Abstract:

The optical bichromatic force (BCF) relies on coherent momentum cycling in two-color laser fields to produce extremely large decelerations. Our prototype BCF slower for metastable helium can slow atoms by more than 350 m/s in just a few cm, using only low-cost diode lasers. With minor improvements it will slow atoms sufficiently to load a magneto-optical trap, an attractive alternative to Zeeman slowers with lengths of 2–3 m. The key is to utilize computer-controlled frequency chirping to keep the force centered on the slowing atoms. We have also explored the upper limits of the BCF by using very large detunings. The force is eventually disrupted by atomic phase decoherence, setting an upper limit of about 60 million m/s² for the deceleration that is nevertheless quite impressive.

For molecules, the use of direct laser slowing of any kind is still in its infancy, and it is only in 2012 that the DeMille group at Yale reported the first successful attempts using conventional radiative forces. The BCF could serve as a much-needed force multiplier that allows many stimulated cycles during each radiative lifetime, reducing losses from radiative decay into inaccessible “dark” states. We have made detailed estimates of the requirements for transverse deflection and longitudinal slowing of CaF molecules, which have a particularly favorable energy level structure. Deceleration by at least 150 m/s should be possible, and we are presently constructing a CaF beam apparatus for experimental tests.

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