Precision Measurement of Hyperfine Structure of 87Sr II

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I. 12. Precision Measurement of Hyperfine Structure of ^{87}Sr II

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The ion trap technique, which is applied in a variety of fundamental and applied physics, such as precision spectroscopy, mass spectroscopy and metrology [1-3], has great advantages in precision and in sensitivity to measure the hyperfine structure of the ground state of ions by means of the laser-microwave double resonance method. But it has been applied only to a few cases concerning unstable nuclei.

Combining an RF-trap and the ISOL of the Tohoku Cyclotron, we aim to study nuclear properties of nuclei far from stability by measuring the hyperfine structure of trapped ions with the laser-microwave double resonance method.

We have already reported on this experiment. [4] In ref. 4, however, the limitation of the precision came from the fact that when the external magnetic field exists, the each energy level splits into the magnetic sublevels and the observed peak of the double resonance was broadened as a result of convolution of all the sublevel transitions. Recently we have succeeded in observing each transition between sublevels separately. The reasons of this are mainly due to the decrease of the background by controlling the path of laser beam and the change of the observation procedure [5]. The experimental setup was almost the same as the previous experiment. Sr^+ were accelerated to 30 keV and mass-separated by an off-line use of the ISOL. Then the ions were transported into the ion trap through a differential pumping section and implanted onto the surface of a thin Pt foil (20 μm x 5 mm x 10 mm) located along the inner surface of the ring electrode to be re-ionized by surface ionization on the Pt foil, which is heated by a pulse-mode operation. The trap chamber was filled with H_2 buffer gas of high purity of the range of pressure between 10^{-6} - 10^{-4} mbar. A laser light of 421.6 nm inducing the $^2S_{1/2}$ - $^2P_{1/2}$ transition was produced by the second harmonics generation (SHG) system using the infrared laser light from a CW ring dye laser (SP 380A: styryl 9 operation) and a cooled non-linear crystal $KNbO_3$ located outside of the laser. The top view of these experimental setup are shown in Fig. 1. Trapped ions were irradiated by the laser light for optical pumping and by the microwave for de pumping, which was detected by resonant fluorescence of the laser light using the photon counting system.

The spectra observed by laser-microwave double resonance method show the peaks of fluorescence corresponding to the transitions between the magnetic sublevels of $^2S_{1/2}\,F = 4$ and $F' = 5$ (Fig. 2). There are twenty seven transitions between these levels allowed by the selection rule and the fact that some pairs of transitions have the same frequency should reduce the number of observed peaks to nineteen. Since most levels are influenced by the external stray magnetic field, only the frequency of the transition between the $M_F = 0$ and $M_{F'} = 0$ states, which is independent of the intensity of the external magnetic field to the first order, indicates directly the hyperfine splitting of the ground state of $^{87}Sr^+$. Hence we determine the frequency of the hyperfine splitting as;

$$\nu_0 = 5002.354\ (0.012)\ \text{MHz}$$

by the peak fit of 0-0 transition and derived the value of magnetic dipole hyperfine constant A from the equation $\nu_0 = 5A$ as A = -1000.4708(0.0024) MHz. The experimental error includes a statistical one (2 kHz) and an systematic one (~10 kHz). The present precision is considered to be sufficient for the study of hyperfine anomaly.

Now we make effort not only for higher resolution but also for higher trapping efficiency for the application of this method to radioactivity using the ISOL.

References

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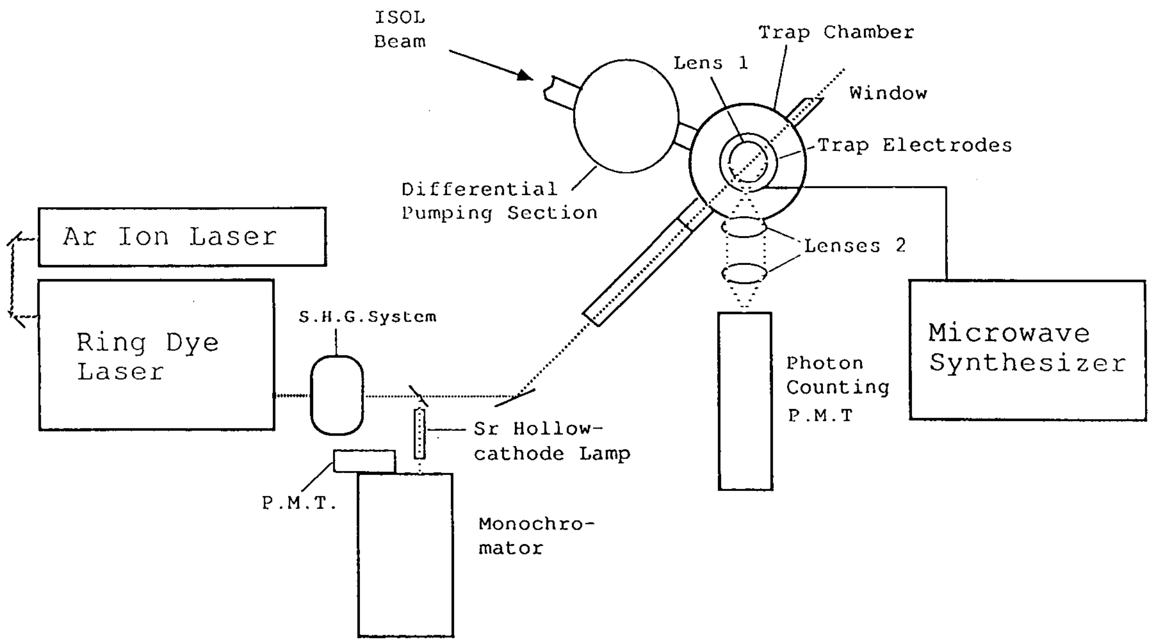

