Application of High Repetition Rate Solid State Lasers at IGISOL Facilities

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Motivation

At the Leuven Isotope Separator On-Line (LISOL) in Louvain-La-Neuve the **Ion Guide Isotope Separator On-Line** (IGISOL) technique is combined with **resonant laser ionization** inside a shadow gas cell. This technique allows for investigations on **short-lived radionuclides far off stability** produced by nuclear reactions. A medium repetition rate dye laser system, which ensures high extraction efficiency for the radionuclides is presently used.

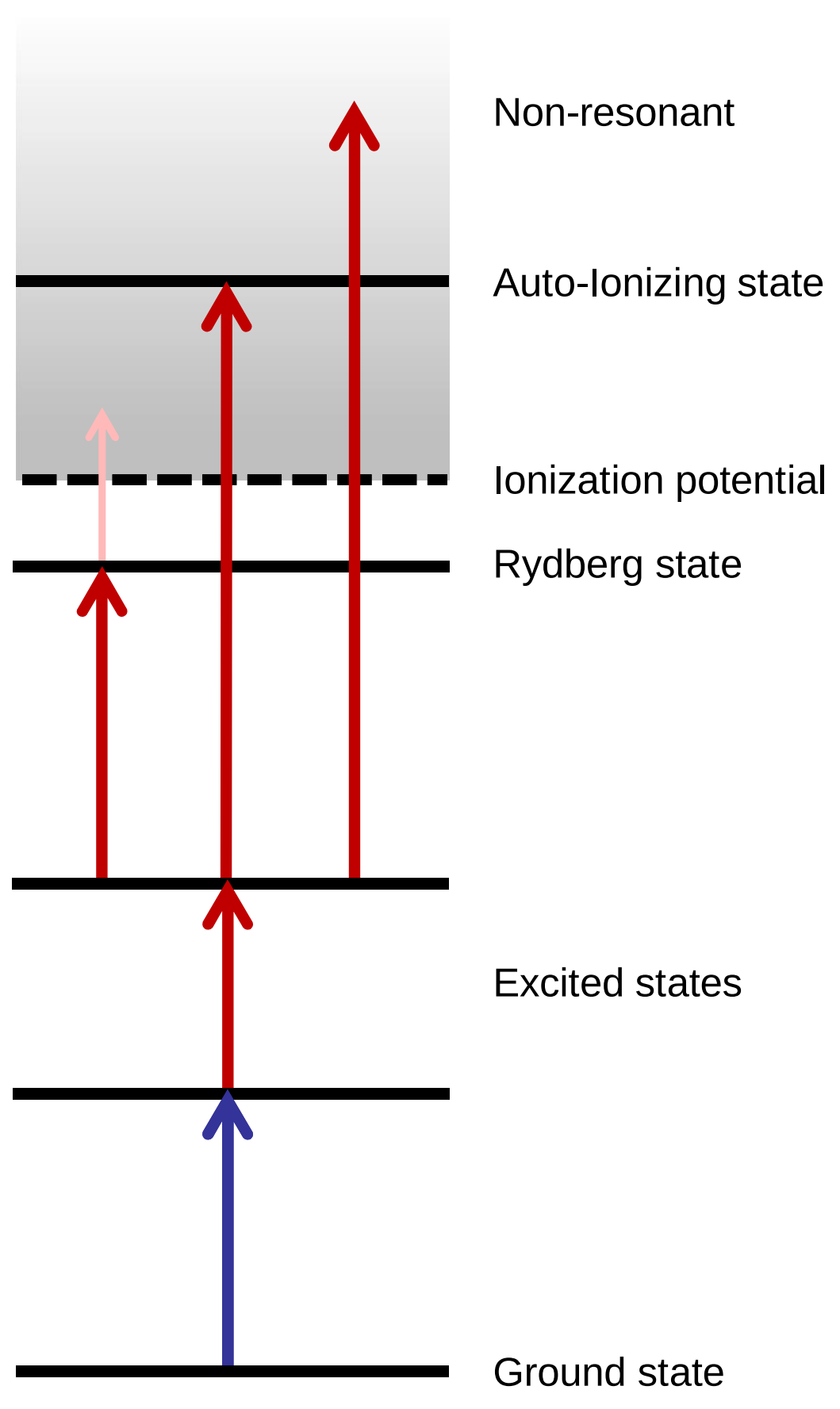
Nevertheless, future applications request higher specifications in respect to isobaric selectivity and efficiency of the ionization process, which could possibly be met by the use of **high repetition rate laser systems**, like modern titanium-sapphire (Ti:sa) laser systems. First studies were carried out in April 2011, which provided new information on the ongoing processes in- and outside the gas cell. The **direct comparison** of laser operation with **different repetition rates** at gas cells also tested the possible gain in ionization efficiency and selectivity within the sextupole ion guide (SPIG) and serves as **preparation** for the developments at other gas cell facilities (e.g. JYFL, S³ @ SPIRAL2, PALIS).

