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MIRACLS: A Multi Ion Reflection Apparatus for Collinear Laser Spectroscopy

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Laser spectroscopy is a well-established technique for studying nuclear ground-state properties in a model-independent way. By observing the isotope shifts and hyperfine structures of the atoms' spectral lines, the technique provides access to the charge radii and electromagnetic moments of the nuclear ground- and isomeric states [1, 2]. While in-source laser spectroscopy in a hot cavity is a very sensitive method that is able to measure rare isotopes with production rates below one particle per second at ISOL facilities [3], the spectral resolution of this method is limited by Doppler broadening to ~5 GHz. Collinear laser spectroscopy (CLS) on the other hand, provides an excellent spectral resolution of ~10 MHz [1] which is of the order of the natural line widths of allowed optical dipole transitions. However, CLS requires yields of more than 100 or even 10,000 ions/s depending on the specific case and spectroscopic transition [4].

The MIRACLS project at CERN aims to develop a laser spectroscopy technique that combines both the high spectral resolution of conventional fluorescence CLS with an enhanced sensitivity factor of 20-600 depending on the mass and lifetime of the studied nuclide. The sensitivity increase is derived from an extended observation time provided by trapping ion bunches in a Multi-Reflection Time-of-Flight device where they can be probed several thousand times [5]. A proof-of-principle apparatus, operating at 2 keV beam energy, has been assembled at CERN ISOLDE with the goal of demonstrating the MIRACLS concept, benchmark simulations [6] that will be employed to design a future device operating at 30 keV and further technological developments.

Recently, first measurements have been performed with the proof-of-principle apparatus using stable magnesium isotopes as a first test case. Laser spectroscopy has been performed on 24,26Mg+ ions trapped for more than 5000 revolutions in the MR-ToF. Line widths close to the Doppler limit in this 2-keV machine have been achieved. Furthermore, a.o. collinear-anticollinear spectroscopy has been performed on 40Ca+ ions. Extensive characterizing study of the device is ongoing.
This talk will introduce the MIRACLS concept, present the first results and current status of the project as well as an outlook towards further developments.

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