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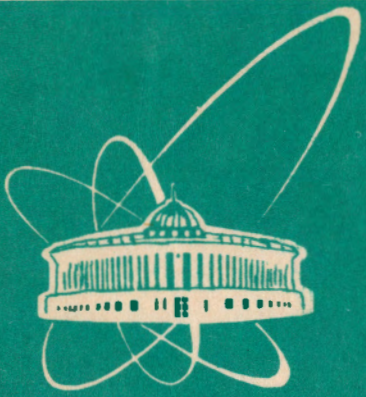

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OPTICAL TRAP FOR FREE RADIOACTIVE ATOMS ON BASE OF LIGHT INDUCED DRIFT

1993

The Light Induced Drift (LID) predicted by F.Kh. Gel'mukhanov and A.M. Shalagin in 1979 [1] has been studying very actively for the last several years (see ref. [2]). Using LID one can control the movement of free atoms. It gives wide possibilities to use the LID in atomic physics. One of them is a space localization and accumulation of free atoms [3]. Using LID the authors [3] have increased sodium vapor density in the concentrator up to 150 times. There was used paraffin coating for elimination of adsorption on inner cell surface. The chemical lifetime value of the free sodium atoms was about 20 ms. The value is too little, and that is why, it is not possible to use this concentrator as an optical trap.

The paper is devoted to using of the LID optical trap for radioactive atoms with the decay half time up to several days. There is maximal microgram amount of the isotopes. Our aim is to keep the radioisotopes in the free atom form for a long time in optical trap. Than it is not feasible to eliminate the adsorption by the paraffin coating. The elimination of the adsorption can be reached by heating of the metallic tube surface [4]. It is based on the thermochromatographic experiment results [5]. The purification of the buffer gas is necessary [6]. A capacity of this trap is determined by an optical density of kept atoms. It is possible to keep up to 10^{13} atoms per cm^3 in the trap, when the "optical piston" regime is realized [7].

An experimental set up is given in Fig. 1. The LID trap represents a stainless steal tube with the length of 15 cm and inner diameter of 2,5 mm with the one closed end. An aluminum foil containing 100 kBq (about 10^{10} atoms) of ^{24}Na was inserted into the tube at the distance of 4 cm from the open end. The ^{24}Na was produced by spallation reaction on the aluminum by the proton beam with the energy of 660 MeV. The tube was covered by a quartz jacket. The jacket contains

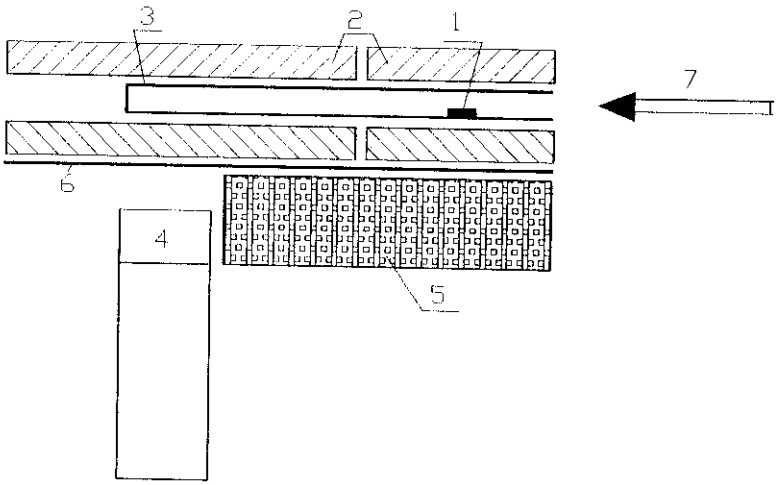

Fig. 1. Experimental set up
1 - aluminum containing ^{24}Na; 2 - ovens; 3 - stainless steal tube with one closed end; 4 - scintillation detector; 5 - lead protection; 6 - cooled screen; 7 - laser beam.

