

Symposium Trends in atom interferometry (SYAI)

organised by Working Group young DPG (AKjDPG)

supported by all divisions of the section AMOP

Baptist Piest
 Institut für Quantenoptik
 Leibniz Universität Hannover
 Welfengarten 1
 30167 Hannover
 piest@iqo.uni-hannover.de

Kai Frye
 Institut für Quantenoptik
 Leibniz Universität Hannover
 Welfengarten 1
 30167 Hannover
 frye@iqo.uni-hannover.de

Knut Stolzenberg
 Institut für Quantenoptik
 Leibniz Universität Hannover
 Welfengarten 1
 30167 Hannover
 Stolzenberg@iqo.uni-hannover.de

Alexander Herbst
 Institut für Quantenoptik
 Leibniz Universität Hannover
 Welfengarten 1
 30167 Hannover
 herbst@iqo.uni-hannover.de

Jonas Böhm
 Institut für Quantenoptik
 Leibniz Universität Hannover
 Welfengarten 1
 30167 Hannover
 boehm@iqo.uni-hannover.de

Atom interferometry is a versatile tool to probe various aspects of fundamental physics at the interface of quantum mechanics and gravity. Starting with the first demonstration of light pulse interferometry in the beginning of the 90s, the field has developed to a flourishing research subject at the frontier of modern physics. Building upon recent insights and groundbreaking results, this symposium will discuss future experiments ranging from compact setups and space-borne apparatuses to very long baseline facilities. Especially young graduate students in master programmes are highly encouraged to participate on this symposium.

Overview of Invited Talks and Sessions

(Lecture hall e415)

Invited Talks

SYAI 1.1	Mon	14:00–14:30	e415	Atom interferometry and its applications for gravity sensing — •FRANCK PEREIRA DOS SANTOS, LUC ABSIL, ROMAIN CALDANI, XIAOBING DENG, ROMAIN KARCHER, SÉBASTIEN MERLET, RAPHAËL PICCON, SUMIT SARKAR
SYAI 1.2	Mon	14:30–15:00	e415	Atom interferometry for advanced geodesy and gravitational wave observation — •PHILIPPE BOUYER
SYAI 1.3	Mon	15:00–15:30	e415	Fundamental physics with atom interferometry — •PAUL HAMILTON
SYAI 1.4	Mon	15:30–16:00	e415	Atoms and molecules interacting with light — •LUCIA HACKERMÜLLER

Sessions

SYAI 1.1–1.4	Mon	14:00–16:00	e415	Trends in atom interferometry
--------------	-----	-------------	------	--------------------------------------

SYAI 1: Trends in atom interferometry

Time: Monday 14:00–16:00

Location: e415

Invited Talk

SYAI 1.1 Mon 14:00 e415

Atom interferometry and its applications for gravity sensing — ●FRANCK PEREIRA DOS SANTOS, LUC ABSIL, ROMAIN CALDANI, XIAOBING DENG, ROMAIN KARCHER, SÉBASTIEN MERLET, RAPHAËL PICCON, and SUMIT SARKAR — LNE-SYRTE, Observatoire de Paris, Université PSL, CNRS, Sorbonne Université, 61 avenue de l'Observatoire, 75014 Paris, France

The measurement of gravity, gravimetry, or its gradients, gradiometry, allows for static and dynamical studies of mass distributions, from local to global scales. Applications of gravimetry cover many disciplinary fields, such as geophysics, natural resources exploration, hydrology, geodesy, inertial navigation, fundamental physics and fundamental metrology.

Gravity measurements are performed with different kinds of relative and absolute sensors, which measure the gravity acceleration g and its variations, or its gradients. Among these, quantum gravity sensors, based on cold atom interferometry techniques, reach excellent sensitivities and accuracies, and outperform in many respects current state of the art commercially available technologies.

