Optimal Matterwave Gravimetry

Michail Kritsotakis, Stuart S. Szigeti, Jacob A. Dunningham, and Simon A. Haine

Department of Physics and Astronomy
University of Sussex
e-mail: M.Kritsotakis@sussex.ac.uk

Atom inteferometry is a leading inertial sensing technology, having demonstrated state-of-the-art absolute gravimetry and gradiometry measurements. However, there is a continued push to boost the sensitivity of these devices in order to provide improved navigation, minerals exploration, and hydrology. A simple theoretical treatment shows that the sensitivity in g of the Kasevich-Chu (KC) interferometer, Fig. (1a), is given by $\Delta g = \frac{1}{\sqrt{N}k_0 T_\pi^2}$ (1), where N is the total number of particles entering the interferometer, $\hbar k_0$ is the momentum splitting of the two arms and $2T_\pi$ is the total interrogation time [1]. We theoretically investigate the behaviour of these devices via a new approach [3]. We examine the quantum Fisher information (QFI) for the KC interferometer and find that sensitivities greater than equation (1) are possible. We essentially found that the gravitational field does not just create a phase shift between the two arms, as it is currently considered [1,2], but it also affects the wavefunction of the particle itself, giving rise to additional routes to improved sensitivity. By examining the classical Fisher information (CFI), we find that this additional metrological potential can be simply attained by altering what is measured at the output of the interferometer. In particular, we find that measuring the momentum or the position distribution in each arm, rather than simply the population difference, provides additional sensitivity depending on the initial state of the particle entering the interferometer. We additionally examine a slight modification of the KC interferometer, by just removing the mirror, which more than doubles the sensitivity, Fig. (1b). The only purpose of the mirror is to ensure the spatial overlap

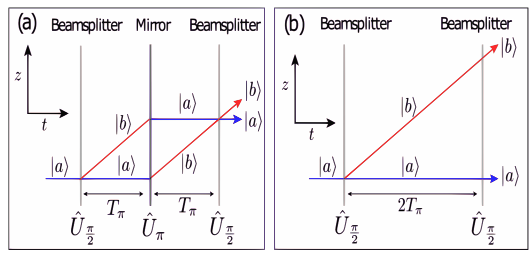

Figure 1: Spacetime diagrams for (a) KC interferometry and (b) Mirrorless interferometer

of the two wavepackets at the end of the interferometer, but this is no longer necessary in the case of a momentum measurement. In conclusion, our work introduces an entirely new way of thinking KC interferometers, which could crucially influence the design of future state-of-the-art gravimeters.

References:

[1] M. Kasevich and S. Chu, *Applied Physics B, 54(5), 321-332.*

[2] W. P. Schleich, D. M. Greenberger, and E. M. Rasel, *Physical review letters 110.1 (2013): 010401.*

[3] M. Kritsotakis, S. S. Szigeti, J. A. Dunningham and S. A. Haine, *arXiv:1710.06340v2.*