10 Torr of krypton as a buffer gas and heated potassium for krypton rectification. The laser beam propagates through the tube from the open end to the closed one. The laser frequency is tuned in the center of the ^{23}Na D_2- line. It produces the LID of ^{24}Na along the laser beam propagation [4] because of the isotope shift 706 MHz [8]. The trap is heated at 900°C with oven. After that the aluminum is heated higher its melting point. The atoms of ^{24}Na leave the source, move to the tube closed end under the effect of LID and accumulate there. The presence of the ^{24}Na in the trap is checked on by a scintillation detector. The signal from the detector is led through the discriminator to the counter. A lead shielding is used to eliminate all gamma quanta falling into the detector outside the trap. The dependence of the count rate on the calibrated gamma ray source position is given on Fig.2.

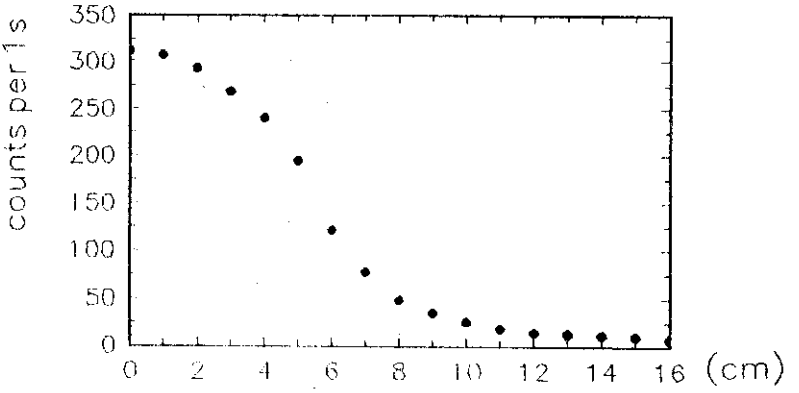

Fig. 2. Dependence of count rate on calibrated gamma ray source position.

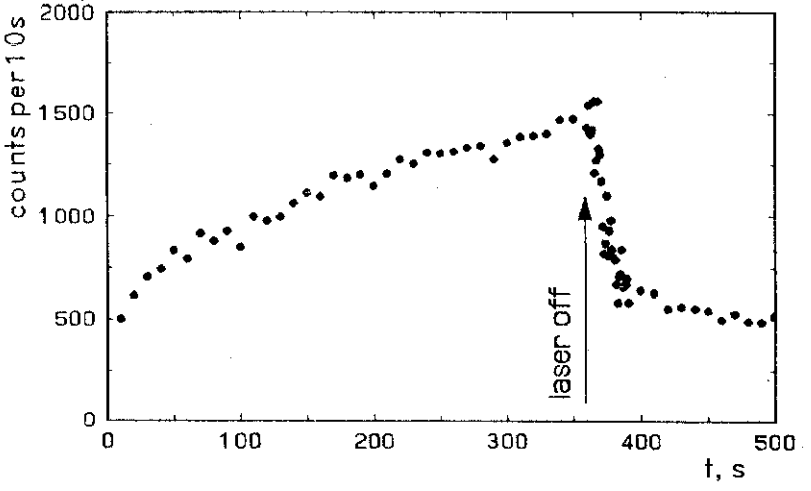

Fig. 3. Time dependence of count rate under laser radiation switching-on and switching-off

The experimental results are given in Fig. 3. When aluminum is heated up over its melting point, the rate of pulses registrated in the detector begins to increase. The

increase continues for some time and becomes more and more slower. The slowing down is connected with the reduction of the number of the sodium atoms in the source. Unfortunately we can not observe a space sodium distribution in the trap, so that it is possible only to determine, that no less than 20 % of ^{24}Na atoms leaving the source is kept in the trap. The amount of ^{24}Na atoms closed in the optical trap is about 100 times higher, than can be achieved due to diffusion from the source without the laser radiation.

