9 NCCR Quantum Photonics

Wednesday, 26.03.2008, Room 2170 (2nd floor)

Time	ID	QUANTUM PHOTONICS 1 *Chair: NN*
10:00		***Coffee Break***
10:30	**911**	**Use of Ultrafast Molecular Dynamics and Optimal Control for Identifying Biomolecules** *Jean-Pierre Wolf [1], Luigi Bonacina [1], Ariana Rondi [1], Jerome Extermann [1], Francois Courvoisier [1], Veronique Boutou [2], Herschel Rabitz [3], Jon Roslund [3], Matthias Roth [3], Laurent Guyon [2]* *[1] GAP-Biophotonics, University of Geneva, 20 rue de l'Ecole de Medecine, 1211 Genève* *[2] LASIM (UMR CNRS 5579), Universite Lyon 1, 43 Bd du 11 Novembre 1918, F-69622 Villeurbanne* *[3] Dept of Chemistry, Princeton University, Princeton, NJ, 08544, United States* The identification and discrimination of molecules that exhibit almost identical structures and spectra using fluorescence spectroscopy is very difficult. A proof of principle experiment based on quantum control has been performed using Riboflavin (RBF) and Flavin Mononucleotide (FMN) as model system. We used a complex multipulse control field made of a pair of pulses (UV and IR). Clear discrimination was observed for optimally shaped pulses, although the linear spectra from both molecules are virtually identical. The relative concentrations of FMN and RBF could also be retrieved while they were mixed in the same solution.
11:00	**912**	**Quantum-path interferences in high harmonic generation** *Mirko Holler [1], Amelle Zaïr [1], Florian Schapper [1], Thierry Auguste [2], Annalisa Guandalini [1], Adam S. Wyatt [3], Antoine Monmayrant [3], Lukas Gallmann [1], Ian A. Walmsley [3], Eric Cormier [4], Pascal Salières [2], Ursula Keller [1]* *[1] Institut für Quantenelektronik, ETH Zürich, Wolfgang-Pauli-Str. 16, 8093 Zürich* *[2] Service des Photons, Atomes et Molécules, Centre d'études de Saclay, Saclay, F-91191 Gif-sur-Yvette* *[3] Clarendon Laboratory, Parks Road, Oxford, OX13PU, United Kingdom* *[4] Centre Laser Intense et Application, Université Bordeaux I, UMR 5107, F-33405 Talence cedex* We report the first experimental observation of interferences between the short and the long quantum path in high harmonic generation. With properly chosen experimental conditions, the quantum path interferences manifest themselves as high harmonic yield modulations when varying the driving laser intensity. We investigated their behavior in different interaction regimes by using different generation media, such as Neon, Argon and Xenon. Our experimental findings are supported by theoretical models including SFA dipole calculations with field propagation and far-field spatial filtering. The theoretical analysis confirms that

