Isotope Selection Characteristics of MOT for the Detection of the Sr Rare Isotopes

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1. Introduction

Trace isotope analysis has become an essential tool in basic research, environmental science, archaeological dating and geology [1]. Especially, the detection of the trace radio isotope ⁹⁰Sr, which is a fission product, has been of an interest because of the nuclear industry and environmental assessment.

Recently, the neutral atom trap method has been developed for analyzing ultra trace isotopes, such as ⁸¹Kr, ⁸⁵Kr and ⁴¹Ca [1-3]. This method is not only free of contamination from different isotopes or isobar, but it is also a higher isotope selective method than any other laser based methods.

To develop the higher isotope selective analytical system to detect rare 90 Sr, MOT(magneto optical trap) has been applied as an isotope selective excitation method. In this paper, MOT has been demonstrated and the fluorescence characteristics have been investigated to have knowledge of the isotope selective process of MOT.

2. Experimental setup

The atomic structure of the strontium is shown in fig. 1. The strong 460.7 nm cycling transition $(5s^2 {}^{1}S_0 - 5s5p {}^{1}P_1)$ is used for slowing down and trapping the strontium atoms. There is a 5s4d ${}^{1}D_2$ leak (decay rate of 3.9 X 10³ s⁻¹) which strongly governs the performance of the Sr MOT. Atoms that decay from the ${}^{1}D_2$ state to the long-lived ${}^{3}P_2$ state are lost from the trap. The leakage shortens the trap lifetime of the strontium MOT.



Figure 1. Strontium level diagram showing relevant transition wavelengths.

The atomic beam was extracted in the atomizer operating at 600 °C and collimated by the two slits. Zeeman slowing technique was used to longitudinally slow down the atomic beam to the capture velocity. The

two anti-Helmholtz coils created the magnetic field gradient 50 G/cm in the trap center. The single mode laser beam was split into two parts, one was used for the slowing beam and the other for the trapping beam after being shifted +110 MHz to the blue side by an acousto optic phase modulator. The laser power of about 100 mW was applied for the trapping beam, the slowing beam and the saturated absorption spectroscopy.

The trap and the slowing beam intensity were controlled by turning on and off an acousto-optic phase modulator and an electro-mechanical shutter, respectively. The pulse delay generator provided the electric signal to synchronize the intensity control and the measurement devices.



Figure 2. Experimental setup for trapping and slowing strontium atoms.

3. Experimental Result

When the trap beam was turned on at t=0, the fluorescence intensity increased with an exponential loading constant τ . In this experiment, the exponential loading constant (the loss rate can be measured from the loading curve) was about 20 ms.

Figure 3 shows the saturated absorption signal in a heat pipe oven (a) and a laser induced fluorescence in an atomic beam (b), respectively. These methods are known as high resolution spectroscopic methods and their spectral resolutions are limited to the intrinsic natural linewidth of the transition lines. Therefore, the isotopes ⁸⁶Sr, ⁸⁷Sr and ⁸⁸Sr, in these experiments, could not be completely resolved by the two methods, because of the small isotope shifts relative to the natural linewidth.



(b)

Figure 3. Saturated absorption signal in heat oven (a); laser induced fluorescence signal in atomic beam (b). The divergence of the atomic beam is less than 10 mrad.

In the case of trapping, the optical selectivity will be increased by repeating the absorption and the emission process just for an isotope. The fluorescence spectrum of MOT is shown in fig. 4. The frequency was scanned slowly, while the trap was in a steady state. If not, the spectrum becomes asymmetric and the spectral resolution reduces.



Figure 4. Fluorescence from the trapped atoms as a function of laser frequency. The fluorescence peaks are positioned at the red side of the corresponding resonance lines. The x-axis shows the relative frequency from the ⁸⁸Sr peak.

In this spectrum, the three peaks which originated from the three isotopes are completely resolved. However, the spectrum profiles have not been analyzed so far due to the complexity of simulating the trap and the slowing. Instead of measuring the isotope selectivity, we compared the relative amount of ⁸⁷Sr and ⁸⁸Sr in the LIF experiment and the total background of the trap fluorescence at the same frequency position of -90 MHz from the ⁸⁸Sr peak.

The ratio of the relative amount of ⁸⁷Sr and ⁸⁸Sr in the LIF and the background in the trap was measured about 10. We expect that the real isotope selectivity at the ⁸⁶Sr position in MOT increase due to the sharp fluorescence profile.

4. Conclusion

Strontium MOT has been demonstrated and its fluorescence spectrum was compared to those of other spectroscopic techniques. The trap method provided a higher isotope selectivity than those of the Doppler free and limited techniques. In our experiment, the selectivity was at least ten times higher than that of the Doppler limited technique. Moreover, we expect the selectivity will be increased with a detailed investigation of the spectrum and it will be an efficient tool for an isotope selective measurement.

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