**Title:** Wavefront Curvature and Transverse Motion in Time-Resolved Atom Interferometry: Impact and Mitigation

**Presenter:** Noam Mouelle

**Abstract:** Time-resolved atom interferometry, as employed in applications such as gravitational wave detection and ultra-light dark matter searches, requires precise control over systematic effects to achieve unprecedented sensitivity. In this work, we investigate phase noise arising from the coupling between the initial transverse center-of-mass motion of the atom cloud and the interferometric phase via laser wavefront curvature in single-photon, large momentum transfer atom interferometers. Focusing on Gaussian laser beams, we use a semi-classical framework to derive analytical expressions for the effective phase shift in position-averaged measurements and validate them using Monte Carlo simulations. Applying these results to a 1-km atom gradiometer, we find that achieving $\mu$m-level stability in initial center-of-mass position and velocity may be necessary to suppress wavefront-induced phase noise below the $10^{-5}$ radian threshold targeted by next-generation experiments such as AION and MAGIS-100. To address this limitation, we propose a mitigation strategy based on position-resolved phase-shift readout. We show analytically and numerically that wavefront-induced phase shifts exhibit a smooth dependence on experimentally accessible parameters, allowing the noise contribution to be learned directly from the data. This approach enables correction without requiring full knowledge of the atomic velocity distribution. Our findings provide a quantitative framework for assessing and mitigating wavefront-induced phase noise, with direct implications for the design and operation of next-generation time-resolved atom interferometry experiments.

**Title:** Searching for dark forces with intermediate-scale atom interferometers

**Presenter:** John Carlton

**Abstract:** Atom interferometers are proving to be powerful tools in the search for new fundamental physics. With high acceleration sensitivities, they are well placed to probe anomalous forces arising from new scalar fields. A new generation of intermediate-scale atom interferometer experiments is poised to emerge in the coming decades, offering significantly enhanced sensitivities. In this work, we propose to leverage the single-photon transitions, longer baseline lengths and higher numbers of momentum transfers in these next-generation setups to significantly advance searches for screened forces. By placing a plate source mass inside the vacuum chamber and selecting an appropriate interferometry sequence, we project sensitivity improvements over existing bounds by several orders of magnitude. Our results indicate that future atom interferometers could decisively test the most theoretically motivated parameter space and impose stringent constraints on the free parameters of screened scalar models.

**Title:** Study of Systematic Effects in Single-photon Atom Interferometry, towards Large Momentum Transfer Enablement

**Presenter:** Simone Ausilio

**Abstract:** Large Momentum Transfer (LMT) is a key technique to enhance sensitivity in light-pulse cold atom interferometers. It uses multiple laser pulses to increase momentum separation between interferometric arms, thereby allowing sensitivity to scale. LMT requires long-lived excited states to be applicable in long-baseline setups; in this sense, optical clock transitions have been recently suggested, especially for free-falling atomic clouds. They constitute the current state of the art for atomic clocks and can leverage their narrow resonance linewidths to achieve extraordinary sensitivity. However, several technical challenges limit Cold Atom Interferometry: thermal expansion of atomic clouds and the effect of beam imperfections and light shifts are some of the major obstacles. On top of this, LMT pulses can exacerbate these issues as the number of pulses increases. In this context, we aim to analyse defects and systematic effects impacting atom interferometers and LMT via numerical simulations and modelling. Our goals are to understand how various perturbations affect the interferometric signal contrast, characterise the error budget for single-photon schemes, and develop optimal ranges of system parameters, ultimately targeting the milestone of 10,000 units of momentum transfer.

**Title:** Method for Phase Extraction from Atom Interference Fringes via Orthogonal Subspace Projection

**Presenter:** Jia-Qi Lei

**Abstract:** We propose a method for extracting the phase from atom interference fringes based on orthogonal subspace projection. By projecting the shearing interference fringes from an atom interferometer into an orthogonal subspace, this method effectively characterizes and removes the atomic ensemble envelope, thereby isolating the pure interference phase information. We systematically investigate the phase extraction accuracy of this method under various conditions, including different atomic ensemble envelope shapes and fringe contrasts, and apply to analysis experimental data from a practical atom interferometer. The study demonstrates that, compared to the direct fitting method, this method more accurately extracts the real interference phase, and enhances the accuracy and robustness of the atom interferometer. This method is particularly useful for non-ideal, dynamically varying atomic ensemble envelopes and low-contrast fringes, and shows potential for long-term, field measurements.

