A chromium surface magneto-optical trap for magnetic microtrap studies

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Abstract: A surface magneto-optical trap for chromium atoms is demonstrated as a first step toward loading atoms into microscopic magnetic traps. Characteristics of the trap and transfer to microscopic magnetic traps will be discussed.

OCIS codes: (020.7010) Trapping; (140.3320) Laser cooling

Because of their large magnetic moment ($6\mu_B$), cold chromium atoms are especially suitable for trapping in microscopic magnetic traps on a surface. Such traps, when occupied by single atoms, present new opportunities for scalable quantum information processing architectures because of the flexibility of geometry with which they can be constructed. This flexibility stems from the fact that they can be fabricated lithographically in a wide range of configurations out of either current-carrying wires or permanent magnetic materials. As a first step toward loading single chromium atoms into an array of microscopic magnetic traps, we have demonstrated a surface magneto-optical trap (MOT) and are studying the transfer of Cr atoms into various magnetic traps.

Building on earlier work [1], in which a conventional MOT was demonstrated using laser light tuned below the $^7S_3 \rightarrow ^7P_4^o$ transition in Cr, a new apparatus has been built for demonstrating a surface MOT. Similar traps have so far been achieved for alkali atoms [2]. In our case Cr atoms are trapped and cooled directly from an effusive source (typically at 1350 °C) that produces a beam of atoms traveling parallel to and just above the surface of an Al or Ag mirror. Two mutually orthogonal laser beams propagate at right angles to the atomic beam and at 45° relative to the mirror surface. A third laser runs at a very small angle along the atomic beam and is retroreflected onto itself. A set of anti-Helmholtz coils, mounted outside the vacuum system with their axis at 45° to the surface, provides the necessary magnetic field gradients for the MOT. Cold Cr atoms are trapped ~1 mm above the mirror surface at the magnetic field zero, which is adjusted with shim coils to lie at the intersection of all laser beams.

Planned experiments include investigating the transfer of Cr atoms to the pure quadrupole trap produced by the MOT anti-Helmholtz coils, and eventually to microscopic magnetic traps incorporated into the surface MOT geometry. Modeling of various micromagnetic structures formed from permanent magnetic materials, such as that shown in Fig. 1, will be presented. Integration with deterministic single-atom production techniques, recently developed in our laboratory [3], will also be discussed.

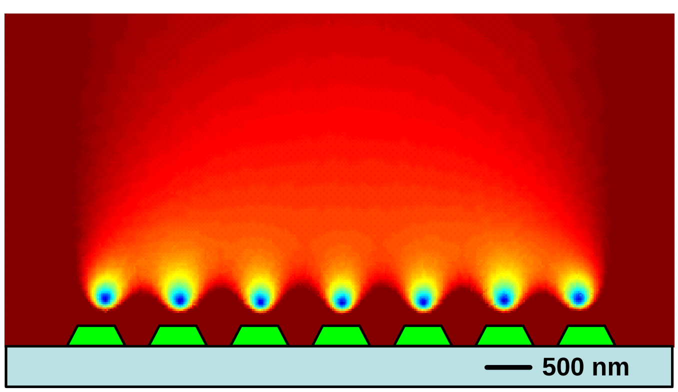

Fig. 1. Model of magnetic microtraps created by combining a bias field with the fields produced by microscopic permanent magnet structures. Color map indicates magnetic field strength with increasing values from blue to red through yellow.

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