Optimal Control techniques for fast excitation-less transport of Bose-Einstein condensates with an atom chip

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Recent proposals for testing foundations of physics assume Bose-Einstein condensates (BECs) as sources of atom interferometry sensors [1,2]. In this context, atom chip devices allow to build transportable BEC machines with high flux and high repetition rates [3], as demonstrated within the QUANTUS (drop tower) [4,5] and MAIUS (sounding rocket) [6] micro-gravity experiments, for instance. In such experiments, the proximity of the atoms to the chip surface is, however, limiting the optical access and the available interferometry time necessary for high-precision measurements.

This justifies the need of very well-designed BEC transport protocols in order to perform long-baseline, and thus precise, atom interferometry measurements.

We present « optimal control theory » (OCT) [8] protocols for the fast, excitation-less transport of BECs with atom chips, i.e. engineering transport ramps with durations not exceeding a 200 ms with realistic 3D anharmonic trapping. This controlled transport is implemented over large distances, typically of the order of 1-2 mm, i.e. of about 1,000 times the size of the atomic cloud. The robustness of the transport protocols against experimental imperfections is evaluated, and the advantages over "shortcut-to-adiabaticity" schemes reported by our team [7] will be discussed. Such exquisite control features and robustness are crucial for the success of novel implementation of atom interfeometry experiments in space, such as the NASA's Cold Atom Laboratory (CAL) [9] on the International Space Station (ISS) or the NASA-DLR Bose-Einstein Condensate and Cold Atom Laboratory (BECCAL) ISS mission, wich is presently in the planning phase [10].

References

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