Laser manipulation of an atomic Cr beam for controlled deposition studies

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Optical pumping and one-dimensional optical molasses have been demonstrated in an atomic chromium beam. These constitute the first steps in a program to use the forces exerted by light on atoms to control deposition on a surface. The eventual goal is to introduce new ways to fabricate microscopic structures with higher resolution and parallelism than can be obtained with conventional methods.

Single-frequency light from a commercial UV-pumped stabilized ring dye laser operating with stilbene 420 dye was used to excite the $^7S_3 \rightarrow ^7P_4^o$ transition in Cr at 425.43 nm. The most abundant isotope of chromium, ^{52}Cr (84%), has no hyperfine structure. Hence optical pumping can be carried out on the $J = 3 \rightarrow J' = 4$ fine structure transition using a single laser frequency without the pumping loss mechanisms found in some alkali systems.[1]

The Cr atomic beam is produced with a high temperature oven containing an electron-beam heated Ta cell filled with 80 g of Cr crystals. Operating temperatures range from 1200–1500 °C. At these temperatures, Cr sublimates inside the cell and vapor effuses through a 1 mm circular aperture. Atomic fluxes as high as 6×10^{19} atoms $m^{-2}s^{-1}$ have been obtained at a distance of 200 mm from the oven aperture.

Using two counter-propagating laser beams, a region of one-dimensional optical molasses has been generated. The laser beams are tuned below the resonant frequency of the atomic transition, and are incident perpendicular to the atomic beam. The transverse velocity spread of the atomic beam is interrogated by measuring the beam profile at a position downstream from the molasses region. The atoms are illuminated with a probe beam tuned to the resonance frequency, and the fluorescence is imaged with a CCD camera. Transverse temperatures near or below the Doppler limit[2] have been observed with perpendicular linear polarizations in the two molasses beams (lin $\perp$ lin configuration). Exact transverse temperature measurements are currently limited because the imaged profile is a convolution of the residual transverse spread and the fundamental atomic beam profile.

In planned experiments, the molasses-collimated Cr atomic beam will be further subjected to light force interactions to effect controlled deposition of structures on a surface. It has been shown that laser light can be used as a lens for neutral atoms, potentially with very high resolution.[3, 4] We will explore various possibilities with the aim of producing novel structures of deposited chromium on appropriate substrates.

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References

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