Symposium Trends in atom interferometry (SYAI)

organised by Working Group young DPG (AKjDPG)
supported by all divisions of the section AMOP

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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 in this symposium.

Overview of Invited Talks and Sessions

(Lecture hall Audimax)

Invited Talks

SYAI 1.1	Mon	14:00–14:30	Audimax	**Atom interferometry and its applications for gravity sensing** — •Franck Pereira dos Santos, Luc Absil, Yann Balland, Sébastien Merlet, Maxime Pesche, Raphaël Piccon, Sumit Sarkar
SYAI 1.2	Mon	14:30–15:00	Audimax	**Atom interferometry for advanced geodesy and gravitational wave observation** — •Philippe Bouyer
SYAI 1.3	Mon	15:00–15:30	Audimax	**3D printing methods for portable quantum technologies** — •Lucia Hackermüller
SYAI 1.4	Mon	15:30–16:00	Audimax	**Fundamental physics with atom interferometry** — •PAUL HAMILTON

Sessions

SYAI 1.1–1.4	Mon	14:00–16:00	Audimax	**Trends in atom interferometry**

SYAI 1: Trends in atom interferometry

Time: Monday 14:00–16:00 Location: Audimax

Invited Talk SYAI 1.1 Mon 14:00 Audimax

Atom interferometry and its applications for gravity sensing — •Franck Pereira dos Santos, Luc Absil, Yann Balland, Sébastien Merlet, Maxime Pesche, 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 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 Audimax

Atom interferometry for advanced geodesy and gravitational wave observation — •Philippe Bouyer — LP2N, IOGS, CNRS, Univ. Bordeaux

In 2016, one century after Einstein predicted their existence, scientists made the first observation gravitationalwaves (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 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 waveantenna 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 sensors 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 Europe.

Invited Talk SYAI 1.3 Mon 15:00 Audimax

3D printing methods for portable quantum technologies — •Lucia Hackermüller — University of Nottingham, UK

I will report on portable quantum devices based on 3D printing methods [1,2], suitable for atom interferometry in space, portable gravimeters or mobile quantum sensors. These enable SWAP (size weight and power) reductions by 80%, enhanced compactness and stability. I will also discuss prospects of creating high-atom number Bose-Einstein condensates, therefore bringing ultracold atom systems into a regime where they can act as a tool to probe quantum gravity.

In addition, I will report on hybrid quantum devices, incorporating both atoms and photons for quantum information and quantum computation applications. Compact, robust atom-photon interfaces enable scalable architectures for quantum computing and quantum communication, as well as chip-scale sensors and single-photon sources. Here, we demonstrate a new type of interface where atoms are trapped in a micromachined hole and show the interaction of cold cesium atoms with guided resonant photons [3,4]. We trap about 300 atoms at a temperature of 120μK. When the guided light is on resonance with the caesium D2 line, up to 87% of it is absorbed by the atoms. This is an excellent starting position to demonstrate photon storage or 4-wave mixing.

[1] S. Madkhaly et al., PRXQ in print, arXiv:2102.11874 (2021).
[2] N. Cooper et al., Additive Manufacturing, 40, 101898 (2021).
[3] E. da Ros et al., Phys. Rev. Res. 2, 033098 (2020).
[4] N. Cooper et al., Nat. Sci. Rep. 9, 7798 (2019).

Invited Talk SYAI 1.4 Mon 15:30 Audimax

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.