Efficient atom guiding in a hollow laser beam

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We present an experimental study of atom guiding in a blue-detuned hollow laser beam(HLB). We have investigated how the guiding efficiency changes with the propagation direction of HLB. Comparing the guiding efficiencies by using various guiding schemes, we find that when the propagation direction of the HLB is the same as the guiding direction, the guiding efficiency is higher than that by using the HLB counterpropagating to the guiding direction., especially, in small detuning region. The experimental results are consistent with the theoretical results predicted by a developed model based on Ref. [1] and [2]. Therefore, if one wants to transfer as many atoms from one place to another place as possible at the expense of a higher temperature, the efficient way is by using the HLB copropagating with the guiding direction. However, through the time-of-flight measurement, we also find that when the atoms are efficiently guided by the copropagating HLB, the atoms are seriously heated, especially, in the longitudinal direction. Therefore, if the coherence of atoms (e.g. Bose-Einstein condensate) during guiding needs to be preserved, the detuning of the HLB should be set large enough to neglect the destructive contributions of the radiation pressure force and momentum diffusions. In this case, the guiding efficiency is similar to that by using the counterpropagating HLB.

In our experiments, we have used a standard vapor cell MOT apparatus for trapping ^{85}Rb atoms, where the atoms were further cooled down to a typical temperature 16 μK by the polarization gradient cooling (PGC) technique. After the PGC, the cooling and repumping laser beams were blocked by the mechanical shutters, and the HLB was simultaneously introduced into the atom cloud by opening a mechanical shutter. At the end of the above procedure, the atoms started gravitational falling into the HLB. Figure 1 shows the several TOF signals of the atoms guided inside the HLB copropagating with the guiding direction over a distance of 11 cm, and the maximum guiding efficiency is about 55%. For comparison, the TOF signal of atoms freely-falling by gravity is also shown in Fig. 1 (PGC). When the detuning of the HLB is 2 GHz, the number of atoms detected is about 20 times larger than that without the HLB, and the guiding efficiency is about 55%. At a detuning of 10 GHz, the signal is only increased 10 times, and the guiding efficiency is about 28%, then comparing with the initial velocity distributions of atoms, the final velocity distributions of guided atoms become narrower in radial direction and slightly broadened in longitudinal direction.

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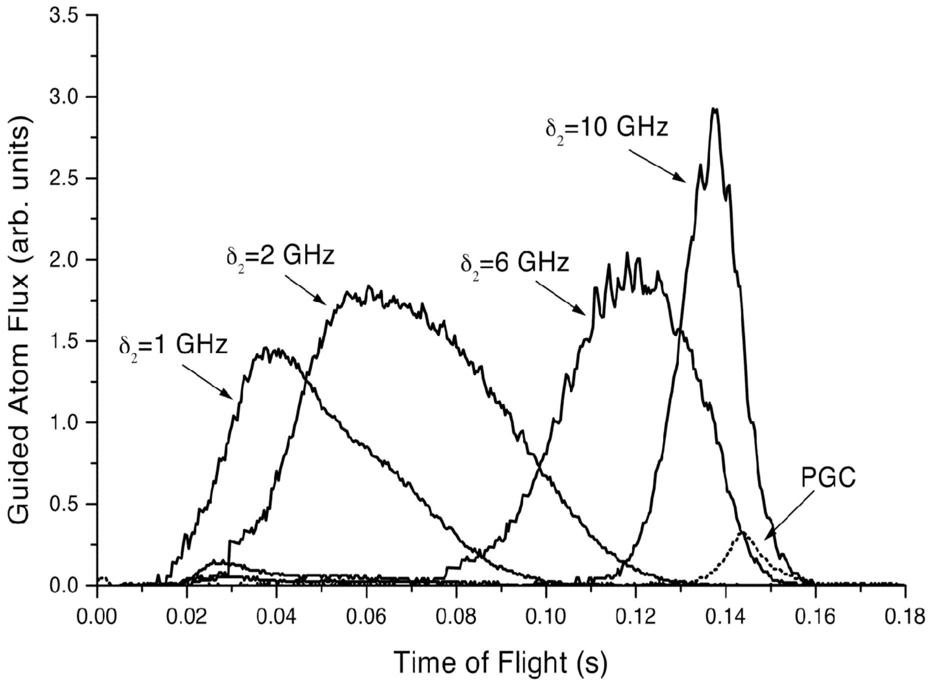

Figure 1: The TOF signals of the atoms guided by a copropagating HLB for various detunings. The initial temperature of atoms was 16 μK and the power of the HLB was 250 mW.

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