Fig. 1. Layout of the experiment. Lens 1 is inside of the trap chamber. Lens 2 and photon counting PMT are above the trap chamber.

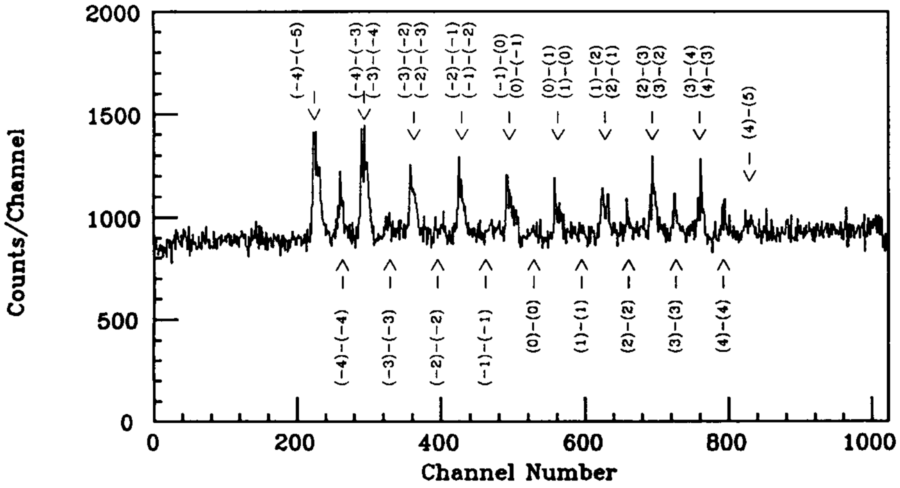

Fig. 2. Typical laser fluorescence spectrum by laser-microwave double resonance method (5 kHz/ch.; 0 ch and 1000 ch correspond to 5005 MHz and 5000 MHz of the microwave, respectively).

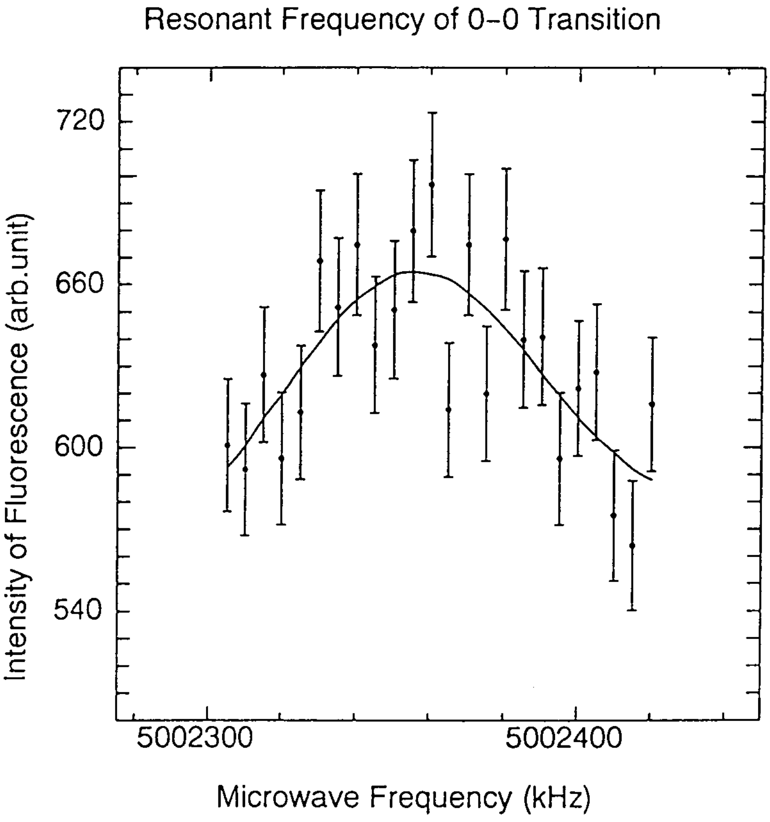

Fig. 3. Resonant frequency of the 0-0 transition. The dots are experimental data, which are of a different run from those of figure 2, and the solid line is the fitted curve. The peak frequency is ν_0 = 5002.354 (0.012) kHz.