In my talk, I will review state of the art quantum gravity sensors, and discuss their limits in performances, both in terms of stability and accuracy. I will discuss solutions currently explored to overcome these limits, such as based on the use of ultracold atom sources and large momentum transfer beamsplitters, as well as some of their present and future applications.

Invited Talk

SYAI 1.2 Mon 14:30 e415

Atom interferometry for advanced geodesy and gravitational wave observation — ●PHILIPPE BOUYER — LP2N, IOGS, CNRS and Univ. de Bordeaux, 33400 Talence, France

In 2016, one century after Einstein predicted their existence, scientists made the first observation of gravitational waves (GW). Since this first observation, many more events have been detected, confirming that GW opens a new window for studying the cosmos. There is today a growing interest in GW astronomy; The scientific potential of it is enormous, in terms of providing a deep view into the past of our universe, and complement other observation windows such as radio telescopes or infrared observatory. The success of this new astronomy relies on our faculty to expand our observation frequency window to other frequencies. The Laser Interferometer Space Antenna (LISA) to investigate frequency sources at very low frequency gives a partial, long term answer to this challenge. Nevertheless, it leaves a large gap, the infrasound (mHz to tens of Hz) band, uncovered. An underground gravitational wave antenna can provide a quick response to this problem and would naturally complete and enhance the present and future set of GW observatories. MIGA is a long baseline, mid-frequency, GW observation infrastructure relying on quantum sensor technology to study space-time and gravitation. We will present the progress of this first step towards a Laboratory for Gravitation and Atom-interferometric Research in Eu-

rope.

Invited Talk

SYAI 1.3 Mon 15:00 e415

Fundamental physics with atom interferometry — ●PAUL HAMILTON — University of California, Los Angeles, USA

Astrophysical evidence for dark matter and dark energy suggest there is new physics beyond the Standard Model of particle physics. Models describing this new physics generally have interactions that can lead to new forces on atoms. I will discuss two experiments using the ability of atom interferometry to make precise force measurements to constrain these possible new forces.

The first experiment uses interferometry of freely falling cesium atoms to search for a new force near a test mass in ultra-high vacuum. The resulting constraints have ruled out a large range of parameter space for several dark energy theories which predict forces that are typically screened in the presence of matter. The second experiment will use an optical cavity to continuously monitor ytterbium atoms trapped in an optical lattice. A force on the atoms leads to periodic Bloch oscillations in their wavefunction which can be detected in the transmission of light through the cavity. I will discuss a proof-of-principle experiment measuring the temperature of the ytterbium gas in microseconds by using the cavity to monitor sub-optical wavelength changes in the atomic distribution as well as future plans to search for new oscillating forces from ultralight dark matter.

Invited Talk

SYAI 1.4 Mon 15:30 e415

Atoms and molecules interacting with light — ●LUCIA HACKERMÜLLER — School of Physics and Astronomy, University of Nottingham, University Park, Nottingham, NG7 2RD, UK

Large, complex and massive particles can show interference effects in a Talbot-Lau interferometer reaching beyond 10000 amu. I will detail the operation principle and touch upon recent records achieved in the group of M. Arndt and discuss interferometry applications for cold atoms.

For quantum information applications efficient atom-photon interactions are important. For this we have constructed an atom-light interface, where cold atoms are introduced into an orthogonal hole in an optical fibre. This method allows the construction of a highly compact and robust interface that is compatible with many existing waveguide and chip technologies. For this caesium atoms are cooled in a magneto-optical trap, transferred to an optical dipole trap and positioned inside a transverse, $30\mu\text{m}$ diameter through-hole in an optical fibre, created via laser micromachining. We trap about 300 atoms at a temperature of $140\mu\text{K}$. When the guided light is on resonance with the caesium D2 line, up to 87% of it is absorbed by the atoms. We also discuss the influence of hole shapes on transmission and prospects of adding a micro-cavity. Our techniques should be equally effective in optical waveguide chips and other existing photonic systems.