Q 13: Quantum Technologies

Time: Monday 17:00–19:00 Location: HS 3219

Q 13.1 Mon 17:00 HS 3219

Alternative approach to quantum pulse gates — •Ankita Khanda, Laura Serino, Michael Stefszky, Benjamin Brecht, and Christine Silberhorn — Integrated Quantum Optics, Institute for Photonic Quantum Systems, Paderborn Univerisity, Warburger Str. 100, 33098 Paderborn, Germany

Deep space communications and time-of-flight LiDAR applications can utilize ultrashort optical pulses for high bit rate and precision; however, successful implementation of such systems is challenging and requires single- or few-photon detection with very low mean photon numbers and high SNR. Noise rejection is critical in free-space, where background light is present or detected photon count is low. The most efficient method of noise elimination in the spectral-temporal domain is coherent time-frequency filtering. A quantum pulse gate (QPG) is a highly selective coherent temporal mode (TM) filter based on sum-frequency generation in a periodically-poled lithium niobate (PPLN) waveguide capable of single-photon level operation at telecom wavelengths without additional noise. In this work, we investigate noise effects of frequency up-conversion in target TM detection at telecom-only wavelengths in a PPLN QPG down to single-photon level. The pump and signal photon location in the telecom-range with small spectral separation allows for easy integration into the standard fiber-optic networks, but may give rise to additional noise channels. We will report progress on the project, including first results.

Q 13.2 Mon 17:15 HS 3219

Maiman's heritage, a thin disk cw singlemode Ruby laser for high precision metrology — •Walter Luhs[1], Thomas Müller-Wirts[2], Carsten Reinhardt[3], and Bernd Wellegehausen[4] — [1]Photonic Engineering Office, Herbert-Hellmann-Allee 57, 79189 Bad Krozingen, Germany — [2]TEM Messtechnik GmbH, Großer Hillen 38, 30559 Hannover, Germany — [3]Hochschule Bremen, Neustadtswall 30, 28199 Bremen, Germany — [4]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

Maiman's three-level 694 nm Ruby laser is well known as a pulsed laser but is considered to be difficult to operate as a cw system. This recently changed due to successful cw operation pumped with 405 nm diode lasers, Ref. [1] and further refs. therein. Here, we report on the first realization of a thin disk (microchip) cw Ruby laser of only 0.5 mm crystal thickness, allowing highly stable single-frequency operation without any further frequency selective element. Details of the system will be presented, and applications for high-precision metrology will be discussed.

[1] W. Luhs, B. Wellegehausen; Diode pumped compact single frequency cw ruby laser, J. Physics Communications 7 (2023) 0055007

Q 13.3 Mon 17:30 HS 3219

Hybrid Fiber-Solid State Laser with 3D-Printed Intracavity Lenses — •Simon Angstenberger, Pavel Ruchka, Mario Hentschel, Tobias Steinle, and Harald Giessen — 4th Physics Institute and Stuttgart Research Center of Photonic Engineering, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

Microscale 3D-printing has revolutionized micro-optical applications ranging from endoscopy, imaging, to quantum technologies. In all these applications miniaturization is key, and in combination with the nearly unlimited design space it is opening novel avenues. Here, we push the limits of miniaturization and durability by realizing the first fiber laser system with intra-cavity on-fiber 3D-printed optics. We demonstrate stable laser operation at over 20 mW output power at 1063.4 nm with a full width half maximum (FWHM) bandwidth of 0.11 nm and a maximum output power of 37 mW. Furthermore, we investigate the power stability and degradation of 3D-printed optics at Watt power levels. The intriguing possibilities afforded by free-form microscale 3D-printed optics allow us to combine gain in a solid-state crystal with fiber guidance in a hybrid laser concept. Therefore, our novel ansatz enables the compact integration of bulk active media in fiber platforms at substantial power levels.

Q 13.4 Mon 17:45 HS 3219

Ultra-low frequency noise diode-laser systems for quantum applications — •Niklas Kolodzie[1,2], Ivan Mirgorodskiy[1], Kai Dietze[2], Christian Nölleke[1], and Piet O. Schmidt[2,3] — [1]TOPTICA Photonics AG, Gräfelfing, Germany — [2]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [3]Institut für Quantenoptik, Leibniz Universität Hannover, Hannover, Germany

Narrow-linewidth lasers are essential in many quantum applications which exploit ultra-cold atoms. Tasks like optical trapping or coherent qubit manipulation have high requirements on the laser frequency noise (FN). In many experiments it is crucial to keep FN at a minimum level: slow FN is responsible for the long-term stability, while fast FN ultimately limits the fidelity of qubit operations.

External-cavity diode lasers (ECDL) are the tool of choice for such applications due to their versatility and robustness: A wide range of atomic transitions in the visible and infrared frequency ranges can be addressed. However, ECDLs typically have a high level of FN due to relatively high cavity losses compared to other laser concepts.

We demonstrate an ultra-low noise laser (ULNL) by applying weak optical feedback from an additional external cavity to an ECDL. This method reduces fast FN i.e. reducing the Lorentzian part of the linewidth. We investigate the characteristics of the ULNL in detail: FN reduction with respect to different feedback power-levels, mode-stability and frequency stabilization to an optical reference. Finally, we integrate the ULNL into a calcium ion experiment and compare the performance to a state-of-the-art laser.