**Title:** Novel regimes in 689 nm Narrow-Line Laser Cooling of $^{88}Sr$ for AION

**Presenter:** Jiajun Chen, Yijun Tang

**Abstract:** The Atom Interferometer Observatory and Network (AION), a consortium of UK institutes, is developing a network of long-baseline atom interferometers to explore fundamental physics, such as decihertz gravitational waves, scalar- and vector-ultralight dark matter, fifth-force searches, and macroscopic tests of quantum mechanics. AION will complement current detectors, bridging frequency gaps for gravitational waves and setting bounds on dark matter models. At the University of Cambridge, we are developing advanced cooling and transport technologies for long-baseline atom interferometry in AION. Our work aims to realise the efficient production and rapid delivery of ultracold atomic ensembles via enhanced optical transport techniques, aiming to achieve high repetition rates with large number of atoms and meet stringent sensitivity requirements. This will support integration into long-baseline interferometers (10m–1km) for enhanced sensitivities. We will present our progress in these key technologies for AION.

**Title:** Parametric Instability Mitigation in gravitational-wave detectors

**Presenter:** Stéphanie Grabielle

**Abstract:** Parametric instabilities (PI) are a major limitation to increasing the intracavity power in the interferometer arms of gravitational-wave detectors. PI arise in high-power optical cavities through a three-mode opto-mechanical interaction that couples a mechanical eigenmode of a cavity mirror with two optical modes: the fundamental cavity mode and a higher-order optical mode. To mitigate this effect, we propose a novel technique based on radiation pressure. As with any active damping approach, it requires real-time tracking of the evolution of parametric instabilities, for example by continuously monitoring the resonant mechanical modes involved in the three-mode coupling. We present, here, a diagnostic Michelson interferometer designed to characterize the mechanical modes of a mirror. The device achieves a shot-noise limited displacement sensitivity of $2 \times 10^{-16}\,\mathrm{m}/\sqrt{\mathrm{Hz}}$ for frequencies above 35 kHz, sufficient to resolve the thermally excited modes of a mirror with a quality factor of $5 \times 10^{5}$. Because the scheme relies on a Michelson geometry rather than an auxiliary optical cavity, it can be integrated into existing gravitational-wave detector, enabling real-time monitoring and active suppression of parametric instabilities in high optical power interferometers.

**Title:** Single-bounce quantum gravimeter to measure the free-fall of anti-hydrogen

**Presenter:** Joachim Guyomard

**Abstract:** The observed asymmetry between matter and antimatter repartition in the universe has yet to be explained. This raises the question of testing with the best accuracy the Weak Equivalence Principle for antimatter. The sign of $\bar{g}$, the free fall acceleration of $\bar{H}$ in the gravity field of the Earth, has been directly measured only recently. Several experiments are ongoing at the CERN Antimatter Factory to improve the precision of this crucial test. In the GBAR project, cold antihydrogen atoms will be produced by trapping and cooling $\bar{H}^+$ ions, then photodetaching the excess positron. A classical timing of the free fall of the neutral $\bar{H}$ from the trap to an annihilation plate should lead to a measurement of $\bar{g}$ at the 1% level with 1000 annihilation events. Quantum interference techniques have been proposed to improve this accuracy by a factor of the order of 1000 (with the same number of annihilation events), by using quantum bounces of $\bar{H}$ on the Casimir-Polder potential at the approach of the annihilation plate. In this talk, we propose a new scheme for this (anti)matter-wave interferometer, with only one quantum bounce of $\bar{H}$ so that the interference pattern has a much simpler shape. We describe numerical simulations of the evolution of the wave function, using a discrete decomposition on gravitational quantum states or a continuous decomposition over freely falling eigenwaves. Emulating an experimental data analysis, we show that it should be possible with this scheme to measure $\bar{g}$ at the $10^{-5}$ level with $100$ annihilation events. This may help to address the main question in the GBAR project, that is to achieve the expected number of annihilation events, and also possibly provide us with a new kind of gravity quantum sensors for rare exotic species.

