ON-LINE LASER SPECTROSCOPY AT THE ARGONNE SUPERCONDUCTING LINAC

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This project, a collaboration between Argonne National Laboratory, Iowa State University, and the University of Minnesota, will use on-line laser spectroscopy to study the optical hyperfine structure of radioactive atoms. The objective is to extract information on spins, moments, and the variation of charge radii for ground states and isomers. The species under investigation will be produced by heavy-ion beams from the Argonne superconducting linac. The radioactive atoms recoil from the production target, become thermalized in a helium atmosphere, and then are transported by a liquid-nitrogen-cooled helium jet to the laser interaction region. Resonance fluorescence spectroscopy will be employed to observe the optical transitions. Essentially Doppler-free linewidths will be obtained by collimating the atoms into an atomic beam as they emerge from the helium jet. Two cooled photomultiplier tubes will detect the fluorescent light.

Figure 1 shows an outline drawing of the target chamber, including the cryogenic helium jet and the laser interaction volume. The target chamber, sealed by 8 mg/cm² Ta entrance and exit windows, has space for 5 or more foil targets. It is coupled to the 0.8 mm 1.0-, 50 cm long capillary tube by a funnel-shaped section. Both the capillary and target chamber are mounted on a large copper heat sink which is kept at 78ºK by a continuous flow of liquid nitrogen.

The capillary discharges into a volume pumped by a 120 l/s Roots blower, and is positioned over a skimmer with a 0.63 mm dia. hole. Below the skimmer, the atomic beam is intersected at 90º by laser light at the common focus of a double elliptical cylinder. Since the interaction region is 2 cm long, several hundred photons will be scattered on resonance by a single atom possessing an appropriate allowed transition. Pressure in this region is kept at $3 \times 10^{-4}$ torr by a 6" diffusion pump directly below the cylinder.

To study the transport of radioactivities through the system, provision has been made for the insertion of catcher foils directly under the capillary exit and under the skimmer. In the first measurement, a beam of 59 MeV $^{12}$C ions was used to bombard a natural Ni foil of thickness 1.1 mg/cm². Based on cross sections calculated with the program "Alice", the efficiency of the helium jet transport was estimated to be $\approx 35\%$. Skimmer transmission was determined to be $2.6 \pm 0.2 \times 10^{-2}$ under the present conditions. It is hoped that this figure will be improved in future tests.

Figure 2 shows a block diagram of the laser system. These components are located in a shielded room immediately adjacent to the linac beam line. The laser beam will be conducted through a hole in the wall to the interaction chamber, a distance of about 3 meters. Currently we have a CW ring dye laser, Spectra-Physics Model 380A, which is pumped by a 5 watt Ar$^+$ laser. The laser frequency is controlled using an offset locking technique, based on a 6328 A stabilized He-Ne laser. Light from the dye laser has a frequency width of less than 5 MHz, and the centroid can be controlled to an accuracy of several hundred kHz by the stabilization system. A separate atomic beam chamber for stable isotopes provides a convenient frequency reference. To set the laser frequency approximately within ±0.5 GHz, a digital wavemeter based on a Michelson interferometer has been constructed.

Initial experiments are planned for atomic transitions in which the photon burst technique can be used. In this method, bursts of photons originating from multiple excitation of the same atom in the laser beam are recorded in separate multiplicity spectra as a function of laser.
wavelength. The resulting suppression of random background noise leads to the ability to detect resonance-fluorescence peaks with as few as 10 atoms/sec crossing the laser beam.

Barium will be the first element studied. It has an appropriate photon burst transition, and measurements of the isotope shift exist for many short-lived isotopes, thus providing a convenient testing ground for the techniques and apparatus.

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DISCUSSION

D.E. Maassik: The photon-burst method, though sensitive, may have several potential problems - branching to metastable states, sensitivity to optical pumping to inaccessible levels and ineffectiveness for low oscillator strengths, for example. I believe that it will only be useful for a few atomic species. How are the recoil atoms neutralized? And what is the velocity profile of the final atomic beam?

C.N. Davida: The photon-burst technique is not universally applicable to all atoms. The requirements are a recyclable transition with a lifetime in the tens of nanoseconds. Where the atomic spin J of the ground state is 0, no optical pumping limitations are present if a depolariser is used. This depolarization can be done either spatially or temporally, at rates comparable to the optical pumping rate. Optical pumping problems are not present if the total spin F of the lower level is less than that for the upper level of the transition. In cases where the ground state atomic spin J is >0, techniques like RF double resonance can be brought to bear to eliminate optical pumping problems. All the atoms may not be neutral. We are counting on the large number of collisions in the capillary and the free electrons in the target chamber due to the bombardment to maximize the neutral atom fraction. The atomic beam exists from the capillary at the local speed of sound.

W.-D. Schmid-Ott: Have you thought about using a laval-nozzle at the exit of your capillary in order to obtain a focused jet and to increase the Skimmer efficiency?

C.N. Davida: Yes, we have prepared these nozzles and will be trying them in our next beamtime.