Resonance Ionization Spectroscopy

Using the unique set of states of each element, resonance ionization via multi-step (typically 1 to 3 steps) resonant excitation is the ionization technique with the highest achievable **element selectivity**.

Proper laser wavelength tuning to strong optical resonance transitions ensures **high ionization rates**. The strength of the individual transitions and finally the ionization mechanism chosen determine the ionization efficiency. Ionization through auto-ionizing states or high-lying Rydberg-states near the ionization potential are two to three orders of magnitude more efficient than simple non-resonant ionization.

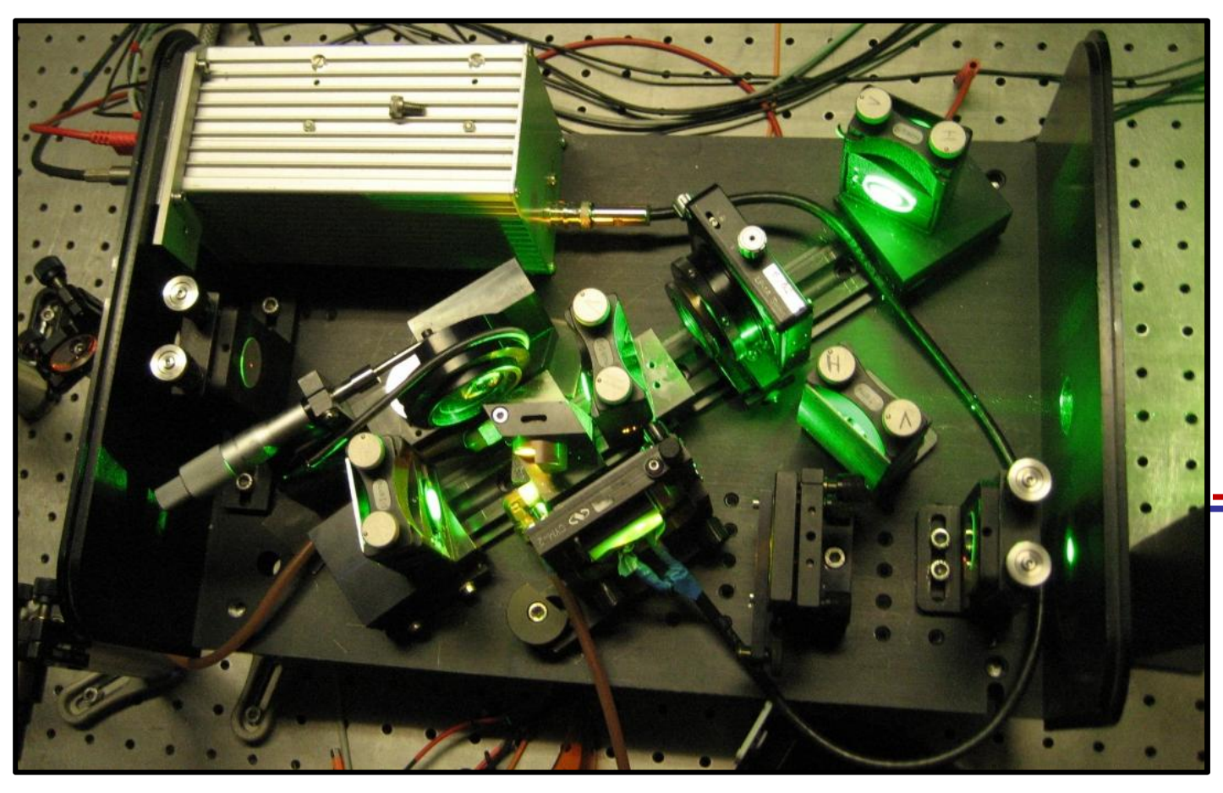
The combination of this element selective method and conventional mass separation accomplish **high isotopic and isobaric selectivity** as well as ionization efficiency.



