HL 42: Focussed Session: Silicon Photonics

Time: Wednesday 14:00–17:45 Location: H13

Invited Talk HL 42.1 Wed 14:00 H13
Recent advances in silicon-based photonic devices — •Delphine Marris-Morini[1], Laurent Vivien[1], Gilles Rasigade[1], Papichaya Chaisakul[1], Xavier Le Roux[1], Eric Cassan[1], Jean-Marc Fedeli[2], Daniel Chrastina[3], and Giovanni Isella[3] — [1]Institut d'Electronique Fondamentale, Université Paris Sud - CNRS, bât. 220, 91405 Orsay, France — [2]CEA, LETI, Minatec 17 rue des Martyrs, 38054 Grenoble cedex 9, France — [3]L-NESS Politecnico di Milano, Polo Regionale di Como, Via Anzani 42, 22100 Como, Italy

In the past few years, the interest in silicon photonics has greatly increased. Silicon on insulator (SOI) guiding structures have been successfully demonstrated and research focuses now on active devices. The state of the art in optical modulators and photodetectors will be presented, and recent results obtained in the group will be detailed. For optical modulation, both electro-refraction and electro-absorption can be used. In silicon, free-carrier concentration variation is the most efficient way to achieve refractive index variation. We have experimentally demonstrated a 15 GHz modulator with low insertion loss and large modulation contrast. We are also investigating electro-absorption mechanisms, especially the quantum confined Stark effect (QCSE), in SiGe/Ge multiple quantum well (MQW) heterostructures. For high performance integrated photodetectors, we have chosen to use pure germanium grown on silicon. 40 Gbit/s data transmission has been achieved with a responsivity of 1 A/W in the 1.3 1.6 um wavelength range.

Topical Talk HL 42.2 Wed 14:30 H13
3D silicon photonic crystals — •Georg von Freymann — Institut für Nanotechnologie, KIT, Karlsruhe, Germany

We report on our recent progress in the fabrication and characterization of three-dimensional silicon photonic crystals. Structures are fabricated by direct laser writing (DLW) and subsequent silicon inversion or silicon double inversion.

DLW is a very versatile technique and allows for a variety of structures ranging from woodpile photonic crystals over chiral photonic crystals to photonic quasicrystals. We will present a novel resonator design for woodpile photonic crystals and discuss future developments.

Topical Talk HL 42.3 Wed 15:00 H13
Miniband-related IR luminescence of Ge/Si quantum dot superlattices — •Peter Werner — MPI für Mikrostrukturphysik, Weinberg 2, Halle (Saale)

Highly strained Si/Ge multi-layer heterostructures incorporating Ge quantum dots may show strong IR luminescence even at room temperature. Calculations of the electronic band structure and luminescence measurements prove the existence of an electron miniband within the columns of the QDs. Such a miniband formation results in a conversion of the indirect to quasi-direct excitons. The optical transitions between electron states within the miniband and hole states within QDs are responsible for an intense photoluminescence in the 1.4 - 1.8 micrometer range. The talk will present basics of the crystal growth of such staked multi-layers as well as the analysis of their luminescence properties. Such multi-layers can be applied for LED concepts including etched nanostructures.

Topical Talk HL 42.4 Wed 15:30 H13
Transient optical gain in Germanium quantum wells — •Christoph Lange[1,2], Niko Köster[1], Martin Schäfer[1], Mackillo Kira[1], Stephan Koch[1], Danny Chrastina[4], Giovanni Isella[4], Hans von Känel[4], Hans Sigg[3], and Sangam Chatterjee[1] — [1]Faculty of Physics and Material Sciences Center, Philipps-Universität, Renthof 5, D-35032 Marburg, Germany — [2]Department of Physics University of Toronto 60 St. George St. Toronto ON, M5S 1A7 Canada — [3]Laboratory for Micro and Nanotechnology, Paul Scherrer Institut, CH-5232 Villigen PSI, Switzerland — [4]CNISM and L-NESS, Dipartimento di Fisica del Politecnico di Milano, Polo di Como, via Anzani 42, I-22100 Como, Italy

