiosity to being the basis of numerous commercial products. This change in emphasis is represented in the papers in this topical area which cover the entire field of nonlinear optics from Raman lasers and supercontinuum generation in fibres to engineering the nonlinear response of materials and using nonlinear optics for measurements. The highlights of these papers include a keynote address by Prof. Eggleton, invited talks on slow light, nonlinear photonic crystals, and high power fibre lasers. Complementing these invited papers are full technical sessions allowing the participant to obtain a clear view of how nonlinear optics is progressing and where the next important break throughs will appear. Of particular interest are the talks on slow light which emphasis the growing importance of this topic on future all-optical communications systems. We are also pleased to present two full sessions on quasi-phase matched materials for harmonic generation. This field has matured as can be seen by the number of talks presenting applications of QPM structures and the talks looking at more futuristic designs that have the potential to radically alter how we think about QPM in the future.

Frequency generation remains a popular area of work with numerous papers showing different ways to achieve this. This work covers everything from supercontinuum generation in photonic crystal fibres, Raman lasers in silicon waveguides, QPM materials, terahertz and microwave generation, cascaded effects in BBO, OPOs etc.

Papers on new materials for nonlinear optics can be found in many of our sessions. Examples of such materials are improved fibres, photonic crystal structures, doped nonlinear crystals, and templated growth of GaP.

Participants are also encouraged to look out for poster presentations in this area. These excellent papers showcase the diversity of nonlinear optics and demonstrate the different approaches to this area from experimental and numerical simulations to elegant theoretical analyses of difficult problems.

CE - Optical Materials, Fabrication and Characterisation

The subject area "Optical Materials, Fabrication and Characterisation" covers a very wide range of optical materials with very different optical properties, such as rare-earth-ion and transition-metal-ion doped crystalline and glass materials in bulk, waveguide, fiber and nano-size geometry, inorganic and organic semiconductor materials, again also in nano-size structures, as well as polymers, but also quite novel approaches such as ultra-thin transparent metal films and liquid micro-structures for optical applications.
Among these topics, the undoped and doped insulating materials have in general well matured, but there are still new discoveries of materials or material modifications providing high absorption and emission cross-sections, larger bandwidths, or enhanced nonlinear effects. Also novel (photonic-crystal) fiber geometries and waveguide fabrication methods have evolved. Also the investigation of nano-size crystalline

materials advances with further investigations of specific structures and their inpact on the optical properties of rare-earth ions.
Regarding the area of micro-structured fibers and fiber devices, highlights include the report on the fabrication of a large-pitch Kagome structured fiber for gas lasers, quantum and non-linear optics applications, as well as the development of an LP_{01} to TE_{01} mode converter based on photonic crystal fibers. Besides the fiber fabrication aspects, particularly interesting is a report on the application of femtosecond laser machining techniques on various types of micro-structured fibers to achieve selective gas/liquid filling for the development of devices suitable for sensing.
A considerable number of contributions was related to the implementation of a wide range of techniques for the fabrication of waveguide lasers. These include methods such as Pulsed Laser Deposition, radio-frequency magnetron co-sputtering, and the inclusion of nano-particles in glass and crystalline hosts. There were reports on the development of novel waveguide fabrication techniques based on UV laser exposure and on "unconventional" waveguide geometries such as micro-ring resonators. In this topical area, particularly interesting is a report on the development of a novel approach for fabrication of liquid channel waveguides by forming aqueous channels on chemically modified metal substrates. These devices are suitable for optical sensing of analytes in aqueous solutions.
On the semiconductor side, novel material properties and devices are demonstrated thanks to a further refinement in material fabrication and characterization techniques. Growth control of InGaN along the nonpolar m-plane is shown to lead to high quality LEDs, exciting emission properties for the LT GaAs are reported at 1.5µm, investigation on SiC polytypes show that these could be promising for development of LEDs. Carrier localization in AlGaN is evidenced by near-field optical imaging to be highly sensitive to the excitation wavelength. Other aspects of semiconductor properties are also highlighted, like for instance the broadband birefringence measured on GaP nano-wires which dependence on filling factor is discussed. Finally, improvement of rare-earth doping of silicon nano-crystalline materials by Ge introduction is further demonstrated.
Significant progess in the field of organic nonlinear and laser properties is evidenced. New information on relaxation processes in organic systems implies that rare-earth organic complexes may be promising alternatives to the silica-based systems. Results presented suggest new pathways to electrically pumped organic laser diodes and organic semiconductor materials which may be used as active layers of laser devices.
Advanced devices based on organic systems have been developed. An all solid-state polymer laser system comprising a semiconductor diode laser as pump source and an innovative energy-transfer gain medium is demonstrated. Planar waveguide structure formation in inorganic DAST crystals by H^+ ion implantation is a promising alternative to conventional photolithography.