Experimental Setup

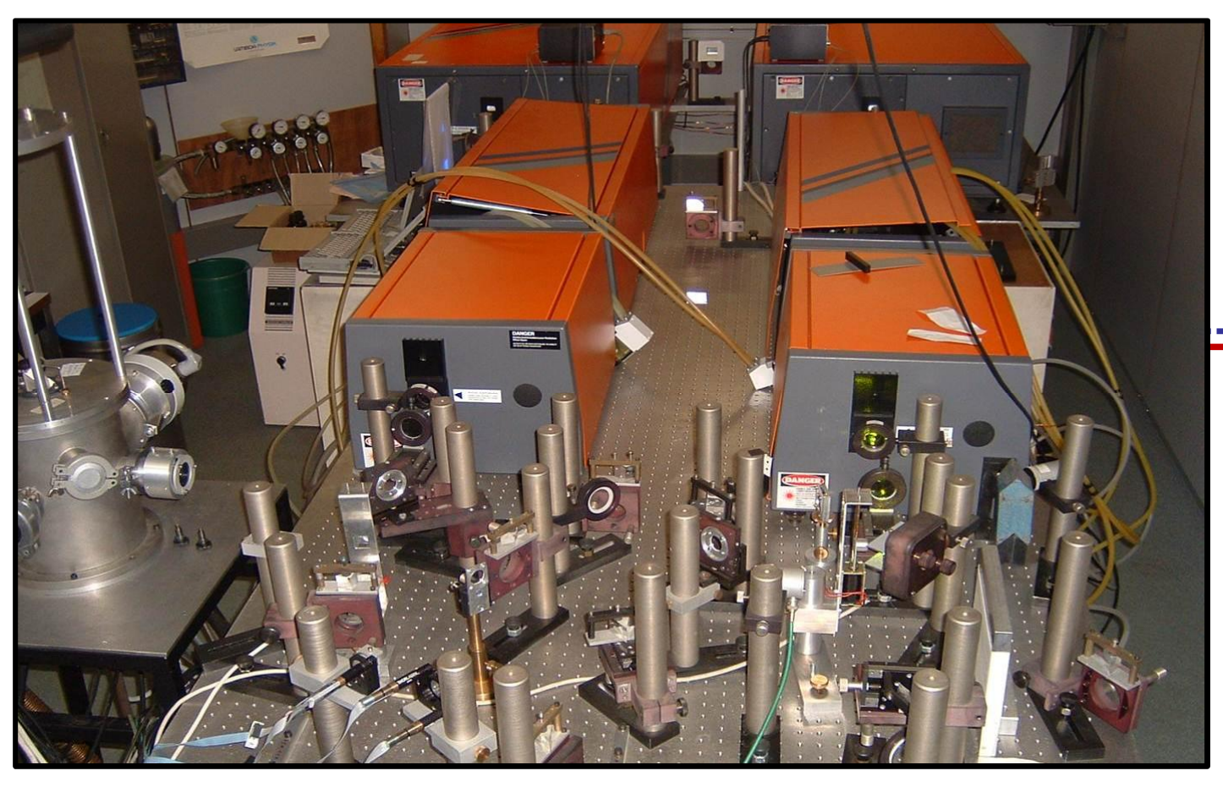
Ti:sa laser system (JGU)

Pump laser:	Nd:YAG
Repetition rate:	1 Hz – 10kHz
Typical pulse energy*:	300 µJ
Wavelength*:	690 – 960 nm
Used schemes:	up to 3 steps



Dye laser system (KUL)