**Title:** Scenario Building of a Quantum Space Gravimetry Mission

**Presenter:** Gina Kleinsteinberg

**Abstract:** Satellite gravity missions are invaluable for measuring the global Earth's gravity field and its dynamic changes. In low-low Satellite-to-Satellite Tracking (ll-SST) missions, accelerometers are essential for detecting non-gravitational accelerations, which are treated as disturbances. Cold atom interferometry (CAI) accelerometers hold significant promise for enhancing the accuracy of future gravity field satellite missions.

Classical electrostatic accelerometers are characterized by a low-frequency drift, while CAI accelerometers offer high long-term stability. Hybridizing classical electrostatic accelerometers with CAI technology leverages the strengths of both approaches. This concept has already been demonstrated in simulations (HosseiniArani et al. 2022, HosseiniArani et al 2025). A closed-loop simulator has been developed in order to evaluate scenarios of orbit configurations and system/instrument parameters on the level of gravity field solutions (Knabe et al. 2022).

Furthermore, as part of the ongoing CARIOQA-PMP project, the development of a simulation library was initiated to realistically model space-borne atom interferometers. The software package already includes several key functionalities and can generate synthetic phase signals for basic experimental configurations for applications in Earth Observation as well as in Fundamental Physics (Struckmann et al. 2024).

**Title:** MIGA II: Gravitational Wave Testbed

**Presenter:** Yiming Meng

**Abstract:** This poster presents recent advances in the MIGA (Matter-wave laser Interferometric Gravitation Antenna) gradiometer project. We report on our experimental results using optical cavities to achieve large momentum transfer (LMT) in atom interferometry, a critical step toward realizing high-precision, large-scale gravity gradient measurements. The development of the large-scale MIGA gradiometer is introduced, highlighting technical challenges and our latest progress. In addition, we showcase experimental outcomes from the MIGAII test platform, which serves as a validation system for the large-scale gradiometer. Results include Raman velocity selection and Bragg diffraction of cold atoms, demonstrating key techniques for enhancing sensitivity and stability. These results mark important milestones in the pursuit of advanced gravity gradiometers based on atom interferometry and pave the way for future applications in geoscience and fundamental physics.

**Title:** Efficient simulations for interacting Bose-Einstein condensate mixtures

**Presenter:** Annie Pichery

**Abstract:** Efficient simulations for interacting Bose-Einstein condensate mixtures Ultra-cold atomic ensembles are a prime choice for sources in quantum sensing experiments. The development of dual species sources would offer the possibility to implement simultaneous interferometry for applications such as tests of the Universality of Free Fall. The Cold Atom Laboratory (CAL) is a multi-user Bose-Einstein Condensate (BEC) machine aboard the International Space Station, operated by NASA's Jet Propultion Lab. After its upgrade in 2020, it enabled the production and manipulation of dual-species BEC mixtures of K and Rb. We report here about the first quantum mixture experiments realized in space [E. Elliott et al., Nature 623, 502 (2023)] The presence of gravity impacts greatly the trapping conditions of interacting dual species mixtures, thus influencing the geometry of the ground state of the system. On the other hand, space provides an environment where atom clouds can float for extended times with different miscibility conditions. In both cases, the atom clouds can be displaced and expand over large extents during their free expansion, providing computational challenges to simulate the dynamics of the interacting quantum gases. In this contribution, we present scaling techniques to overcome these limits [A. Pichery et al.,AVS Quantum Science 5.4 (2023)], and show applications to the interpretation of mixture results obtained by the MAIUS collaboration in Hannover.

**Title:** An all-optical ultracold Yb-174 source for quantum clock interferometry

**Presenter:** Ali Lezeik

**Abstract:** We present our progress on the ytterbium atom source to be installed at the Very Long Baseline Atom Interferometry (VLBAI) facility. Optimized cooling and trapping techniques have allowed us to trap above 800M atoms in the intercombination MOT with more than 80% transfer efficiency in from the singlet MOT. We report on the optical dipole trap setup using a 400W fiber laser through which we have generated a deep trap capable of trapping 80M atom in the cross.

