Optical Trapping of Neutral Atoms
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Optical trapping of neutral atoms is an important experimental technique that allows experimentalists to probe the properties of cold, weakly interacting atomic particles. Optical lattices allow experimentalists a way to study study topics in condensed matter physics including topics such as the motion of electrons in a crystal lattice or superconductivity and superfluidity. The use of magneto-optical traps can be used to study Bose-Einstein condensation and other low temperature phenomena. Many experiments require ultracold atoms and molecules and optical trapping provides a way to trap and cool these particles.

The simplest model that can be studied theoretically is that of a two level atom in a standing electromagnetic wave. The oscillating electric field causes a shift of the atomic energy levels, the AC Stark shift, and the spatial variation of this shift causes the atom to experience a spatially varying potential. A brief derivation of this optical potential from the book by Metcalf and Straten (H. J. Metcalf, P. Straten, Laser Cooling and Trapping, 3rd Ed. (Springer-Verlag, New York, 1999), p. 4) will be presented in order to facilitate a discussion of optical lattice experiments.

Another important topic in optical trapping and cooling is that of Sisyphus cooling. In Sisyphus cooling schemes the atomic particle is made to climb a potential hill, and then pumped into a lower energy state, thus dissipating kinetic energy and cooling the atom. If this is repeated enough times the atomic particle can be localized to a region of low potential energy. An early paper on Sisyphus cooling using a polarization gradient created by counter-propagating lasers of linear but perpendicular polarization to one another by Dalibard and Cohen-Tannoudji (J. Dalibard, C. Cohen-Tannoudji, "Laser cooling below the Doppler limit by polarization gradients: simple theoretical models," J. Opt. Soc. Am. B, **6,** 2023-2045 (1989)) will be discussed.

Finally a brief discussion of magneto-optical traps will conclude the presentation. Magneto-Optical traps are robust traps which utilize both laser fields and an inhomogeneous magnetic field to cool and trap atoms in the trapping region. These kinds of traps require an electronic transition between two states with Je = Jg + 1. The magnetic field varies linearly near the center of the trap and alters the excited state energy levels through the Zeemann effect. The applied laser field consists of two counter-propagating, oppositely circularly polarized beams detuned red of resonance. As a consequence of atoms leaving the center of the trapping region the atoms experience a shift of their energy levels that brings them closer to resonance with the applied laser fields, increasing the scattering of light, returning them to the center of the trapping region. The treatment of Metcalf and Straten (from the same book) will be presented briefly.