Development of Ion Trap and Laser Cooling Apparatus for $^{41}Ca^{+}$ Spectroscopy

東京大学[1] ○(D)WELLS Stephen R.[1], 長谷川 秀一[1]
Tokyo Univ.[1], ○Stephen R. Wells[1], Shuichi Hasegawa[1]
E-mail: wells@lyman.q.t.u-tokyo.ac.jp

Introduction

^{41}Ca is a cosmogenic radioisotope of calcium with long half-life (9.94×10^{4} years) and unusual decay pathway (EC to ^{41}K, X-ray/Auger electron release with $E \leq 3.3$ eV). The long half-life makes it a prime candidate for radiometric dating past the carbon-14 range, and is also a cosmologically interesting isotope as a method of investigating stellar anomalies[1]. However, its extremely low natural abundance ($\sim 10^{-14} - 10^{-15}$ relative to ^{40}Ca) has prevented active use from becoming feasible. In addition, while data on the atomic structure of ^{41}Ca I is available, the ^{41}Ca II ion is under-reported, particularly in isotope shift and hyperfine structure data. Therefore, we are motivated to investigate these properties via the Doppler-broadening minimized technique of trapped ion laser spectroscopy.

Methods and Preliminary Results

The ion trap is a linear quadrupole type trap (length, diameter = 10mm), with Ca ions produced through external liquid sample introduction into a modified (detector removed and replaced with ion guide introduction into external vacuum chamber) inductively coupled-mass spectroscopy (ICP-MS) Perkin-Elmer ELAN DRC II unit. The ions are mass-selected by the ICP-MS before being guided through a system of ion lenses to the trap region[2]. Ions are laser cooled by an all external cavity diode laser (ECDL) system, stabilized by digital fringe offset lock (DFOC) to a master ECDL itself stabilized to the Rb D2 line via sub-Doppler dichroic atomic vapour laser lock (SD-DAVLL)[3]. Spectroscopy is performed by frequency scanning one laser, holding the rest constant. An enriched sample (up to 10^{-6} ^{40}Ca relative) is used to ensure ^{41}Ca concentrations are adequate for the experiment. Experiments on ^{43}Ca trapping using similar or lower concentrations are performed as a confirmation of the system capability for ^{41}Ca.

Conclusion

The current status of an ICP-MS sample introduced ion trap system for the first trapping and spectroscopy of the trace isotope ^{41}Ca is described. Progress in trapping ^{40}Ca and the isotope ^{43}Ca as preliminary steps are demonstrated, as well as the next step requirements and current activities for laser cooling, trapping and final spectroscopy of ^{41}Ca.

References

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