One of today's most-sought goals in semiconductor technology is the monolithic integration of microelectronics and photonics on Si. Optical gain is, in general, not expected for Si and Ge or its alloys due to the indirect nature of the band gap in this material system. Here, we show that Ge/SiGe QWs show transient optical gain and may thus be used as an optically-pumped amplifier at room temperature [1]. Further, the nonequilibrium effects which govern the relaxation dynamics of the optically injected carrier distributions in this material were observed and analyzed using a microscopic many-body theory. Strong non-equilibrium gain was obtained on a sub-100 fs time scale. Longlived gain arising from Γ-point transitions is overcompensated by a process bearing the character of free carrier absorption.

[1] C. Lange et al., Phys. Rev. B **79**, 201306(R) (2009)

15 Min. Coffee Break

Invited Talk HL 42.5 Wed 16:15 H13
SiGe based quantum cascade systems: 10 years after. — •Hans Sigg — Paul Scherrer Institut, Villigen PSI, Switzerland

The exploration of a Si-technology based long-wavelength laser for gas sensing, medical screening and airport security monitoring etc., started ten years ago, with the demonstration of electro-luminescence in SiGe based quantum cascade structures [Dehlinger, Diehl et al. Science 290, 2277 (2000)]. At the beginning, most activities focused on the development of a relaxed buffer substrate, and the implementation of intersubband systems in the valence band, i.e. cascade emitters based on hole-transport. Recently, despite the reduced band offsets, intersubband systems in the conduction band have come into the focus, because of their simpler bandstructure. Alternative approaches, such as optical pumping and intersubband Raman lasing have also been investigated. The present outline of these basic developments allows the remaining significant technological and fundamental problems to be brought into perspective.

Invited Talk HL 42.6 Wed 16:45 H13
A Germanium Laser on Silicon — •Jurgen Michel, Jifeng Liu, Lionel C. Kimerling, Xiaochen Sun, and Rodolfo Camacho — Massachusetts Institute of Technology, Cambridge, MA 02139, USA

Lasers on silicon are one of the most crucial components for silicon-based electronic-photonic integration. Epitaxial Ge-on-Si is a particularly interesting candidate due to its pseudo-direct band gap behavior and its compatibility with advanced electronic devices on Si. Integrated photonic devices such as waveguide-coupled photodetectors and electro-absorption modulators have already been demonstrated based on the direct band gap transition of Ge. Our theoretical analysis has shown that Ge can be band-engineered by tensile strain and n-type doping to achieve efficient light emission and optical gain from its direct gap transition. Indeed, direct gap photoluminescence (PL) and electroluminescence (EL) at room temperature have already been demonstrated from these band engineered Ge-on-Si materials. We will present the experimental observation of optical gain and lasing in epitaxial tensile strained n+ Ge-on-Si at room temperature. Lasing has been achieved by pumping a Ge waveguide with nanosecond pulses from an NdYAG laser at 1064nm.

Topical Talk HL 42.7 Wed 17:15 H13
Monolithic integration of lattice-matched Ga(NAsP)-based laser device structures on (001) Silicon — •Kerstin Volz and Wolfgang Stolz — Philipps University Marburg, Materials Science Center and Faculty of Physics, Marburg, Germany

The novel, direct band gap, dilute nitride Ga(NAsP)-material system allows for the first time for the monolithic integration of a III/V-based active laser material lattice matched to exact (001) Si substrates. This lattice-matched approach results in a high-quality, low defect density integration leading to long-term stable laser devices on Si-substrates.

Broad area laser structures consist of pseudomorphically strained active Ga(NAsP)/(BGa)(AsP) multi-quantum-well heterostructures embedded in thick doped (BGa)P waveguide layers, grown by a specific low-temperature metal organic vapour phase epitaxy (MOVPE) process on (001) Si-substrate. The optimization of the laser properties focus on improvements in material quality based on MOVPE growth and nucleation conditions as well as the design parameters such as optimal carrier and light field confinement, doping levels and post-growth annealing treatments.

This paper will present and discuss the current status to realise electrical injection laser diodes as a basis for Si-photonics.