		spatial far field selection is the crucial ingredient for successful detection of quantum path interferences. Moreover, we find that varying the laser intensity allows us to control the timing between the electron quantum paths with a sensitivity of a few 10 as.
11:20	**913**	**Correlation between Morphology and picosecond Time-Resolved Cathodoluminescence Measurements of InGaN/GaN Quantum Wells** *Samuel Sonderegger, Nicolas Grandjean, Benoit Deveaud, Jean-Daniel Ganière, Eric Feltin,* *Institut de Photonique et d'Electroniques Quantiques, EPFL, 1015 Lausanne* Because of their unique property to yield very high spatial resolution, cathodoluminescence (CL) techniques have proven to be very useful to study various GaN based nanostructures. However, to get a complete picture of carrier recombination and diffusion processes one needs a spectroscopic tool which yields a high temporal resolution at the same time. We have therefore developed an original picosecond Time Resolved Cathodoluminescence (pTRCL) setup using an ultrafast pulsed electron gun. This setup reaches remarkable spatial and temporal resolution of 50 nm and 10 s, respectively. We have studied MOVPE (Metal-Organic Vapour Phase Epitaxy) grown $In_{0.18}Ga_{0.82}N$/GaN double quantum wells on an ELO (Epitaxial Lateral Overgrowth) GaN substrate with a nominal dislocation density of $4\cdot10^{7}$ cm^{-2}. The investigated well is located next to the surface and has a thickness of 1.5 nm. This allows to increase the achievable resolution. We observe a contrast inversion of monochromatic cathodoluminescence maps between the high energy side 3.13 eV and the low energy side 3.07 eV of the quantum well (QW) luminescence peak. The observed CL contrast can be perfectly correlated with the morphology of the sample surface obtained by AFM (Atomic Force Microscopy) measurements. AFM images clearly show regions where the QW thickness almost decreases to zero. These regions are valleys with an average width of approximately 200 nm. Local CL spectra from these valleys show a clear blueshift of the QW luminescence peak compared to the regions between the valleys where the QW has its nominal thickness. pTRCL measurements show a pronounced spectral diffusion to lower energies which is an unambiguous indication of carrier diffusion processes from high to lower energy regions (i.e. from the narrow to the wider regions of the well).
11:40	**914**	**Multi-Objective Approach to Optimal Control** *Ariana Rondi [1], Jerome Extermann [1], Luigi Bonacina [1], Veronique Boutou [2], Jean-Pierre Wolf [1]* *[1] GAP - Biophotonics, University of Geneva, 20 rue de l'Ecole de Medecine, 1211 Genève* *[2] LASIM (UMR CNRS 5579), Universite Lyon 1, 43 Bd du 11 Novembre 1918, F-69622 Villeurbanne* Femtosecond pulse shaping techniques are commonly used to increase the degree of control in light-matter interactions. In order to identify the optimal pulse shape to drive a given photodynamic process, one approach relies on closed-loop learning procedures based on genetic algorithms. This approach presents however a series of drawbacks, one of them being the difficulty to identify the global maximum. To overcome these shortcomings, we adapted a recently

		published multi-objective genetic algorithm, and tested its performances in a simple benchmark experiment. The algorithm outperforms single-objective optimizations, being totally independent from the bias of user defined parameters and giving simultaneous access to a large set of feasible solutions.
12:00		***Postersession, Lunch***
12:45		***SPS GENERAL ASSEMBLY***
		QUANTUM PHOTONICS 2 *Chair: NN*
13:30	**921**	**Attosecond angular streaking** *Petrissa Eckle [1], Ursula Keller [1], Jens Biegert [1], Philip Schlup [1], Harm Geert Muller [2], Reinhard Dörner [3], André Staudte [3], Markus Schöffler [3], Mathias Smolarski [3]* *[1] ETH Zürich, Departement of Physics, Institute of Quantum Electronics, Wolfgang-Pauli-Strasse 16, 8093 Zürich* *[2] FOM-Institute for Atomic and Molecular Physics, Kruislaan 407, 1098 SJ Amsterdam, Netherlands* *[3] Institut für Kernphysik, Max-von-Laue-Str. 1, DE-60438 Frankfurt am Main* To date attosecond pulses do not have sufficient energy to directly use them for traditional pump-probe measurements using two attosecond pulses. We have demonstrated for the first time "attosecond angular streaking" using only a 5.5 fs, carrier envelope offset phase stabilized, circularly polarized pulses to map temporal dynamics to angular momentum. We fully resolve sub-cycle structures in our pulse field by photoionizing Helium in the tunneling regime. We have demonstrated a temporal localization accuracy of 24 as and estimate a temporal resolution of 200 as. In contrast to energy streaking that requires a combination of attosecond and femtosecond pulses, attosecond angular streaking promises to offer a direct access to a fundamental aspect of quantum physics: the process of tunneling of an electron through an energetically forbidden region.
14:00	**922**	**Broadband external-cavity quantum cascade laser** *Andreas Hugi [1], Andreas Wittmann [1], Arun Mohan [2], Stéphane Blaser [3], Marcella Giovannini [4], Jérôme Faist [1]* *[1] Institut für Quantenelektronik, ETH Zürich, Wolfgang-Pauli-Str. 16, 8093 Zürich* *[2] Laboratory of Physics of Nanostructures, EPFL, Station 3, 1015 Lausanne* *[3] Alpes Lasers SA, 1-3 Maximilien-de-Meuron, 2000 Neuchâtel* *[4] Applied Optics, IMT, UNINE, Rue A.-L.-Breguet 2, 2000 Neuchâtel* We present the latest advances in the field of broadly tunable external-cavity quantum cascade lasers (EC-QCL). Room-temperature, continuous-wave operation was achieved over a tuning range of 120cm^{-1} utilizing gain chips based on the bound to continuum design. Gap-free tuning is demonstrated for an antireflection-coated laser. Lasers with two different active regions, so called two-color devices, promise an even wider tuning range.

