Off-line Ionization scheme development for the ISOLDE RILIS

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Motivation

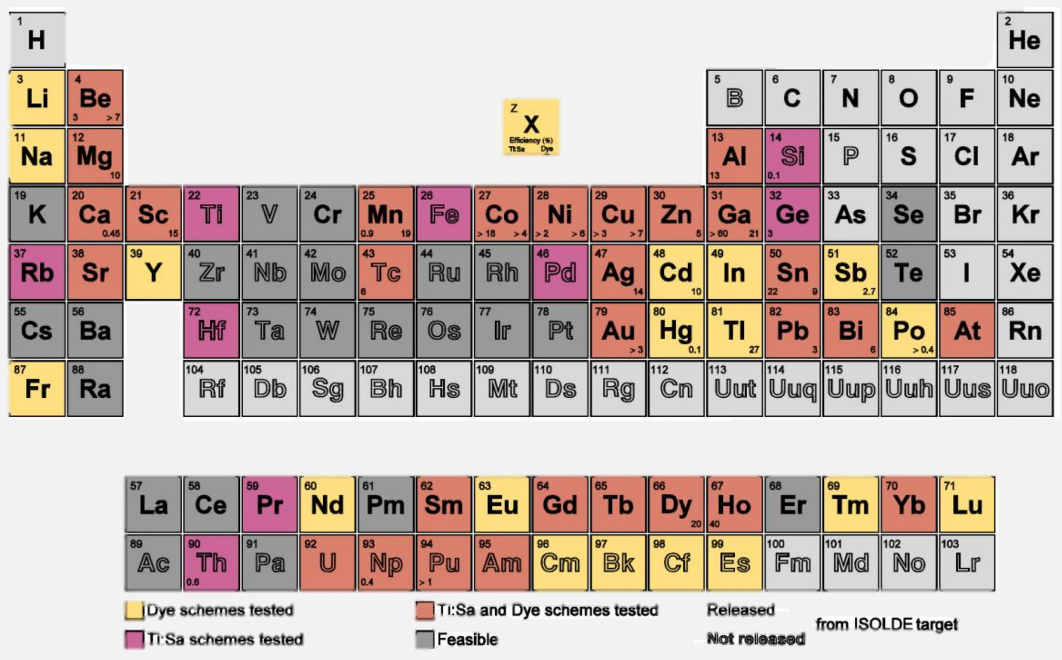

Figure 1. Elements with available schemes at RILIS. The key identifies which lasers are used in the schemes and also the elements where it is feasible that schemes could be developed. Image by Sebastian Rothe.

The addition of 3, Nd:YAG pumped, titanium sapphire (Ti:Sa) lasers to the ISOLDE resonance ionization laser ion source (RILIS) presents the opportunity to consider ionization schemes that require laser wavelengths beyond the effective range of the dye laser system. The proven ability to use a combination of dye and Ti:Sa lasers for a single ionization scheme (Rothe, 2012), enables a broadening of the search for optimal ionization pathways. An extensive ionization scheme study, to localise suitable auto-ionizing states (AIS) and to establish new ionization schemes, for elements of potential interest at ISOLDE, is underway.