CF - Ultrafast Optics and Applications

This year’s ultrafast session reflects the trend to broadband high power laser sources. Many contributions deal with experiments and theoretical work regarding supercontinuum generation based on filamentation in gases as well as broadband radiation generated in highly nonlinear fibers. Optical parametric amplification towards high power laser pulses becomes more popular, and many groups deal with OPA/OPCPA schemes even with carrier-envelope stabilization. Frank Wise reports on self-similar pulse evolution in fiber oscillators, enabling the scaling towards high energy output. Converting ultrashort optical pulses to electron pulses is the subject of the group

of Christoph Lienau at the Max Born Institute. They demonstrate ultrahigh resolution near field imaging of local electric fields.
Apart from novel generation schemes, a complete session describes progress in measurement of such extremely short pulses, and many groups are involved in research about new and improved techniques for pulse characterization. One further subject is the transfer of ultrafast technology in remote wavelength areas like the UV and the THz range. A few applications of ultrafast laser sources are reported, e.g. in waveguide writing and material processing, but also in fields as remote as archaeology. These sessions emphasize the fact that ultrafast optics is one of today's most important enabling technology in different areas of science.

CG - High-field laser physics and applications

The development of intense femtosecond lasers capable of generating electric fields comparable to the strength of the Coulomb interactions that hold together molecules has motivated extensive fundamental research in the last twenty years. This has led to a detailed understanding of the way that atoms and molecules ionize and dissociate in intense laser fields, or lead to the production of high density plasmas upon irradiation of solid targets. Many of these studies have led to important spin-offs. An example is the development of coherent light sources in the extreme ultra-violet part (XUV) part of the spectrum by means of high harmonic generation, a technique that recently has been shown to generate attosecond pulses. Laser-driven plasmas have been shown to be a highly effective route towards particle acceleration, and promise to reduce the scale of high energy particle accelerators to the laboratory scale. Finally, in the last few years, a new trend can be witnessed in molecular physics research using intense laser fields, where this field is beginning to make contributions to the determination of molecular structure and molecular wave functions.
The session on high-field laser physics and applications reflects the latest developments in this rapidly evolving field.
Two sessions will be dedicated to the generation of energetic particle sources produced with plasma accelerators driven by intense and powerful lasers, which is a new and emerging field combining expertise in laser science, plasma physics and accelerator physics. An overview of the development of several ultra-high power laser facilities will be presented, and the tremendous evolution of compact accelerators will be highlighted in a series of invited talks.
Attosecond physics made its debut less than ten years ago, opening new roads towards studies of ultrafast electron dynamics in all states of matter. The field is still far from mature and extremely rapidly evolving. There will be two sessions devoted to this topic. A session on ultrafast dynamics at XUV/x-ray wavelengths will highlight groundbreaking applications of XUV attosecond radiation and femtosecond x-rays. And a session on attosecond metrology will be devoted to the latest developments in few-cycle CEP stabilized sources as well attosecond generation, characterization and application.
High harmonic generation is the foundation of the attosecond science, and one session is dedicated to new experiments targetting new understanding of the fundamentals of harmonic generation as well as the development of the intense few-cycle laser systems that are crucial in this research.
Finally, one session is devoted to molecular dynamics in intense laser fields, highlighting the latest developments in laser-driven molecular alignment and ionization, the use of harmonic generation for tomographic imaging of molecular orbitals and new and important theoretical developments addressing electron dynamics in intense laser fields.

CH - Optical Sensing and Metrology

Optical Sensing and Metrology is now a developed enabling technology for a very wide range of scientific applications in diverse fields ranging from precision metrology to advanced sensing technologies. The *Applications of Optical Sensing* topic area of CLEO Europe 2007 reviews the latest advances in this rapidly expanding field with invited and contributed papers.
Invited talks will describe state of the art research in optical sensing based on conventional and photonic crystal fibers. A number of high quality contributed papers cover the topic area in series of thematic oral sessions.

Photonic Crystal Fibers for Sensor Applications includes an invited paper describing the first demonstration of photochemical long-period grating fabrication in pure silica photonic crystal fiber. This technique allows for inscription of stronger resonances with narrower bandwidth gratings. The properties of two-mode interferometer are paving the way to novel sensors and new scientific applications with PCFs.

