Q 42: Quantum Optics and Photonics II

Time: Wednesday 14:00–16:00 Location: K 0.016

Group Report Q 42.1 Wed 14:00 K 0.016

The Accelerator on a Chip International Program: Status and Outlook — •Joshua McNeur[1], Norbert Schönenberger[1], Ang Li[1], Peyman Youseffi[1], Johannes Illmer[1], Peter Hommelhoff[1], and The ACHIP Team[2,3,4,5,6,7] — [1]Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Staudtstr. 191058 Erlangen, Germany — [2]Stanford University, Stanford, USA — [3]SLAC National Accelerator, Stanford, USA — [4]University of California - Los Angeles, Los Angeles, USA — [5]Uni Darmstadt, Darmstadt, Germany — [6]Paul Scherrer Institut, Villigen, Switzerland — [7]Deutsches Elektronen-Synchrotron, Hamburg, Germany

Dielectric laser acceleration (DLA) is based on the interaction of electrons and laser-excited near-fields at photonic structures. The resulting demonstrated acceleration gradients approaching 1 GeV/m over varying wavelengths and electron energies make this technology promising as a candidate for a small-footprint accelerator. The Accelerator on a Chip International Program (ACHIP) has been researching DLA in order to realize many of its exciting applications. Specifically, it aims to design and demonstrate a MeV electron accelerator with a shoebox-sized footprint. Here the status and outlook of this endeavor are summarized. Specifically, challenges and developments related to the necessary high brightness cathodes, transverse and longitudinal subrelativistic electron dynamics, on-chip photonics-based laser coupling and the integration of all components of the envisioned MeV accelerator are detailed. This work is supported by the Gordon and Betty Moore Foundation.

Q 42.2 Wed 14:30 K 0.016

Driving Transitions between States in Topological Systems — •Christina Jörg[1], Fabian Letscher[1,2], Christoph Dauer[1], Axel Pelster[1], Sebastian Eggert[1], Michael Fleischhauer[1], and Georg von Freymann[1,3] — [1]Physics Department and Research Center OPTIMAS, TU Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Kaiserslautern, Germany — [3]Fraunhofer Institute for Industrial Mathematics ITWM, Kaiserslautern, Germany

On the one hand, edge states in topologically ordered systems have shown to be robust against many local perturbations [1-4]. On the other hand, it is known that periodic driving can induce transitions between different continuum states [5]. Here, we examine how to drive a transition between bulk states and an edge state in topologically nontrivial systems using a local AC-field. Our model system consists of evanescently coupled waveguides. They are positioned along x to form a Su-Schrieffer-Heeger (SSH) lattice with a defect that is periodically modulated in its position. We study how the time evolution of this system depends on the driving frequency and amplitude of the defect modulation. While for low frequencies the edge mode remains localized, we observe a strong coupling to bulk modes whenever the driving frequency is resonant with a bulk band in the SSH model.

[1] C. Jörg, et al., New J. Phys. **19**, 083003 (2017).
[2] S. Mittal, et al., PRL **113**, 087403 (2014).
[3] M. C. Rechtsman, et al., Nature **496**, 196 (2013).
[4] Z. Wang, et al., Nature **461**, 772 (2009).
[5] S. Reyes, et al., New J. Phys. **19**, 043029 (2017).

Q 42.3 Wed 14:45 K 0.016

Coupled Resonators for Topologically Stabilized Photonic Circuits — •Maik Stappers[1,2], Nico Gruhler[1,2,3], Robert Löw[4], Tilman Pfau[4], and Wolfram H. P. Pernice[1,2] — [1]University of Münster, Physics Institute, Wilhelm-Klemm-Straße 10, 48149 Münster, Germany — [2]CenTech - Center for Nanotechnology, Heisenbergstraße 11 48149 Münster, Germany — [3]Institute of Nanotechnology, Karlsruhe Institute of Technology, 76344 Eggenstein-Leopoldshafen, Germany — [4]5. Physikalisches Institut and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart, Germany

Topological effects offer interesting applications in photonic circuits. Ring resonators can be coupled to one another in an 2D array in such a way that they exhibit optical edge states similar to the eletrical edge states in topological insulators. These edge states are protected from pertubations and could be utilized to build all-optical switches with a high integration density. In this scheme an optically excited thermal atomic vapor interacts with the evanescent light field inside the resonators and thus switches the path the light takes through the resonator array.

In this talk our progress towards integrated all-optical switches utilizing topological protection is presented.