14:20	**923**	**Population inversion by resonant tunneling in quantum wells** *Giacomo Scalari [1], Romain Terazzi [1], Marcella Giovannini [2], Jérôme Faist [1]* *[1] Institute of Quantum Electronics, ETHZ, Wolfgang-Pauli-Str. 16, 8093 Zürich* *[2] Institute of Microtechnology, Rue A. L. Breguet, 2, 2000 Neuchâtel* A terahertz quantum cascade laser based on a single quantum well active region is reported. It displays laser action at 3.74 THz with extremely low threshold current densities around 30 A / cm^2. Analysis of the optical and electrical characteristics and their comparison with a transport model based on a density matrix approach clearly demonstrate the role of resonant tunneling for both injection and extraction of the electrons from the upper and lower states of the laser transition.
14:40	**924**	**Femtosecond mid-infrared difference-frequency-generation tunable between 3.2 µm and 4.8 µm from a compact fiber source** *Christian Erny [1], Konstantinous Moutzouris [1], Jens Biegert [1], Ursula Keller [1], Dietrich Kühlke [2], Florian Adler [3], Alfred Leitenstofer [3]* *[1] ETH Zürich, Departement of Physics, Institute of Quantum Electronics, Wolfgang-Pauli-Strasse 16, 8093 Zürich* *[2] University of Applied Sciences Furtwangen, Institute for Applied Research, Robert-Gerwig-Platz 1, DE-78120 Furtwangen* *[3] Universität Konstanz, Departement of Physics and Center of Applied Photonics, Fach M 696, DE-78457 Konstanz* We demonstrate a femtosecond mid infrared (mid-IR) laser source continuously tunable between 3.2 µm and 4.8 µm and an average output power of more than 1 mW. The spectral bandwidth of up to 325 nm supports sub-60-fs pulses. The system is based on a compact two-branch mode-locked femtosecond Er:fiber laser with a center wavelength of 1585 nm with one output beam frequency shifted down to 1100 nm (NIR) in a highly nonlinear fiber. This beam is spatially and temporally overlapped with the other laser output at 1585 nm in a periodically poled $LiNbO_3$ and the difference frequency between the two beams is generated. The conversion ratio of NIR-photons to mid-IR-photons is greater than 30%.
15:10	**925**	**Studies on trapped 0-dimensional exciton-polaritons** *Roland Cerna, François Morier-Genoud, Ounsi El Daif, Maxime Richard, Augustin Baas, Gaël Nardin, Taofiq Paraiso, Barbara Pietka, Marcia Portella Oberli, Benoît Deveaud-Plédran, IPEQ, EPFL, 1015 Lausanne* We present studies on confined polaritons in semiconductor microcavity quantum boxes under strong coupling regime. The quantum boxes consist of mesas etched on the top of the spacer of a microcavity, thus confining the photonic part of the polaritons. The degree of confinement which leads to different energy spacing between the quantized eigenstates of the trapped polaritons is changed by the size of the mesas. In the smallest mesas we are able to excite and observe the wave function of one single state, while in the larger mesas we always excite an ensemble of nearly degenerated states. This allows us to study scattering and mode matching processes of confined polaritons with increasing number of excited states. We have investigated Resonant Rayleigh Scattering in this system with finite number