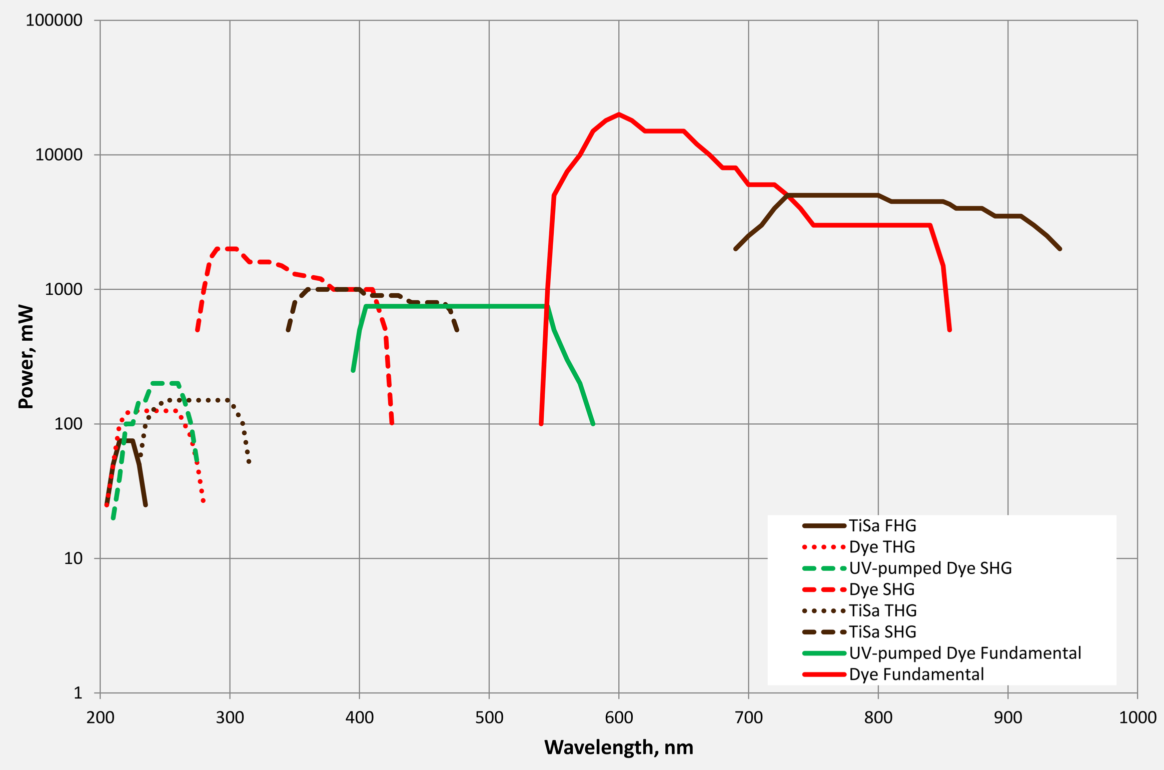

Figure 2. The wavelength range now available at RILIS. Fedosseev et al. (2012).

Elements of Interest

Elements for which resonance ionization, with the RILIS lasers, is feasible but a suitable scheme has yet to be developed:

Er Cr Se

Specific elements identified because of potential ISOLDE user interest.

Scheme development will take place with a reference cell to be installed at RILIS.

Opportunistic scheme development, during normal RILIS operation, is possible by taking advantage of suitable laser configurations, in place for other runs.

Elements with a low ionization potential so surface ionization suppression and/or a particularly efficient scheme is required:

Ba Li

Scheme development at the LARIS lab is preferable due to the broad scanning capability of the MOPO system.

The new availability of the Laser Ion Source and Trap (LIST) for surface ion suppression (PhD work of Daniel Fink and Sven Richter) increases the potential interest in using RILIS for surface ionized elements.

Elements where a scheme exists that uses non-resonant ionization, but an auto-ionizing state is desired:

Co Ge Nd

Co, Ge: compare existing non-resonant RILIS schemes to AIS schemes developed by Mainz/Ganil (Kessler et al., 2007; Gottwald, 2011) .

Nd: look for a more efficient scheme than currently exists, done in collaboration with LAL at ORSEY.

Co, Ge development will take place at RILIS, Nd at LARIS.

Elements with suboptimal schemes or laser configurations:

Hg

Hg: improve existing sub-optimal scheme by incorporating a Ti:Sa within the previous dye laser scheme.

The incorporation of a Ti:Sa allows for the dye pumping to be concentrated on producing fewer beams.

Development to take place at RILIS as part of an extended setup for a Hg run.

