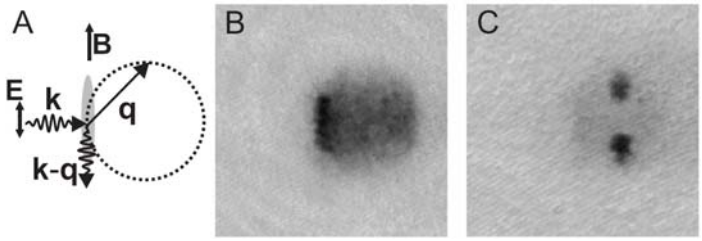
Raman Amplification of Matter Waves

With the realization of coherent, laser-like atoms in the form of Bose-Einstein condensates it has become possible to explore matter-wave amplification, a process in which the number of atoms in a quantum state is amplified due to bosonic stimulation. In previous amplifiers based on superradiant Rayleigh scattering the atoms remained in the same internal state [1, 2], a fact that severely limited the performance since the amplified atoms were scattered out of the final state or served as a gain medium for higher-order processes. We have now realized a Raman atom amplifier in which the gain medium and the amplified atoms are in different internal states [3]. Such a system has analogies to an optical laser in which different transitions are used for pumping and lasing.

The gain mechanism is provided by a polarization grating, a coherence between two different hyperfine states. We observed an exponential growth of this grating and characterized its coherence time.



Observation of superradiant Rayleigh scattering. (A) Experimental configuration. A laser beam (wave vector k) is incident perpendicularly to the long axis of the condensate; its electric field vector E is parallel to it and the applied magnetic field B. Each scattering event results in a recoiling atom (momentum $\hbar$q) and a scattered photon (momentum $\hbar$(k-q)). The recoiling atoms lie on a shell of radius $\hbar$k. (B) Spontaneous Rayleigh scattering. The absorption image shows a halo of atoms. The intensity of the beam was 1 mW/cm^2; the pulse duration was 1 ms. (C) Superradiant Raman scattering as observed for a beam intensity of 18 mW/cm^2 and a pulse duration of 100 μs (the original condensate was fully depleted after ~10 μs). In both cases the field of view was 1.05 mm x 1.05 mm.

1. S. Inouye, T. Pfau, S. Gupta, A.P. Chikkatur, A. Görlitz, D.E. Pritchard, and W. Ketterle, *Observation of phase-coherent amplification of atomic matter waves*, Nature **402**, 641 (1999).
2. M. Kozuma, Y. Suzuki, Y. Torii, T. Sugiura, T. Kuga, E.W. Hagley, and L. Deng, *Phase coherent amplification of matter waves*, Science **286**, 2309 (1999).
3. D. Schneble, G.K. Campbell, E.W. Streed, M. Boyd, D.E. Pritchard, and W. Ketterle, *Raman Amplification of Matter Waves*, preprint cond-mat/0311138.