**Title:** Recoil measurement schemes with optical clock atoms

**Presenter:** Jesse Schelfhout

**Abstract:** The highest-precision test of the Standard Model of Particle Physics is limited by an unresolved discrepancy between recoil measurements of Rb and Cs atoms. Atom interferometry with optical clock transitions presents an opportunity to provide additional high-precision determinations of the fine-structure constant with independent systematics [1]. The comparatively large difference in internal energy between the ground and excited states results in contributions to the differential phase shift from the wavepacket separation within each interferometer and from the clock phase accumulated while each laser pulse propagates between interferometers. I present a novel recoil measurement scheme with large momentum transfer (LMT) to both arms of an interferometer within each Ramsey sequence, suitable for implementation with ${}^1S_0 - {}^3P_1$ intercombination lines of atoms such as Sr. Implementation of LMT requires high-fidelity pulses robust against variations in pulse area and detuning across an ensemble of ultracold atoms. Coherent control is a promising approach for designing shaped pulses for atom interferometry. I present pulses optimised with phase-only control using the seedless software [2], which has been developed for NMR applications, whose suitability for LMT shall soon be tested experimentally.

[1] J.S. Schelfhout et al., PRA 110, 053309 (2024)

[2] C. Buchanan et al., bioRxiv 2024.01.31.578133

**Title:** Fundamental physics tests using the Very Long Baseline Atom Interferometer facility

**Presenter:** Guillermo Alejandro Perez Lobato

**Abstract:** This project explores the frontiers of experimental and theoretical gravitational physics. By combining cutting-edge precision measurements with innovative theoretical approaches, we aim to probe the foundations of gravity and quantum mechanics with unprecedented sensitivity and eventually discover new physics. Objectives of this investigation include: Exploring the propagation phase shift testing the gravitational Aharanov Bohm effect, testing the validity of the Schrödinger equation with atom interferometry [1].

[1] M. Plávala - “Today's Experiments Suffice to Verify the Quantum Essence of Gravity” (arXiv:2508.03052)

**Title:** Design and development of a laser system for air-borne gravimetry

**Presenter:** Alisa Ukhanova

**Abstract:** The “AeroQGrav” project strives to demonstrate an atom interferometry based air-borne gravimeter, with a higher spatial and temporal resolution and a better long-term stability compared to the existing commercial solutions. At HU Berlin, we develop a compact and robust modular flight laser system. Three modules will provide the light fields for laser cooling of $^{87}Rb$ atoms in 2D- and 3D-magneto optical traps, Raman interferometry, and state detection during the flight. This poster explains design, manufacturing assembly and integration of the laser system, presents results of the ground characterization and provides information on the current process of the integration with the electronic control system. This project is supported by the VDI Technologiezentrum GmbH with funds provided by the Federal Ministry of Research, Technology and Space (BMFTR) under grant number 13N16518.

**Title:** Floquet Thoery of Sequential Bragg and Bloch Oscillation Based Large Momentum Transfer

**Presenter:** Ashkan Alibabaei, Patrik Mönkeberg

**Abstract:** Large momentum transfer techniques are essential tools to enhance the sensitivity of atom interferometers. So far, elastic scattering processes like Bloch Oscillations and sequential Bragg diffraction have proven to be effective means of implementing large momentum transfer. To fully exploit the potential of these methods, an accurate theoretical description is crucial. In this work, we utilize a Floquet theoretical approach to describe both Bloch Oscillations and sequential Bragg diffraction as two limiting cases of a more general framework. We verify its accuracy through comparison with an exact numerical solution of the Schrödinger equation. Using our approach, we investigate the efficiency and limits of the covered large momentum transfer pulses. We compare these results to current state-of-the-art experiments.

