Differential Mach-Zehnder interferometry with trapped Bose-Einstein condensates

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We report on the first realization of a gradiometric sensor based on Mach-Zehnder trapped atom interferometers. By using innovative Beat Note Superlattices [1] we create an array of double-well traps loaded with Bose Einstein condensates of atomic potassium (See Fig.1). Once the collisional scattering length is cancelled with a broad magnetic Feshbach resonance, we can operate the beam splitters of the interferometers with simple control of the tunneling probability of the atoms through the central barrier. This allows us to determine the phase of each interferometer without releasing the atoms from the trap and measuring the final atomic population in the two modes. The simultaneous operation of the interferometers allows us to perform a differential analysis and cancel the common phase noise of the sensors (See Fig. 2). A coherence times of several hundred milliseconds is reported [2].

Our system opens the possibility to exploit quantum entangled states in trapped atom interferometry, even in presence of strong noise and paves the way to high precision measurements of forces with high spatial resolution. In the long term, we envision the possibility of exploiting our system for the measurement of higher-order interaction terms, such as magnetic dipolar interaction and three-body elastic collisions and the production of maximally entangled atomic quantum states.

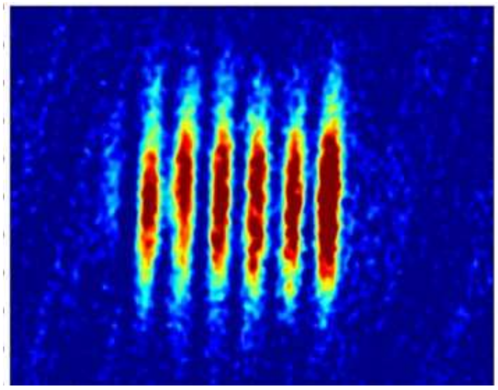

Fig. 1. Absorption image of three balanced double well traps loaded with Bose Einstein Condensates of potassium atoms.

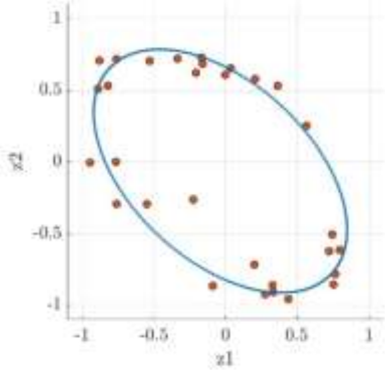

Fig. 2. Final atomic imbalance of interferometer 2 vs interferometer 1. The common mode noise distributes the data on an ellipse whose eccentricity is linked to the phase difference of the two interferometers output.

[1] L. Masi et al. “Spatial Bloch oscillations of a quantum gas in a “beat-note” optical superlattice”, PRL **127** 020601 (2021).

[2] T. Petrucciani et al. in preparation.