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Quantum Model based on Fluid Energy Laws and String Solution for Laser Cooling Dependent on the Photon Density and Frequency

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Abstract

A useful expression for cooling conditions was found using energy conservation Law of a fluid for liquids and gases by treating atoms as vibrating strings subjected to gas and photon pressure. These conditions can be applied to nano and quantum systems since the model recognises the particle dual nature, which is the corner stone of quantum laws. The findings showed that the atoms density, as well as the photon density and frequency, affected the cooling process. High cooling degree requires decreasing the gas density, increasing the applied photon density, or the frequency, or both.

Keywords: energy conservation, cooling, atoms, photon, density, frequency, quantum, nano

Introduction

Light is one of the most oldest well known energy source. It is used for lightining and generating electricity using solar cells. Light can be amplified and concentrated in a very narrow beam with single frequency known as a . Laser is generated due to the process of stimulated emission of radiation. In this process a photon having energy equal to the energy difference between the ground and excited state forces the electron in the excited state to return back to the ground state emitting a photon having the same frequency, direction and phase of the incident photon [2] . The two photons when incident on two excited atoms force them to emit two additional coherent photons .This amplifiction process continues till larger number of coherent photons emerge in the form of a highly very narrow powerful beam known as laser [3]. Laser is used in modern technology in many fields such as computer optical fibers in industry and magnetic resonance imaging in medicine [4].

Recently laser cooling is used in many industrial applications including superconductors . Superconductors can be used in improving the image quality of magnetic resonance imaging devives. Cooling can also be utilized to generate powerful magnetic field which in turn can generate powerful electric energy [5,6,7]. Cooling requires slowing the atoms and molecules motion by decreasing their kinetic energies, using photon pressure. According to the kinetic theory of gases the decrease of the kinetic e decreases the temperature [8,9,10]. Ordinary laser cooling is based on the mechanical effect of single-photon transitions between ground states and electronically excited states. One can also use multiple laser wavelengths and multiple atomic transitions for laser cooling and atoms traping by quantum optics tool. Traditional laser cooling relies largely on mechanical forces due to light scattering from a single frequency laser. Multiple wavelengths and transitions can lead to usual "single-photon" cooling: access to substantially different effective photon momenta, access to different atomic line widths and saturation intensities, the possibility of coherence and EIT effects, and the possibility to easily separate atom fluorescence from laser excitation by the three-laser excitation. Such technique is based on mechanical forces arising from excited state to excited state transitions. For example, replacing the single laser excitation by the three-laser excitation can lead to larger light scattering forces, and the fluorescence would be at a very different wavelength from the excitation lasers, which could be easily filtered away. This work study theoretically laser cooling feasibility of the molecule LuF, in the fine structure level of approximation. An ab-initio complete active space self-consistent field (CASSCF)/ MRCI with Davidson correction calculation has been done in the $\Lambda^{(\pm)}$ and $\Omega^{(\pm)}$ representations. The corresponding adiabatic potential energy curves and spectroscopic parameters have been investigated for the low-lying electronic states. The results of the internuclear distances of the $X^3\Sigma_{0+}$ and $(1)^3\Pi_{0+}$ states show the candidacy of the molecule LuF for direct laser cooling$_+$. Franck– Condon factors, the radiative lifetimes, the total branching ratio, the slowing distance, and the laser cooling scheme study prove that the molecule LuF is a good candidate for Doppler laser cooling [11]. isotopes using gray molasses operating on their respective D_1 atomic transitions was investigated. For ^{7}Li, the results show that the sub-Doppler cooling can be achieved with two distinct Λ-type transitions, where the upper level can be either of the two $2^2\ P_{1/2}$ hyperfine states. A temperatures of 85 μK, was obtained with atom numbers of 10^8, and phase-space densities in the range of 10^{-6} 10^{-5} for both isotopes. These conditions provide a good starting point for loading the mixture into an optical dipole trap and performing evaporative cooling to quantum degeneracy. This provides a valuable simplification for the preparation of ultracold ^{6}Li-^{7}Li mixtures, which were proven to be a successful system for the study of impurity physics and Bose-Fermi superfluids [12] The influence of a strongly inhomo- geneous magnetic field used for trapping neutrals on the trapping and laser cooling of a single Ca+ ion in a radiofrequency ion trap is studied theoretically using molecular-dynamics simulations based on multilevel rate equations. The inhomogeneous magnetic field couples the different components of the ion motion and introduces position-dependent Zeeman splitting. Laser cooling was found to work efficiently as the ion samples different magnetic field strengths and directions along its trajectory. Offsetting the centres of the two traps generates a linear magnetic-field gradient so that multiple lasers are required to address the resulting range of Zeeman splittings in order to ensure efficient cooling. The present study yields detailed insights into the ion cooling dynamics in combined magnetic and radiofrequency electric fields [13] The integration of a laser cooler onboard an observation satellite study focuses on size, weight and power (SWaP) criteria, at both satellite payload and platform levels. Its goal is to assess the interest of using an optical cryocooler over a mechanical cryocooler for low earth orbit (LEO) infrared observation missions. A preliminary space-borne laser cooler (LC) architecture composed of two parts. The first part is the cooling head, based on state-of-the-art cooling crystals 10%Yb:YLF and an astigmatic multipass cavity. The second part is the cryocooler opto-electronics, based on redundant laser diodes and fiber coupled to the cooling head. The cooling power is estimated for a small focal plane, taking into account the thermal load of an infrared detector and the parasitic heat fluxes inside the cryostat. The required optical and electrical powers of the laser cooler are then estimated considering the crystal efficiency, the thermal link losses and the opto-electronics efficiency. The overall impact of a laser cooler shown that even if the power requirement of a laser cooler is high, the reduction of mass and internal volume makes it possible for small satellite payloads [14]. Other attempts were also made for conditions of laser cooling, beside colling mechanisms and the factors that affected the cooling rate and degree [15,16,17] .

