Q 53: Quantum Optics and Photonics III

Time: Thursday 10:30–12:30 Location: K 0.016

Q 53.1 Thu 10:30 K 0.016

Waveguide-integrated superconducting nanowire single photon detectors — •Simone Ferrari[1,2], Fabian Beutel[1,2], and Wolfram Pernice[1,2] — [1]University of Münster, Institute of Physics, Germany — [2]University of Münster, CeNTech - Center for Nanotechnology, Germany

Nanophotonic technology empowers the realization of low-loss, small-footprint and scalable hybrid architectures for generating, manipulating and detecting single photons [1]. Thanks to their high efficiency, wide optical detection bandwidth, fast response and low timing uncertainty, waveguide-integrated superconducting nanowire single photon detectors represent a catalyst for the development of quantum technology and life science. We show our recent achievement on the integration of single photon detector devices to complex nanophotonic architectures. We demonstrate the realization of a fully integrated device with electrically driven single photon emitters and single photon detectors [2]. To overcome the inability for superconducting detectors to resolve photon energy, we integrate eight detectors in a multi-channel arrayed waveguide grating realizing a fully integrated single-photon spectrometer [3] and, as further improvement, we demonstrate an on-chip quantum limited heterodyne detection technique with ultra-high spectral resolution [4]. [1] Science 318 (5856), 1567 (2007) [2] Nature Photonics 10, 727 (2016) [3] Optica 4 (5), 557 (2017) [4] Scientific Reports 7, 4812 (2017)

Q 53.2 Thu 10:45 K 0.016

Hot-spot relaxation time current dependence in niobium nitride waveguide-integrated superconducting nanowire single-photon detectors — •Simone Ferrari[1], Vadim Kovalyuk[2], Gregory Gol'tsman[2], and Wolfram Pernice[1] — [1]University of Münster, Institute of Physics, Germany — [2]Moscow State Pedagogical University, Department of Physics, Russia

Superconducting nanowires detectors embedded in nanophotonic circuitry provide an attractive solution for on-chip fast and efficient single-photon detection. Their working principle is based on the localized destruction of superconductivity, called hot-spot, after the absorption of a photon, which generates a recordable electrical pulse. To investigate the ultimate detection timescale for these devices, we adopt a pump-probe technique in the near-infrared region [1,2]. We study the bias current dependence of the hot-spot temporal dynamic for niobium-nitride superconducting nanowire single photon detectors atop silicon nitride waveguides. Our study reveals a strong increase of the picosecond relaxation time with increasing bias current. A minimum relaxation time of 22 ps is obtained when applying a bias current of 50% of the switching current at a bath temperature of 1.7K. [1] Phys. Rev. B 93, 094518 (2016) [2] Optics Express 25 (8), 8739 (2017)

Q 53.3 Thu 11:00 K 0.016

Shape fidelity of 3D printed microoptics — •Simon Ristok[1], Simon Thiele[2], Timo Gissibl[3], Alois Herkommer[2], and Harald Giessen[1] — [1]4. Physikalisches Institut, Universität Stuttgart — [2]Institut für technische Optik, Universität Stuttgart — [3]Nanoscribe GmbH, Eggenstein-Leopoldshafen

Complex three dimensional structures on the micrometer scale can be fabricated by focusing a femtosecond laser at 780 nm into a UV sensitive photoresist. The photoresist is polymerized via two-photon absorption at 390 nm in a small volume element around the laser focus, resulting in sub-micrometer resolution. By moving the focus through the photoresist arbitrary shapes can be produced.

Particularly the high resolution renders this direct laser writing technique suitable for the fabrication of high quality optical elements on the micrometer scale. However, many of the used materials exhibit shrinkage after polymerization, leading to deviations from the optical design and therefore reducing the imaging quality.

In this work we focus on the compensation of the shrinking behavior in order to achieve high shape fidelity. Furthermore, we present applications such as aspheric microlens arrays on CMOS sensors.

Q 53.4 Thu 11:15 K 0.016

Aberration compensation by complex beam shaping in direct laser writing implementing a SLM — •Mathias Hünecke, Haissam Hanafi, Jörg Imbrock, and Cornelia Denz — University of Münster, Institute of Applied Physics and Center for Nonlinear Science (CeNoS), Corrensstraße 2-4, 48149 Münster, Germany

Direct laser writing (DLW) is a powerful technique for creating complex refractive index structures in transparent materials. This technique paved the way to fabricate discrete waveguide arrays that allow tailored linear and nonlinear light propagation. Further applications of DLW are, for instance, diffractive optical elements or, in a visionary way, integrated optoelectronic devices.

The desired circular profile of waveguides is limited by spherical aberration and axial elongation caused by a refractive index mismatch when focusing from air into a high refracting material. These effects increase with larger writing depth, higher refractive index mismatches and higher numerical apertures. To overcome these limitations and enhance both, the variety of accessible materials and the writing depths, we apply complex beam shaping methods.

We will present an adaptive compensation of these aberrations by a spatial light modulator (SLM), which we implemented in a conventional DLW system. By applying a specific phase hologram, the initial wavefront is modified and reaches a spherical focus inside the writing volume. We demonstrate adaptive aberration correction in fused silica and nonlinear optical lithium niobate and characterize its performance for different parameters such as writing depth and numerical aperture.