		of states and observe a strong enhancement in the back scattering direction, which is bigger than expected from the existing theory of Rayleigh scattering for polaritons.
15:30		***Coffee Break***
		Quantum Photonics 3 *Chair: NN*
16:00	**931**	**Very long wavelength terahertz quantum cascade lasers** *Christoph Walther, Giacomo Scalari, Milan Fischer, Romain Terazzi, Jérôme Faist, ETH Zürich, Institute for Quantum Electronics, Wolfgang-Pauli-Strasse 16, 8093 Zürich* We report on our recent development of very long wavelength terahertz quantum cascade lasers which operate from 2.0 THz down to 1.2 THz. The laser scheme is based on a bound-to-continuum transition with an energy gap which combines high injection efficiency and low intersubband absorption. The development of intense radiation sources in the so far underdeveloped terahertz range is of technological interest for applications such as imaging or sensing.
16:30	**932**	**InP/InGaAs/InAlAs terahertz quantum cascade lasers** *Milan Fischer, Christoph Walther, Giacomo Scalari, Jérôme Faist Institute of Quantum Electronics, ETHZ, Wolfgang-Pauli-Str. 16, 8093 Zürich* We demonstrate laser action at a frequency of 3.6 THz (λ = 83 µm) with $In_{0.52}Al_{0.48}As/In_{0.53}Ga_{0.47}As$ quantum cascade structures lattice matched on InP substrate. The performance of these devices are closely comparable to the ones based on the same quantum design and realised in the GaAs/AlGaAs material system. The maximum operating temperatures of 87 K in pulsed mode and 68 K in CW mode are still limited by the waveguide losses. Given the superior oscillator strength of the InGaAs/AlInAs structures due to the lighter electron effective mass such terahertz lasers represent a very promising alternative to the GaAs-based ones.
16:50	**933**	**Vortices in a Polariton Condensate** *Konstantinos Lagoudakis [1], Michiel Wouters [1], Augustin Baas [1], Maxime Richard [1], Benoit Deveaud-Pledran [1], Daniel Le Si Dang [2], Regis Andre [2], Iacopo Carusotto [3]* *[1] EPFL, IPEQ, LOEQ, Batiment PH, Station 3, 1015 Lausanne* *[2] Institut Néel, CNRS, 25 Avenue des Martyrs, F-38042 Grenoble* *[3] INFM-CNR BEC and Dipartimento di Fisica, Universita di Trento, via Sommarive 14, IT-38050 Povo (Trento)* The recently achieved Bose Einstein condensation of exciton-polaritons in CdTe microcavities, provided the opportunity to observe extraordinary phenomena related to the quantum nature of low temperature interacting bosons in the solid state. It is this nature that can give rise to superfluidity, a phenomenon with striking features like the vanishing of viscosity and the appearance of quantised vortices. Such vortices are accompanied by a rotation of the phase around their

