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Laser Cooling with Two Wave Mixing

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The process of laser cooling in a quasi resonant standing laser wave is one of the principal techniques of laser cooling of free atoms. It will be shown that the nonlinear interaction between the counter propagating waves in a standing wave have a profound affect on the mechanical manifestations of the light on the atoms. This can be understood simply by noting that in the Two Wave Mixing (TWM) process, a momentum kick of $2\hbar k$ is transferred to the atom, as a photon is absorbed from one wave and emitted into the counter propagating wave.

This process is in fact responsible for the so called "Dipole force" Or "Stimulated Molasses" and has been verified experimentally[1]. However, since the TWM process requires high laser intensity under normal conditions it does not usually lead to lower equilibrium temperatures. Nevertheless, It has been shown that the TWM process can be modified when the normal decay rates of the atom are altered. This modification can give rise to the appearance of the TWM at lower intensity and can even change its lineshape. This in turn have an important implications on the laser cooling process in a standing wave. Among the important effects: (i) The appearance of the stimulated force at lower intensity when the dipole decay rate is increased by dephasing events.(ii) The appearance of a narrow resonance characterized by the ground state decay in an open system.[2] (iii) The modification of the stimulated force when the quantum fluctuations of the vacuum field are modified by quadrature squeezing[3].

Processes (ii) and (iii) can change the sign of the stimulated force from a heating force to a cooling force at the red side of the atomic resonance and give additional cooling force much larger than the radiation pressure force.

References:

1) A. Aspect *et-al*, Phys. Rev. Lett, 57, 1688 (1986).

2) Y. Shevy, Phys. Rev. A, in review.

3) Y. Shevy, Phys. Rev. Lett., in review.