To be convinced, that sodium is in the trap in atomic state and is not connected chemically with impurities or wall material, we have to cut off the laser beam. The count rate has been immediately decreased (fig. 2). The decrease time is about 100 times longer than the diffusion time. It can be explained by the adsorption of the sodium atoms on the cell wall.

The count rate under laser radiation frequency scanning from "red" to "blue" side of ^{24}Na adsorption line is given in Fig. 4. The scanning velocity is about 1 GHz/min, and inertness of the trap is too great for accurate comparison with theoretical description. But it should be noted, that half-width of the LID contour is about 2 GHz, and it corresponds with width of absorption line (about 4.3 GHz due to a hyperfine structure [9] and Doppler broadening). The maximum of the drift velocity of ^{24}Na is achieved with the laser frequency tuning near the center of the ^{23}Na line.

The time of atom keeping in the trap has been determined by the following experiment. When sufficient quantity of the atoms is accumulated in the trap, the source oven is turned off. 40 minutes later the counter quantity decreases only for 5%, that is explained by radioactive decay of ^{24}Na (the half-life time is 15 h). When the laser beam is cut off, the sodium leaves the trap again. The time dependence of the count rate decrease has been similar , when the sodium atoms have been kept for some minutes or for about one hour in the trap. It means, that sodium can be kept in the LID optical trap for some hours in the atomic state.

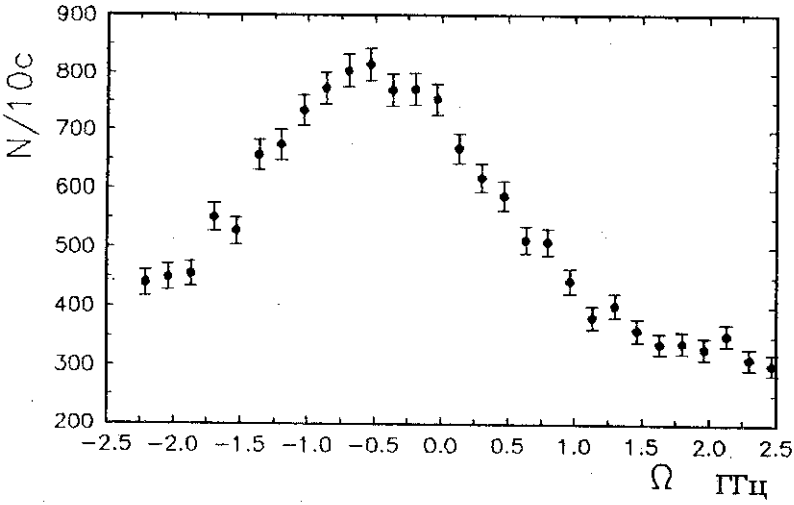

Fig. 4. Dependence of count rate on laser frequency detuning from ^{24}Na line center under laser frequency scanning from "red" to "blue" side

Let us discuss some possible application of the LID optical trap.

1. Atomic nuclei can be polarized by an interaction with the polarized laser radiation [10]. Studying nuclear radiation anisotropy and angular correlation between nuclei spin, electron and neutrino momenta, one can obtain information on the possible breaking of the standard weak interaction model (neutrino helicity, admixture of tensor interaction etc.). Now these experiments are carried out with atoms polarized in low temperature refrigerator [11].

2. LID is shown to be used for studies of an adsorption time and adsorption energy of sodium atoms on sapphire [12] and pyrex [13]. Observation of atom motion based on their radioactivity gives any advantages. First, it is possible to measure the adsorption time of drifting atoms on optical non-transparence surfaces. Secondly, it gives possibility to observe both atom and molecule forms. It is not difficult to

distinguish atom quantity reduction due to diffusion and chemical connection.

3. The LID optical trap can be used for an isotope rectification. It is possible to keep in the trap only one isotope, while other isotopes leave the trap due to the diffusion, if their spectra are sufficed different.

We would like to thank A.Anastasov, K.P.Marinova, B.N. Markov, V.Vorobel and S.G.Zemlyanoi for help in the experiments.

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Received by Publishing Department
on January 22, 1993.