An injection-locked Titanium:Sapphire laser for high-resolution in-jet resonance ionization spectroscopy at PALIS

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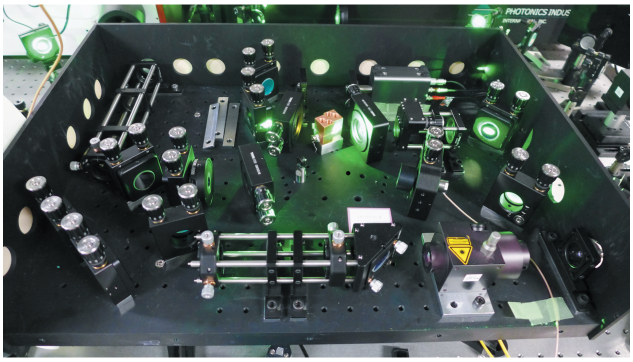

Fig. 1. Injection-locked laser in operation

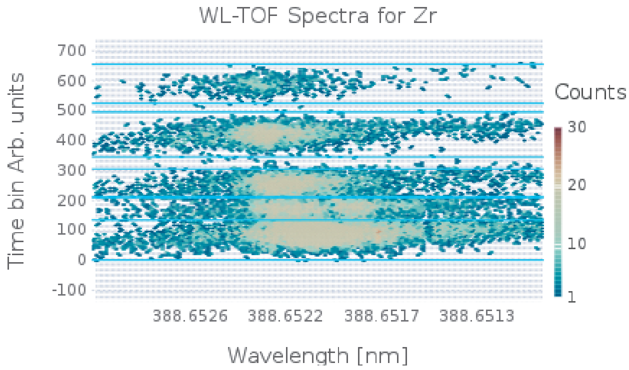

Fig. 2. Wavelength vs. time-of-flight spectra for stable Zr.

The PArasitic Laser Ion-Source (PALIS)[1)] of the SLOWRI -facility[2)] at RIKEN Nishina Center is a gas-cell -based device intended for producing pure, low-energy beams of exotic nuclei. The device primarily operates by first stopping and neutralizing the discarded fraction of the isotopes produced in projectile fragmentation and in-flight fission reactions, followed by selective re-ionization by lasers and subsequent mass separation.

The present PALIS laser system consists of broadband, high-power dye lasers and of a Titanium:Sapphire laser operating at a 10 kHz repetition rate. The combination of dye and solid-state lasers coupled with harmonic generation capability provides high-pulse power and a broad wavelength coverage from the near-infrared to deep UV regions thus enabling access to a wide selection of ionization schemes. The wide $\geq$1.5 GHz bandwidth of these lasers is optimal for efficient in-gas-cell resonance ionization where the atomic transitions are broadened owing to the high buffer gas pressure (up to 1000 mbar).

The broad overall linewidth in the case of the in-gas-cell resonance laser ionization masks the small perturbations the nucleus exerts on the atomic energy levels. The inability to resolve features such as hyperfine structure and isotope shift limits the applicability of in-gas-cell resonance ionization spectroscopy (RIS).

However, upon exiting the gas cell, the buffer gas expands to a supersonic jet where the temperature and pressure, and thus the primary line broadening mechanisms, are greatly suppressed[3)]. In order to take advantage of this environment and to provide a high-resolution RIS capability for the PALIS -facility, a program to develop a narrowband Titanium:Sapphire laser has been initiated. The ring cavity based slave resonator is an evolution of the design from the University of Mainz[4)] and from the University of Jyväskylä[5)]. The laser produces a narrowband output by utilizing the so-called injection-locking that enables bandwidth down to $\sim$20 MHz, while preserving the high pulse power required to efficiently drive atomic transitions. The laser, presented in Fig. 1, has been designed and constructed in collaboration with the University of Nagoya, where it has also been commissioned via resonance ionization of zirconium using a transition at 388.65 nm combined with an non-resonant ionization step (see Fig. 2). Initial results indicate a total resolution of $\leq$500 MHz, sufficient to partially resolve the hyperfine structure in ^{91}Zr and isotope shift $\delta\nu^{90,A}$.

The near future plan is to study the laser properties in detail in order to determine the fundamental bandwidth and stability, and to expand the laser wavelength range to 732 nm and 980 nm regions in order to gain access to elements such as copper and silver. Following this, the initial off-line in-jet RIS of stable copper isotopes will be performed at PALIS in order to verify the lasers feasibility for nuclear laser spectroscopy.

References
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