Q 4: Matter Wave Optics I

Time: Monday 10:30–12:30 Location: K 1.013

Q 4.1 Mon 10:30 K 1.013

Compact diode laser system for dual-species atom interferometry with Rb and K in space — •Oliver Anton[1], Klaus Döringshoff[1], Vladimir Schkolnik[1], Simon Kanthak[1], Benjamin Wiegand[1], Moritz Mihm[3], Ortwin Hellmig[4], André Wenzlawski[3], Patrick Windpassinger[3], Markus Krutzik[1,2], Achim Peters[1,2], and The MAIUS Team[1,2,3,4,5,6] — [1]Institut für Physik, HU Berlin — [2]Ferdinand-Braun-Institut, Berlin — [3]Institut für Physik, JGU Mainz — [4]ILP, Universität Hamburg — [5]ZARM, Universität Bremen — [6]IQO, Leibniz Universität Hannover

The MAIUS 2/3 missions will perform dual-species atom interferometry with BEC's onboard sounding rockets, enabling longer, uninterupted timescales of microgravity than any ground based facility. As a result of increasing microgravity times beyond the typical earthbound limits, future missions with dual-species atom interferometry will allow for high-precision tests of Einsteins's Equivalence principle. This talk presents the design of our laser system for this mission in detail and shows first performance test results. The laser sources are extended cavity diode laser (ECDL), master oscillator power amplifier (MOPA) modules emitting at wavelengths of 780 nm and 767 nm for Rb and K as well as 1064 nm for a dipole trap. Key components such as micro-integrated high power diode lasers, optical fiber splitter system and Zerodur benches will be presented.

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Q 4.2 Mon 10:45 K 1.013

An optical dipole trap for dual-species atom interferometry with K and Rb in space — •Simon Kanthak[1], Klaus Döringshoff[1], Martina Gebbe[2], Sven Abend[3], Matthias Gersemann[3], Markus Krutzik[1], Achim Peters[1], and The MAIUS Team[1,2,3,4,5] — [1]Institut für Physik, HU zu Berlin — [2]ZARM, Universität Bremen — [3]IQ, LU Hannover — [4]Institut für Physik, JGU Mainz — [5]Ferdinand-Braun-Institut, Berlin

An important challenge for dual-species atom interferometry experiments is the preperation of the quantum probes entering the interferometer which, amongst others, requires precise control of the relative center-of-mass positions. In the MAIUS 2/3 sounding rocket missions, a mixture of Rubidium and Potassium is initially trapped and cooled in an atom chip based trap and then transferred into an optical dipole trap (ODT), which allows for tuning of the collisional properties via Feshbach resonances and optical delta kick collimation for both species.

We present the ODT laser system at 1064 nm for the MAIUS 2/3 payload. It is based on a microintegrated extended cavity diode laser, master oscillator power amplifer (ECDL-MOPA) module. We report in detail on design and performance of our flight-qualified, all-fibered system including acusto-optical modulator and optical switch, as well as on results of loading a BEC from an atom chip based trap into the dipole trap and systematic studies of the transfer efficiency.

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Q 4.3 Mon 11:00 K 1.013

Compact and stable potassium laser system for dual speciesatom interferometry in microgravity — •Julia Pahl[1], Julien Kluge[1], Aline N. Dinkelaker[1], Christoph Grzeschik[1], Markus Krutzik[1], Achim Peters[1,2], and The QUANTUS Team[1,3,4,5,6,7] — [1]HU Berlin — [2]FBH Berlin — [3]U Bremen — [4]LU Hannover — [5]JGU Mainz — [6]U Ulm — [7]TU Darmstadt

The QUANTUS-2 apparatus is performing atom-chip based rubidium BEC experiments at the drop tower in Bremen. For future dual species experiments in microgravity, we developed and qualified a laser system for potassium 41 which meets the drop tower's demands of mass, size and robustness. This is achieved by high-power, micro-integrated distributed-feedback laser diodes, miniaturized opto-mechanics as well as compact electronics that provide the necessary driving and control capabilities. In this talk we present the design of our diode laser system, discuss the performance and functionality as well as the latest results of the first campaigns.

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Q 4.4 Mon 11:15 K 1.013

Simulation of Bose-Einstein condensates in accelerated Bloch lattices towards large momentum transfer atom interferometers — •Jan-Niclas Siemss[1], Ernst Maria Rasel[2], Klemens Hammerer[1], and Naceur Gaaloul[2] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover, Germany — [2]Institut für Quantenoptik, Leibniz Universität Hannover, Germany

Large momentum transfer (LMT) schemes for atom interferometry increase the spatial separation of the two interferometer arms enhancing the sensitivity of such atomic detectors. Alternatively, one would employ large interrogation times in microgravity[1] and fountains[2].

Novel LMT schemes for atom interferometry combine Bragg pulses and Bloch oscillations in optical lattices to coherently split and recombine the atomic wave packets.

The use of delta-kick collimated Bose-Einstein condensates is crucial as the performance of such an interferometer is limited by the fidelity of the LMT atom-light interaction which is constrained by the finite momentum width of the atomic ensemble and tunneling to higher-order bands of the optical lattice.

