Precision Spectroscopy of Atomic and Molecular Negative Ions at the Frankfurt Low Energy Storage-Ring FLSR

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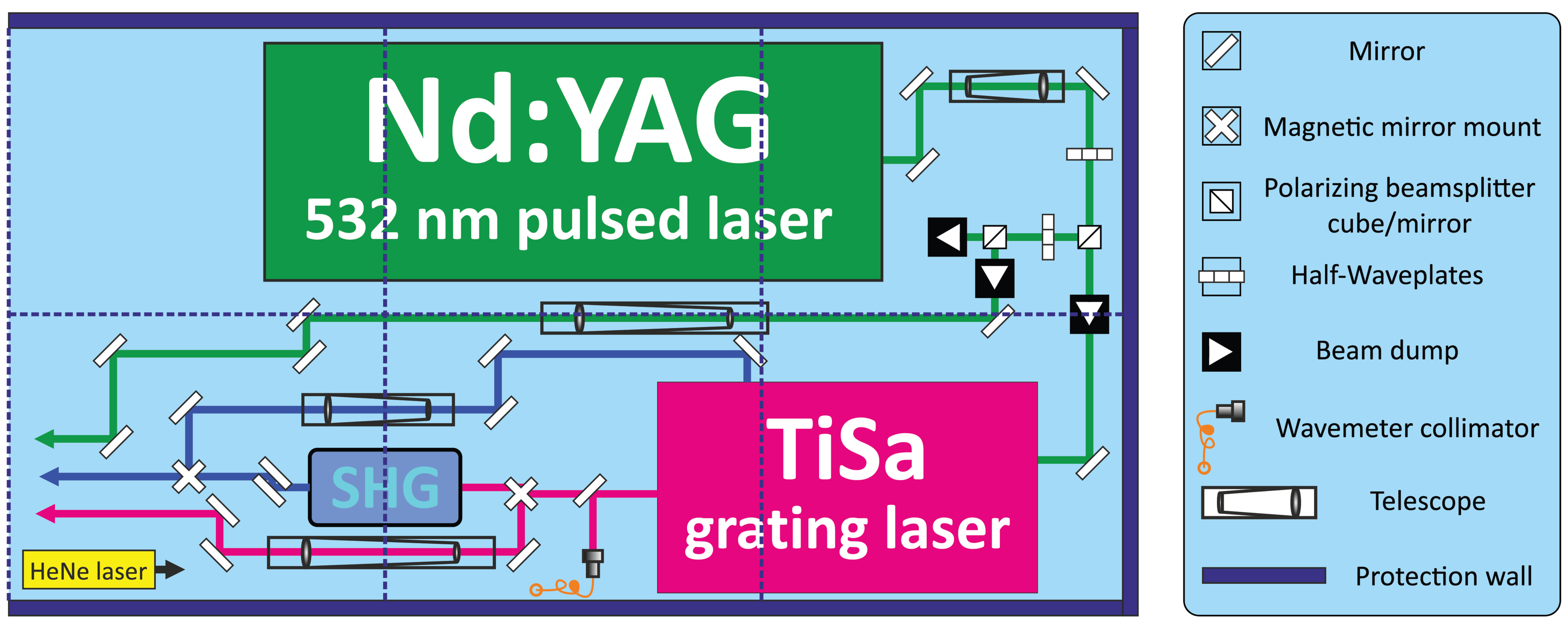
INTRODUCTION

Negative ions are complex quantum systems in which an additional electron is bound by a weak van der Waals force resulting from polarization of the electron shell. Due to the lack of long ranged Coulomb force the resulting binding energies (electron affinity, EA) are small (~ 1 eV) and exhibit rarely any excited states. Further there are almost no states with opposite parity and therefore lack of optically allowed transitions. The currently most precise measurement of the EA is by laser photodetachment threshold spectroscopy (LPT). The aim of our study is to perform precision spectroscopy on vibrationally cooled molecules in an electrostatic storage ring by letting the stored negative ions interact with a tunable laser beam and scanning the photon wavelength around the photodetachment threshold.