Q 42.4 Wed 15:00 K 0.016

Characterization of ultra-high-Q Si_3N_4 micro-ring resonators with high-precision temperature control — •Paul Kaufmann[1], Xingchen Ji[2], Kevin Luke[2], Michal Lipson[2], and Sven Ramelow[1] — [1]Humboldt-Universität zu Berlin, Berlin, Deutschland — [2]Columbia-University, New York City, USA

On-chip integrated micro-resonators with vastly enhanced nonlinearities are increasingly relevant for application in quantum optics, e.g. as ultra-compact sources of entangled photon pairs. While commonly used in the telecom band, their application in the near-visible wavelength range of 800-900 nm is particularly interesting both for free space communication and to interface photons with optical transitions in alkali vapors used in quantum memories (i.e. Cs D2 at 852 nm). Here, we report the observation of ultra-high-Q resonances in high-confinement Si_3N_4 micro-ring resonators, reaching loaded Q-factors of 2×10^6 at 850 nm corresponding to linewidths of 150 MHz. In contrast to common laser-scanning techniques, we characterize these narrow resonances using robust and cost-effective mK-precision temperature tuning of the chip. This allows us to control and characterize the temperature shift of the resonances with an unprecedented precision of 4 MHz/K. We will discuss advantages and limitations of this method and describe potential applications for our ultra-high-Q resonator devices as bright and compact narrow-band photon pair sources.

Q 42.5 Wed 15:15 K 0.016

Integrated nonlinear silicon-nitride microresonators for multi-wavelength generation — •Helge Gehring[1,2], Nico Gruhler[1,2], and Wolfram H. P. Pernice[1,2] — [1]University of Münster, Physics Institute, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany — [2]CeNTech - Center for NanoTechnology, Heisenbergstr. 11, 48149 Münster, Germany

The need for higher data rates in both, classical and quantum communication, is rapidly increasing in recent years. One approach for satisfying this demand is transmitting signals on multiple wavelengths. Instead of using multiple laser sources, integrated nonlinear microring resonators can be employed for generating narrow-band emission at several well-separated wavelengths from a single pump laser source. At sub-threshold pump powers even spectrally correlated single-photon pairs can be produced.

Here we present our steps towards integrated sources for multi-wavelength communication using nonlinear silicon-nitride ring resonators on silicon chips. We present a theoretical study of the group velocity dispersion, which is a crucial parameter for efficient wavelength conversion and the development of a fabrication process that enables four-wave-mixing in nanophotonic circuits.

Q 42.6 Wed 15:30 K 0.016

Non-Abelian Gauge Fields in Integrated Photonic Waveguide Structures — •Mark Kremer, Lucas Teuber, Alexander Szameit, and Stefan Scheel — Institut für Physik, Universität Rostock, D-18055 Rostock, Germany

Simulating quantum effects using platforms like ultra cold atoms, waveguides, and microwave resonators offers new insights into numerous intriguing physical effects such as particle interaction, disorder-induced localization, and topological insulation. In the past few years, the concept of quantum simulators was extended to the realm of non-Abelian physics in the framework of lattice gauge theory, in particular using the platform of ultra cold atoms [1].

In our work we demonstrate how non-Abelian gauge fields can be simulated in photonics, using integrated laser-written photonic waveguide structures. To this end, we utilize dark states of a STIRAP-like process, originally introduced for manipulating the population of different (atomic) states by geometric phases [2]. A well adjusted modulation of waveguides forming a four-site system induces a non-Abelian gauge field whose gauge-independent Wilson loop can be experimentally retrieved via intensity measurements at the end facet of the waveguide structure.

[1] Dalibard, J. et al., Rev. Mod. Phys. 83, 1523 (2011).
[2] Unanyan, R. G. et al., Phys. Rev. A, 2910 (1999).

Q 42.7 Wed 15:45 K 0.016

Calculating with light - an all-optical abacus using phase-change materials — •Johannes Feldmann[1], Matthias Stegmaier[1], Nico Gruhler[1], Carlos Rios[2], Harish Bhaskaran[2], David Wright[3], and Wolfram Pernice[1] — [1]Physikalisches Institut, WWU Münster, Germany — [2]Department of Materials, University of Oxford, United Kingdom — [3]Department of Engineering, University of Exeter, United Kingdom

Since conventional data processing based on the von Neumann architecture faces more and more difficulties in increasing the processing speeds due to limitations in electrical data transfer and heat dissipation, substantial research is dedicated to developing new and unconventional processing schemes as e.g. brain inspired computing using neural networks or accumulation based computing.

A recently emerging technology in this field is based on memristor devices that combine memory and resistor in one element and help to circumvent the need to shuffle data between processor and memory but instead calculate and store it in the same physical location. In our work we transfer these ideas to a nanophotonic platform using phase-change materials embedded on top of integrated waveguides to enable fast and low energy arithmetic in analogy to an abacus. Employing single picosecond optical pulses with energies below 20 pJ our on-chip devices are capable of addition, subtraction, multiplication and division directly in base ten in speeds approaching the GHz-range. Using a waveguide-crossing array we present a scalable nanophotonic framework providing first steps towards non-von Neumann computation.