Photonic Sensor Technologies and Applications includes an invited talk from professor Michel Digonnet, who addresses advanced technologies in fiber sensors. It is followed by papers describing recent related developments in the field of THz sensing and all-organic waveguide application.

Bio and environmental sensing technology includes an invited talk from professor Kazuo Hotate dealing with a novel technique of distributed strain measurements, which provides millimeter-order resolution. It will be followed by a number of papers on monitoring the biological, environmental or production conditions.

Optical spectroscopy and precision metrology includes a number of papers on nanoscale spatial resolution, high sensitivity spectroscopy and force measurements.

Many interesting results are expected to stimulate lively discussions in the poster session which includes many good quality papers from this topic area covering both fundamental and applied research in the field.

CI - Optical Technologies for Lightwave Communications and Networks

The massive growth in demand for bandwidth is continuing to drive the need for advanced lightwave communications and networks, and this in turn is driving the research and development of new optical technologies that will be employed in these future networks. ***The Optical Technologies for Lightwave Communications and Networks*** topic area of CLEO Europe 2007 reviews the latest advances in this expanding field with invited and contributed papers.

The invited paper presented by Prof. Ludwig, from Heinrich Hertz Institute, will review the latest advances in ultra-fast optical transmission technologies and explore some of the key building blocks that will be required to achieve optical transmission at data rates in excess of Terabit/s. The second invited paper, presented by Prof. De Waardt from COBRA Research Institute, will detail the most recent research on the applications of

SOA's in ultra-high speed optical networks, and present how these devices can be used for optical demultiplexing at bit rates up to 640 Gbit/s.

The large number of high quality contributed papers will cover the topic areas in 8 thematic oral sessions.

DPSK Transmission Technologies includes work from Aston University which details the performance analysis of RZ-DPSK non-slope matched transoceanic submarine links.

Optical Signal Generation session will include a paper detailing the development of 100 GHz pulse source from a passively mode-locked Er:Yb:glass laser at 1530 nm from ETH Zurich.

Transient Effects and Packet Switching includes work from Bell Labs, which examines the evolution over distance of power transient excursions in "broadband Raman amplifier transmission system" as a function of surviving channel wavelength.

Optical Regeneration session will demonstrate novel research on a self-phase modulation based 2R optical regenerator for the simultaneous processing of two WDM channels carried out by the Optoelectronics Research Centre at the University of Southampton.

Advanced Communication Devices includes work from CNRS in France detailing a novel passive all-optical semiconductor device that can be used for bit-1 noise level reduction and research by the University of Kalsruhe which details gain and phase dynamic measurements on a 1310 nm quantum dot amplifier.

All-Optical Signal Processing includes research carried out at the National Institute of Information and Communications Technology, which outlines all-optical phase multiplexing from DPSK WDM signals to DQPSK using four-wave mixing in highly non-linear fibre.

Novel Transmission Techniques session will present work detailing a high-capacity, high spectrally efficient transmission system using a single DFB laser with NRZ Coherent WDM and polarisation multiplexing undertaken at Tyndall Institute, University College Cork and research from COM.DTU detailing the generation of flat top pulses for ultra fast OTDM demultiplexing.

Signal Monitoring and Conditioning includes work from CUDOS at the University of Sydney, which demonstrates reconfigurable dispersion trimming in an LCOS-based dynamic wavelength processor.

CJ - Fibre and guided wave lasers and amplifiers.

The rapid development in fibre laser technology in the past few years, resulting in a family of compact, highly reliable sources with controllable diverse operational parameters in efficient, cost effective packages has meant that the fibre laser is rapidly replacing conventional laser sources in numerous applications areas both in the laboratory and in the industrial workplace. The diverse parameters of the fibre based source are well represented in this conference, covering aspects of femtosecond pulse

generation, new wavelength lasers, amplification and high power operation, microstructed fibres, high power superfluorescent sources and non linear wavelength conversion .

Professor David Richardson of the ORC, Southampton University, UK, in his Keynote Presentation highlights the diversity describing the evolution of the cw high power fibre laser from a hundred watts in 2001 to the 3kW commercially available single mode devices of today and the inroads that beam combined multimode systems are making into the heavy industry markets. Richardson will cover many of the key areas of fibre laser technology, describing the impact that MOPFA (master oscillator power fibre amplifiers) are having on science and technology with seed systems operating from narrow line to ultrashort pulse.

