To deduce the parameters of the nuclear density distributions from the measured cross sections, the Glauber multiple scattering theory was applied. Calculations were made with phenomenological one-body-density point distributions of Gaussian type to determine their root mean square radii $< r^2 >^{1/2}$ by fitting the measured cross sections.

One of the versions obtained by calculations with the Glauber multiple scattering theory is shown in Fig.2. The p^{4}He cross section is well described using a single Gaussian distribution for the density with $< r^2 >^{1/2}$ = 1.49±0.02 fm which corresponds to the nuclear charge radius determined from electron scattering [7]. For p^{6}He and p^{8}He scattering a better description of the data is obtained by using a nuclear matter distribution which is parametrized by 2 Gaussians, one describing the distribution of the core nucleons, and the other describing the distribution of the skin (halo) neutrons. For p^{6}He case the values of $< r^2 >_c^{1/2}$ = 1.95±0.10 fm for core nucleons and $< r^2 >_s^{1/2}$ = 2.88±0.27 fm for skin (or halo) neutrons thus obtained correspond to the average $< r^2 >_{av}^{1/2}$ = 2.30±0.06 fm. The values for p^{8}He scattering are: $< r^2 >_c^{1/2}$ = 1.68±0.07 fm, $< r^2 >_s^{1/2}$ = 3.04±0.09 fm, $< r^2 >_{av}^{1/2}$ = 2.46±0.04 fm. The indicated errors are statistical only. The present status of the analysis is in agreement with the existence of a neutron skin in ^{6}He and ^{8}He. The analysis of the measured cross sections using other density parametrizations and the work on estimation of the errors in extracted density parameters due to some possible systematical uncertainties are in progress. Further measurements of neutron-rich lithium and beryllium isotopes with the same experimental techniques are in preparation.

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THE PROBLEM OF NUCLEAR CHARGE RADIUS DETERMINATION FOR ^{11}Li BY LASER SPECTROSCOPY

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At present light nuclei near the neutron drip line attract much attention owing to their large neutron radii inferred from the anomalous total reaction cross sections for such nuclei as ^{11}Li,^{14}Be,^{17}B on various targets. This fact is considered as manifestation of a neutron halo. A neutron halo conception was supported by the subsequent experiments on the fragmentation and electromagnetic dissociation of ^{11}Li.

Nevertheless, there is no direct measurements of the size of this halo and the available estimations are model-dependent, though the sizes of the neutron halo and the charge radius are of crucial importance for understanding the ^{11}Li structure.

Here we propose a high-sensitivity high-resolution method for measurements of isotope shifts for Li isotopes to obtain the nuclear charge radius for ^{11}Li with the accuracy comparable with the expected accuracy of its matter radius determination.

The optical isotope shift (IS) $\delta\nu_{A,A'}$ for two isotopes with the mass numbers A and A' is the sum of the mass shift (MS) $\delta\nu^{MS}_{A,A'}$ and the field shift (FS) $\delta\nu^{FS}_{A,A'}$. The first is due to the change of a nuclear mass and the second is due to the change of a nuclear size:

$$\delta\nu^{FS}_{A,A'} = F\delta<r^2>= F(<r^2>_A - <r^2>_{A'}).$$

The difficulty of extraction of $\delta<r^2>$ for light atoms is in a too large mass shift as compared to a field shift. For Li atom $\delta\nu^{FS}_{A,A'}/\delta\nu^{MS}_{A,A'}$ $<10^{-4}$. Usually, MS is calculated in the first order of the perturbation theory. But in the case of Li, bearing the smallness of the field shift in mind, it is necessary to take into account the second order contribution.

FS for the stable Li isotopes was calculated with the electronic factor F =-2.4(1) MHz/fm^2 [1] and $\delta<r^2>_{6,7}$ =0.74(6) fm^2 [2]. After subtraction of FS from the total experimental IS [3], MS for the stable Li isotopes was obtained and transformed to MS for the radioactive ^{9,11}Li isotopes through the simple scaling relation with the known masses of the isotopes involved and taking the small second order correction [1] into account. The final result is: $\delta\nu^{MS}_{9,11}$ =8985.1(6) MHz.

The uncertainty of $\delta\nu^{MS}_{9,11}$ is composed of the theoretical uncertainty of the second order correction and electronic factor, and of the experimental errors of $\delta<r^2>$ and $\delta\nu_{6,7}$. These uncertainties may be substantially reduced in the course of future calculations and experiments.

