

Optimal pulse design for enhanced interferometer sensitivity and contrast

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The mirrors and beamsplitters of atom interferometers often suffer from inhomogeneities in coupling strength and effective detuning because different atoms see different laser intensities, Zeeman and Doppler shifts and are in different Zeeman sub-states. This limits the fringe visibility for a simple interferometer, which falls off rapidly if extra mirrors are added, for example to increase the interferometer area. In practice, one usually therefore filters the atomic velocities/sub-states, thus losing signal, and/or restricting operation to small-area interferometers with low sensitivity.

The problem is familiar in the field of NMR, where, instead of using simple π or $\pi/2$ pulses, the phase and potentially amplitude are modulated during the pulse so as to make the result robust to the inhomogeneities encountered. Despite the similarities with NMR systems, the numbers, correlations and performance measures for atom interferometry are different. We have used optimal control theory to obtain robust high-fidelity mirror pulses for atom interferometry. Importantly, while the designs are found by computational simulation, we can validate them experimentally, with remarkably good agreement.

We have addressed the optimization of individual mirror pulses, but the eventual aim is to optimize the interferometer as a whole: errors introduced in one pulse can be compensated at a later stage, for example. Our pulses yield high contrast without the need to filter the atomic sample and maintain this even in the case of extended pulse sequences, thus making it possible to achieve significantly larger interferometer areas than with simple π pulses.