NEW HIGHLY EFFICIENT METHOD OF ATOMIC SPECTROSCOPY FOR NUCLIDES FAR FROM STABILITY

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A new method for measuring isotope shifts and hyperfine structures in optical transitions of radioactive atoms is based on application of laser resonance ionization inside the mass separator ion souce, the photoions after mass-separation being detected by their α-decay. The method has been tested by isotope shift and hyperfine structure measurements for $^{154-156}$Yb in the 555.6 *nm* transition using three-step resonance photoionization.

The experimental set-up is shown in fig.1.

The isotopes for the study were produced in a 12 *g* tantalum target (*5*) by a 1 *GeV* proton beam (*4*). The target was heated up to 2300 – 2500^{o} *K* in order to release the reaction products into an ion source (*6*) — niobium tube of 60 *mm* in lenth and 2 *mm* in diameter. Laser beams with different radiation frequencies

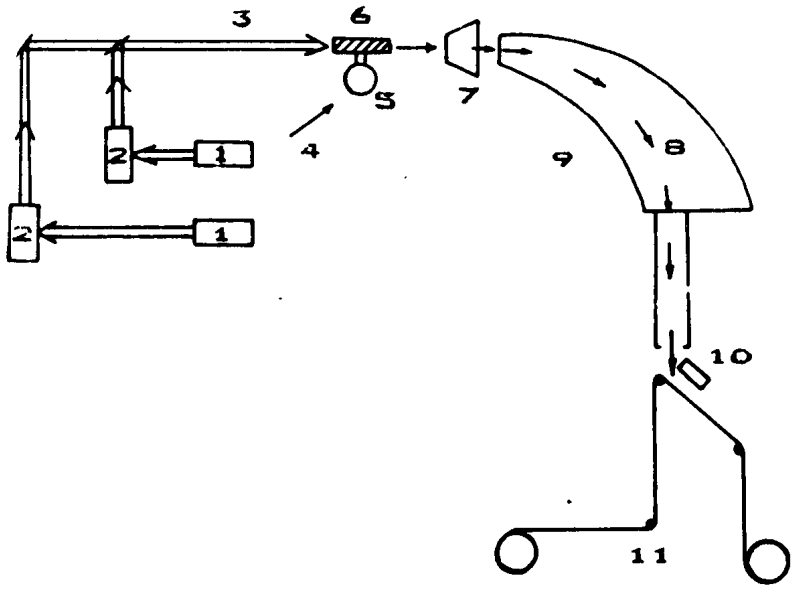

Fig.1. Experimental set-up

from two dye lasers (*2*) pumped by two copper-vapor lasers (*1*) (at 10 *kHz* repetion rate) were merged into one beam (*3*) and directed into the ion source (*6*). The photoionization scheme was such that the same dye laser with the bandwidth of 30 *GHz* was capable to excite simultaneously the second and third transitions in Yb atoms. The radiation for the first-step excitation was generated by a tunable narrow-band (1.7 *GHz*) laser. The photoins emerging from the ion source were accelerated up to 30 *keV* by the electric field between the ion source and electrode (*7*) and then passed through the mass separator (*9*). For every frequency point of the measured optical spectrum, the ion beam (*8*) from the mass separator was being implanted into a tape (*11*) during 3—5 s and the α-spectrum from the decay of the collected isotope was being detected at the same time with the Si surface-barrier detector (*10*). On completion of the cycle the collected radioactivity was driven off and the above process for a new frequency point was repeated. An example of the optical spectrum for ^{154}Yb is shown in fig.2. Besides, for the even isotopes $^{160-166}$Yb with a higher yield in the target, the isotope shifts were measured by detecting the intensity of the ion beam (*8*) with a channel electron multiplier. The isotope shifts are given in the table. Obtained is also the magnetic moment (— 0.84(8) n.m.) of ^{155}Yb from the hyperfine splitting. The main achievement of the work is a high sensitivity, which allowed to perform the measurements at as low production rate of isotopes under study as $2 \cdot 10^{-3}\ s^{-1}$. From the obtained result, it can be concluded that the measurements are possible at lesser production rate, such as 1—10 atoms per second. This high sensitivity is due to two factors — high effficiency of the laser ion source (1% in the considered case) and a low background ensured by the detectionb system. The first factor is a result of multiple passing of the atoms restrained inside the ion source through the laser beam, as well as, a result of a sudden leap (at the walls inside the source) of the electric potential arising in intensive thermoelectron emission, which prevents the photoions from neutralization on the walls. The second factor

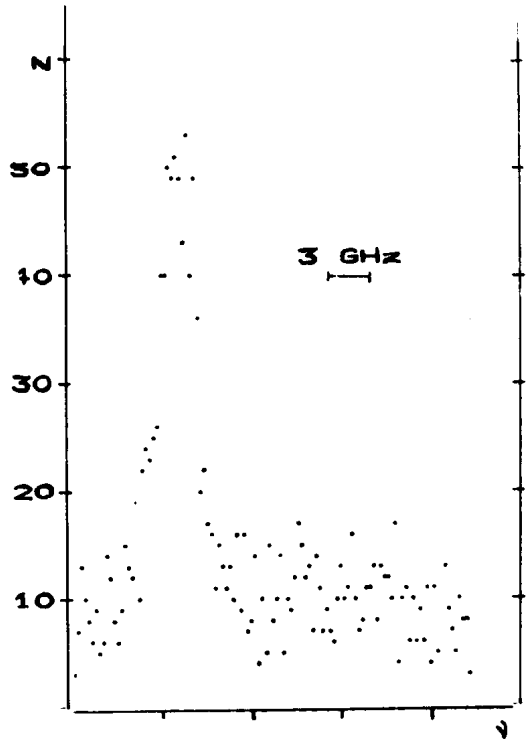

Fig.2. 555.6 *nm* transition in ^{154}Yb

allows to get rid of the ions resulting from surface ionization of isobars in the ion source in the mass separator ion beam.

This method, which underwent a good test, will be applied to corresponding studies of the long chains of α-decaying isotopes in the lead region.

Table

555.6 nm transition isotope shifts $\Delta\nu$ in Yb

A	168	166	164	162	160	156	154
$\Delta\nu$,*MHz*	0	1560(120)	3590(100)	6150(110)	8670(110)	13650(160)	16940(85)