Pump laser:	Excimer
Repetition rate:	1 Hz – 200 Hz
Typical pulse energy*:	3 mJ
Wavelength*:	330 – 985 nm
Used schemes:	2 steps



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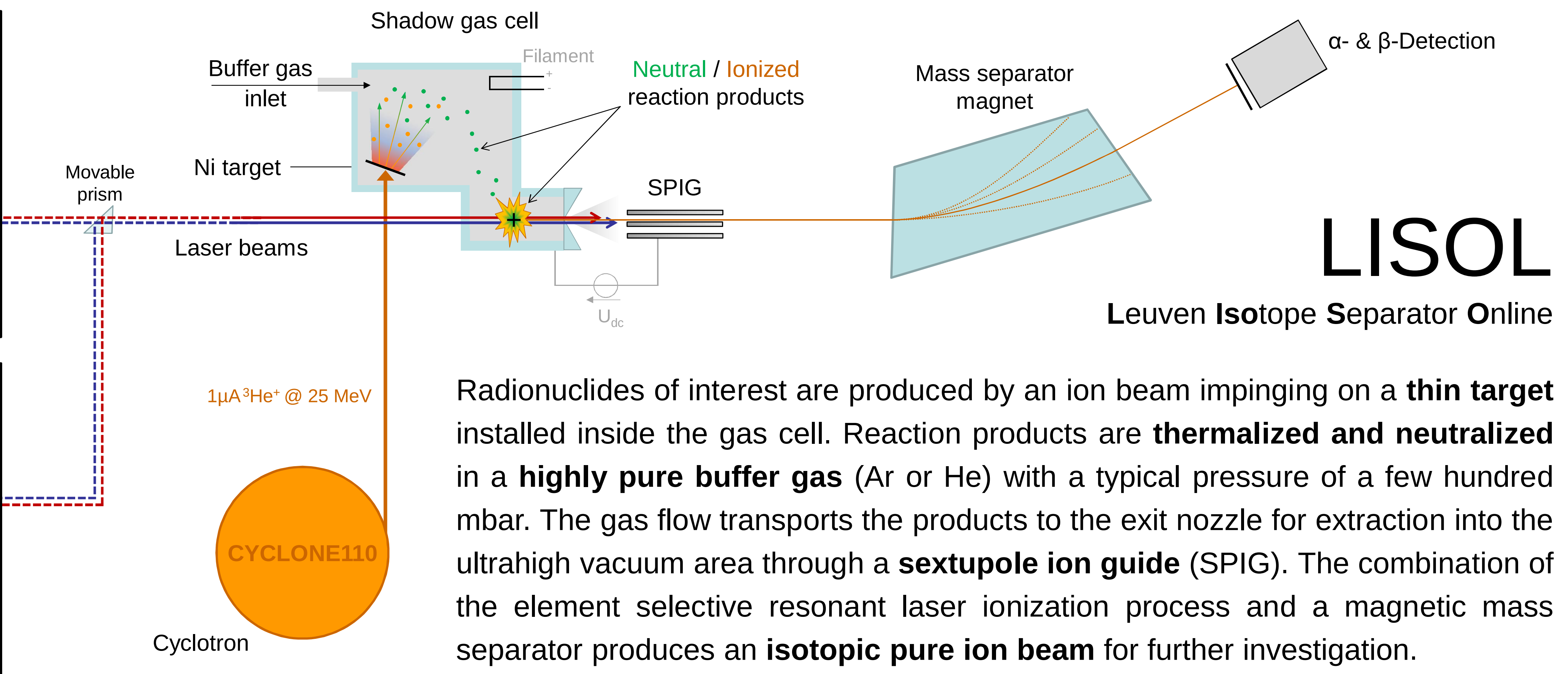