The palette of applications of fibre lasers has also been enhanced by the dramatic advance of the microstructured fibre, allowing non linearity to be enhanced or eliminated and allowing fibres with designer selectable fibre parameters impossible in conventional structures. In an invited presentation Phillipe Roy of Université de Limoges will describe the remarkable control available with doped microstructured fibres and their application.

One particular area where strict control of the operational parameters is of vital importance in fibre systems is in high power ultrashort pulse generation, where non linearity can completely distort pulse shapes and spectra. Dr Jens Limpert of Friedrich Schiller Universität Jena in another invited presentation will describe advanced fibre designs and techniques used to overcome these limitations in high power oscillator amplifier schemes. Two sessions highlight research in short pulse fibre laser technology, where optimized pulses as sort as 30 fs have been generated in an exceedingly simple one step compression all-fibre configuration.

Although high power fibre lasers have primarily concentrated on Yb-doped devices, considerable progress has been made in high power outputs using other dopants, including Er and Tm. D. Shen from the ORC, Southampton describes their progress on high power Tm based superfluorescent sources. Recently considerable interest has been directed at Bi doped fibre as a broad bandwidth laser in the near infra red. Dianov's group from the GPI Moscow describe the use of a Bi-doped fibre laser, pumping an integrated Raman laser further extending wavelength coverage. A complete session also deals with fibre based Raman sources, both cw and pulsed. With increased operational power, photodarkening becomes a vital consideration and several presentations will be made on this technologically important topic.

CK - Photonic crystals, photonic nanostrucures and Integrated optics

The intensive research in the area of nanostructured materials for photonic applications has branched in many directions. They contribute to deepening the knowledge and finding new applications and devices that profit form the novel phenomena occurring with light in nanometric size environments
CLEO 2007 has attracted contributions that highlight the progress in these areas and will constitute a show case of the most recent and exciting advances in the field. The study and application of photonic crystals, and nanostructures and their integration in optical structures and devices will be reported in several sessions.

Photonic crystal fibres have enabled a rapid progress in the application of photonic crystals concepts to the development of mainly non-linear optics devices as will be highlighted by a tutorial lecture by *Ph.St.J. Russell* and contributed papers.

The **negative refractive index** (meta-)materials are a new class of materials conceived only very recently but based on relatively old ideas. These novel concepts and recent developments will be featured in CLEO sessions on this topic and in particular in the lecture by recent Descartes Prize *C. Soukoulis*. In this same area **Plasmonic** nanostructures and related concepts have gathered good deal of momentum in the nanophotonics arena for their ability to concentrate electromagnetic fields to the nanometre range. These hold the key to new applications including lensless focusing, superresolution, etc.

2D Photonic crystals have largely led the research in applications of photonic crystals owing to the already mature technology adopted for their fabrication. New results on techniques and materials are constantly being produced and will be reported in CLEO. Also **Photonic nanostructures** and devices like lasers and specially Silicon photonics will be major highlight of the CLEO conference. *H. Rong* from Intel will be opening a session with recent results on their Raman silicon laser that will be completed with several examples of devices and fabrication techniques.

3D photonic crystals continue to attract attention from the photonic band gap community as they the hold the key to several applications. Also research in fabrication methods will be reported among which self assembly will be specially featured in the invited contribution by *G.A. Ozin*, world-leading researcher in the field who will be reporting on the potential of this method.

The study of **Photonic states and propagation** of electromagnetic fields in complex photonic structures is a hot area of research that involves not only the understanding of light matter interaction but also the conception of new means to mould the flow of light. **Disorder in photonic** nanostructures is emerging as a new frontier in the study of propagation in complex dielectrics. It constitutes a topic that is rapidly maturing and is offering enticing new results. **Imaging and spectroscopy** tools are constantly being developed for sensors and other applications on which new reports will be heard in the conference.

Non linear optical properties of PCs are capitalizing on the novel possibilities offered by the photonic crystals environment whence new applications are being designed.

CL - Biophotonics and Applications

Optics and biology have been interacting since the invention of the microscope but in recent years the field of biophotonics has greatly expanded bringing its ideas and expertise beyond simple imaging to the investigation of various problems of biological interests ranging from single molecule spectrocopy, to manipulation of cells and diagnosis and treatment of tissues.

Techniques such as fluorescence or two photon microscopy are now used on a daily basis by biologists and are still evolving and improving. Furthermore, the latest ideas of physics and optics such as whispering gallery modes, multiphoton and nonlinear optics to name just a few, are moving fast towards new techniques and instrumentation for

biomedical applications. The range of these applications is as wide and diverse as these new ideas: the sessions will feature applications for diagnosis, treatement as well as investigation of fundamental biological processes.

