Resonance ionization spectroscopy of Nb utilizing a narrowband injection-locked Titanium:Sapphire laser

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Hyperfine structures and isotope shifts in electronic transitions contain readily available model-free information on the single-particle and bulk properties of exotic nuclei, namely the nuclear spin, magnetic dipole and electric quadrupole moments as well as changes in root-mean-square charge radii.[1)]

Recently, the implementation of resonance ionization spectroscopy (RIS) in a low-temperature supersonic gas jet[2)] utilizing a narrowband first step excitation has gained considerable interest.[3)] An optimal solution to combine high pulse powers required for efficient ionization with a narrow bandwidth is the pulsed amplification of a narrow-band continuous wave (CW) laser. While for high-gain dye lasers a single pass amplification is sufficient, the lower gain Titanium:Sapphire gain medium requires a different approach. In a regenerative amplifier, the cavity length is locked to a multiple of the seed wavelength allowing Titanium:Sapphire -based lasers to reach a final output power of several kW (during the pulse) from the few mW of CW input.

In this work, we present a pulsed injection-locked Titanium:Sapphire laser for the PALIS laser laboratory[4)] based on a design presented in Ref. 5). Numerous advancements over the previous iterations have been included into the design to improve stability and usability. These include design choices such as mounting the cavity mirrors directly on the baseplate and positioning the laser feet to minimize the vibration sensitivity. Furthermore, the laser was designed to accept the seed laser via a fiber input thus improving reproducibility when, for example, modifying the Master laser setup.

The laser cavity was designed for flexibility. It can be reconfigured to two different round-trip lengths and crystal locations in order to operate the laser with different pulse width and gain modes. The longer cavity round-trip configuration allows us to extend the tuning range using birefringent plates and has a intracavity second harmonic generation option. The latter option can lead to increased second harmonic power and, more importantly, to high-quality beams required by the long laser transport path at PALIS.

The laser has been shown to perform as designed with a tuning range across the whole Master laser range, with a 30% slope efficiency. Importantly, the laser was applied to hyperfine spectroscopy of ^{93}Nb (See Fig. 1). These measurements yielded a total FWHM of $\sim$ 400 MHz and hyperfine A coefficient of 1866 ± 8 MHz for the ground state and 1536 ± 7 MHz for the first excited state in a good agreement with the literature values.[6)] Possible future goals for niobium include the determination of the efficiency of the newly developed ionization scheme and its application for RIS of radioactive niobium isotopes, as well as studying the possibility to separate the $^{93\mathrm{m}}$Nb isomer from the ground state for the application in integrated fast neutron dosimetry.[7)] In conclusions, the injection-locked Titanium:Sapphire laser system has been demonstrated to be ready for high-resolution in-gas-jet spectroscopy at the PALIS facility in the near future.

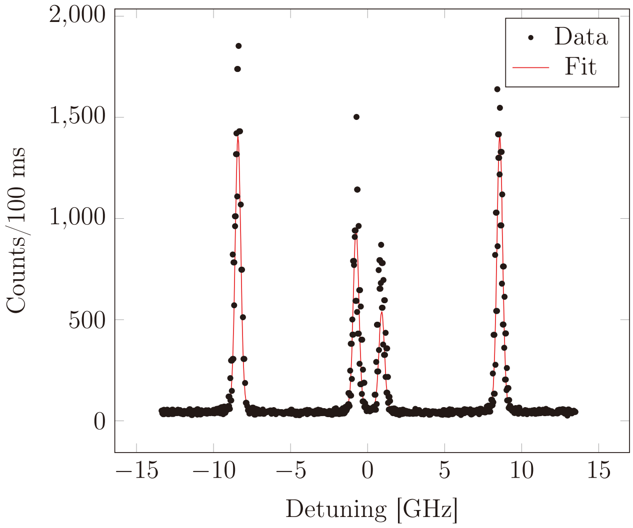

Fig. 1. An example hyperfine spectra for transition $4d^4 5s\ a\ ^6D^0_{1/2} \rightarrow 4d^3 5s5p\ y\ ^6D_{1/2}$ in ^{93}Nb.

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