LISOL

Leuven **Iso**tope **S**eparator **O**nline

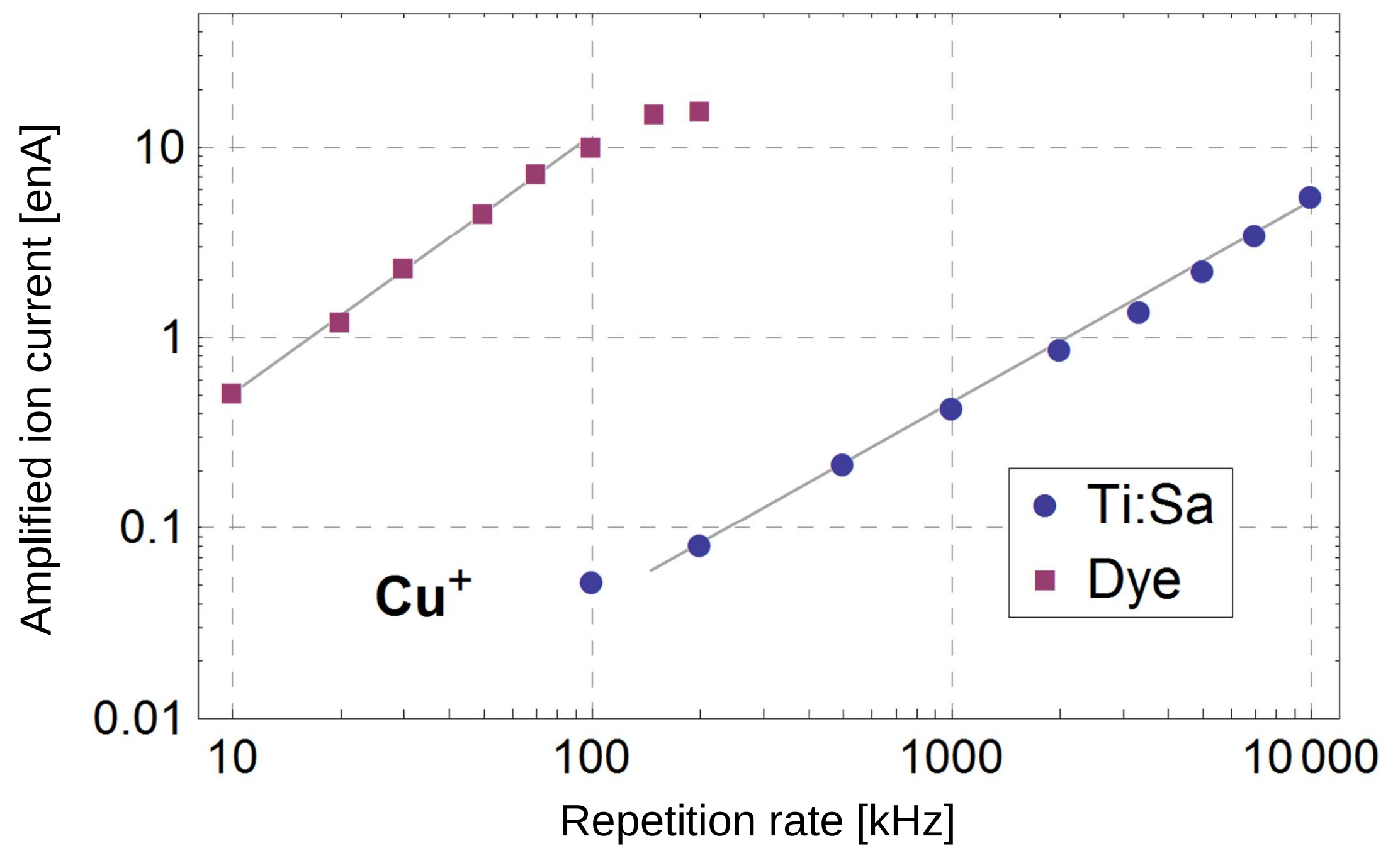
Radionuclides of interest are produced by an ion beam impinging on a **thin target** installed inside the gas cell. Reaction products are **thermalized and neutralized** in a **highly pure buffer gas** (Ar or He) with a typical pressure of a few hundred mbar. The gas flow transports the products to the exit nozzle for extraction into the ultrahigh vacuum area through a **sextupole ion guide** (SPIG). The combination of the element selective resonant laser ionization process and a magnetic mass separator produces an **isotopic pure ion beam** for further investigation.