The biophotonics and applications conference will feature four oral sessions and a poster session.

"Enhanced biosensing" focusses on how interaction of light with nanoparticles and structured surfaces through plasmon or other resonances can dramatically increase the detection sensitivity of biophotonics instruments and techniques.

Optical tweezers are continously evolving and allow now the go beyond simple trapping of objects. Combined with the use of femtosecond pulses the field of single cell modification, or surgery, can be be forseen. These ideas and techniques will be present in a session titled "Optical trapping, manipulation and modification" of biological objects.

"Tissue optics" will tackle the difficult problem of light propagation in highly scattering biological media. The complexity of optical characterization has an impact not only on imaging of the tissues but also on techniques in which light acts as a mediator such as drug delivery for example.

New "Multiphoton and fluorescence" microscopy techniques and their application to the study of fundamental biological processes will be featured.

CM - Fundamentals and Modelling of Materials Processing with Lasers

The session considers the fundamentals and modelling of materials processing with the use of lasers. The processes considered are manufacturing techniques. Topics include laser welding, cutting, surface treatment, drilling, ablation, pulsed laser deposition and others. The fundamental physics during materials processing is discussed. The processes considered include optical phenomena, absorption, non-linear interaction, heat conduction and convection, phase transformations and plasma formation. Moreover the session deals with fluid flow of melts, gases, vapours and plasmas and the formation of stress and strain. The process geometry, in particular the interaction front, is of central importance. Beside experimental methods like imaging, the processes are investigated by modelling in order to understand the fundamentals.

The session is subdivided into two parts. The first part is on laser macroprocessing, particularly surface treatment and drilling. Materials such as ceramics, metals and biomaterials are studied. The processes aim, for example, at the optimisation of wear and friction of machine tools, or biocompatibility of orthopaedic implants.
The second part is devoted to microprocessing by means of ultra-short pulses. For example, pulse shaping due to non-linear effects is studied. Moreover, the generation of nano-particles is investigated as well as their properties. The session is supplemented by a series of posters covering similar areas, and additional fields and materials.

IQEC 2007

Nearly 50 years after its invention, the laser continues to spark scientific and technological developments. From the very beginning, the International Conference on Quantum Electronics has brought together physicists to advance fundamental research in fields ranging from laser physics to quantum optics to new optical materials. Researchers will report groundbreaking results from their laboratories and discuss further applications of laser light.

For instance, new kinds of microscopic sensors and information processors are based on the subtle and often unexpected behaviour of quantum mechanics. The devices may use single atoms, or single particles of light (photons) trapped between tiny mirrors, or even artificially made quantum objects such as quantum dots or microscopic tuning forks. A whole new science is being developed as we understand how to use the interactions of these quantum objects with each other to address problems of measurement, sensing and computation. These building blocks form the basis of an emerging new technology. One breakthrough is the construction of a tiny atomic clock the size of a grain of rice, which could enhance battery-operated devices such as GPS receivers and mobile phones. Participants can learn how light can be slowed down or even stopped with vapour cells or waveguides. Promising applications are presented for optical buffering, data synchronization, optical memories and optical signal processing.

The laser has emerged as probably the most precise of all measurement devices we possess today. With so-called optical frequency combs we can now directly count the cycles of an optical wave, making optical atomic clocks possible and revolutionizing precision spectroscopy. This breakthrough, pioneered by J. L. Hall and T. W. Hänsch, was recognized with the 2005 Nobel Prize in physics. J. Hall will open the symposium on frequency combs with personal reminiscences. T. Hänsch will review the relentlessly advancing art of measuring optical frequencies in his plenary lecture. Another highlight of precision physics will by presented by G. Gabrielse with his new measurement of the electron's anomalous magnetic moment, which constitutes the best present test of quantum electrodynamics.

Optical devices are also following the quest for ever more compact, micro structured devices. Tiny optical micro cavities are more stable and more sensitive than their macroscopic counterparts. The new fields of nanophotonics and metamaterials emerge when we force light to interact with nano-structures, artificial optical materials arranged at the scale of only billionths of a meter. These artificial materials promise functionalities not available with natural materials.

Needless to say, the full range of optical research topics ranging from quantum optics to quantum information and light control of ultracold atoms will be presented in this show, highlighting how fundamental research in optics may potentially contribute to the advancement of physics and technology.

