

Kolloquium des Instituts für Angewandte Physik



Zeit: **Dienstag 04.11.2025, 16 Uhr**

Ort: Gebäude S2 | 15, Raum 134 (Handbibliothek)

Tunneling and matter waves for quantum sensors of gravity and relativistic effects

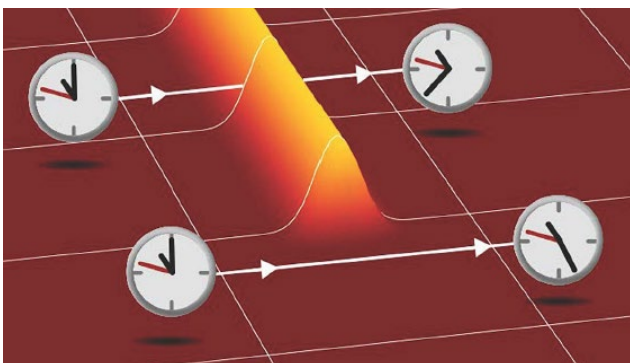
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Ultracold gases represent a unique and versatile platform for a wide range of sensing applications. Atom interferometers utilize large spatial separation of cold atomic clouds to facilitate precise measurements of accelerations and inertial forces. The inherent atomic structure serves as a fundamental element for precise timekeeping, utilizing atomic transitions for precise time measurements. By combining both external and internal degrees of freedom, novel applications and possibilities emerge.

The advent of ultracold clouds cooled below the Doppler limit enables coherent and precise manipulation of external degrees of freedom. These systems play a crucial role for the investigation of tunneling phenomena, relying on the manipulation and observation of the atomic motion. Furthermore, combining external and internal degrees of freedom provides insights into tunneling times and associated phenomena.

As promising application of quantum tunneling, we study the transmission spectrum of matter-wave Fabry-Pérot interferometers, present their sensitivity to accelerations and discuss their applicability to gravimetry [1]. Exploring the tunneling process, we investigate the phase difference of tunneled quantum clocks in various differential measurements. We identify relativistic contributions accumulated by a tunneled quantum clock due to time dilation and mass defect. In particular, we relate these contributions to a tunneling time and highlight the relations to conventional approaches [2]. Scaling atom interferometers to large-baseline experiments has opened the prospect of atom interferometers sensitive to gravitational waves. We explicitly optimize the allocation of the available resources and account for the finite spatial extent of



individual interferometers, baseline constraints, and atom loss from imperfect pulses [3].

[1] P. Schach, A. Friedrich, J. R. Williams, W. P. Schleich & E. Giese, Tunneling gravimetry. EPJ Quantum Technol. 9, 20 (2022)

[2] P. Schach & E. Giese, A unified theory of tunneling times promoted by Ramsey clocks. Sci. Adv. 10, ead16078 (2024)

[3] P. Schach & E. Giese, Spatial and pulse efficiency constraints in atom interferometric gravitational wave detectors. Quantum Sci. Technol. 10, 045031 (2025)