Results: Ionization Efficiency and Spectroscopic Resolution in Cu

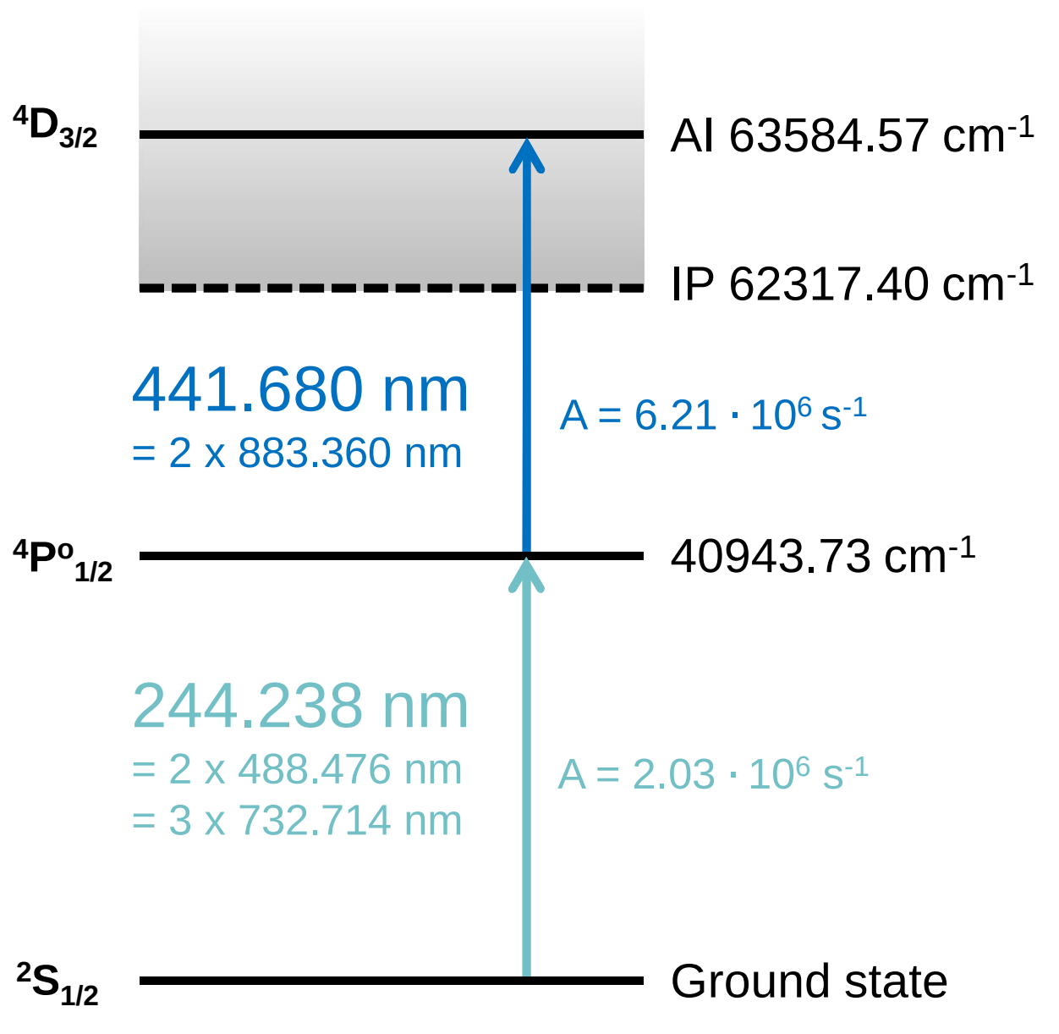
Ionization inside the gas cell

For ionization inside the gas cell the Ti:sa laser system (10 kHz) reaches similar to slightly lower **ionization efficiency** than the dye laser system (200 Hz), which has a significantly higher pulse energy. The systems were compared in measurements on **Co and Cu**. For Cu the identical excitation scheme could be used for direct intercomparison. As shown in the graph the dependence on the repetition rate for both laser systems is essentially linear. In the ionization of the on-line produced **radioisotope ^{59}Cu** a total ion production **efficiency of 0.6 %** was found, similar for both laser systems.