**Title:** Digital twinning for quantum sensors

**Presenter:** Samuel Lellouch

**Abstract:** Recent advances in quantum sensing have sparked global efforts to transition quantum sensors from laboratory research to practical applications. These include their deployment in large-scale, highly sensitive detectors for fundamental physics experiments, as well as real-world uses in geophysics, civil engineering, space, healthcare, and navigation systems. To meet the demands of these applications, quantum sensors must not only achieve disruptive levels of sensitivity but also demonstrate resilience to environmental noise and external perturbations. At the University of Birmingham, our group is developing a dedicated modelling and simulation programme aimed at accelerating the development, design, optimisation and adoption of quantum sensors through the realisation of quantum sensor digital twins.

**Title:** Constraining the spin-gravity coupling effects with dual-species atom interferometers

**Presenter:** Dongfeng Gao

**Abstract:** Spin is one fundamental property of microscopic particles. A lot of theoretical work has postulated the possible coupling between spin and gravitation, which could result in the violation of the equivalence principle. In our recent joint mass-and-energy test of the weak equivalence principle with a 10-meter $^{85}$Rb-$^{87}$Rb dual-species atom interferometer, the Eötvös parameters of four $^{85}$Rb-$^{87}$Rb combinations with specific atomic spin states were measured to the $10^{-1}$ level [L. Zhou et al., Phys. Rev. A 104, 022822 (2021)]. Here these experimental results are used to constrain the postulated spin-gravity coupling effects. The bounds on the spin-independent and spin-dependent anomalous passive gravitational mass tensors in Lämmerzahl's model are set to the $10^{-10}$ level, which improves existing bounds by three orders of magnitude. The constraints to the spin-independent electron- and proton-gravity coupling parameters in the gravitational standard-model extension are set to the $10^{-6}$ GeV level.

**Title:** Seismic noise suppression for Very Long Baseline Atom Interferometry

**Presenter:** Kai Grensemann

**Abstract:** High precision gravity measurements are in high demand to observe geological effects such as solid earth tides or shifts in ground water reservoirs. The current most sensitive devices, superconducting gravimeters, offer short term stabilities of a few nm/s2 at 1 s, but suffer from long-term drifts and require frequent recalibration. Gravimetry based on atom interferometers with sufficiently long free fall time 2T is expected to offer competing or even superior stabilities, while providing absolute measurements. The Very Long Baseline Atom Interferometer (VLBAI) facility in Hannover features a 10 m baseline, allowing for 2T = 2.4 s and shot-noise stability limits below 1 nm/s2 at 1 s in launch mode. To elimintate the most prominent technical noise source, vibrations of the inertial reference mirror, the VLBAI facility is equipped with a state-of-the-art in-vacuum seismic attenuation system (SAS). The SAS combines vertical passive seismic attenuation via geometric anti-spring filters with active stabilization in all six degrees of freedom. In this contribution, we present the features and capabilities of the SAS and report on our progress in optimizing the active stabilization.

**Title:** Sensitivity constraints imposed by baseline and pulse efficiency

**Presenter:** Patrik Schach, Enno Giese

**Abstract:** Next-generation terrestrial atom interferometers promise a new window into the universe, hunting gravitational waves and dark matter with unprecedented sensitivity. These detectors rely on three key performance boosts: resonant-mode operation using multiple loops for signal amplification, large-momentum-transfer (LMT) pulses to widen the interferometer arms, and very long baselines to separate measurement sites and suppress noise. But the path to higher sensitivity faces a complex trade-off: more loops and higher LMTs increase signal strength, yet demand taller atomic fountains and more light pulses, both of which amplify losses from imperfect atom–light interactions. The interplay between loop number, momentum transfer, and interferometer height means that "more" is not always "better." We present a study of multi-loop geometries in realistic long-baseline setups, scanning atomic cloud parameters, pulse sequences, and geometry constraints. Our results give practical formulas for the optimal number of pulses, revealing that many ambitious designs require pulse fidelities well beyond current capabilities. This limitation is now a central challenge, solving it will be key to unlocking the potential of terrestrial very-long baseline atom interferometry.