Development Methods

Literature search and use of databases

Resonance ionization spectroscopy

Saturation measurements

Efficiency measurements

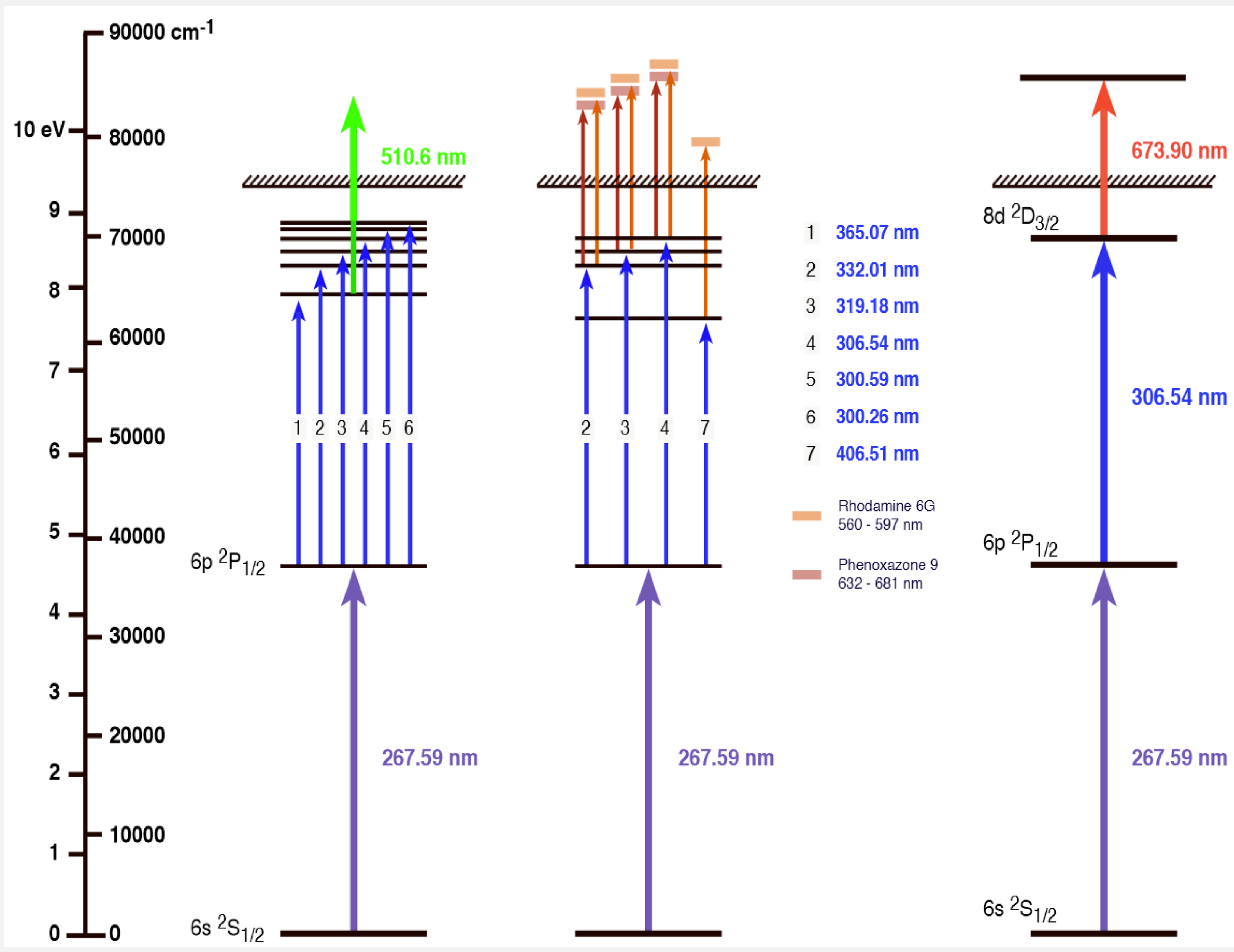

Figure 3. An example of ionization scheme development for Au. First the efficiency of different second steps is investigated using a powerful green laser for a non resonant final step. Having chosen the most efficient of these transitions, a dye laser is used to scan for auto-ionizing third steps. In this way the most efficient scheme was identified.

LARIS

The LARIS lab is equipped with 3, Nd:Yag pumped, tunable lasers: a dye laser and 2nd and 3rd harmonic pumped OPOs.

Two complementary atomic beam sources:

- Rotating rod laser ablation source with gas extraction and TOFMS – for refractory elements.
- Tantalum oven atom source with residual gas analyser and TOFMS.

On going work at the LARIS lab:

- Scheme development of Nd in collaboration with LAL at ORSAY for ^{150}Nd enrichment by atomic vapour laser isotope separation. This is for a search for neutrino-less double-beta decay.
- Scheme development of Ba and Li for ISOLDE users.

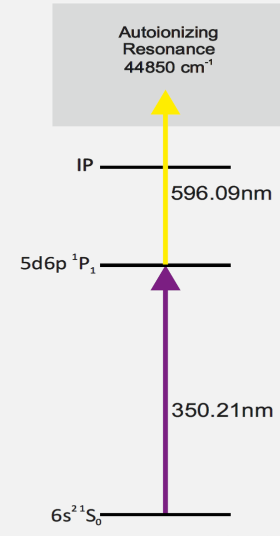

Figure 4. Ba AIS identified by Kaylar et al. 2009.