		core and by the lack of fluid at the core's centre. In this experiment we observed the existence of singly quantised vortices in the condensed phase of an exciton-polariton fluid. The experimental observation was realised by means of a high resolution imaging setup in conjunction with interferometric techniques and spectrally resolved imaging. We were able to observe the characteristic 2π phase shift around the vortex and we probed the diminishing of the polariton population at the vortex core. Additionally we provided a theoretical insight to the possible origin of these vortices by means of a model based on the Generalised Gross-Pitaevskii equation.
17:20	**934**	**Passive cantilever cooling below 80mK** *Quang Thai [1], Raphaëlle Dianoux [1], Alexis Baratoff [2], Hans J. Hug [1]* *[1] EMPA, Nanoscale Material Science, Überlandstr. 129, 8600 Dübendorf* *[2] University of Basel, Dept. of Physics, Klingelbergstr. 82, 4056 Basel* To cool down small objects such as atoms to μK temperatures, laser cooling was successfully used. Recently, Karrai et al. have shown that the fundamental mode of a cantilever could be cooled by photon-induced forces. With our home-built UHV low temperature scanning force microscope (LTSFM), including a Fabry-Pérot interferometer with a finesse of about 20, we have performed cantilever cooling experiments at RT, 77K and 4.3K. This was done by recording narrow-band spectra of the measured deflection of the cantilever around its resonance at optical powers from 1 - 800μW. The noise level of the interferometer decreased from 200 - 3fm/sqrt (Hz). The lowest temperature determined from the area below the resonance peak dropped to 79mK at 750μW, a world record with passive damping. In order to investigate the quantum limit with a macroscopic object, further reduction of the cantilever temperature at its fundamental mode must be reached.
17:50		***END***
18:15		***Conference Dinner***

Thursday, 27.03.2008, Room 2170 (2nd floor)

Time	ID	PLENARY SESSION AND SPS AWARD CEREMONY
08:30	**901**	***Quantum Photonics Plenary Talk: see page 32***
09:15		***Plenary Session continued***
10:00		***Coffee Break***
10:30		***Plenary Session continued***
11:15		***SPS AWARD CEREMONY***
11:45		***Plenary Session continued***
12:30		***Postersession, Lunchbuffet***

Time	ID	**QUANTUM PHOTONICS 4** *Chair: NN*
14:00	**941**	**Quantum storage in solid state atomic ensembles** *Hugues de Riedmatten, Group of Applied Physics, University of Geneva, Rue de l'Ecole de médecine 20, 1211 Genèva* Reversible and coherent storage of quantum information between light and matter is an important experimental challenge in quantum information science. In recent years, atomic ensembles have proven to be a promising system in order to implement such a task. We will describe our efforts towards the realization of a storage device for single photons in a solid state environment. Our approach uses solid state atomic ensembles implemented with rare-earth ions doped into dielectric crystals. Due to the weak interactions with the crystal environment and to the absence of atomic diffusion, the rare-earth ions can be considered as a frozen gas of atoms. Single photons can be in principle stored and recalled with high efficiency in such a media using a modified photon echo approach based on coherent control of the inhomogeneous broadening of the optical transition. After an introduction to motivate the need for quantum memories in quantum communication, we will present the physical system and the storage protocol, before reviewing first experimental steps towards the practical realization of quantum memories in rare-earth doped materials.
14:30	**942**	**Quantum Nature of a Strongly Coupled Quantum Dot-Cavity System** *Martin Winger, Antonio Badolato, Kevin Hennessy, Dario Gerace Institute of Quantum Electronics, Quantum Photonics Group, ETH Zürich, Wolfgang Pauli-Strasse 16, 8093 Zürich* We study the interaction of a single self-assembled quantum dot coupled to a photonic crystal defect nanocavity. The spatial and the spectral alignment of the cavity mode with respect to the quantum dot is ensured in a deterministic manner. We show that the system is in the strong coupling regime of cavity QED and prove its quantum nature by observing quantum correlations in photoluminescence. Additionally we find a novel coupling mechanism that provides excitation of the cavity mode via the quantum dot for an arbitrary detuning from quantum dot transitions. From cross correlation measurements we can conclude that this off-resonant cavity excitation is mediated by the quantum dot alone.
15:00	**943**	**Single Photon Detection and Applications** *Robert Thew, Noé Curtz, Patrick Eraerds, Hugo Zbinden, University of Geneva, Group of Applied Physics, 20 rue de l'école de médecine, 1211 Genève* Optical detection is an enabling technology and detection at the single photon level represents the ultimate level of sensitivity. We are currently studying a diverse range of techniques for single photon detectors: InGaAs/InP avalanche photodiodes (APDs); Up-Conversion + Si hybrid detectors - systems based on the nonlinear conversion of telecom wavelengths to the visible regime and combined with Silicon APDs; SSPDs (superconducting single photon detectors); SiPM (Silicon Photo-multiplier) - operate in the visible regime and consist of

		an array of over 100 detectors and are capable of resolving the numbers of photons in an optical pulse, as well as high-speed operation with counting rates over 400MHz. We will briefly present our most recent work on the development of all of these detectors and highlight a couple of applications that cover both the fundamental and the applied while giving an insight into the diversity and power of single photon detection.
15:30		***Coffee Break, END***

