Laser cooling of magnesium atoms with increased ultracold fraction

A.E. Bonert[1], D.V. Brazhnikov[1,2], A.N. Goncharov[1,2,3], A.M. Shilov[1,2], A.V. Taichenachev[1,2], and V.I. Yudin[1,2,3]

[1] *Institute of Laser Physics SB RAS, Novosibirsk 630090, Russia*
[2] *Novosibirsk State University, Novosibirsk 630090, Russia*
[3] *Novosibirsk State Technical University, Novosibirsk 630073, Russia*

Presenting Author: phd7@rambler.ru

At present, there are several atomic candidates for designing a new-generation optical-lattice-based frequency standard: Yb, Sr, Hg, Ca and Mg. The problem of deep laser cooling of large number of these atoms is very urgent and important for quantum metrology and other interesting applications. Scientists have already reached success with the first four elements (T$\sim$1 μK), but long time that problem has not been solved for magnesium atoms [1,2]. Recently the group of experimentalists from Hunnover University [3] has managed to cool ^{24}Mg down to 5 μK, but only 5000 of ultracold atoms have been accumulated in a dipole trap. It is about 0.05% from initial number of cold atoms in a magneto-optical trap.

We present the theoretical analysis of sub-Doppler laser cooling of ^{24}Mg atoms using dipole transition $3^3P_2 \rightarrow 3^3D_3$ under two counterpropagating light waves with opposite circular polarizations (1D $\sigma^+\sigma^-$ configuration). For numerical calculations the standard semi-classical approach based on the Fokker-Planck equation for linear momentum distribution of atoms is exploited. The distributions are gained beyond the limits of slow atoms approximation and for arbitrary light field intensity. The absence of these limits allows us to determine the optimal parameters of light field to maximize a fraction of ultracold atoms (T$\approx$5-10 μK) in a whole atomic cloud. In particular, at certain conditions the fraction can reach the value of 50% (see Fig.1). In 3D case the profile at Fig.1 may quantitatively change, but we believe that existence of some optimum with the large percentage also should present. So, solution of the existing problems in deep laser cooling of large number of magnesium atoms has obvious prospects for atomic optics and quantum metrology.

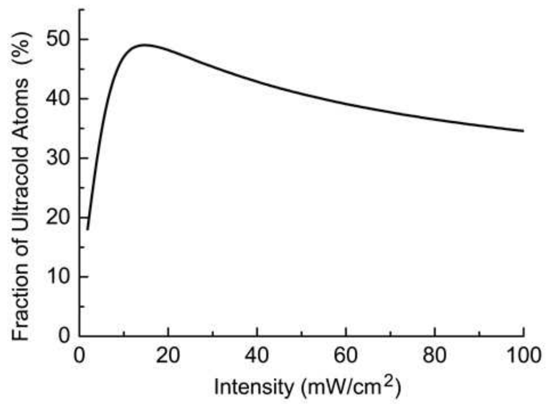

Figure 1: *Fraction of ultracold atoms in a cold atomic cloud, detuning equals to -2γ.*

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