Cooling condition using Energy conservation Law

Consider a gain a fluid having the same effects of fluid and phton pressure beside potential V. The equation of motion is given by

$$n_a m dv/dt = (\Delta p_p - \Delta p)A - \Delta v \quad (1)$$

Hence

$$n_a m \frac{dv}{dx}\frac{dx}{dt} = \frac{\partial P}{\partial x}A - \frac{\partial P_p}{\partial x}A - \frac{\partial V}{\partial x}$$

$$n_a m v \frac{dv}{dx} = \frac{d}{dx}A\,(p_p - p) - V \quad (2)$$

Integration of both sides gives

$$n_a m \int v dv + \int d(V - AP + AP_p) = \text{constant} = \text{co} \quad (3)$$

With co standing for the integration constant. Thus

$$\frac{1}{2} n_a m v^2 + V - AP + AP_p = \text{co} \quad (4)$$

Clearly this constant represents the total energy

$$E = \frac{1}{2} n_a m v^2 + V - AP + AP_p \quad (5)$$

Since the atoms which are needed to be cooled are at the same place thus one expects their potential and drift speed to be the same this means that.

$$\frac{1}{2} n_a m v_1^2 = \frac{1}{2} n_a m v_2^2 \quad (6)$$

$$V_1 = V_2 \quad (7)$$

Since the energy is conserved it follows that

$$E_2 = E_1 \quad (8)$$

$$\frac{1}{2} n_a m v_1^2 + V_2 - Ap_2 + Ap_{p2} = \frac{1}{2} n_a m v_2^2 + V_1 - Ap_1 + Ap_{p_1} \quad (9)$$

$$p_2 - p_{p_2} = p_1 - p_{p_1} \qquad (10)$$

Assuming that the laser power is changed by changing the number of photons and the amplitude while keeping the frequency un changed thus (4.3.13) and (4.3.14) requires

$$\frac{1}{2} n_a kT_2 - n_2 hf = \frac{1}{2} n_a kT_1 - n_1 hf$$

$$T_2 - T_1 = \frac{2(n_2 - n_1)}{n_a k} hf = nhf \qquad (11)$$

One can obtain the same results by assuming that before the laser was applied the temperaturis T1. If at time t laser was applied

im this case the new temperature T2 is given according to equation (4.4.10 to satisfy

$$\frac{1}{2} n_a kT_2 - n_2 hf = \frac{1}{2} n_a kT_1 \qquad (12)$$

Therefore the new temperature T1 becomes

$$T_1 = T_2 - \frac{2n_2 hf}{n_a k} \qquad (13)$$

Discussion

The factors that affected cooling of ba gas by a laser source can be found using the energy conservation Law for a fluid. Using the equation of motion (1) based on the second Newton second law for fluid particles ,the energy expression was found in equation (5).This New energy expression is different from the conventional one for a single particle. This is because it consists of an additional terms standing for photons and gas pressure. This expression for gases energy indicated, in equation (11) , that the gas can be cooled from T2 to T1 when applying photons with well known pressure. According to this equation the cooling rate can be increased upon increasing either the photon density n or the frequency f or both. For very dense gases the cooling rate becomes very slow. These findings are in agreement with observations and common sense

Conclusion

Using Energy conservation Law for a fluid conditions for gases cooling by laser were found. The results obtained indicated that lowering temperature from T2 to T1 requires applying photons with density n and frequency f. The lowering rate can be increased by increasing either the photon density n or the frequency f or both. The lowering rate can be increased also by decreasing the gas density.

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