Off-line Lab

Dedicated off-line experiment using a target and mass marker.

Enables optimization of RILIS specific parameters.

Efficiency can be measured.

Limited to stable isotopes.

Figure 5. Off-line mass separator.

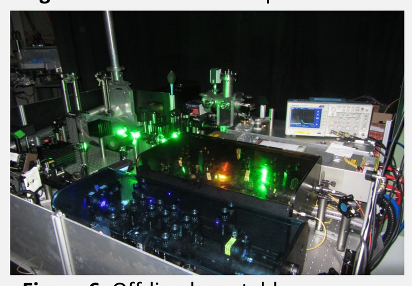

Figure 6. Off-line laser table.

Refractory Metals at ISOLDE?

The Off-line lab is also being used to test the suitability of RILIS for ionizing refractory metals.

A method of extracting refractory metals from a thick target is required.

The aim is to investigate the breakup of volatile molecules of refractory metals, using either laser light or electron impact.

Reference Cell

Developed at the University of Mainz by Tobias Kron (Kron et. al 2013) for the active control and monitoring of laser beam characteristics during runs.

Currently installed for testing at the Off-line lab.

Plans to fibre couple the laser light directly into the reference cell.

Water cooling for the rear and a gas spectrum analyser, that would be installed opposite the SEM, are also being considered.

Figure 7. The reference cell with pumping unit.

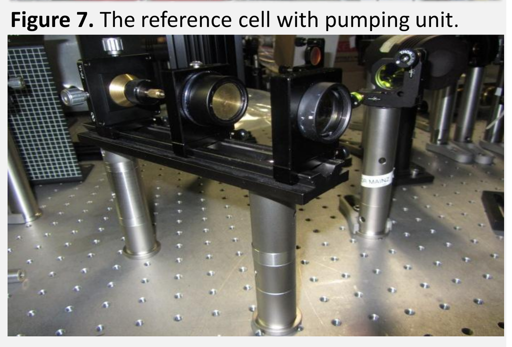

Figure 8. Fibre coupling mount and rail.

ISOLDE RILIS

The RILIS lab at ISOLDE is equipped with 3, Nd:Yag pumped, dye lasers and 3, Nd:Yag pumped, Ti:Sa Lasers.

Tests are performed with the RILIS system under standard operating conditions, therefore there is no uncertainty about a developed scheme's compatibility.

Time constraints due to limited beam time and complex scheduling mean that dedicated scheme development is limited to 1-2 weeks per year. All other tests must be performed in an opportunistic way during standard RILIS operation.

At ISOLDE, scheme development can be performed 'on-line' for elements with no stable isotopes, examples of this include Polonium (Cocolios and Marsh et al. 2008) and Astatine (Rothe 2012).

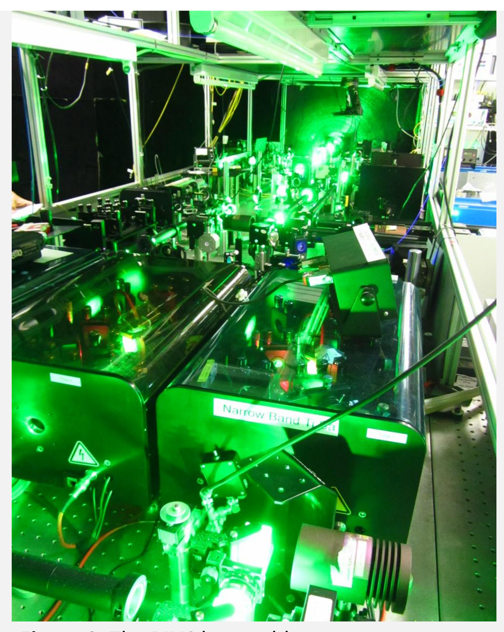

Figure 9. The RILIS laser table.

Collaboration

http://riliselements.web.cern.ch

RILIS elements database developed by Martin Klein and Sebastian Rothe.

A communal resource for all RILIS (not just ISOLDE's) schemes.

Unsuccessful AIS searches could be recorded in the notes: saving everybody's time!

