Heterogeneous Integration of Uni-Travelling-Carrier Photodiodes using Micro-Transfer-Printing on a Silicon-Nitride Platform

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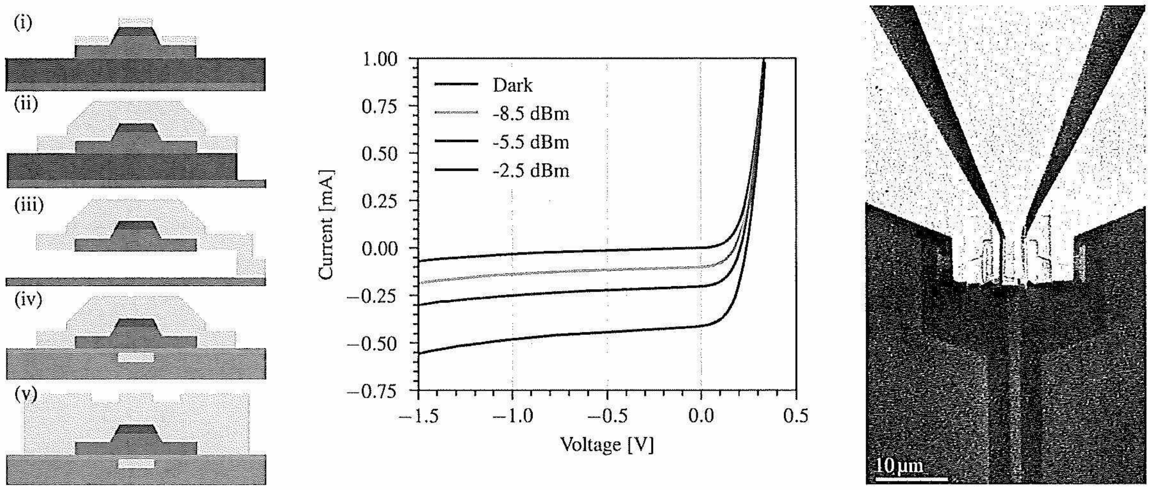
High-speed photodiodes often compromise responsivity in exchange for a reduced footprint. However, using waveguide photodiodes circumvents this limitation [1]. We combine uni-travelling-carrier photodiodes (UTC PDs) on a silicon nitride (SiN) photonic platform to achieve both high responsivity and high speed detectors. The SiN-platform has excellent properties such as low-loss waveguides and does not suffer from two-foton absorption at high optical power. A high responsivity is obtained through evanescent coupling of waveguide UTC photodiodes to SiN waveguides while still maintaining a small footprint.

The devices are integrated using the micro-tansfer-printing (μTP) technology for hybrid integration of different material platforms [2]. First, photodiode chiplets are made in an InP/InGaAs-technology using a standard fabrication flow. The epitaxial layer stack is adapted from [3] and includes a 500 nm thick sacrificial InAlAs release layer. This material is used for its excellent selective underetching properties [4]. Figure 1a summarizes the processing steps to create a waveguide-coupled UTC PD. (i) Photodiodes are made on the source wafer. (ii) The InAlAs release layer is anisotropically etched using a hard mask. (iii) A new SiN layer is deposited and patterned to create tethers to the InP-substrate. The device is under-etched (isotropic) to create a suspended coupon. (iv) The coupon is transfer-printed on a SiN target chip. (v) Vias are etched and metal connections are made.



(a) (b) (c)

Fig. 1 **(a)** Fabrication steps, **(b)** IV-curves for different incident on-chip powers, and **(c)** SEM-image of a 2 μm × 10 μm waveguide-coupled UTC PD.

The waveguide-coupled PDs show a responsivity of 0.80 A/W for a bias voltage of −1 V, illuminated at 1550 nm. This corresponds to an external quantum efficiency of 65 %. We believe this can be further increased for longer devices or by incorporating a reflection-reducing design in the InP subcollector. The IV-characteristic for a PD with an active area of 2 μm × 10 μm is shown in Figure 1b. High dark currents of 10-20 μA and 20-50 μA, at respectively −0.5 V and −1.0 V biasing, are thought to be a result of surface leakage currents, and are currently being investigated and remedied. Given the small surface area of 20 μm^2 and the average measured series resistance of 30 Ω, a high intrinsic bandwidth is expected. This will be verified using RF photoresponse measurements in the near future.

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ROOM 7

CK-4.2 THU 9:00

InGaAs microdisk cavities monolithically integrated on Si with room temperature emission at 1530 nm

•*P. Tiwari, A. Fischer, S. Mauthe, E. Brugnolotto, N. Vico Triviño, M. Sousa, D. Caimi, H. Schmid, and K.E. Moselund; IBM Research Europe, Rueschlikon, Switzerland*

We present monolithically integrated InGaAs cavities on Si by template-assisted-selective-epitaxy with evidence of room-temperature lasing at 1530nm, and compare them with previously demonstrated InP-on-Si lasers. This allows for integrated InP/InGaAs QWs for increased carrier confinement.

CK-4.3 THU 9:15

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•*D. Maes*[1,2], *G. Roelkens*[1], *M. Zaknoune*[2], *C. Op de Beeck*[1], *S. Poelman*[1], *M. Billet*[1], *M. Muneeb*[1],

ROOM 8

content, up to the soft x-rays. Remarkably, the emitted harmonics present extremely low divergence, which further decreases with frequency

EE-2.3 THU (Invited) 9:00

High energy high harmonic generation (HHG) in liquids

S. Jarosch, O. Alexander, T. Avni, J. Barnard, C. Ferchaud, E. Larson, •*M. Matthews, and J. Marangos; Imperial College London, London, United Kingdom*

We present carrier-envelope-phase (CEP) dependent extreme-ultraviolet (XUV) harmonic emission from isopropanol which extends to 50eV with emission features supporting a recombination mechanism. The emission is damped by scattering of the driven electron from neighbouring molecules.

