A two-state Raman coupler for coherent atom optics

J. E. Debs, D. Döring, N. P. Robins, C. Figl, P. A. Altin, and J. D. Close
ACQAO, College of Science, The Australian National University

Making the analogy with light, a coherent, bright beam of atoms outcoupled from a Bose-Einstein condensate (BEC), known as an atom laser [1], is a promising tool for high precision atom interferometry [2]. Key to achieving maximum precision with an atom laser is the ability to maximise flux and minimise beam divergence. Previous work in our group has shown that by using a Raman transition to drive the outcoupling process, the flux limit is increased, and the divergence minimised [3, 4]. Furthermore, our theoretical calculations have shown that maximum flux is achieved by using a two-state outcoupling scheme [5]. However, to date, Raman outcoupling has operated via three- and five-state schemes, by targeting transitions between Zeeman sub-levels in a given hyperfine manifold [6, 3]. We have developed a Raman laser-system that resonantly couples only two levels in different hyperfine ground states of ^{87}Rb [7]. Operated as an outcoupler, this system produces an atom laser beam in a single internal state with all the aforementioned advantages of Raman outcoupling.

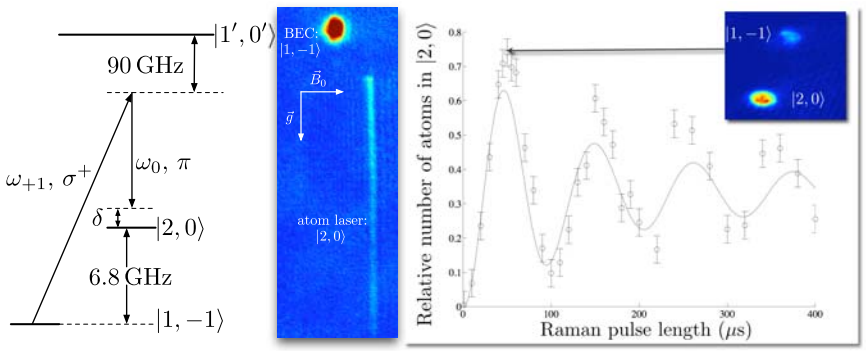

Fig. 1: The two-state Raman outcoupler. Left: The outcoupling level scheme. Middle: A typical absorption image for 5 ms of outcoupling. One of the Raman beams is directed horizontally, and the other vertically, thus transfering momentum to the atoms at 45° to gravity resulting in the parabolic beam trajectory seen. Right: Rabi oscillation of out two-state system. The oscillations decay due to the decreasing wavefunction overlap between the trapped and untrapped F=1 and F=2 states.

The versatile system has also been used as an internal state beamsplitter for atom lasers, and we have employed its use in our free space coherent Ramsey interferometer project also discussed in this report. Following the work of Haine et al. [8, 9], a rather interesting avenue of exploration is to use the Raman outcoupler to generate non-classical atom laser states, in direct analogy with squeezed light. This could be used to further boost the sensitivity of an atom interferometer, and to investigate massive particle entanglement when combined with single atom detection schemes.

References

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