Laser Setup

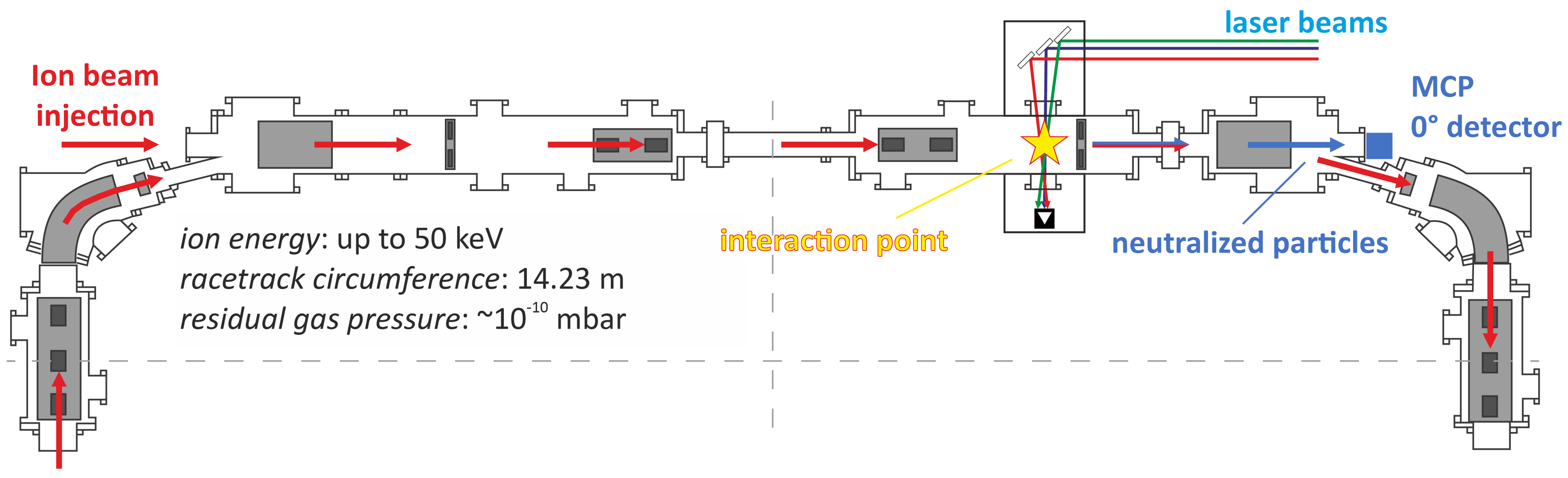
The laser system has been developed at the University of Mainz. It consists of a tunable solid-state Ti:Sapphire laser pumped by a frequency-doubled Nd:YAG laser (40 W @ 5 kHz). This allows to produce laser radiation at the wavelength range 690 - 960 nm with up to 3 W output power. Via second harmonic generation (SHG) the wavelength range of the Ti:Sapphire laser can be expanded. The system is highly reliable and requires almost no maintenance during operation.

- **Pump laser:** ORC-1000, Nd:YAG, 500 nm, ~500 ns pulse, 40 W @ 5 kHz
- **Tunable laser:** Mainz design Ti:Sapphire, fund.: 690-960 nm, ~40-50 ns pulse, up to 3 W output power, SHG up to 1.5 W @ 340-480 nm.