With the statistical experimental error of $\simeq$1 MHz the total uncertainty of $\delta\nu^{FS}_{9,11}$ will not exceed 1.6 MHz, which corresponds to the uncertainty of $\simeq$0.7 fm^2 for $\delta<r^2>$. The accuracy of $<r^2>_{11}$ ($\simeq$5%) will be close to the expected accuracy of the ^{11}Li matter radius determinaion. With this accuracy one can determine to what extent $<r^2>$ of ^{11}Li differs from that of the other Li isotopes.

For Li isotope shift investigations the application of the saturation resonance ionization spectroscopy in the mass separator ion source [4] is proposed here. It is a combination of resonance ionization and Doppler-free saturation spectroscopy. Resonance ionization spectroscopy in the mass separator ion source has proved to be so sensitive as to allow one to carry out measurements at a production rate of an isotope under study down to 1-10 atoms per second. But it is unfortunately a Doppler-limited method. The involvement of the saturation spectroscopy must improve the resolution radically.

The following three step resonance ionizaton scheme will be used:

$$2S_{1/2} \overset{671nm}{\longrightarrow} 2P_{1/2} \overset{610nm}{\longrightarrow} 3D_{3/2} \overset{<810nm}{\longrightarrow} continuum.$$

The first and the second transitions can be saturated by the laser radiation with the average power of some mW. The photoionization cross section ($3D \rightarrow continuum$) near the threshold is $\sigma \simeq 10^{-17}$cm^2 . With a Cu-vapor laser with an average power of $\simeq$3 W, a light beam diameter of 1 mm and a repetition rate of 10 kHz, saturation of this transition can be achieved. The laser ion source (LIS) is a hot capillary. The atoms to be studied get into it from a target, where they are produced in nuclear reactions, and ionized in multistep excitation by laser radiation passing through the capillary. The high efficiency of LIS is due to two factors. First, the atoms restrained in the capillary cross the laser beam many times.

Second, the photoions are prevented from striking the capillary wall with their subsequent neutralization, owing to a repulsive electric field caused by thermoelectron emission near the wall.

Doppler - free saturation spectroscopy requires that laser beams for multistep ionization, after passing through the capillary, are reflected and put through it again in the opposite direction. Spectra must be measured with a narrow frequency band laser at the first-step transition. If the radiation intensity is sufficient to saturate the first-step transition, dips in the photoion yield dependence of frequency will occur corresponding to each optical line of the transition [4] (see Fig.). FWHM of such dips are the same as the bandwidth of the first-step laser radiation.

At a 30 MHz laser bandwidth photoionization efficiency in the standard laser ion source capillary (50 mm in lenth and 2 mm in diameter) amounts to about 10^{-2} when the centre of the laser radiation spectrum profile is tuned to the centre of the optical line [4]. We have estimated that with a production rate $\simeq$500 atoms ^{11}Li per second in a Ta target of the IRIS mass separator the total time expenditure will be $\simeq$1 hour so as to achieve a 1 MHz statistical accuracy in determination of an optical line position. It is quite reasonable for on-line experiments at ISOL installation.

To summarize, it seems to be quite accessible from the theoretical as well as from the experimental point of view to obtain such an important characteristic of the ^{11}Li nucleus as its charge radius with the accuracy sufficient to draw definitive conclusions on the structure of this unusual nucleus.

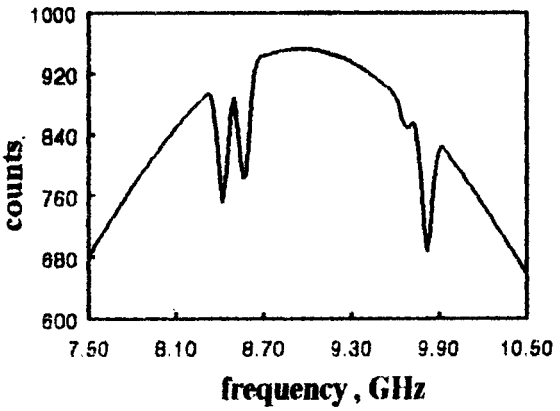

Fig. Expected saturation hfs spectrum for ^{11}Li

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