

Measurement of the Hyperfine Constant of 87Sr^+ Stored in an Ion-trap by a Laser-Microwave Double Resonance Method

著者	Wada M., Sunaoshi H., Fukashiro Y., Hayashibe S., Shinozuka T., Fujioka M., Satoh I., Yagi M., Matsuki S.
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Wada M., Sunaoshi H., Fukashiro Y., Hayashibe S., Shinozuka T.*, Fujioka M.*, Satoh I.**, Yagi M.**, and Matsuki S.***

*Department of Physics, Faculty of Science, Tohoku University Sendai 980 Japan
Cyclotron and Radioisotope Center, Tohoku University Sendai 980 Japan*
Institute for Material Research, Tohoku University Sendai 980 Japan**
Research Center for Nuclear Physics, Osaka University Osaka 560 Japan****

Ultra high precision atomic spectroscopy is a very much attractive method for studying unstable nuclei but it has been only applied to a few nuclei, though. A series of precision measurements of the hyperfine structure allows us to study not only the nuclear magnetic moments or nuclear quadrupole moments but also the distributions of nuclear magnetisation within a nucleus.

Ion-trap technique combined with laser and microwave double-resonance spectroscopy is much useful to study hyperfine structure of the ground state of ionic atoms. Since the ions are confined in a small free space, we can get great advantages in sensitivity and precision; one ion can be observed many times until it decays, Extremely long interaction time between ions and observing microwave field is essential to get an ultra high precision, and one can easily realize a Doppler free condition by confining the ions within a region smaller diameter than the observing wavelength (Dicke's regime)¹).

We have constructed an ion-trap apparatus at the isotope separator facility of the Tohoku University cyclotron. The ion-trap was operated in RF mode for confining ions to perform laser and microwave spectroscopy. The mass-separated ion beam was introduced to the ion-trap through a differential pumping section and implanted on a surface of a thin Pt filament to be re-ionised by surface ionization. The trapped ions were irradiated by laser for optical pumping and measured by microwave in terms of double-resonance spectroscopy.

We trapped stable strontium isotopes of mass number 88 and 87, and measured the ground state hyperfine splitting of $^{87}\text{Sr}^+$. Figure 1 is a fluorescence spectrum of $^{87}\text{Sr}^+$ as a function of laser frequency. There are two peaks corresponding to the two hyperfine states of $F = 4$ and $F = 5$. Another small peak between the two peaks is due to $^{88}\text{Sr}^+$ which was intentionally implanted on purpose as a marker. Since $^{88}\text{Sr}^+$ has no hyperfine structure it can be always observed because of the absence of optical pumping. The interval between the two peaks is the splitting which we want to measure. It is obvious, however, that these peaks are

not narrow enough to determine the splitting accurately due to the effect of Doppler broadening. Hence another mechanism, so called double-resonance, is required to measure the splitting accurately.

Laser was used for optical pumping into one of the two hyperfine states of $F = 4$ and 5 and for detecting the population of the one state in the double resonance spectroscopy. The splitting was measured directly by a microwave which destroys the pumping at the resonance. The microwave resonance spectrum is shown in Fig. 2. We could determine the hyperfine splitting of the $5s\ 2S_{1/2}$ state of $^{87}\text{Sr}^+$ as

$$\nu = 5002.40 \pm 0.14\text{MHz.}$$

The present error is 36 times smaller than the previous measurement by colinear fast beam laser spectroscopy ²⁾.

References

- 1) H. Dicke R. , Phys. Rev. **89** (1953) 472.
- 2) Buchinger F. et al, Phys. Rev. C **41** (2886) 1990.

