속 빈 레이저 빔을 이용한 원자 가이드

Hollow Beam Atom Tunnel

송 연호
서울대학교
근접장 이용 극한 광기술 연구단
yonho@phya.snu.ac.kr

One of the more promising proposals for guiding and focusing neutral atoms involves dark hollow laser beams. When the frequency of the laser is detuned to the blue of resonance, the dipole force the atoms feel in the light confines them to the dark core where the atoms can be transported with minimal interaction with the light. The ability of the all-light atom guides to transport large number of ultracold atoms for long distances without physical walls leads to the possibility of a versatile tool for atom lithography, atom interferometry, atomic spectroscopy as well as for transporting and manipulating Bose-Einstein condensates. Furthermore since the atoms transported in all-light atom guides do not come into contact with matter, they can in principle be used to transport antimatter as well. The ability to vary the core size of the hollow beam makes the all-light atom guide potentially useful for focusing neutral atoms. The atoms could be focused as tight as the core size of the hollow beam at its waist. This new focusing scheme, called the atom funnel, would not show spherical and chromatic aberrations that conventional harmonic focusing suffers from.

In this presentation we describe a simple way to construct a hollow beam atom tunnel with simple optics. The fractionless hollow beam was generated from a TEM_{00} mode diode laser at 852 nm using a series of axicons and a spherical lense. The axicon generated hollow beam has a dark core extended for most of its diameter and steep walls suitable for an atom guide as shown in Fig. 1. Ultracold atoms loaded into the tunnel from a Magneto-Optical Trap (MOT) spend 90% of their time in the dark, scattering photons only when they collide with the light walls. Consequently the axicon-generated hollow beam can be exploited for long distance transport of ultracold atoms with minimal heating.

We have demonstrated transportation of 10^8 atoms through a 1 mm diameter tunnel that is 18 cm long[1]. As shown in Fig. 2, the wall of the hollow beam confines the atoms to the dark core region. The source of cold atoms was an ellipsoidal-shaped cloud of atoms produced by a vapor-loaded Cs MOT. The MOT was formed inside the tunnel with its major axis parallel to the tunnel and oriented in the vertical direction. This allowed the atoms to fall under gravity. The atoms, however, are being accelerated at 15 m/s^2, faster than would be expected from gravity alone. The extra acceleration is due to the interaction between the atoms and the light walls. We modeled the interaction to determine the optical acceleration and heating, which agreed well with experimental observations. The direction and speed of the atoms in the tunnel can be controlled by varying the detuning of the tunnel beam.

1. Y. Song and W. T. Hill III, "Long narrow all-light atom tunnel", *Opt. Lett.* **24** 1805-1807 (1999)

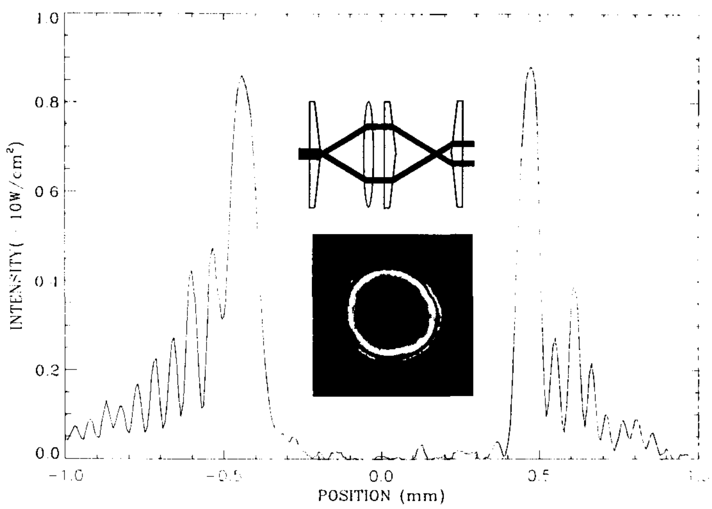

Figure 1. The optical components to generate a 1 mm hollow core beam (upper inset) and the spatial image (lower inset) of the hollow core beam. The main plot is the radial intensity profile of the hollow core beam.

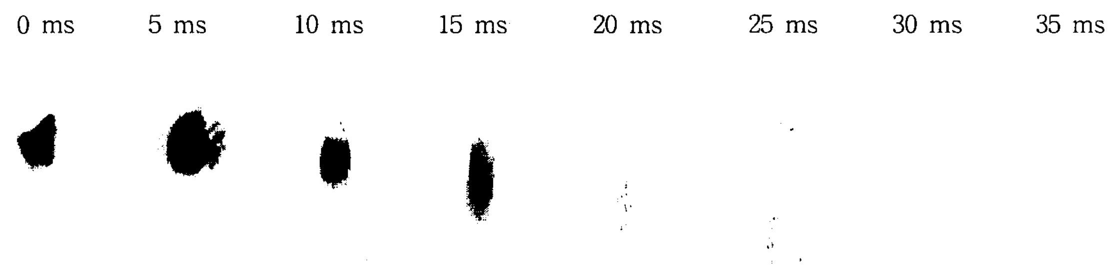

Figure 2. Shadow images of the atoms cloud in the hollow beam atom tunnel for first 35 ms of flight with the tunnel directed parallel to gravity and the laser detuning of 1.5 GHz from resonance. The center of mass of the atom cloud is accelerated at 15 ms/s^2.