CO.CO.MAT

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Optimal control of external state atom interferometers

Atom interferometers using confined Bose-Einstein condensates (BECs) offer new prospects for matter wave interferometry and precision measurements. Coherent manipulation and interference using optical dipole traps, atom chips, and radio-frequency potentials have been demonstrated in a series of experiments.

External state interferometers seek to measure a potential difference between two separate BECs with a sub-shot noise or Heisenberg limited phase sensitivity. To achieve this goal in presence of atom-atom interactions, elaborate control strategies for the time variation of the trapping potential are necessary, which we obtain by employing Optimal Control theory (OCT). Moreover, an accurate numerical modeling of the trapped BECs is required. This is provided by the Multi-configurational time-dependent Hartree for Bosons (MCT-DHB) method, which allows to describe both the spatial and the hopping dynamics. When applying OCT to MCTDHB, we found that the function space of the control is crucial.

With these tools we demonstrate various stages of both Mach-Zehnder and Time-of-flight interferometers. For the Mach-Zehnder interferometer we have shown recently, that it is stable against atom-atom interactions inside the interferometer. First, we report the preparation of number squeezed input states by splitting of a trap much faster than with adiabatic controls. We proceed with optimal control of nonlinear beam splitters, showing preparation of phase squeezed input states. Finally we present a full Mach-Zehnder sequence in presence of interactions.

In order to discuss the role of condensate excitations during the control sequences, we present also numerically exact simulations with MCTDHB beyond two modes.

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