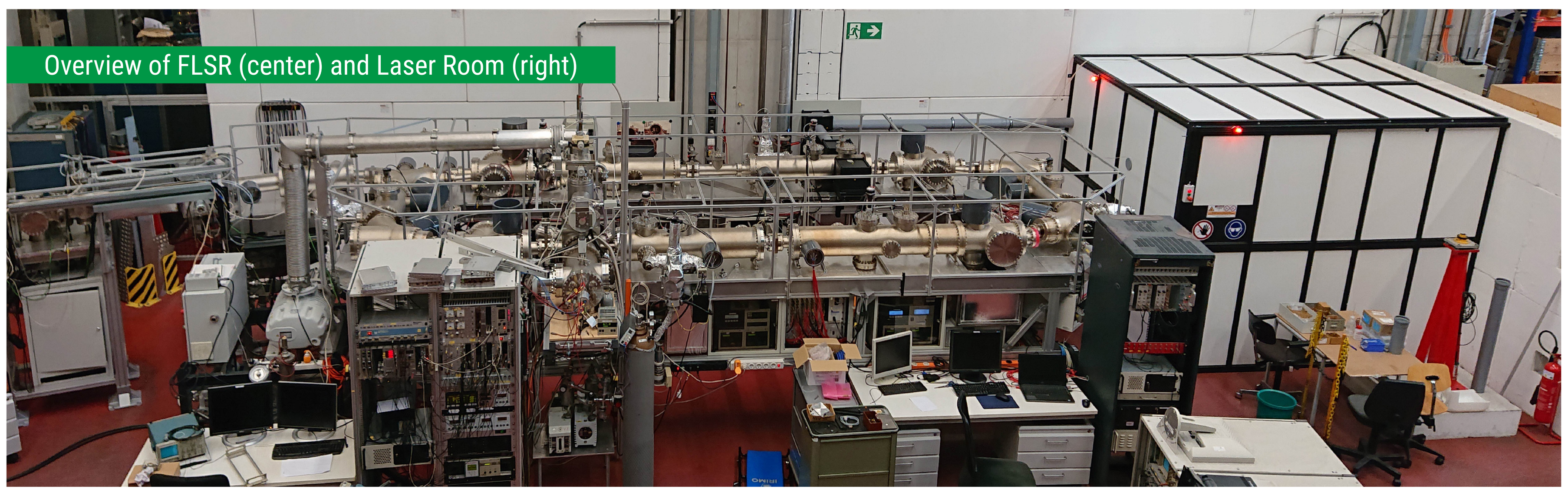


*F*rankfurt *L*ow-Energy *S*torage *R*ing FLSR

The Frankfurt low energy Storage Ring FLSR [1] is a purely electrostatic storage ring operating at room temperature. It is installed at the Institut für Kernphysik of the Goethe University, Frankfurt am Main, Germany. It has been designed as a novel tool for experiments of the reaction dynamics of vibrational cool molecular ions. It is capable of storing ions with a maximum energy of 50 keV. It is designed in a racetrack geometry with 14.23 m circumference. To perform studies on negative ions a rf charge-exchange ion source has been installed. After reversing all polarities successful storage of He^-, O^- and OH^- at 20 keV could be achieved.

