Interferometric laser cooling of atomic rubidium

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We report the 1-D cooling of ^{85}Rb atoms using a velocity-dependent optical force based upon Ramsey matter-wave interferometry. The velocity-dependent interferometer phase, which stems from the change in kinetic energy when a photon is absorbed, is that which in a differential configuration is the basis for a range of atom interferometric accelerometers and gyroscopes [1, 2]. Here, as proposed by Weitz and Hänsch [3], it provides a cooling effect within the atomic sample. In this first demonstration, we omit the intervening compensation pulses of the original proposal.

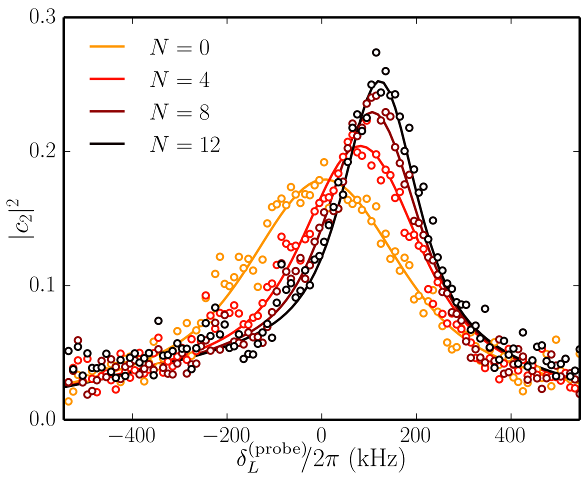

Figure 1: *Raman velocimetry measurements after N interferometric cooling cycles. Each point is the average of 16 fluorescence measurements at probe detuning $\delta_L^{(probe)}$, and the lines for $N = 0$, 4, 8 and 12 cycles are numerical simulations for temperatures of 21 μK, 10 μK, 4.8 μK and 3.2 μK respectively. The same 250 μK background is present in each case.*

Using stimulated Raman transitions between ground hyperfine states, detuned by ∼10 GHz from the 780 nm single-photon resonance, each cooling cycle comprises a pair of $\pi/2$ 'beamsplitter' pulses separated by around 600 ns. The velocity distribution is then probed by weak Raman pulses of longer duration, whose Raman detuning $\delta_L^{(probe)}$ is scanned across the Doppler-sensitive hyperfine resonance. As shown in Figure 1, 12 cycles of the interferometer sequence cool a freely-moving atom cloud, initially prepared in a conventional magneto-optical trap, from 21 μK to 3 μK [4]. The accompanying shifts of the velocity distributions in this first configuration could be eliminated by switching the directions of the counter-propagating Raman beams after each cycle.

This pulsed analogue of continuous-wave Doppler cooling is effective at temperatures down to the recoil limit; with augmentation pulses to increase the interferometer area [3, 5, 6] and using composite pulse error-correction [7], it should cool more quickly than conventional methods, and suit species that lack a closed radiative transition. By interleaving the beamsplitter and augmentation pulses, more complex manipulations are conceivable, resembling the operations of a momentum-state quantum computer [8].

References

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