In our work, we simulate interferometric sequences involving Bose-Einstein condensates driven by symmetric optical lattices to interpret and optimize pioneering experiments performed in the QUANTUS collaboration. To this end, a time-dependent Gross-Pitaevskii model is developed and adapted to typical experimental environments.

[1]H. Müntinga et al. Phys. Rev. Lett. 110, 093602 (2013)

[2]S. M. Dickerson et al. Phys. Rev. Lett. 111, 083001 (2013)

Q 4.5 Mon 11:30 K 1.013

Light-pulse atom interferometry with ultracold thermal clouds and realistic laser pulses — •Jens Jenewein, Albert Roura, Wolfgang P. Schleich, and the QUANTUS team — Institut für Quantenphysik and Center for Integrated Quantum Science and Technology ($\mathrm{IQ}^{\mathrm{ST}}$), Universität Ulm, D-89069 Ulm

Using our real-time simulation of Mach-Zehnder light-pulse atom interferometry, we investigate results of ground experiments with lensed thermal states carried out with the QUANTUS-1 device. We apply data analysis methods to the evaluation of the experimental data and compare them with our simulated results. Because our simulation incorporates the effects of realistic laser pulses (i.e. velocity selectivity and off-resonant diffraction orders), it is particularly suitable for the description of these interferometry experiments. This feature can be exploited to investigate in detail how the combination of delta-kick collimation with different amounts of evaporative cooling affects the contrast and the sensitivity of the interferometric measurements, which is also influenced by the total atom number.

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Q 4.6 Mon 11:45 K 1.013

Controlling the directionality and the quantum-to-classical transition of a quantum walk in momentum space — •Alexander Gresch[1], Siamak Dadras[2], Caspar Groiseau[1], Gil S. Summy[2], and Sandro Wimberger[3,4,1] — [1]ITP, Heidelberg University, Philosophenweg 12, 69120 Heidelberg, Germany — [2]Department of Physics, Oklahoma State University, Stillwater, Oklahoma 74078-3072, USA — [3]Dipartimento di Scienze Matematiche, Fisiche ed Informatiche, Università di Parma, Parco Area delle Scienze 7/A, 43124 Parma, Italy — [4]INFN, Sezione di Milano Bicocca, Gruppo Collegato di Parma, Parma, Italy

Randomness is the crucial characteristics in a huge variety of phenomena ranging from Brownian motion to game theory. Its quantum counterpart might play a key role in quantum computation algorithms as it intrinsically differs due to its quantum features: interference and entanglement. Both resources are featured in quantum walks. They use entanglement to determine the walker's direction of motion. Several proof-of-principle experiments have already been conducted for quantum walks, our walk scheme, however, features robustness and controllability as they stem from the synthesis of the well-studied atom-optics kicked rotor with a quantum ratchet for the ballistic states dynamics. Our quantum walk is realized in momentum space using a BEC. This very feature guarantees controllability and possibly an expansion to higher walk dimensions and to investigations of many-body correlations.

Q 4.7 Mon 12:00 K 1.013

Quantum Interference of Force — •Raul Corrêa[1,2], Marina F. B. Cenni[1], and Pablo L. Saldanha[1] — [1]Departamento de Física, Universidade Federal de Minas Gerais, Caixa Postal 701, 30161-970, Belo Horizonte, MG, Brazil — [2]Institute für Optik, Information und Photonik, Universität Erlangen-Nürnberg, 91058 Erlangen, Germany

We discuss how, due to an interference effect, the superposition of a positive force with a null force on a quantum particle may result in a negative momentum transfer to the particle when the appropriate post-selection is made. This quantum interference of force represents a novel manifestation of the wave-particle duality, since forces act on particles and interference is a property of waves. We discuss two experimental schemes that could verify the effect with current technology: one with quantum particles (electrons, atoms or neutrons) in a Mach-Zehnder interferometer in free space, and another with atoms from a Bose-Einstein condensate.

Q 4.8 Mon 12:15 K 1.013

Spherical aberration correction in a scanning transmission electron microscope using a sculpted thin film — •Roy Shiloh[1,3], Roei Remez[1], Peng-Han Lu[2], Lei Jin[2], Yossi Lereah[1], Amir H. Tavabi[2], Rafal E. Dunin-Borkowski[2], and Ady Arie[1] — [1]School of Electrical Engineering, Fleischman Faculty of Engineering, Tel Aviv University, Tel Aviv, Israel — [2]Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons and Peter Grünberg Institute, Forschungszentrum Jülich, Jülich, Germany — [3]Currently at: Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), 91058 Erlangen, Germany

Nearly eighty years ago, Scherzer showed that rotationally symmetric, charge-free, static electron lenses are limited by an unavoidable, positive spherical aberration. A major breakthrough in the spatial resolution of electron microscopes was reached two decades ago by abandoning the first of these conditions, with the success of multipole aberration correctors. Here, we use a refractive silicon nitride thin film acting as a diffractive optical element for free electron beams, to tackle the second of Scherzer's constraints and demonstrate an alternative method for correcting spherical aberration in a scanning transmission electron microscope. We reveal features in Si and Cu samples that cannot be resolved in an uncorrected microscope. Our thin film corrector can be implemented as an immediate low cost upgrade to existing microscopes without re-engineering of the column or complicated operation protocols, can correct additional aberrations and may be useful in other beamline schemes such as particle accelerators and free electron lasers.