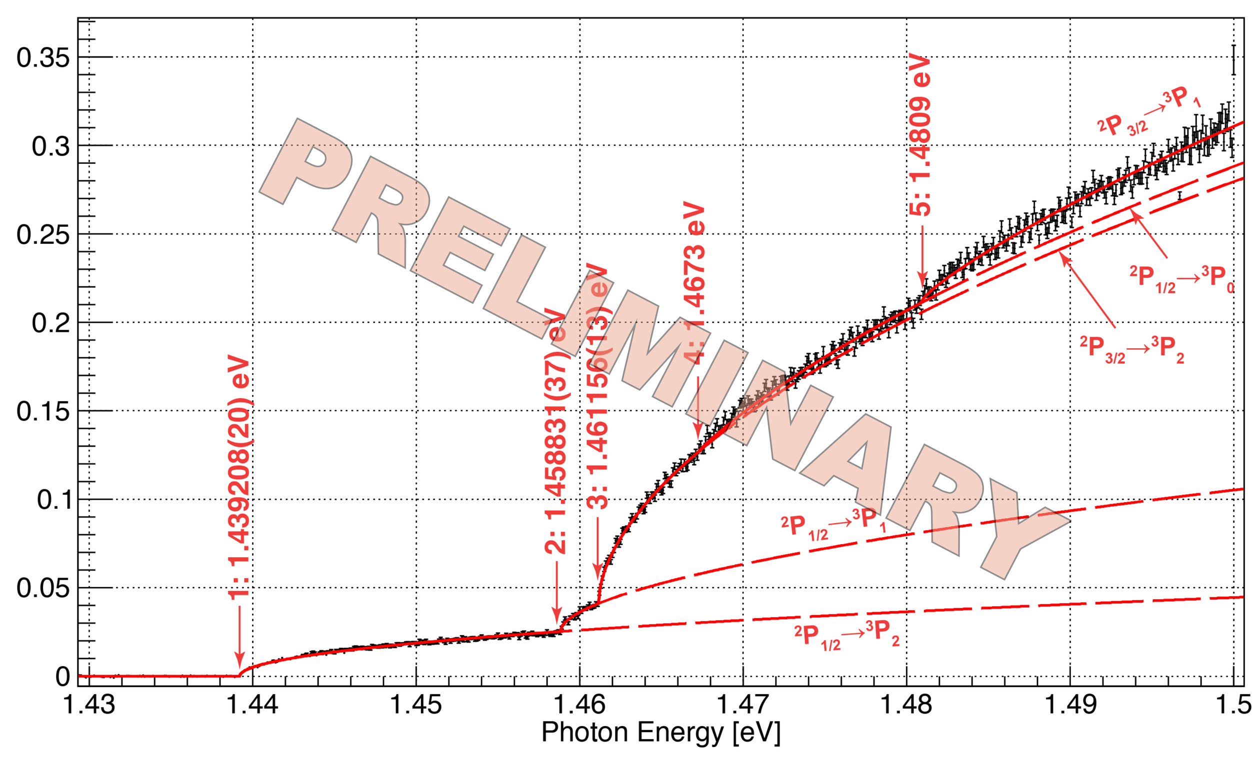


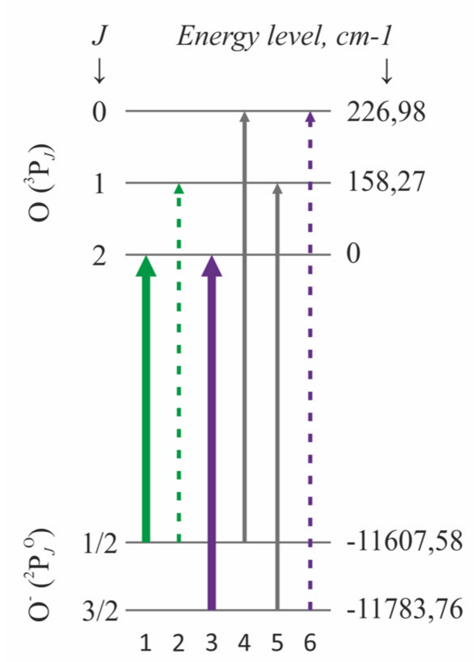
Optical grade vacuum windows have been installed at an interaction point of FLSR. The laser beam interacts transversally in this region of high ion density. The neutralized particles are detected downstream on a position sensitive detector.



First Photodetachment Measurements on O^-

In 2022 first series of laser photodetachment threshold spectroscopy at FLSR was performed, testing the technology on negative oxygen ions. The wavelength was tuned around the photodetachment threshold and the neutralized particles were detected on the position sensitive MCP. The fine structure splitting of the levels is clearly observable.





References

[1] K.E. Stiebing, V. Alexandrov, R. Dörner et al., FLSR –The Frankfurt low energy storage ring, Nucl. Instr. and Meth. A614, 10 (2010).

[2] O. Forstner et al., Opportunities for negative ions studies at the Frankfurt Low-energy Storage Ring (FLSR), Hyp. Int. 241, 53 (2020)

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