Q 13.5 Mon 18:00 HS 3219

Performance Comparison of Polarization Compensation Devices on a Deployed Inter City Fiber Link for Quantum Communication Applications — •Saili Naik[1,2], Gregor Sauer[1,2], Pritom Paul[1,2], and Fabian Steinlechner[1,2] — [1]Fraunhofer Institute for Applied Optics and Precision Engineering, Albert-Einstein-Str. 07, 07745 Jena, Germany — [2]Friedrich Schiller University, Institute of Applied Physics, Abbe Center of Photonics, Albert-Einstein-Str. 15, 07745 Jena, Germany

Within a quantum network, different properties of photons can be used to transmit quantum information. One such technique involves utilizing the polarization state of photons, due to ease of manipulation and detection. However, when such qubits are transmitted over long optical fiber links, their polarization state undergoes unpredictable changes caused by environmental factors. So, accurate measurement of quantum correlations in the polarization basis necessitates fast and precise compensation of these polarization drifts.

Several motorized polarization manipulation devices are available in the market, distinguished by distinct operating principles. In this work, we examine a range of performance parameters associated with these devices, including the response linearity, hysteresis, and operation speed. We also run compensation algorithms on these devices to assess their capacity for polarization compensation in low and high drift speed scenarios. This study aims to enhance our understanding of long-term behavior of polarization-based QKD systems in real-world application environments.

Q 13.6 Mon 18:15 HS 3219

Development of micro-integrated optical systems for compact atom-based quantum sensors — •Conrad Zimmermann, Marc Christ, Alisa Ukhanova, and Markus Krutzik — Ferdinand-Braun-Institut (FBH), Berlin, Germany

The miniaturization of atom-based quantum sensor experiments towards robust and compact quantum sensor devices holds great potential to improve a variety of applications, such as timekeeping, navigation and high-sensitivity field sensing. Working on the physics packages, we develop and qualify necessary integration technologies to realize miniaturized, ultra-stable optical systems to generate, manipulate and detect atomic quantum gases. For further functionalization, active optical components are investigated. We report on our technology toolbox and the latest qualification efforts regarding the micro-integration of free-space optical systems using adhesive bonding processes.

Towards higher grades of system integration, one approach is to integrate optical subsystems within the ultra-high vacuum (UHV) system, requiring ultra-low outgassing properties of all bonds and components. Furthermore, additive manufacturing of ceramics and metals is utilized, e.g. to realize compact and functionalized vacuum systems.

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Q 13.7 Mon 18:30 HS 3219

Investigation of diffraction gratings and additively manufactured vacuum components for miniaturized atomic physics packages — •Alisa Ukhanova, Marc Christ, Conrad Zimmermann, Jörg Fricke, Olaf Brox, Robert Smol, Daniel Bandke, Jenichi Clairvaux Felizco, Andrea Knigge, and Markus Krutzik — Ferdinand-Braun-Institut (FBH), Leibniz-Institut für Höchstfrequenztechnik, Berlin

Atom-based quantum devices allow precise timekeeping and field sensing. The application of these sensors beyond the laboratory environment requires improvements of size, stability and user-friendliness. Here, we are developing a technology toolbox towards miniaturized cm-scale physics package. In this presentation we show results of the optical qualification of diffraction gratings for GMOTs with varying periods, duty cycles and coatings. Furthermore, 3D-printed ceramic and aluminum components for vacuum applications are investigated and a next generation compact physics package envisioned.

This work is supported by FBH and partially supported by the German Space Agency (DLR) with funds provided by the Federal Ministry for Economic Affairs and Climate Action (BMWK) due to an enactment of the German Bundestag under grant number 50WM1949 and 50WM2070.

Q 13.8 Mon 18:45 HS 3219

Industrially fabricated ion trap chips for double-well coupling experiments — •Michael D.J. Pfeifer[1,2], Simon Schey[1,3], Matthias Dietl[1,2], Fabian Anmasser[1,2], Jakob Wahl[1,2], Marco Valentini[2], Martin van Mourik[2], Thomas Monz[2], Fabian Laurent[1], Clemens Rössler[1], Yves Colombe[1], and Philipp Schindler[2] — [1]Infineon Technologies Austria AG, Villach, Austria — [2]University of Innsbruck, Innsbruck, Austria — [3]Stockholm University, Stockholm, Sweden

We present surface ion trap chips, industrially fabricated at Infineon Technologies [1,2], that are capable of trapping ions in two separate rf potential wells. The chips are designed for investigating rf shuttling in the large separation and in the coupling regimes as element of a scalable architecture [1]. The design parameters of a surface ion trap in the rf coupling regime with optimal ion height and ion-ion distance are investigated.

The ion traps are fabricated on the dielectric substrates Fused Silica and Sapphire. The status of the microfabrication on these materials is discussed, with a focus on optical and electric properties, as well as on wafer bow.

[1] Ph. Holz, S. Auchter et al., Adv. Quantum Technol. 3, 2000031 (2020)

[2] S. Auchter, C. Axline et al., Quantum Sci. Technol. 7, 035015 (2022)