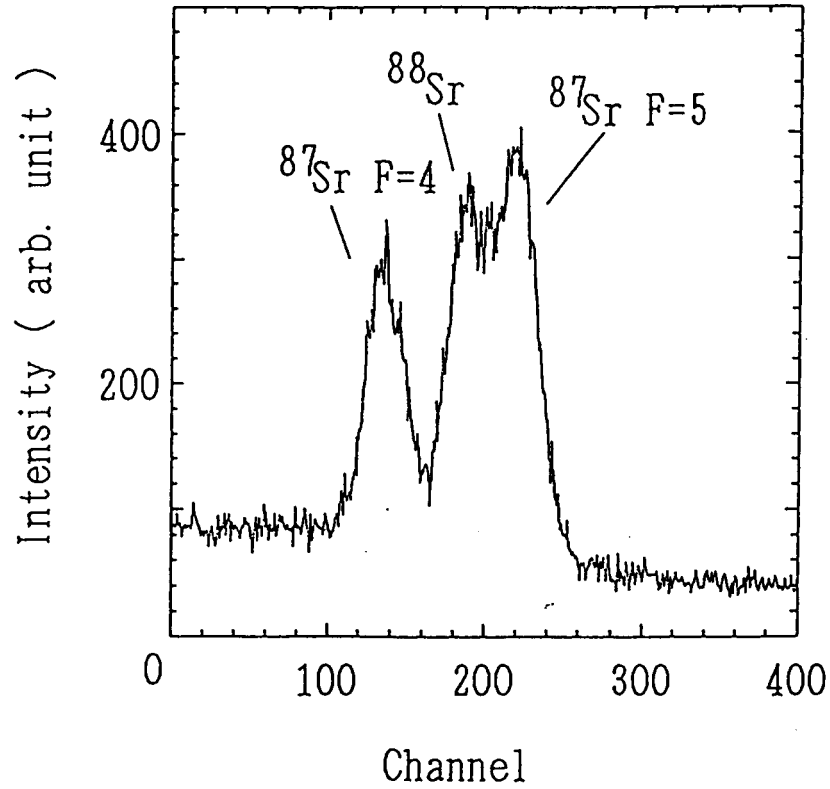


Fig.1 Fluorescence spectrum of $^{87}\text{Sr}^+$ as a function of laser frequency. The three peaks are each corresponding to $^{87}\text{Sr}^+$ F = 4 (left), $^{88}\text{Sr}^+$, $^{87}\text{Sr}^+$ (center) and F = 5 (right).

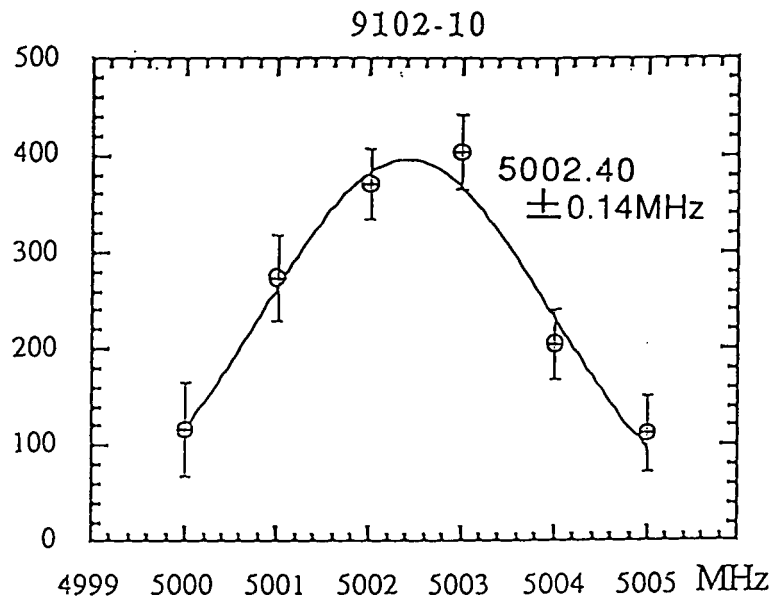


Fig.2 Microwave resonance spectrum. The broadened peak is a result of convolution of all sublevel transitions.