IA - Microstructured devices for Quantum Optics and Atom Optics

Researchers are starting to use atomic vapour, sometimes cooled almost to the absolute zero of temperature, to make new kinds of microscopic sensors and

information processors. These are based on the subtle and often unexpected behaviour of quantum mechanics. The devices may use single atoms, or single particles of light (photons) trapped between tiny mirrors, or even artificially made quantum objects such as quantum dots or microscopic tuning forks. A whole new science is being developed as we understand how to use the interactions of these quantum objects with each other to address problems of measurement, sensing and computation. These building blocks form the basis of an emerging new technology.

Scientists are bringing these ingredients together with the aim of inventing practical devices that are robust, simple to use and offer new capabilities. One breakthrough is the construction of a tiny atomic clock the size of a grain of rice, which could enhance battery-operated devices such as GPS receivers and mobile phones. Other important developments are the demonstration of single-atom detectors and single photon sources, which are crucial steps in the realisation of quantum computing devices on a chip.

IB - Cold Atoms and Molecules

The ability to cool atoms with the aid of lasers to temperatures far less than a thousandth of a degree above absolute zero has allowed to enter a new realm of physics where the behaviour of atoms is completely governed by quantum mechanics. The study of ultracold atoms and recently also ultracold molecules is meanwhile a well established research area at the interface between atomic, molecular and condensed matter physics, and two Nobel prizes have been awarded to researchers in this field.
Now physicists routinely control the quantum behaviour in atomic systems at an exquisite level of precision and are currently pursuing the extension of quantum control to molecules. A major step in this direction was realized by sticking ultracold atoms into egg-cartoon-like potentials created by optical standing waves. This environment serves as a micro-laboratory in which novel states of matter are created and atoms are converted to molecules in a very well controlled way. The importance of optical lattices is reflected by a tutorial and several contributed papers that are dedicated to experimental and theoretical studies of ultracold particles in these optical lattices.
Recently, several groups focused on the realization of systems in which novel interactions between the particles strongly modify the behaviour of ultracold gases. Prominent examples which are presented at the conference are the realization of magnetic quantum gases and the excitation of so-called Rydberg atoms in Bose-Einstein-Condensates and. While in most ultracold systems that have been studied so far, the interaction of the atoms was very similar to that of round balls, in these new systems the orientation of the atoms becomes relevant. These efforts to create new kinds of ultracold gases are supported by ongoing developments to improve the cooling and trapping schemes and in particular to extend direct cooling methods to molecules.

IC - Quantum Information

Quantum information processing has progressed rapidly in the past decade, growing into a large interdisciplinary activity. Potential platforms for quantum information processors range from photons to atoms to superconductors, and frequently require interfacing such disparate systems, providing significant technological challenges, as well as revealing exciting new physics.

The conference program highlights a number of significant advances in the field, across the broad scope of platforms. There are invited talks in the areas of optical entanglement distillation, coupling of superconducting qubits, and opto-mechanical entanglement. These areas represent the forefront of some newest strands of the field; demonstrating new protocols for the conditional preparation of quantum optical states, showing precise control over macroscopic quantum systems of many electrons, and proposing and experimentally demonstrating a new direction for light-matter interactions.

These papers are supplemented by sessions on quantum cryptography, quantum repeaters and memories, cavity quantum electrodynamics and the theory of quantum information, some of which are jointly scheduled with quantum optics and cold atoms topical areas. These sessions emphasize the importance of developments in many fields to the progress of quantum information processing as a whole.

Three significant themes underpin the current work. First, the idea of precise control over individual particles: atoms, photons and ions. Second, the concatenation of these microscopic systems to enable the generation and distributions of large-scale entanglement. And third, the implementation of qubits directly in macroscopic quantum systems, including the coupling of such systems via electromagnetic fields. These themes severally indicate that the interface of static and flying qubits will be a central feature of future quantum processors, and the ability to control the interface between radiation and matter at the quantum level is likely to be a key enabling technology for future systems. The work to be reported at this conference will describe a number of important breakthroughs in these areas.

ID - Photonics Applications in Fundamental Physics

The topical section on “Photonics Applications in Fundamental Physics” has emerged from the former very vast topical section on “Laser Spectroscopy”. Nonetheless, laser spectroscopy remains a dominant feature of the presentations in this section which splits into one poster session with 9 presentations and three sessions with oral presentations covering the areas of “Optics at the micro- and nano-scale”, “High precision metrology”, and “From spectroscopy to relativity”.