ID	QUANTUM PHOTONICS POSTER
951	**Interference of multi-mode photon echoes generated in spatially separated solid state atomic ensembles** *Matthias U. Staudt, M. Afzelius, H. de Riedmatten, S. R. Hastings-Simon, C. Simon, R. Ricken, H. Suche, W. Sohler, N. Gisin* *Université de Genève, GAP-Optique, Rue de l'École-de-Médecine 20, 1211 Genève* Many proposed quantum repeater protocols exhibit as a common feature the distribution of entanglement by interference of quantum states of light stored and released from spatially distant quantum memories. From this perspective we present interference experiments of light stored and released from spatially separated solid state ensembles (Erbium doped $LiNbO_3$ waveguides) placed in the two arms of a balanced Mach-Zehnder interferometer. The transition of interest is at 1532 nm. In a first experiment bright coherent states of light in several temporal modes (up to 3) are stored in the optical memories using two-pulse photon echoes. The retrieved optical pulses, when combined at a beam splitter, show almost perfect interference (visibility of 92%). In a second experiment using the same interferometer high visibility interference of collective spontaneous emission is demonstrated. Here classical pulses excite the ions in the two solid state ensembles, leading into collective spontaneous emission, which at the output of the interferometer is at single-photon level. We use the interference fringe visibility in both experiments as a measure of the phase coherence of the optical memories. Our results clearly demonstrate indistinguishability and phase preservation of both the photon echoes and the collective spontaneous emission.
952	**Entanglement Swapping with independent sources** *Olivier Landry, Jeroen van Houwelingen, Enrico Pomarico, Hugo Zbinden, Nicolas Gisin, Matthäus Halder* *GAP-Optique, Université de Genève, 20 rue de l'Ecole-de-Médecine, 1211 Genève 4* Entanglement swapping is a tool of quantum communication that allows two qubits, in our case represented by photons, to be entangled even if they have never interacted. We present two different swapping schemes, one which uses continuous wave lasers and another which uses picosecond pulsed sources. Both use entirely independent sources, by which we mean physically separated lasers with relaxed synchronization requirements.

953

UV-femtosecond pulse shaping with a micromirror device

Stefan M. Weber [1], Luigi Bonacina [1], Jérôme Extermann [1], Denis Kiselev [1], Jean-Pierre Wolf [1], Severin Waldis [2], Wilfried Noell [2], Nico de Rooij [2]

[1] GAP - Biophotonics, Université de Genève, Rue de l'École-de-Médecine 20, 1211 Genève

[2] IMT / SAMLAB, Université de Neuchâtel, Rue Jaquet-Droz 1, 2002 Neuchâtel

Quantum control of photochemical reactions employing femtosecond laser pulses has expanded its field of application tremendously in the last years. Recently, the first fs-pulse shaping experiments in the 250-400 nm region using indirect methods [1] have been reported. We are currently developing a pulse shaping device with micromirrors based on MEMS technology [2] which enables a direct access to this frequency band with novel targets such as aromatic rings of organic and biological molecules, in particular amino-acids within proteins and DNA bases [3]. The device, featuring binary amplitude- and continuous phase modulation, has also potential use for high harmonic generation and attosecond science.

[1] Appl. Phys. B 88 (2007)
[2] Appl. Phys. B 76, 711-714 (2003)
[3] Appl. Phys. Lett. 87(6) 063901 (2005)