объединенный
институт
ядерных
исследований
дубна

E13-92-197

Yu.P.Gangrsky, C.Hradecny, J.Slovak, T.Tethal,
I.M.Yermolayev

LIGHT INDUCED DRIFT OF ^{22,23,24}Na IN WIDE COLD TUBE

Submitted to "Physics Letters"

1992

The Light-Induced Drift (LID) predicted by F.H.Gel'mukhanov and A.M.Shalagin in 1979 [1] is being studied very actively in last several years (see ref. [2]). Using LID one can control the movement of free atoms and separate individual isotopes and isomers, if their optical spectra are sufficed different from each other [3]. Another prospective field for LID using is "on-line" measurements of optical transition frequencies of short-lived isotopes and isomers [4]. The basic scheme of the LID-spectrometer can be described as follows: recoil nuclei are neutralized in buffer gas and stopped in a volume of ~ 1 cm in size. The volume is irradiated by the cw laser radiation with the wavelength scanning in the spectral region where the presence of the resonance transition of the investigated isotope (isomer) is supposed. The LID of the investigated isotope atoms occurs when there is the laser wavelength in the Doppler outline of the transition. The investigated isotope (isomer) distribution along the laser beam is distorted. The distortion is monitoring by two nuclear radiation detectors, that are situated along the laser beam on the opposite sides of the localization volume. The LID spectrometer signal can be the counting rate difference or relation of the detectors. The method can be very sensitive and is suitable for measurement of isotope shift and hyperfine structure of some short-lived isotopes and isomers (^{24m}Na, ^{130m}Ba, ^{136m}Ba, ^{242m}Am).

The paper presents a model experiment demonstrating the abilities of such LID-spectrometer. We select sodium as an object for the experiment due to the following reasons. First, the LID of stable sodium vapor is well investigated [5]. Secondly, ^{22}Na and ^{24}Na are suitable isotopes for investigation. Their isotope shifts for D_1 line are -756.9 and 706 MHz, respectively [6]. The laser radiation wavelength tuning at the center of the ^{23}Na line produces the LID of

^{22}Na and ^{24}Na atoms in the opposite directions. Both LID velocities of the ^{22}Na and ^{24}Na atoms are near the maximum velocity that can be reached at the optimum laser wavelength tuning. As a result of that ^{22}Na and ^{24}Na enrichments are produced on the opposite collectors. The enrichment can simulate a signal value of the LID spectrometer. Causal factors, which could provide the asymmetry of the vapor movement to collectors, don't influence upon the enrichment.

We had to use the wide laser beam, in order that the main part of atoms in the localization volume interacts with the radiation. A paraffin coating is used usually in the experiments of alkaline atoms LID to eliminate the adsorption on cell walls [5]. But as recoil nuclei are stopped in buffer gas the great quantity of ions and ultraviolet radiation appear and anti-adsorption property of paraffin is deteriorated. Therefore the model experiment is carried out in a wide cold tube without coating.

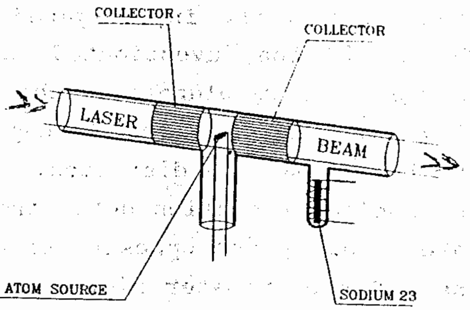

Fig. 1. *Experimental cell.*

The scheme of an experimental cell is given in Fig.1. It represents a glass tube with the inner diameter of 8 mm. A radioactive sodium vapor source is situated in the center of the tube. The source represents the graphite rod containing ^{22,24}Na. Graphite could be heated at ~ 2000°C. There are collectors on the left and on the right of the radioactive sodium source. The beam of a dye laser (Spectra Physics 380 D) with a power of 130 mW is expanded by telescope to fill the tube. We use a stable sodium to rectify a buffer gas (Kr under a pressure of ~ 10 Torr). ^{23}Na vapor penetrate into the tube from a heated appendix.

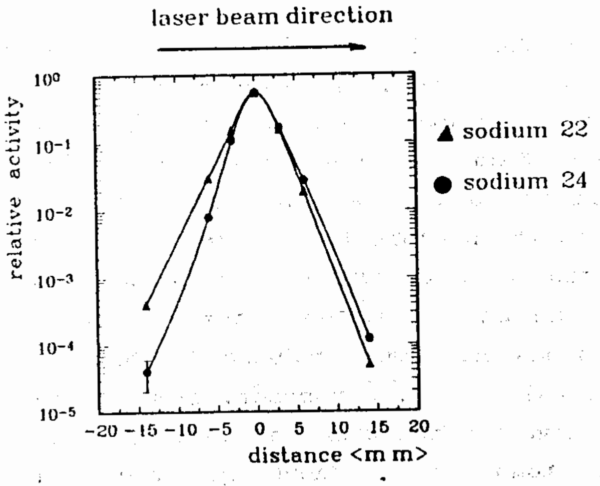

Fig. 2. *The ^{22}Na and ^{24}Na integral activities on the collectors far from the source than distance x.*

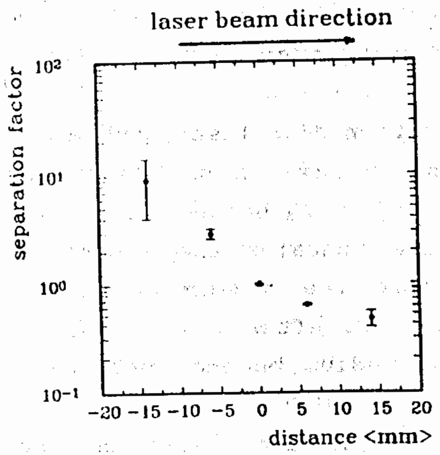

Fig. 3. *The distribution of the separation factor α on distance x from the source.*