ROOM 9

of Physics, Friedrich Alexander University Erlangen-Nuremberg, Erlangen, Germany

We present experimental and theoretical self-switching behaviours in counterpropagating light in a Kerr microresonator, due to symmetry restoration on average. These results pave the way for chip-integrated all-optical generation of waveforms, encoding, and cryptographic applications.

EF-5.3 THU (Invited) 9:00

Lithium-Niobate-Based Frequency Combs

•*M. Yu; John A. Paulson School of Engineering and Applied Sciences, Harvard University, Cambridge, USA*

We discuss the recent development of electro-optic and Kerr frequency combs, powered by integrated lithium niobate photonics. Specifically, I will cover the generation, control and dynamics of microcombs in modulator-based, single- and coupled-cavity based geometries.

ROOM 10

Kingdom

We demonstrate that a plasmonic nanocavity enhances two-photon excited photoluminescence by 106 - 108 and this efficient nonlinear interaction elicits new trap states emission in single quantum dots while suppressing band-edge emission.

EH-4.3 THU 9:00

Energy-resolved few-cycle nanoplasmonic photoemission dynamics

P. Sándor[1], •*B. Lovász*[1], *Z. Pápa*[1], *B. Bánhegyi*[1], *P. Rácz*[1], *C. Prietl*[2], *J.R. Krenn*[2], *and P. Dombi*[1]; [1]*Wigner Research Centre for Physics, Budapest, Hungary;* [2]*Institut für Physik, Karl-Franzens-Universität, Graz, Austria*

Energy-selective and time-resolved photoemission from nanoparticles of various geometries enables localized characterization of few-cycle plasmon transients.

EH-4.4 THU 9:15

Mechanisms of Spontaneous Emission Rate Enhancement in Metal-Insulator-Metal Cavities

•*D. Ghindani, A.R. Rashed, and H. Caglayan; Tampere University, Tampere, Finland*

Tailoring the emission and radiation properties of an emitter is of fun-

ROOM 11

We report nanodiamond-embedded core optical fibers drawn from silicate glass canes and tubes. Two techniques of ND nanofilm deposition are compared and presence of NDs in a free-form core is confirmed with photoluminescence imaging.

CE-8.3 THU 9:00

High-temperature polymer multimaterial fibers

•*P. Akrami*[1], *A.I. Adamu*[1], *G. Woyessa*[1], *H.K. Rasmussen*[2,3], *O. Bang*[1,4], *and C. Markos*[1]; [1]*DTU Fotonik, Department of Photonics Engineering, Technical University of Denmark, 2800 Kgs. Lyngby, Denmark;* [2]*DTU Mekanik, Department of Mechanical Engineering, Technical University of Denmark, 2800 Kgs. Lyngby, Denmark;* [3]*University College Absalon, Centre for Engineering and Science, 4400 Kalundborg, Denmark;* [4]*SHUTE Sensing Solutions A/S, 3490 Kvistgård, Denmark*

The fabrication of a heat-resistant multimaterial polymer optical fiber withstanding temperatures up to 180 degrees consisting of two different grades of the cyclo-olefin polymer Zeonex and high-performance thermoplastic PSU developed using a co-extrusion method

CE-8.4 THU 9:15

Nanocrystal-doped fibres using glass powder doping – towards new laser transitions in fibre lasers

•*M. Jäger*[1], *M. Lorenz*[1], *R. Müller*[1], *J. Kobelke*[1], *K. Wondraczek*[1], *R. Valiente*[2], *A. Diego-Rucabado*[2], *I. Cano*[2], *F. Aguado*[2], *J. Gluch*[3],

ROOM 12

EG-5.2 THU 9:00

Optical trapping and self-assembly of particle clusters using on-chip plasmonic nanotweezers

C. Pin[1,2,3], *G. Magno*[4,5], *A. Ecarnot*[4], *E. Picard*[2], *E. Hadji*[2], *V. Yam*[4], *F. de Fornel*[1], *B. Dagens*[4], *and* •*B. Cluzel*[1]; [1]*ICB, Université Bourgogne Franche-Comté, Dijon, France;* [2]*CEA Grenoble, Université Grenoble Alpes, Grenoble, France;* [3]*RIES, Hokkaido University, Sapporo, Japan;* [4]*C2N, Université Paris-Saclay, Palaiseau, France;* [5]*DEI, Politecnico di Bari, Bari, Italy*

Single beads and self-assembled bead clusters are trapped using a periodic chain of gold nanorods on a photonic silicon waveguide. The trapping efficiency, orientation, compactness, and stability of the observed cluster configurations are statistically analysed.

EG-5.3 THU 9:15

Optical Suppression of Energy Barriers in Single Molecule-Metal Binding

•*Q. Lin*[1], *S. Hu*[1], *T. Földes*[2,3], *J. Huang*[1], *D. Wright*[1], *J. Griffiths*[1], *B. de Nijs*[1], *E. Rosta*[2,3], *and J. J. Baumberg*[2,3]; [1]*Nanophotonics Centre, Department of Physics,*

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