A continuous Raman atom laser

N. P. Robins, A. K Morrison, C. Figl and J. D. Close
ACQAO, Faculty of Science, Australian National University, Australia

In precision measurement applications, atom lasers have the potential to outperform optical lasers and non-optical techniques by many orders of magnitude provided we can increase their flux, and achieve shot noise limited operation at least in some frequency band. To produce an atom laser, a Bose-Einstein condensate (BEC) is used as a quantum degenerate reservoir of atoms, from which a coherent output coupling mechanism converts atoms from trapped to untrapped states. Due to gravitational acceleration the output coupled atoms form a quasi-collimated beam, with the divergence determined by the repulsive interactions between the condensate and atomic beam. The majority of atom lasers experiments have used a radio frequency (RF) mechanism to produce the beam. However, we have recently found that this type of output-coupler is not suitable for the production of a high flux continuous atom laser [1].

Here we report on the production of the first continuous atom laser based on multi-photon Raman transitions (Fig1(b)). This system has the potential to surpass the output flux achievable in an RF atom laser by more than an order of magnitude, because of the large momentum kick imparted by the Raman lasers (up to $4\hbar k$ or a velocity of $\sim 2.35 \text{cm/s}$). In contrast to the pulsed Raman atom laser [2], the output beam in our system is homogeneous, in a single Zeeman state ($m_F = 0$) and has an energy linewidth at least 3 orders of magnitude narrower.

Briefly, our experimental setup is as follows. A single beam from a 70mW diode laser is split and sent through two separate, phase locked AOMs which have a frequency difference corresponding to the Zeeman plus kinetic energy difference between the initial and final states of the multi-photon Raman transition (Fig1(c)). The beams are then coupled via a single mode, polarization maintaining optical fiber, directly to the BEC through a collimating lens and $\lambda/2$ plate, providing a maximum power of 250 mW/cm$^2$ per beam. The beams are alligned parallel to the weak axis of the magnetic trap and separated by 45 degrees in the vertical direction (Fig1(a)). With the laser polarizations chosen appropriately atoms acquire a momentum kick of $4\hbar k \sin(45)$ downwards. We are currently pursuing quantitative studies of flux and fluctuations in this type of atom laser output-coupler.

Figure 1. (a) Schematic diagram of the optical set up used for creating the Raman transitions, (b) Absorption image of an 8.5 ms continuous Raman atom laser produced with 40µW per beam, and (c) Transitions from the $^5S_{1/2} F = 2, m_F = 2$ state to the $F = 2, m_F = 0$ state via the $^5S_{1/2} \rightarrow ^5P_{3/2}$ transition of $^{87}\text{Rb}$.

References