The low-energy properties of atomic nuclei are predicted to show dramatic changes when the ratio of neutrons-to-protons in the nucleus becomes extremely unbalanced. My research group is working to deduce the electromagnetic properties of nuclei which have extreme neutron-to-proton ratios. The desired nuclei, which exist for only fractions of a second, are produced in very small quantities using intermediate-energy reactions at the National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University.

Two electromagnetic properties of interest are the nuclear magnetic dipole moment and nuclear electric quadrupole moment. The dipole moment is sensitive to the orbital component of the angular momentum of any unpaired protons and/or neutrons in the nucleus. The dipole moment provides information on the nuclear quantum structure and the occupied single-particle states. The quadrupole moment is a measure of the deviation of the average charge distribution of the nucleus away from spherical symmetry. The shape of the collection of protons and neutrons in the nucleus, e.g. the nuclear collectivity or “deformation”, can be inferred from the quadrupole moment.

One way to deduce the electromagnetic moments of nuclei is via Collinear Laser Spectroscopy (CLS). The CLS method involves the co-propagation of a low-energy beam (~60 keV) of atoms/ions with laser light. Fixed-frequency laser light is Doppler tuned into resonance by varying the energy of the beam, with the subsequent fluorescence detected by a photomultiplier tube. The resulting hyperfine spectrum, a product of the interaction of atomic electrons with the nucleus, is analyzed to extract the nuclear magnetic dipole and electric quadrupole moments.

We have installed and commissioned a CLS beam line in the low-energy experimental area at NSCL as part of the Beam Cooling and Laser Spectroscopy (BECOLA) facility. The BECOLA facility also includes a cooler and buncher, which accepts the rare isotope beams from the NSCL beam thermalization area and converts them into a low-emittance, pulsed beam to improve the sensitivity of the CLS measurement. Stable beams of Ca, K, Fe, and Mn have been produced from off-line ion sources, and the hyperfine spectra have been collected and analyzed.

A hyperfine spectrum was measured for the short-lived radioisotope $^{37}$K ($T_{1/2}=1.2 \text{ s}$), which was delivered to BECOLA at a rate of order $10^3$ per second. The shift in the center of gravity of the hyperfine spectra for the K isotopes presented in the accompanying figure relates directly to a systematic change in nuclear size. On-line CLS measurements on neutron-deficient K and Fe isotopes are planned for the near term.

**Hyperfine spectra for $^{37}$K – $^{41}$K measured via CLS at the BECOLA Facility**