An absolute highlight of this topical section will be the invited lecture of Prof. G. Gabrielse from Harvard University on his new measurement of the electron’s anomalous magnetic moment which constitutes the presently best test of quantum electrodynamics. A second invited lecture by Prof. A. Peters from the Humboldt University in Berlin deals with modern optical tests of relativity and Prof. K. Vahala (Caltech, U.S.A.) will deliver an invited keynote lecture on new physics using high finesse optical cavities with applications ranging from photonic clocks to back-action cooling on a chip.

The contributed papers cover a wide range of laser applications in fundamental and applied physics. Several contributions are in the domain of precision metrology covering inertial sensing, new deep-UV light sources, the electron/proton mass ratio, and optical clocks. High resolution spectroscopy, both in the conventional transmission/absorption geometry as well as in reflection spectroscopy play a predominant role. An original topic which has emerged in recent years is the spectroscopy of alkali vapors in cells with a sub-wavelength sized thickness.

The session contents of this topical section illustrate the broad field of applications of high resolution and high precision spectroscopy and demonstrate that this field is very much alive.

IE - Nonlinear Optics and Ultrafast Phenomena

The Nonlinear Optics and Ultrafast Phenomena topic brings together a large, high quality and diverse set of exciting advances including femtosecond dynamics, coherent control of matter with light, soliton behavior and nonlinear manipulation of light. The session on slow light and resonant systems starts with the tutorial by Prof. Gauthier on using room temperature waveguides to slow down light. Slow light has potential for applications in optical buffering, data synchronization, optical memories and optical signal processing. The following session on frequency mixing and harmonic generation presents new results and techniques in 6 contributed talks. An invited talk on femtosecond terahertz studies of excitons leads off the session on Ultrafast Dynamics of Excitonic Systems. Terahertz spectroscopy can test the quasi-particle of excitons in a direct, time-resolved way and explore new quantum optical processes. A series of exciting talks is highlighted by a talk on theoretical proposal for use of attosecond pulses to study light-matter interactions on an unprecedentedly short time scale. The possibility to coherently manipulate magnetism on an ultrashort timescale is described by two invited talks in the session on coherent dynamics. In the first of these talks, laser generated magnetic fields are used as a fundamental novel stimulus of magnetism that can be employed for excitation and coherent control of spins on a subpicosecond timescale. The second invited talk, reports a powerful technique for imaging the spin dynamics of magnetic nanostructures with high spatial resolution on an ultrafast timescale. Soliton dynamics in both the spatial and the temporal domains are discussed in a pair of sessions. Interactions between temporal solitons, which can form bound pairs, are discussed in the context of optical fibers. Similarly, interactions between spatial solitons are presented in several talks in the second of these sessions including X-waves, which are weakly localized wavepackets that propagate without experiencing beam spreading. The discoveries presented in this rapidly evolving field push the frontiers of manipulating light and matter and pave the way for further advances and future applications in a wide range of fields from telecommunications to semiconductor devices.

IF - Quantum Optics

The quantum properties of photons and atoms become more accessible to experiments and play an increasing role in future applications. Photons are used for sensing and for the transmission of information. One future goal is to use atoms for the storage of quantum information.

This topical program shows new trends, techniques and results. This includes the observation of single atoms and photons in optical resonators and the effect the strong coupling with the modes of the cavity can provide. Impressive progress will be reported in the generation of non-classical light, using a wide range of systems such quantum dots, optical fibres, photonic materials and micro cavities. Experiments show that spatial effects that can now be used to improve imaging beyond the conventional limits and to

transmit quantum information. Great progress has been made in the measurement of atom spin near and below the quantum noise limit.

This program shows the recent progress in the design of light source, proposals and demonstrations in measurement techniques and new demonstrations of the transfer of quantum properties, in particular entanglement, between atoms and photons.

IG - Abstract on Dynamics, Instabilities and Patterns

This session presents recent advances on spatiotemporal instabilities in optical systems. It includes actual and relevant research on temporal instabilities in quantum dot lasers, studies on the generation, control and applications of cavity solitons in semiconductor materials, work on localized structures (also called dissipative solitons), spatio-temporal instabilities in novel materials, and intriguing propositions involving microspheres, fractal, left-handed or other unconventional systems.

The appearance of quantum dots lasers is one of the most recent advances in semiconductor laser technology. Here several papers deal with the dynamical behavior of such lasers, including effects of feedback and modulation of control parameters.

During the last years there was noticeable progress in the study of localized structures in optical systems, also called cavity solitons or dissipative solitons. This research subject, a natural evolution of the study of spatial instabilities in optics, strongly advanced recently after their existence had been demonstrated in several experimental set-ups. As a result we present here two sessions dedicated to dissipative solitons, one of them fully dedicated to semiconductor materials. In fact, semiconductor materials feature fast time scales, and therefore they represent a natural choice for applications in information technology.

