1–14 Selective Detection of Trace Sr Isotopes Using Lasers

—Simplified Pretreatment of Samples Containing Isobars and Stable Isotopes—

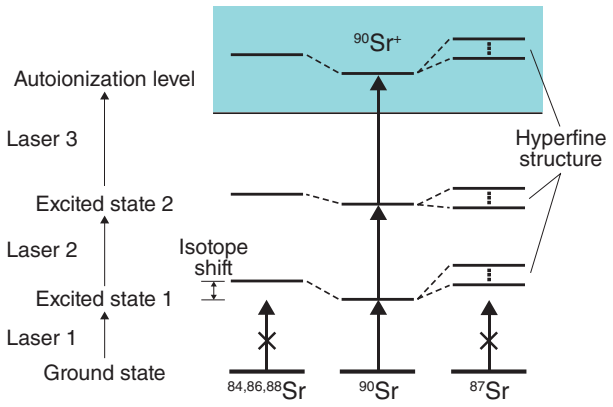

Fig.1-27 Element and isotope-selective laser resonance ionization of ^{90}Sr atoms
Owing to the presence of isotope shifts and hyperfine structures (^{87}Sr only), ^{90}Sr atoms can be isotope-selectively ionized using wavelength-tuned lasers.

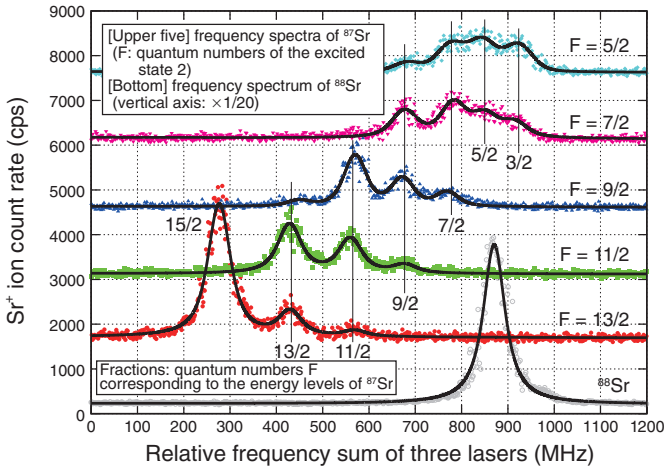

Fig.1-28 Example of the observed ^{88}Sr and ^{87}Sr frequency spectra
Laser-3 frequency is scanned to observe the spectra of ^{88}Sr and ^{87}Sr using scheme (B) 689.4 nm–472.4 nm–404.2 nm. Splitting of the energy level of ^{87}Sr due to the hyperfine structure of the autoionization level can be observed.

Table 1-2 Measured optical isotopic selectivities of ^{90}Sr with respect to stable Sr isotopes (^{84}Sr, ^{86}Sr, ^{87}Sr, and ^{88}Sr)
The measured ^{90}Sr optical isotopic selectivities with respect to stable Sr isotopes ranged from 10^3 to 10^5 for both resonance ionization schemes: (A) 689.4 nm–487.4 nm–393.8 nm and (B) 689.4 nm–472.4 nm–404.2 nm.

Scheme	^{84}Sr	^{86}Sr	^{87}Sr	^{88}Sr
(A)	4×10^5	1×10^4	2×10^5	5×10^3
(B)	6×10^5	3×10^3	2×10^5	1×10^4

Strontium 90 (^{90}Sr, half-life of 28.8 years) is one of the major radionuclides that was released into the environment during the TEPCO's Fukushima Daiichi NPS accident in 2011. Because its biochemical behavior is similar to that of calcium, ^{90}Sr tends to accumulate in the human bones, causing long-term internal exposure.

Several methods have been reported so far for determining ^{90}Sr. These methods are classified into radiation measurement and mass spectrometry. The former is the conventional method of detecting β radiation from ^{90}Y, and it requires a time-consuming process of ^{90}Y separation; therefore, it is considered unsuitable for rapid analysis. The latter is a method of detecting $^{90}Sr^+$ ions after ionization, and an example is inductively coupled plasma mass spectrometry (ICP-MS). However, ICP-MS suffers from isobaric interference caused by zirconium 90 (^{90}Zr), and mass spectral interference of ^{88}Sr in samples with high concentrations of stable Sr isotopes.

In this work, we developed a device for measuring Sr^+ ions using a quadrupole mass spectrometer, where three wavelength-tuned lasers are used for element- and isotope-selective laser resonance ionization of ^{90}Sr atoms, as shown in Fig.1-27. Isotope shifts of stable Sr isotopes (^{84}Sr, ^{86}Sr, ^{87}Sr, and ^{88}Sr) and energy-level splitting of ^{87}Sr due to the hyperfine structure were observed for each of the two ionization schemes: (A) 689.4 nm–487.4 nm–393.8 nm and (B) 689.4 nm–472.4 nm–404.2 nm, both of which are expected to have high isotopic selectivity. Fig.1-28 shows an example of the observed ^{88}Sr and ^{87}Sr frequency spectra using scheme (B) where Laser-3 (404.2 nm) frequency was scanned. The measured ^{90}Sr optical isotopic selectivities with respect to the stable Sr isotopes ranged from 10^3 to 10^5 for both schemes, as shown in Table 1-2. Compared to the existing mass spectrometry, our method is expected to greatly simplify the sample pretreatment process, especially in the analysis of soil and marine samples containing large amounts of ^{90}Zr and stable Sr isotopes, respectively.

A part of this work was supported by the JAEA Nuclear Energy S&T and Human Resource Development Project through concentrating wisdom (JPJA18B18071760), "Development of technology for rapid analysis of strontium-90 with low isotopic abundance using laser resonance ionization".

(Yoshihiro Iwata)

Reference

Iwata, Y. et al., Isotope Shift and Hyperfine Structure Measurements on Triple Resonance Excitation to the Autoionizing Rydberg State of Atomic Strontium, Journal of Quantitative Spectroscopy and Radiative Transfer, vol.275, 2021, 107882, 9p.