Q 53.5 Thu 11:30 K 0.016

Birefrigent phasematching in an unpoled KTP waveguide as a source of pure infrared single photons — •Laura Padberg, Vahid Ansari, Matteo Santandrea, Christof Eigner, John M. Donohue, and Christine Silberhorn — Universität Paderborn, Integrierte Quantenoptik, Warburger Str. 100, D-33098 Paderborn

Integrated pure single photon sources are a key component for quantum optical applications like quantum computation or quantum key distribution. Waveguides sources with tailored spatial modes are necessary for efficient coupling to optical fibres and integration into quantum networks.

We show our in-house fabrication of unpoled rubidium exchanged waveguides in potassium titanyl phosphate (KTP) and the birefringent characterisation of the generated parametric down conversion (PDC) state in our source. We demonstrate that our source design offers the possibility for asymmetric group velocity matching in the near-infrared telecommunication regime [1], which is a favourable condition for pure single photon generation. This makes it a perfect candidate for fibre-based networks and quantum protocols.

[1] arxiv.org/abs/1711.09678

Q 53.6 Thu 11:45 K 0.016

Ultrafast single photon detection on a photonic waveguide — Julian Muenzberg[2,4], Andreas Vetter[4,5], Wladick Hartmann[1,2,3], Fabian Beutel[1,2,3], •Simone Ferrari[1,2,3], Carsten Rockstuhl[4,5], and Wolfram Pernice[1,2,3] — [1]University of Münster, Institute of Physics, Germany — [2]University of Münster, CeNTech - Center for Nanotechnology, Germany — [3]University of Münster, Münster Nanofabrication Facility, Germany — [4]Karlsruhe Institut of Technology, Institute of Theoretical Solid State Physics, Germany — [5]Karlsruhe Institut of Technology, Institute of Nanotechnology, Germany

A key building block for quantum photonics is represented by integrated detectors with high efficiency and timing resolution [1]. For high bandwidth quantum communication ultrafast detection is also needed. We realized extremely short superconducting nanowire detectors onto silicon nanophotonic platform which, thanks to their reduced kinetic inductance, can provide an extremely high detection rate [2]. To enhance their efficiency, we embedded these detectors into a two-dimensional photonic crystal cavity obtaining efficient and fast detectors with sub-ns recovery time. [1] Science 318 (5856), 1567 (2007) [2] Nano Lett., 16 (11), 7085 (2016)

Q 53.7 Thu 12:00 K 0.016

Fine tuning of third harmonic phase-matching in tapered fibre via external gas pressure — •Jonas Hammer[1,2], Riccardo Pennetta[1], Philip St.J. Russell[1,2], and Nicolas Y. Joly[1,2] — [1]Max-Planck Institute for the Science of Light, Erlangen, Germany —

[2]University of Erlangen-Nuremberg, Erlangen, Germany

Micrometer-scale fibre tapers (FTs) are an interesting platform for nonlinear optics, since tight light confinement can provide very high effective nonlinearity. This allows the observation of nonlinear effects at moderate pump energies, provided the dispersion landscape is designed to satisfy the phase-matching (PM) conditions [1]. Here, we focus on the generation of third harmonic. For this process the conservation of photon momentum implies that $n(\omega_p) = n(3\omega_p)$, where ω_p is the pump frequency [2]. In waveguides the chromatic dispersion prevents intra-modal PM. The inter-modal PM conditions set strict constraints on the diameter of the FT, which are hard to fulfill during the fabrication procedure. Here, we fabricated a FT with a waist diameter of $0.68 \mu m$. We obtained inter-modal PM between the HE_{11} mode in the IR and HE_{12} in mode in the visible. Surrounding the FT with argon gas permits the third-harmonic wavelength to be tuned by 0.12 nm/bar. Pressure-tuning greatly relaxes the fabrication tolerances for third harmonic generation in FT, which is extremely advantageous in systems with a fixed pump wavelength.

References

[1] T.A. Birks et al., Opt. Lett. (25), 1415 (2000).
[2] R.W. Boyd, Nonlinear Optics, 3rd ed. (Academic press, 2008).

Q 53.8 Thu 12:15 K 0.016

Twisted coreless photonic crystal fibre — •Gordon K. L. Wong, Ramin Beravat, Michael H. Frosz, Paul Roth, and Philip St.J. Russell — Max Planck Institute for the Science of Light, Staudtstrasse 2, 91058 Erlangen, Germany

We report a new mechanism of light guidance, based on a continuously twisted photonic crystal fibre without any core structure. The permanent twist around the fibre axis was induced by spinning the fibre preform during the drawing process. Twisting the uniform periodic array of hollow channels creates a topological channel where light can be trapped. This unusual phenomenon arises from the quadratic increase in optical path length with radius, creating a potential well within which light is confined by photonic bandgap effects. The effective area of these orbital angular momentum carrying modes shrinks with increasing twist rate, so that by varying the twist rate along the fibre, it would be possible to create fibers whose mode-field diameter changes with axial position. Another advantage is the combination of a large mode area with anomalous dispersion at shorter wavelengths compared to conventional fibres. The ability of the fibre to transmit modes carrying orbital angular momentum and exhibit optical activity suggests that yet more applications will emerge.