A 3: Precision Measurements and Metrology I (with Q)

Time: Monday 11:30–12:45 Location: G/gHS

A 3.1 Mon 11:30 G/gHS

Testing the universality of free fall with very large baseline atom interferometry — •Christian Schubert, Jonas Hartwig, Sven Abend, Dennis Schlippert, Christian Meiners, Étienne Wodey, Holger Ahlers, Katerine Posso-Trujillo, Naceur Gaaloul, Wolfgang Ertmer, and Ernst Maria Rasel — Institut für Quantenoptik, Leibniz Universität Hannover

The scaling factor of atom interferometers critically relies on its baseline. In case of a gravimeter, it defines the free evolution time and subsequently the response to gravity. For a gradiometer or strainmeter, the signal strength of differential acceleration signal depends on it. Therefore, very large baseline atom interferometers (VLBAI) at the scale of several meters and above are the next step to reach higher precision for advances in applied and fundamental sciences. The perspectives are to compete with superconducting gravimeters, to perform quantum tests of the weak equivalence principle in dual species set up with accuracies comparable to classical state-of-the-art tests, and to establish scalable atom optics for future strainmeters. Our VLBAI setup aims for interrogation of quantum degenerated Ytterbium and Rubidium ensembles in a 10 m vacuum setup. The simultaneous dual species operation will allow a test the universality of free fall. Choosing specifically this combination of atomic elements is motivated by the extensive experience from interferometry with cold and ultra cold atoms, and atomic clock experiments while it also constrains complementary violation parameters compared to existing tests. We will discuss the experimental implementation and the requirements to reach the targeted accuracy.

A 3.2 Mon 11:45 G/gHS

Quantum Test of the Universality of Free Fall with a Dual Species Atom Interferometer — •Logan Richardson, Henning Albers, Hendrik Heine, Jonas Hartwig, Dipankar Nath, Dennis Schlippert, Wolfgang Ertmer, and Ernst Rasel — Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

Possible violations of the universality of free fall would have deep implications on the current state of modern physics. Although the universality of free fall has been well tested classically, atom intereferometers allow access to tests of the principle from a uniquely quantum perspective. We present the results and developments from our experiment which simultaneously measures the gravitationally induced phase shift of ^{39}K and ^{87}Rb through the use of atom interferometery. With our current setup we were able to measure an Eötvös Ratio of $(0.3 \pm 5.4) \times 10^{-7}$. We here present our reasons for test mass choice, and the current limitations for our experiment. We further will discuss future developments, which will allow us to further constrain systematic uncertainty in comparison with previous published results.

A 3.3 Mon 12:00 G/gHS

Mobile Absolute Gravity Measurements with the Atom Interferometer GAIN — •Christian Freier, Matthias Hauth, Vladimir Schkolnik, and Achim Peters — Humboldt Universität zu Berlin, Institut für Physik, Newtonstr. 15, 12489 Berlin

The gravimetric atom interferometer (GAIN) is a transportable experiment which was designed to perform measurements of local gravity at a range of interesting locations in the context of geodesy and geophysics. It is based on ensembles of laser cooled ^{87}Rb in an atomic fountain configuration and stimulated Raman transitions to implement a Mach-Zehnder type interferometer.

We report on mobile gravity measurements comparing GAIN with state-of-the-art falling corner-cube and super-conducting gravimeters. They also demonstrate the robustness and maturity of the instrument, enabling mobile long-term registrations of absolute gravity, something that is not feasible with commercially available absolute gravimeters.

The achieved sensitivity of $1.3\times10^{-8}\mathrm{g}/\sqrt{\mathrm{Hz}}$ without observable drift is comparable to other mobile atomic gravimeters and significantly better than that of falling corner-cube absolute gravimeters.

A remaining gravity value offset of less than 10^{-8}g is due to systematic effects which are discussed along with recent improvements of the set-up in order to further decrease this offset.

A 3.4 Mon 12:15 G/gHS

The effect of wavefront aberrations in atom interferometry — •Bastian Leykauf, Vladimir Schkolnik, Matthias Hauth, Christian Freier, and Achim Peters — Humboldt-Universität zu Berlin, Institut für Physik, Newtonstraße 15, 12489 Berlin

Wavefront aberrations are a large source of uncertainty in current atom interferometers. We present the results of a numerical and experimental analysis based on measured aberrations of optical windows.

The numerical method is based on a simple model of atoms moving along classical trajectories and takes into account parameters such as the size and temperature of the atomic cloud. Despite its simplicity the method is able to faithfully predict the shift of the interferometer phase caused by wavefront aberrations of the beam.

Aberrations of several windows were analyzed with a Shack-Hartmann sensor and the phase bias numerically calculated for a range of experimental parameters. To verify these results, windows with known aberrations were inserted into the beam path of the atomic gravimeter GAIN and their effect on the measured value of the gravitational acceleration g was observed and compared with theory.

The method can be used to pre-select windows and reduce the error by one order of magnitude by post-correcting the measured value of g. We will also present our progress in characterizing the influence of the other contributing optics in the beam path on the wavefront.

Schkolnik et al. *The effect of wavefront aberrations in atom interferometry.* ArXiv pre-prints (arXiv:1411.7914). Nov. 2014.

A 3.5 Mon 12:30 G/gHS

Atom interferometry with Bose-Einstein condensate on sounding rockets — •Stephan Tobias Seidel, Dennis Becker, Maike Diana Lachmann, Jung-Bin Wang, Thijs Wendrich, Ernst Marial Rasel, and Wolfgang Ertmer for the QUANTUS-Collaboration — Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

One of the fundamental principles of nature is the universality of free fall. A precise test for this postulate is the comparison of the free fall of ultra-cold clouds of different atomic species and its readout using atom interferometry. In order to increase the precision of such an interferometer the space-time-area enclosed in it has to be increased. This can be achieved by performing the experiments in a weightless environment.

As a step towards the transfer of such a system in space three rocket-based atom interferometer missions are currently being prepared. The launch of the first mission, aimed at the demonstration of a BEC in space for the first time and using this quantum degenerate matter as a source for atom interferometry is planned for May 2015. It is followed by two more missions that will include the creation of degenerate mixtures in space and simultaneous atom interferometry with two atomic species. Their success would mark a major advancement towards a precise measurement of the equivalence principle with a space-born atom interferometer.

QUANTUS is supported by the German Space Agency DLR under grant number DLR 50 1131-37.