A pumped atom laser

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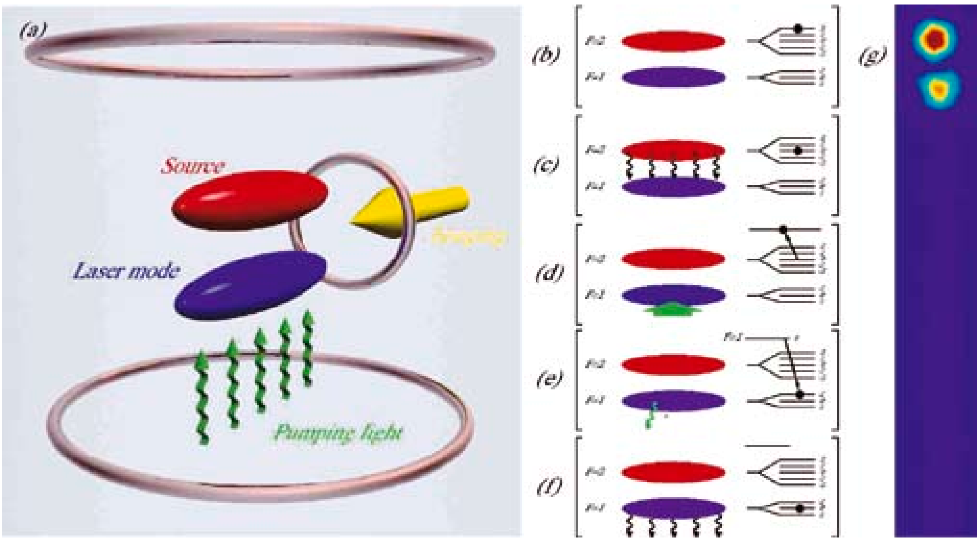
The invention of the optical laser, a bright, pumped source of coherent photons, has revolutionized optics and precision measurement, led to global high bandwidth communication and enabled non-linear optics, quantum optics, and experimental investigations of quantum information, quantum computing and quantum cryptography. The atom laser, a bright, coherent matter wave, holds similar promise for precision measurement and will open new avenues for fundamental tests of quantum mechanics [1]. Atom laser beams are derived from the exotic state of matter known as a Bose-Einstein condensate (BEC), first produced in dilute alkali gases in 1995 [2, 3]. These incredibly delicate states exist at almost zero temperature and exhibit many of the properties of optical lasers. Despite significant experimental efforts, no method has been demonstrated to continuously and irreversibly replenish the fragile Bose-Einstein condensate that forms the laser mode. This process, known as pumping, is considered an essential feature of any true laser [4]. Here we demonstrate a system for pumping a continuous atom laser, in direct analogy to the optical laser. It has taken a decade since the production of the first pulsed atom laser[5] to surmount a number of serious theoretical and technical hurdles. In our work, we show how we have solved these challenges, demonstrating that while continuously output-coupling an atom laser beam we can simultaneously and irreversibly pump new atoms from a physically separate cloud into the trapped Bose-Einstein condensate that forms the lasing mode.



Schematic of the experiment (a) and pumping steps (b-f). A radio frequency field spin-flips the atoms to the $|2,0\rangle$ state (b), and they fall under gravity (c). The light field couples the atoms to the F′=1 excited state from which they are stimulated to emit into the $|1,-1\rangle$ BEC. The atomic momentum is canceled from the absorption and emission of the photons (d) and (e). A second radio frequency field finally output-couples the atoms into the $|1,0\rangle$ atom laser (f). (g) Absorption image of the experimental system, showing source, laser mode and output beam.

References

[1] C.M. Savage, S. Marksteiner, and P. Zoller, in *Fundamentals of Quantum Optics III*, ed.- F.Ehlotzky, p.60 (1993).

[2] M.H. Anderson, J.R. Ensher, M.R. Matthews, C.E. Wieman, and E.A. Cornell, Science **269**, 198 (1995).

[3] K.B. Davis, M.-O. Mewes, M.R. Andrews, N.J. van Druten, D.S. Durfee, D.M. Kurn, and W. Ketterle, Phys. Rev. Lett. **75**, 3969 (1995).

[4] H. M. Wiseman, Phys. Rev. A, **56**, 2068 (1997).

[5] M.-O. Mewes, M.R. Andrews, D.M. Kurn, D.S. Durfee, C.G. Townsend, and W. Ketterle, Phys. Rev. Lett. **78**, 582 (1997).