Q 36: Quantum Technologies (joint session Q/MO/QI)

Time: Wednesday 14:30–16:30 Location: E214

Invited Talk Q 36.1 Wed 14:30 E214

BMBF-Förderprogramm: Wissenschaftliche Vorprojekte — •Bernhard Ihrig und Johannes Mund — VDI Technologiezentrum GmbH

Die zweite Quantenrevolution und die schnell voranschreitenden Entwicklungen in der Photonik bieten großes Potenzial für Anwendungen in Ökonomie, Ökologie und Gesellschaft. Zugleich sind neue Erkenntnisse aus der Grundlagenforschung in einem frühen Stadium hinsichtlich der Herausforderungen und Risiken bei der Umsetzung oftmals kaum zu beurteilen. Daher müssen wissenschaftlich-technische Vorarbeiten eine Grundlage schaffen, die es ermöglicht, das Potenzial einer neuen Erfindung bzw. der neuen wissenschaftlichen Erkenntnis zu bewerten.

Das Bundesministerium für Bildung und Forschung (BMBF) beabsichtigt daher, sogenannte Wissenschaftliche Vorprojekte (WiVoPro) im Bereich der Photonik und der Quantentechnologien auf Grundlage des Forschungsprogramms Quantensysteme zu fördern. Das Ziel dieser Vorprojekte besteht darin, wissenschaftliche Fragestellungen im Hinblick auf zukünftige industrielle Anwendungen in den Quantentechnologien und der Photonik zu untersuchen. Sie sollen die bestehende Forschungsförderung ergänzen und eine Brücke zwischen Grundlagenforschung und industriegeführter Verbundförderung schlagen.

Wir als Projektträger VDI Technologiezentrum GmbH möchten die Maßnahme in diesem Rahmen vorstellen, bewerben und Ihre Fragen für eine mögliche Förderung beantworten.

Q 36.2 Wed 15:00 E214

Mikrofabrikation von Ionenfallen für einen skalierbaren Quantencomputer — •Eike Iseke[1,2], Friederike Giebel[1,2], Nila Krishnakumar[1,2], Konstantin Thronberens[1,2], Jacob Stupp[1,2], Amado Bautista-Salvador[1,2] und Christian Ospelkaus[1,2] — [1]Leibniz Universität Hannover, Hannover, Deutschlad — [2]Physikalisch Technische Bundesanstalt, Braunschweig, Deutschland

Die Ionenfallentechnologie ist eine vielversprechende Option auf dem Weg zur Entwicklung eines skalierbaren Quantencomputers. Eine mögliche Realisierung stellt die Multilagen-Ionenfalle dar [1]. Durch multiple Lagen wird die Integrationsdichte entscheidend erhöht und es können neuartige Ionenfallendesigns realisiert werden.

Die zunehmende Komplexität der Fallen stellt neue Anforderungen an die Mikrofabrikationsmethoden. Forschung und Entwicklung in diesem Feld fokussieren sich unter anderem auf die Interposer-Technologie, das Thermokompressionsbonden und die Substratdurchkontaktierung mittels TSVs (through silicon vias).

Diese fortschrittlichen Fabrikationsmethoden ermöglichen die Skalierung der Plattform sowohl durch die Möglichkeit die Anzahl der geführten Signale zu erhöhen, als auch durch die gesteigerte Zuverlässigkeit der Verbindungstechnologie.

Q 36.3 Wed 15:15 E214

Squeezed States of Light for Future Gravitational Wave Detectors at a Wavelength of 1550 nm — •Fabian Meylahn[1,2], Benno Willke[1,2], and Henning Vahlbruch[1,2] — [1]Max Planck Institute for Gravitational Physics (Albert Einstein Institute), D-30167 Hannover, Germany — [2]Leibniz Universität Hannover, D-30167 Hannover, Germany

The generation of strongly squeezed vacuum states of light is a key technology for future ground-based gravitational wave detectors (GWDs) to reach sensitivities beyond their quantum noise limit. For some proposed observatory designs, an operating laser wavelength of 1550 nm or around 2 μm is required to enable the use of cryogenically cooled silicon test masses for thermal noise reduction. Here, we present the first the direct measurement of up to 11.5 dB squeezing at 1550 nm over the complete detection bandwidth of future ground-based GWDs ranging from 10 kHz down to below 1 Hz. Furthermore, we directly observe a quantum shot-noise reduction of up to 13.5 dB at megahertz frequencies. This allows us to derive a precise constraint on the absolute quantum efficiency of the photodiode used for balanced homodyne detection. These results hold important insight regarding the quantum noise reduction efficiency in future GWDs, as well as for quantum information and cryptography, where low decoherence of nonclassical states of light is also of high relevance.

