Control of Quantum Dynamics on an Atom-Chip

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We work with a novel multi-state cold-atom interferometer that is easy-to-use and fully merged with an Atom-Chip. We do not rely on external variables i.e. on spatially separated paths, but use internal atomic states. The multi-state functionality is achieved by coherent manipulation of BECs in different Zeeman states of the same hyperfine level by means of radio-frequency (RF) and static magnetic fields. The interferometric fringes are sharpened due to the higher-harmonic phase contributions of the multiple energetically Zeeman states. The complete coherence of the atom transfer between the condensates guarantees the full fringe visibility. The increase in sensitivity is paid by a reduction in the interferometer sensing range and an undesirable cross-sensitivity to magnetic fields. While the former is an intrinsic property of multi-path interferometers, we suggest how the effects of the latter can be reduced by using a differential measurement configuration. In addition, our interferometer does not require neither alignment nor high resolution imaging [1].

Driving the complex dynamics of physical systems to perform a specific task is extremely useful but challenging in several fields of science, and especially for fragile quantum mechanical systems. Even harder, and often unfeasible, is to invert the time arrow of the dynamics, undoing some physical process. We theoretically and experimentally drive forth and back through several paths in the five-level Hilbert space of a Rubidium atom in the ground state (see Figure 1). We achieve such an objective applying optimal control strategies to a Bose-Einstein condensate on an Atom-chip via a frequency modulated RF field. We apply also this technique to control the sensitivity of the multi state atom interferometer.

We further prove that backward dynamical evolution does not correspond to simply inverting the time arrow of the driving field neglecting the only-system part of the dynamics. Apart from the relevance for the foundations of quantum mechanics, these results are important steps forward in the manipulation of quantum dynamics that is crucial for several physical implementations and very promisingly powerful quantum technologies.

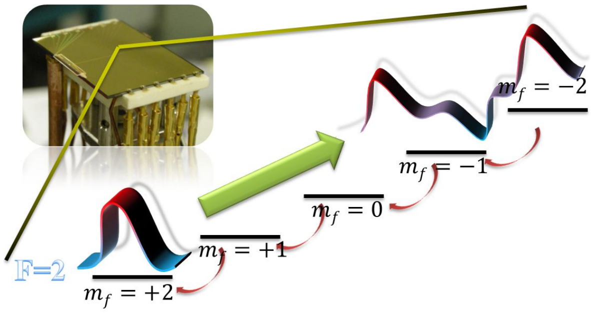

Figure 1: *A condensate of* ^{87}Rb *is created on an Atom-Chip in the* $|F =, m_F = +2\rangle$ *state. The dynamics of the system is driven by coupling the different spin orientations with a radio-frequency electromagnetic field*

References

[1] J. Petrovic *et al.* New Journal of Physics **15** (4), 043002 (2013)