Optimal Floquet Engineering for Large Scale Atom Interferometers

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We have introduced a novel approach to matter-wave optics based on the stroboscopic stabilization of quantum states within an accelerated optical lattice [1]. This method exploits a Floquet engineering scheme that allows the identification of optimal quantum transport. In particular, I will address how this approach effectively integrates various techniques of large momentum transfer atom optics, ranging from adiabatic manipulations (such as Bloch-type acceleration) to highly non-adiabatic regimes involving Bragg pulses. In addition, the Floquet scheme allows for optimal state-to-state control in large Hilbert spaces, surpassing the capabilities of traditional brute-force numerical methods. Using this method, we have experimentally achieved very efficient coherent acceleration of cold atoms, with an efficiency greater than 0.9995 per photon recoil ($\hbar k$). We have also demonstrated atom interferometers with an unprecedented momentum separation of 600$\hbar$k between the two arms of the interferometer [1].

I will further discuss the potential of this approach to support interferometers with momentum separations well beyond 1000$\hbar$k, opening new opportunities for applications in precision metrology and quantum technologies. In particular, this development addresses a critical challenge for the realization of very large scale atom interferometers, which are crucial for future gravitational wave detection and new fundamental tests.

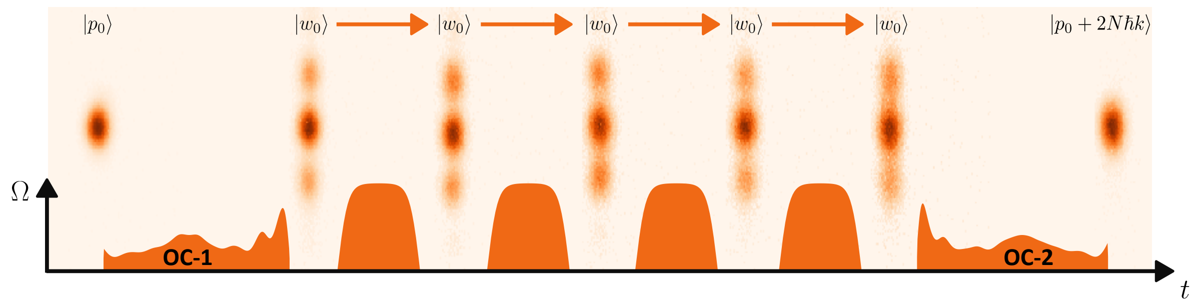

Figure 1: The periodic driving of the optical lattice allows a stroboscopic stabilization of a Floquet state $|w_0\rangle$ in the accelerated frame, leading to an optimal quantum transport. A pulse (OC-1) prepares the Floquet state $|w_0\rangle$ from the initial momentum state $|p_0\rangle$ (and vice versa for OC-2).

[1] T. Rodzinka, E. Dionis, L. Calmels, S. Beldjoudi, A. Béguin, D. Guéry-Odelin, B. Allard, D. Sugny and A. Gauguet, arXiv:2403.14337 (2024).