**Title:** First results on the 10 m baseline of the Very Long Baseline Atom Interferometry facility

**Presenter:** Vishu Gupta

**Abstract:** The Very Long Baseline Atom Interferometry (VLBAI) facility in Hannover opens the possibility of testing questions in fundamental physics, e.g. macroscopic delocalization of wavefunctions and constraining fundamental decoherence mechanisms. The 10m baseline enables free-fall times of up to $2T = 2.4\mathrm{s}$ and therefore large sensitivity scale factors $k_{\mathrm{eff}}T^2$. The use of this equipment imposes a series of technical demands that need to be achieved, such as obtaining an ultracold sample of atoms with the number of atoms on the order of one million, with sub-nanokelvin temperatures.

This contribution focuses on the progress towards achieving highly delocalized matter waves, including the manipulation of rubidium atoms utilizing purely optical potentials for matter-wave lensing. We discuss the performance requirements of the atom source in various parameters of interest, such as number of atoms, temperatures required, and others that are imposed by the manipulation and control methods used for the measurement process. The methods utilized include the use of lensing and dipole-trap launches with painted optical dipole traps, and the coherent manipulation of atomic wave functions by Bragg beam-splitting processes.

**Title:** Towards a two-photon E1-M1 clock transition excitation in neutral Ytterbium

**Presenter:** Mario Montero

**Abstract:** Atom interferometry experiments measuring gravitational redshift require access to long-lived internal states, such as the $^1S_0$ - $^3P_0$ optical transition in group II atoms. In fermionic isotopes, hyperfine mixing of the $^3P_0$ state weakly allows single-photon excitation. For bosons, the transition is strictly forbidden but can be driven by applying a magnetic field to induce an E1 coupling. In both cases, such mixing shortens the clock state's lifetime. A two-photon scheme avoids this limitation. An E1–M1 two-photon excitation directly accesses the clock state from the ground state by coupling to a far-detuned intermediate state through electric- and magnetic-dipole-allowed transitions. Using counterpropagating photons with degenerate frequencies eliminates first-order Doppler effects. We present our experimental approach to drive the two-photon clock transition. An ultracold $^{174}$Yb ensemble is prepared in a dual-stage magneto-optical trap and cooled in a crossed optical dipole trap. The 1156 nm clock laser is frequency-locked to a high-finesse cavity, narrowed to the sub-Hz level, and referenced to a frequency comb for absolute frequency measurement. To maximize excitation probability, the clock pulse power is amplified to 10 W. We outline further applications of two-photon Doppler-free excitation as a beam-splitting method for atom interferometers.

**Title:** Continuous loading of $^{87}$Rb atoms into an optical cavity for squeezed Mach-Zehnder-type atom interferometry

**Presenter:** Sebastian Wald

**Abstract:** We report the progress of our experiment: a spin-squeezed Mach-Zehnder-type atom interferometer enabled by atom-light interactions. A high-finesse propagating-wave cavity mediates all, the far-off-resonant dipole trap, entanglement, and counter-propagating Raman tones. Initial atom-atom correlations are generated through one-axis twisting and quantum non-demolition protocols. State-dependent Raman kicks transfer momentum, mapping internal degrees of freedom and correlations to momentum space. Specifically, we present updates on continuous loading of atoms into the dipole- trap. A weak additional potential counteracts the trap induced AC-Stark shift of the optical excited state, enabling simultaneous loading and cooling.

**Title:** Rapid Preparation Scheme for an $^{85}$Rb – $^{87}$Rb Ultracold Atomic Source for the 10m Atom Interferometer

**Presenter:** Run-Dong Xu

**Abstract:** The use of atom interferometers for testing the equivalence principle represents a frontier in the field of quantum precision measurement, where a high-flux ultracold atomic source is critical for further enhancing measurement precision. The $^{85}$Rb – $^{87}$Rb atomic combination is widely employed in equivalence principle tests. However, current ultracold preparation schemes rely on sympathetic cooling of $^{85}$Rb with $^{87}$Rb in a magnetic trap, which suffers from drawbacks such as prolonged preparation times and limited atom numbers, thereby constraining further improvements in atomic beam flux. Additionally, high-intensity magnetic fields may interfere with other instrumental equipment. To address these limitations, we propose a novel approach that replaces sympathetic evaporative cooling in a magnetic trap with Sisyphus cooling and adiabatic cooling in an optical lattice, and further combined with the matter-wave lens methods.