A Hyperfine Measurement in Laser Trapped Radioactive ^{21}Na

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Radioactive isotopes confined in neutral atom traps will play an important role in future precision measurements of weak interactions such as the parity violating asymmetry in the β-decay of spin-polarized nuclei, electron-neutrino correlation, and parity violation in atoms. Traps provide a localized, isotopically pure sample in which source scattering is eliminated, and neutral atoms are easily manipulated by optical pumping techniques to achieve high nuclear spin polarization. With these goals in mind we have performed microwave spectroscopy on ^{21}Na atoms (22 sec. half-life) collected in a magneto-optical trap on-line at the 88" cyclotron at LBNL.

We have made a precise determination of the hyperfine splitting of the $3S_{1/2}$ ground state of ^{21}Na. This measurement, the first microwave transition observed in laser trapped radioactive atoms, took advantage of the long observation time and sensitive detection available with atoms nearly at rest in a trap. This technique can be useful in rare and short-lived alkalis for precise hyperfine spectroscopy on strings of isotopes.** We are exploring microwave spectroscopy on ^{21}Na primarily as a means of characterizing to <1% the nuclear polarization of an optically pumped group of atoms. Precise knowledge of nuclear polarization will allow the physics of interest to be extracted from beta decay measurements. For instance, the experimentally observed up/down asymmetry of the betas emitted from polarized nuclei requires a measure of polarization to extract the β-asymmetry coefficient. This coefficient is sensitive to deviations from the fundamental V-A structure of the charged current weak interaction.‡

The hyperfine splitting measurement starts with the collection of about 50,000 ^{21}Na atoms in our magneto-optical trap. Next the trap's re-pump laser is turned off. The atoms are driven into the lower ground state level (F=1). The trapping lasers and quadrupole magnetic field are then turned off, leaving only a small bias magnetic field. The cold atoms receive a 1 ms pulse of microwaves. A probe laser is then turned on and the atomic fluorescence, which indicates a transition to the upper level (F=2), is measured. Repeating these steps with different microwave frequencies maps the resonance. Using ^{23}Na as a known standard, the quadratic frequency shift away from the zero magnetic field value was calculated and applied to the ^{21}Na data. A zero field splitting between the $3S_{1/2}$ (F=1) and $3S_{1/2}$ (F=2) levels of ^{21}Na was determined to be 1906471880+/-200Hz. This value represents a one hundred fold improvement in precision over a previous measurement done with an atomic beam.††

We are currently working on moving the trapped ^{21}Na atoms to a second low background trap in which to look for the beta asymmetry from polarized nuclei. We have demonstrated roughly 40% transfer efficiency with ^{23}Na and confirmed the low background in the second trap.

Footnotes and References

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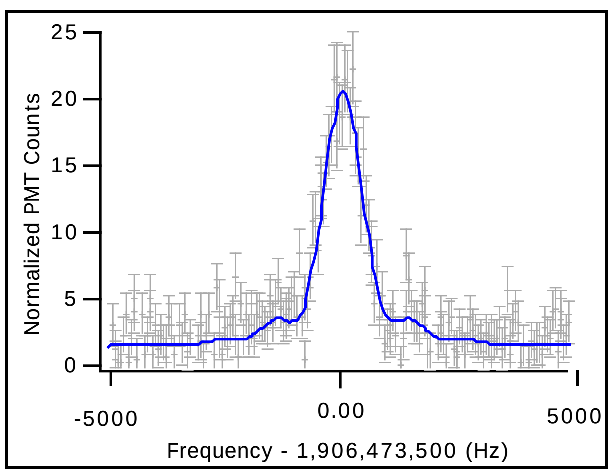

Fig. 1. Hyperfine signal in trapped ^{21}Na.