The website is fully functional but still in the testing phase so recommendations are more than welcome…

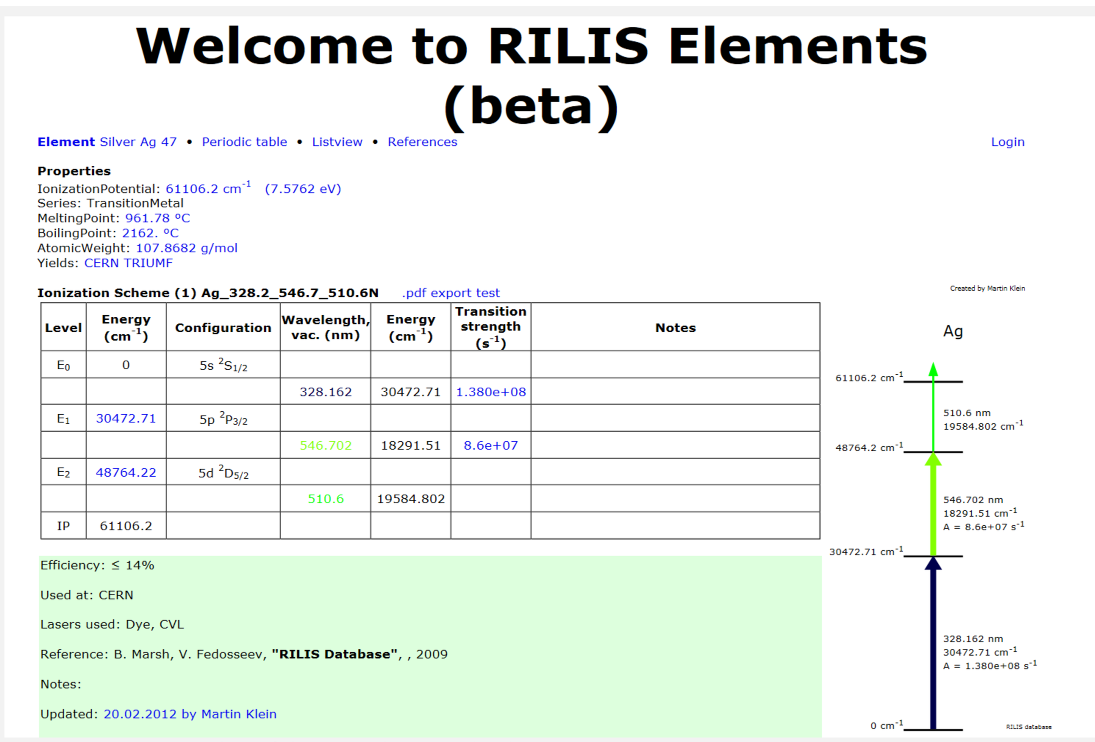

Figure 10. A screen shot of the RILIS elements database.

References

T. E. Cocolios and B. A. Marsh et al. (2008) Resonant laser ionization of polonium at RILIS-ISOLDE for the study of ground- and isomer-state properties, Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms 266 (19-20) 4403–4406. doi:10.1016/j.nimb.2008.05.142.

Fedosseev, V. N. et al. (2012). *Upgrade of the RILIS at ISOLDE; Rev. Sci. Inst 83*(2), 02A903. doi:10.1063/1.3662206.

Gottwald, T. (2011) Studium hochkomplexer atomarer Spektren mittels Methoden der Laserresonanzionisation.

Kaylar, M. A. et al. (2009) **Interaction of the 6*p*2 1*S*0 broad resonance with 5*dnd J*=0 autoionizing resonances in barium,** Phys Rev. A doi: 10.1103/Phys.RevA.80.052505.

Kessler, T. et al. (2007) Three-step resonant photoionization spectroscopy of Ni and Ge: ionization potential and odd-parity Rydberg levels, J. Phys. B: At. Mol. Opt. Phys. 40, pp. 4413–4432.

Kron, T. et al. (2013) Control of RILIS lasers at IGISOL facilities using a compact atomic beam reference cell; Hyperfine Interactions 216 (1-3), pp. 53-58.

Rothe, S. (2012) An all-solid state laser system for the laser ion source RILIS and in-source laser spectroscopy of astatine at ISOLDE/CERN. PhD thesis, Johannes Gutenberg-Universität Mainz.

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