Ultra-Sensitive Detection and Progress towards Creating a Quantum Degenerate Mixed Fermi/Bose System with Radioactive Isotopes

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Progress in the efficient trapping of radioactive atoms has opened up the possibility of detecting selected radioactive species at ultra-sensitive levels using magneto-optical trapping (MOT) technology. Using a MOT coupled to a mass separator, we have recent demonstrated the trapping of ^{135}Cs ($t_{1/2}$ = 2 Myrs) and ^{137}Cs ($t_{1/2}$ = 30 yrs) for the first time. Through a set of sequential ion implantation, release, trap, and fluorescence measurements, we have determined the isotopic ratio of ^{135}Cs/^{137}Cs at the 20,000 trapped atom level from a known isotopic sample. Moreover, we have measured the isotopic discrimination factor between these radioactive species and stable ^{133}Cs to be at least 500,000/1 and through temporal fluorescence measurements further improvements in this discrimination factor can be made. Very recently we have also made several improvements in the efficiency of our release and trapping steps yielding a six times gain in sensitivity. In the near future we will transfer the trapped atoms into a second MOT where light scattering is greatly reduced so that measurements with as few as 10,000 atoms in the original sample could be measured. If successful this would represent a two order of magnitude gain in sensitivity over existing thermal ion mass spectrometry or low-level gamma counting techniques.

Developed in a synergistic fashion with a ^{82}Rb beta-asymmetry experiment and the ultra-sensitive detection work mentioned above, we are working to create and study an ultra-cold Fermi/Bose mixture of ^{84}Rb ($t_{1/2}$ = 33 d) and ^{87}Rb. Theoretical calculations indicate that the scattering lengths of ^{84}Rb/^{87}Rb are large and positive, a desirable condition to achieve Fermi degeneracy through sympathetic cooling of ^{84}Rb with evaporatively cooled ^{87}Rb atoms. As an initial step towards undertaking this experiment, we have recently demonstrated the first MOT trapping of ^{84}Rb and overlapped it with a cloud of ^{87}Rb to investigate inter-isotopic trap losses. Under suitable trapping conditions we have found a negligible increase in trap losses. This encourages us to undertake the next step in the sympathetic cooling experiment - loading these two isotopes into a time-orbiting-potential (TOP) trap. The latest progress on this experiment will be highlighted.