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Ten quectonewton local force sensor with atom interferometry

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Atom interferometers are exquisite tools for force measurements such as gravity. However, state-of-the-art such sensors use free-falling atoms and hence cannot perform purely local force measurements. Instead, we use here optically trapped atoms to perform force sensing close to the surface of a mirror and probe with unprecedented sensitivity atom-surface interactions.

We start with a non-degenerate sample of ultracold Rb87 atoms, which we transport at the vicinity of a mirror with a moving optical lattice. We end up with a 3.5 µm wide atomic cloud at a tunable distance of the mirror, with a position stability of less than a micron.

We then trap them in a mixed optical trap, combining a blue detuned static lattice and a red detuned progressive wave. Inside this trap, we induce laser assisted tunnelling between Wannier-Stark states with Raman laser pulses. This allows us to create a Raman Ramsey interferometer sensitive to the external force applied onto the atoms and to perform force measurements at different distances of our mirror with a sensitivity of 5e-28 N at 1s and less than 1e-29 N on the long-term. We actually measure an attractive force, with a maximum strength of order of 1.4e-27 N, where the expected Casimir Polder force amounts in our conditions to 0.5e-27 N. This force in excess arises from stray electric fields produced by charges or adsorbed atoms. These parasitic forces can be precisely determined in our setup by applying controlled additional electric fields thanks to electrodes placed around the mirror. Ideally, they would be suppressed by eliminating the spurious charges and adsorbed atoms, for instance by using UV illumination or by heating the mirror.
The sensitivity of our sensor opens new perspectives for precise measurements of Casimir-Polder force and other atoms-surface interactions.

Affiliation de l'auteur principal

LNE-SYRTE / Observatoire de Paris

Auteur principal: BALLAND, Yann (SYRTE / Observatoire de Paris)

Co-auteurs: M. ABSIL, Luc (SYRTE / Observatoire de Paris); Dr PEREIRA DOS SANTOS, Franck (SYRTE / Observatoire de Paris)

Orateur: BALLAND, Yann (SYRTE / Observatoire de Paris)

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