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JSI – Cryptographic Techniques in Photonics

With the burgeoning of high speed communications services the need for security in information transmission becomes more and more pressing. Reliance on conventional software encryption alone may compromise the privacy of communications. Hardware encryption schemes will add significantly to the level of security. Two distinct approaches are being vigorously pursued: chaos-based and quantum-based encryption.

Chaos-based encryption exploits the complex dynamical behaviour that naturally emerges in devices utilised in fibre optics communication systems. Such noise-like complex dynamics allows masking of information at high bit rates. The recent successful field trial over the metropolitan area of Athens, Greece, shows the practical applicability of this technique. A key feature of this demonstration was the use of off-the-shelf components and legacy optical fibre network. To bring this technique to the market on a large scale integrated photonics components, specifically designed to generate controllable chaos are being developed.

Quantum cryptography is a hybrid software/hardware level encryption scheme based on fundamental quantum properties of physical systems. Here a dedicated channel is used

to distribute a key that can be then utilised for software encryption prior to transmission over an existing channel. The future development of bespoke components could enable the potential for high level security to be realised. This technique, due to requirement of a “quantum” key channel, would be suitable for such niche market requiring an extremely high level of security.

JSII - Nanophotonics and Metamaterials: From Concepts to Devices

The new fields of Nanophotonics and Metamaterials emerge when we force light to interact with nano-structures, artificial matter engineered and arranged on the scale of only billionths of a meter. Crossing the “quantum bridge” between *nano* and *photonics* produces a remarkable range of new materials and phenomena. Nanophotonics and Metamaterials promise captivating new fundamental physics and functionalities not available with natural materials. Application of these new concepts will lead to new exciting developments such as imaging instruments with incredibly high resolution, low power, ultra-small devices performing at the quantum edge in a wide range of technologies, from information processing and telecommunications, data storage to defence-related monitoring, security, medicine and biotechnologies.

The Joint Symposium feature invited talks by Zhang Xiang (Berkeley) on plasmonic meta-materials. Vlad Shalaev and co-authors (international group led by Purdue University) will give an invited presentation on low-loss photonic meta-materials. A group from CEMES-CNRS in France and Photonics institute in Barcelona (Romain Quidant) was invited to give a presentation on exploiting plasmonic effects in optically-driven manipulation of small metal particles, while Jeremy Baumberg (Southampton) will give a keynote talk on tailoring light-matter interactions in confined photonic structures on the 1-100nm length scale. Topic like tuneable photonic crystals, chirality in metamaterials, slow light in nanostructures, nonlinear and lasing phenomena in nano-structured matter, optical nano-antenna and microcavities will be covered in this symposium.

JSIII - Optical Frequency Combs and Applications

Optical frequency combs based on femtosecond mode-locked lasers have brought about a revolution in optical frequency metrology, providing a simple and robust means of connecting the optical and microwave domains of the electromagnetic spectrum. This has made possible the direct counting of optical cycles, which is a critical milestone in the creation of next-generation optical atomic clocks and techniques of precision spectroscopy. Indeed, the importance of these recent developments, as pioneered by T. W. Hänsch and J. L. Hall, was recognized in the award of the 2005 Nobel Prize in physics. Beyond applications in precise time/frequency metrology and tests of fundamental theories, such combs have opened new research avenues in precise length metrology, remote ranging and sensing, novel broadband spectroscopy techniques, and the synthesis of low-noise/low-jitter waveforms. Moreover, these applications have synergistically motivated important developments in carrier-envelope stabilized femtosecond lasers, coherent linking of multiple broadband sources and nonlinear broadening and frequency conversion techniques that have now pushed frequency combs into new spectral regimes from the XUV to far-IR.

This joint symposium captures the excitement and diversity of this field by gathering experts to present their latest research developments (both fundamental and applied) in the above-mentioned areas. New research highlighted in this symposium includes the use of frequency combs in precise optical frequency transfer over 200 km in an existing urban fiber network. Also featured is the generation of terahertz-spaced frequency comb structure in silica micro-cavities. Frequency combs have been applied to the high precision measurement of the optical properties of various gases, including the determination of the refractive index of air at the part per billion level. Two invited talks on vacuum ultraviolet frequency combs and line-by-line pulse shaping with frequency combs will also be presented.

The symposium will be opened with a special introduction by Dr. John L. Hall, a 2005 Nobel-laureate in Physics.