The theoretical description of this process is connected with the solution of the bidimensional diffusion equation with the drift. We came to nothing more than estimations in this paper. Let us substitute approximately the atom adsorption on cell wall for the atom loss in volume. Then the equation becomes unidimensional, its solution is given in [9]. Let us calculate the enrichment coefficient α (supposing the drift velocity values are equal for both radioactive isotopes):

$$\alpha = \exp(x|U|/D),$$

During the process of the buffer gas rectification we observe the LID of stable sodium atoms in a wide cold tube. A sodium vapor cloud fluoresces above the appendix. When the laser frequency is detuned from the line center the sodium cloud shifts to the right or to the left depending on the detuning sign. The cloud shift is about 1 ÷ 1.5 cm. It is the first observation of sodium LID in the cold tube without special coating of its surface. Up to date the cell wall adsorption of alkaline atoms has been reduced by heating [7,8], or by coating cell wall [9,5]. Our observation is the evidence that LID can be investigated when the adsorption is so strong that adsorbed atoms can't return into the cell volume. It would enable the LID investigations with atoms of refractory metals. It should be mentioned, that in this case the appearance of LID is less impressive than in the paraffin coated cells [5,10].

After the buffer gas rectification the laser radiation wavelength is tuned at the adsorption maximum of ^{23}Na atoms and the radioactive sodium source is heated at high temperature. Unfortunately, graphite contains the essential quantity of stable sodium, therefore the medium of sodium vapor is optically dense at first time. After 10 ÷ 15 s all sodium leaves the graphite and the medium becomes optically transparent.

Then ^{22}Na and ^{24}Na activities $^{22}A(x)$ and $^{24}A(x)$ on the collectors far from the source then distance x are measured. The results are given in Fig. 2. The separation factor α is

$$\alpha(x) = \frac{^{22}A(x)}{^{24}A(x)}\left(\frac{^{22}A_s}{^{24}A_s}\right)^{-1},$$

where $^{22,24}A_s$ are ^{22,24}Na initial activities in the source, respectively. The experimental values of α are given in Fig.3. The lower enrichment on the right collectors can be explained by extinction laser beam in optical dense sodium cloud. It is caused that the LID velocity in the right part of the cell is lower. We have carried out three experiments and there has been a good reproducibility of the results.

where x is a distance from the source, U is the LID velocity, D is a diffusion coefficient of the sodium in a krypton (D = 12 cm^2/s in our conditions [5]). The estimates of the LID velocity are 22 cm/s at the left side of the source and 10 cm/s at the right one. The higher velocity value agrees very well with experimental data given in [5].

About 10% of evaporated sodium in the volume reaches the collectors far than ≈ 0.5 cm from the sodium source (see Fig. 2) and its enrichment is ≈ 2 (see Fig. 3). It corresponds with double change of the counting rate relation of the detectors in the LID spectrometer. Both the efficiency and the signal value are suitable for the short-lived isotopes spectroscopy, they are several times higher than the corresponding parameters in the LINUP experiment used for investigation of ^{240m}Am [11].

The maximum measurable enrichment (about 10 times) essentially exceeds the previous result [3], although the geometry of experiment in [3] was more suitable for isotopes separation (high laser power density, long tube). It means, that the main part of sodium is being in the atomic state during the separation.

We would like to thank A.M.Shalagin for valuable discussion and A.G.Belov, F.Kondev, S.G.Zemlyanoy and P.Zuzaan for assistance in the experiments.

References

[1] F.Kh. Gel'mukhanov, and A.M. Shalagin, Pis'ma Zh. Eksp. Teor. Fiz. **29**(1979)773, JETP Lett. **29**(1979)711.

[2] F.Kh. Gel'mukhanov, and A.M. Shalagin, World Scientific Publishing Co Ltd., Singapore (1986) 280.

[3] C. Hradecny, J. Slovak, T. Tethal, A.M. Shalagin, I.M. Yermolayev, Communication of the JINR, E18-91-549, Dubna 1991.

[4] Yu.P. Gangrsky, C. Hradecny, B.N. Markov, Hyperfine Interaction **61**(1990)1411.

[5] S.N. Atutov, I.M. Yermolayev, A.M. Shalagin, Zh. Eksp. Teor. Fiz. **92**(1987)1215.

[6] F. Touchard, J.M. Serre, S. Büttgenbach, P. Guimbal, R. Klapish, M. de Saint Simon, C. Thibault, H.T. Duong, P. Juncar, S. Liberman, J. Pinard, and J.L. Vialle, Phys. Rev. **C25**(1982)2756.

[7] V.D. Antsygin, S.N. Atutov, F.G. Gel'mukhanov, G.G. Telegin, and A.M. Shalagin, Pis'ma Zh. Eksp. Teor. Fiz. **30**(1979)262, JETP Lett. **30**(1979)243.

[8] H.G.C. Werij, J.E.M. Haverkort, and J.P. Woerdman, Phys. Rev. A **33**(1986)3270.

[9] S.N.Atutov, Phys. Lett. **119A**(1986)121.

[10] S.N. Atutov, St. Lesjak, S.P. Pod'jachev, A.M. Shalagin, Optics Comm. **60**(1986)41.

[11] C.E. Bemis, Jr., J.R. Been, J.P. Young, and S.D. Kramer, Phys. Rev. Lett. **43**(1979)1854.

Received by Publishing Department
on May 6, 1992.