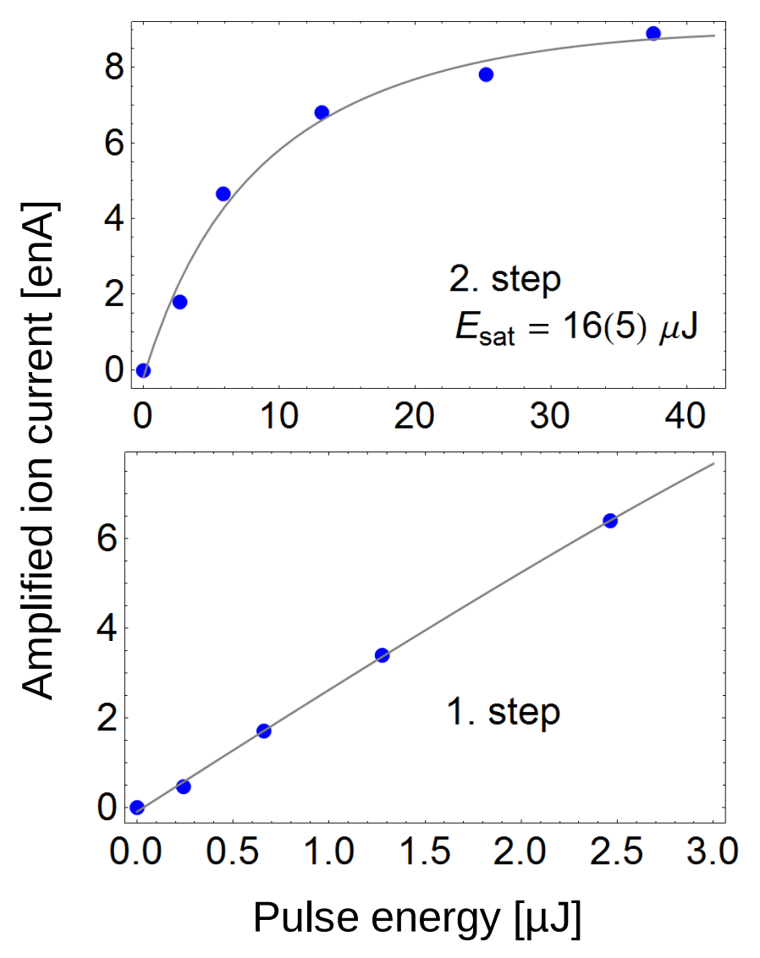
Repetition rate dependency



Ionization scheme for Cu



Saturation Ti:sa system



Ionization outside the gas cell

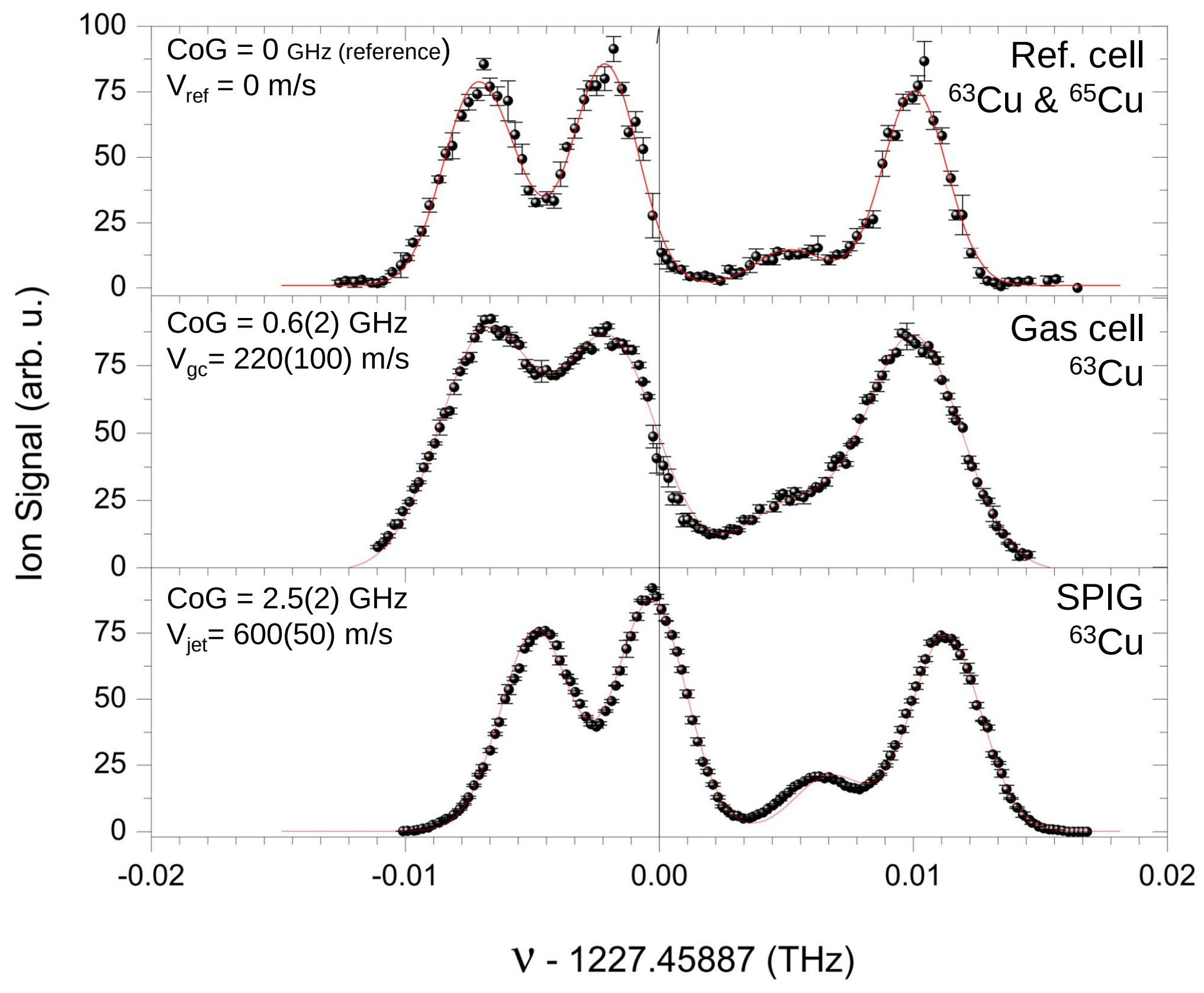
The ionization **efficiency** in the **sextupole ion guide** SPIG located just in front of the IGISOL gas cell is substantially **higher** for the high repetition rate Ti:sa laser system, for the first time leading to a significant signal above background. This is well understood by the gain due to **lower duty cycle losses,** which are important for ionization in the high velocity atomic beam leaving the gas cell.

Reference

R. Ferrer-Garcia et al., Performance of a high repetition pulse rate laser system for in-gas-jet laser ionization and spectroscopy studies with the Leuven laser ion source @ LISOL, *Nuclear Inst. and Methods in Physics Research B* , (accepted)

Hyperfine Structure of first transition

As shown for the **stable isotopes**, the hyperfine structure could be well resolved with the Ti:sa laser system in a **reference cell** as well as in the **SPIG**, limited by a laser linewidth of ~ 2GHz. In the **gas cell** a slight pressure broadening was observed. The shift of the center frequency of the structures in the SPIG is due to the Doppler shift resulting from the high velocity of the atoms in the gas jet behind the nozzle.



Conclusion & Outlook

Herewith high repetition rate Ti:sa lasers have shown their capabilities and usefulness for resonance ionization in combination with the IGISOL techniques. The on-line produced radioisotope ^{59}Cu could be ionized inside the gas cell with **comparable efficiency** to the existing dye laser system, while the main advantage of this laser system shows up in laser ionization in the SPIG, where the ionization takes place in a high velocity gas jet.

Further investigations will concentrate on the adaptation of the high repetition rate laser system to access further elements and to demonstrate **high resolution** in spectroscopic studies on radioisotopes. For this purpose techniques for an **injection locked seeded Ti:sa laser** have been developed in a collaboration of Mainz, JYFL and Nagoya. Installation of the optimized laser system at the different upcoming gas cell facilities for study of radioisotopes worldwide is foreseen for the future.

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