Q 36.4 Wed 15:30 E214

A single-photon source based on hot Rydberg atoms — •Jan Reuter[1,2], Max Mäusezahl[3], Felix Moumtsilis[3], Tilman Pfau[3], Tommaso Calarco[1,2], Robert Löw[3], and Matthias Müller[1] — [1]Forschungszentrum Jülich GmbH — [2]Universität zu Köln — [3]Universität Stuttgart

The leading effects of a single-photon source based on Rydberg atoms are the strong van-der-Waals interaction between the atoms as well as the collective decay of the atom ensemble. Our setup is a vapor cell filled with Rubidium atoms which we excite via three different laser pulses. The decay of this excitation will then lead to the emission of a single photon. To ensure robustness, we investigated the behavior of moving Rydberg atoms and optimized the laser pulse sequence. For that, we simulated the transitions of Rubidium atoms from the ground state over the Rydberg state up to the singly-excited collective states. We can show that the collective decay of the single excitations leads to a fast and directed photon emission, while double excitations show no or only weak collective properties.

Q 36.5 Wed 15:45 E214

Resolving photon numbers using ultra-high-resolution timing single-channel electronic readout of a conventional superconducting nanowire single photon detector — •Gregor Sauer[1,2], Mirco Kolarczik[3], Rodrigo Gomez[1,2], Helmut Fedder[3], and Fabian Steinlechner[1,2] — [1]Institute of Applied Physics, Abbe Center of Photonics, Friedrich Schiller University, 07743 Jena, Germany — [2]Fraunhofer Institute for Applied Optics and Precision Engineering IOF, 07745 Jena, Germany — [3]Swabian Instruments GmbH, 70435 Stuttgart, Germany

Photon-number-resolving (PNR) detectors are indispensable building blocks for applications in quantum communications, computing, and sensing. PNR is commonly achieved by multiplexing onto several superconducting nanowire single-photon detectors (SNSPD) or using transition-edge sensors with energy- and photon-number resolution. This comes at the cost of resource overhead (for multiplexing) or long recovery times (for transition-edge sensors).

Here, we show how ultra-high-resolution timing measurements of the rising and falling edge of electrical pulses generated from the SNSPDs enable to distinguish photon numbers of up to 5 in a single-shot measurement. This provides a practical and comparably low-cost PNR detector, offering high detection efficiency and operational repetition rate. We present the implementation of such a PNR detector system (in the telecom C-band) and its characterization by measuring the photon-number statistics of a 300fs-pulsed coherent input source with tunable average photon number and repetition rate.

Q 36.6 Wed 16:00 E214

N00N-states for super-resolving quantum imaging and sensing — •Gil Zimmermann[1] and Fabian Steinlechner[1,2] — [1]Institute of Applied Physics, Abbe Center of Photonics, Friedrich Schiller University, 07743 Jena, Germany — [2]Fraunhofer Institute for Applied Optics and Precision Engineering IOF, 07745 Jena, Germany

Quantum measurement techniques can serve to improve precision imaging and sensing through entanglement. Employing N00N-states, i.e., maximally path-entangled photon-number states of two modes, the Heisenberg limit 1/N with N photons can be reached in precision phase measurements, thus overcoming the shot-noise limit. Furthermore, the Rayleigh diffraction limit can be overcome by a factor N. Therefore, the goal is to efficiently generate high N00N-states with N>2 to improve current sensing schemes achieving super-resolution and super-sensitivity. High-N00N states with N=5 photons have already been generated experimentally with high fidelity, as shown by Afek et al. This talk will focus on schemes with relatively low complexity to generate high N00N-states. In addition, applications of high-N00N states, e.g., in the context of quantum-enhanced lidar systems or quantum microscopy, are discussed, taking into account their high fragility due to interactions with the environment.

Q 36.7 Wed 16:15 E214

Non-destructive measurement of phonon number states using the Autler-Townes effect — •Marion Mallweger[1], Murilo de Oliveira[2], Robin Thomm[1], Harry Parke[1], Natalia Kuk[1], Ger-

ard Higgins[1,3], Romain Bachelard[2,4], Celso Villas-Boas[2], and Markus Hennrich[1] — [1]Department of Physics, Stockholm University, Sweden — [2]Departamento de Física, Universidade Federal de São Carlos, Brazil — [3]Department of Microtechnology and Nanoscience (MC2), Chalmers University of Technology, Sweden — [4]Université Côte d'Azur, CNRS, Institut de Physique de Nice, France

Quantum technologies employing trapped ion qubits are currently some of the most advanced systems with regards to experimental methods in quantum computation, simulation and metrology. This is primarily due to the excellent control available over the ions' motional and electronic states. In this work we present a new method to measure the distribution of motional number states in a non-destructive manner. The technique can be applied to all platforms where a quantum harmonic oscillator is coupled to a three level system. We demonstrate the technique using a single trapped $^{88}Sr^{+}$ ion. The method relies on the Autler-Townes effect that arises when two levels are strongly coupled while being probed by a third level. If the two levels are coupled on a sideband transition, then the magnitude of the Autler-Townes splitting depends on the phonon number state. This new method provides a robust and efficient way of measuring motional states of quantum harmonic oscillators. It can even be applied to perform single shot measurements of phonon number states in a non-destructive way.