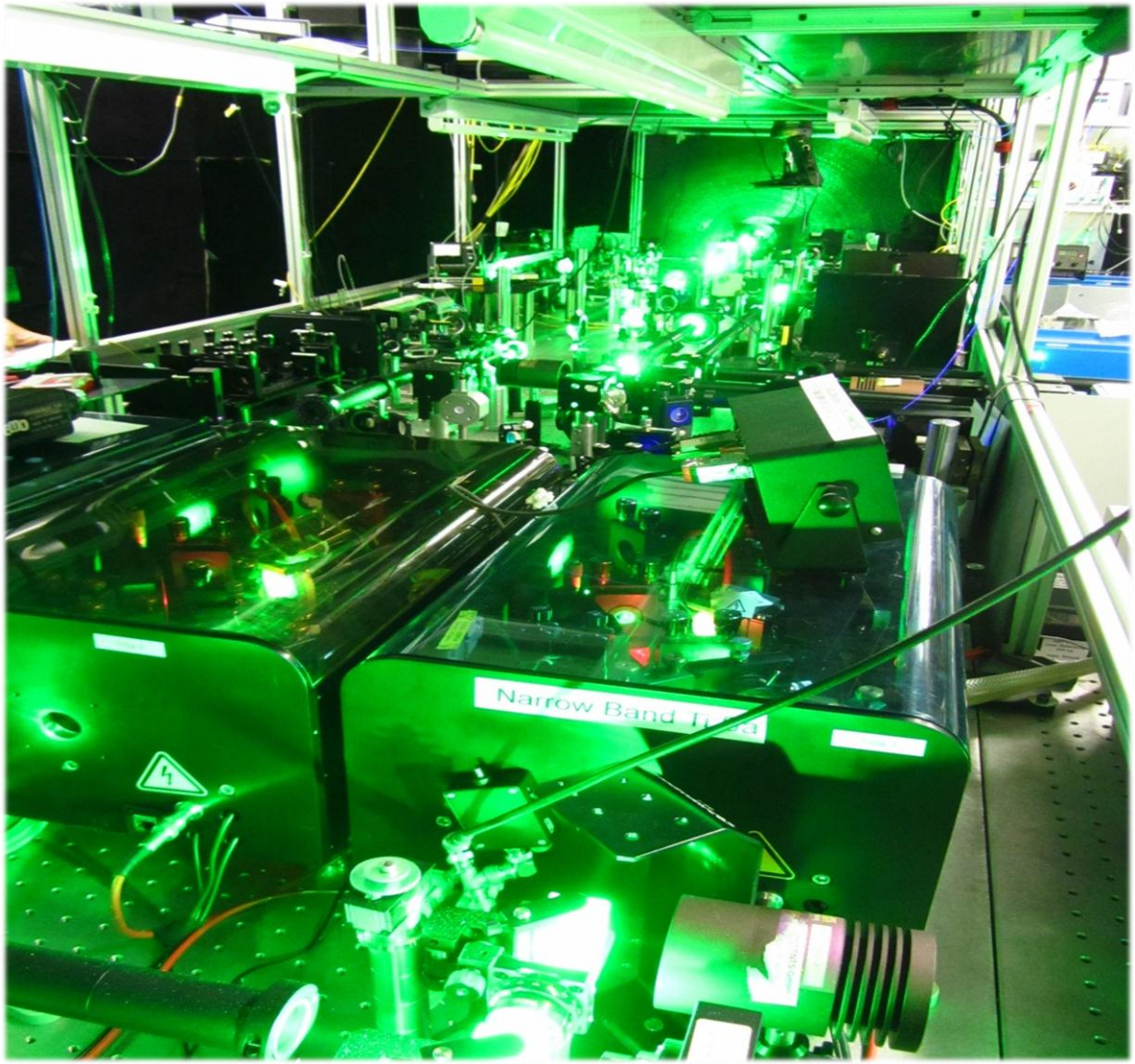
1st LA³NET Topical Workshop

Laser Based Particle Sources

Thomas Day Goodacre

The status of laser ionization schemes at ISOLDE's RILIS and the scope for improving efficiencies

Reasons for Scheme Development for ISOLDE's RILIS



Reasons for Scheme Development for ISOLDE's RILIS

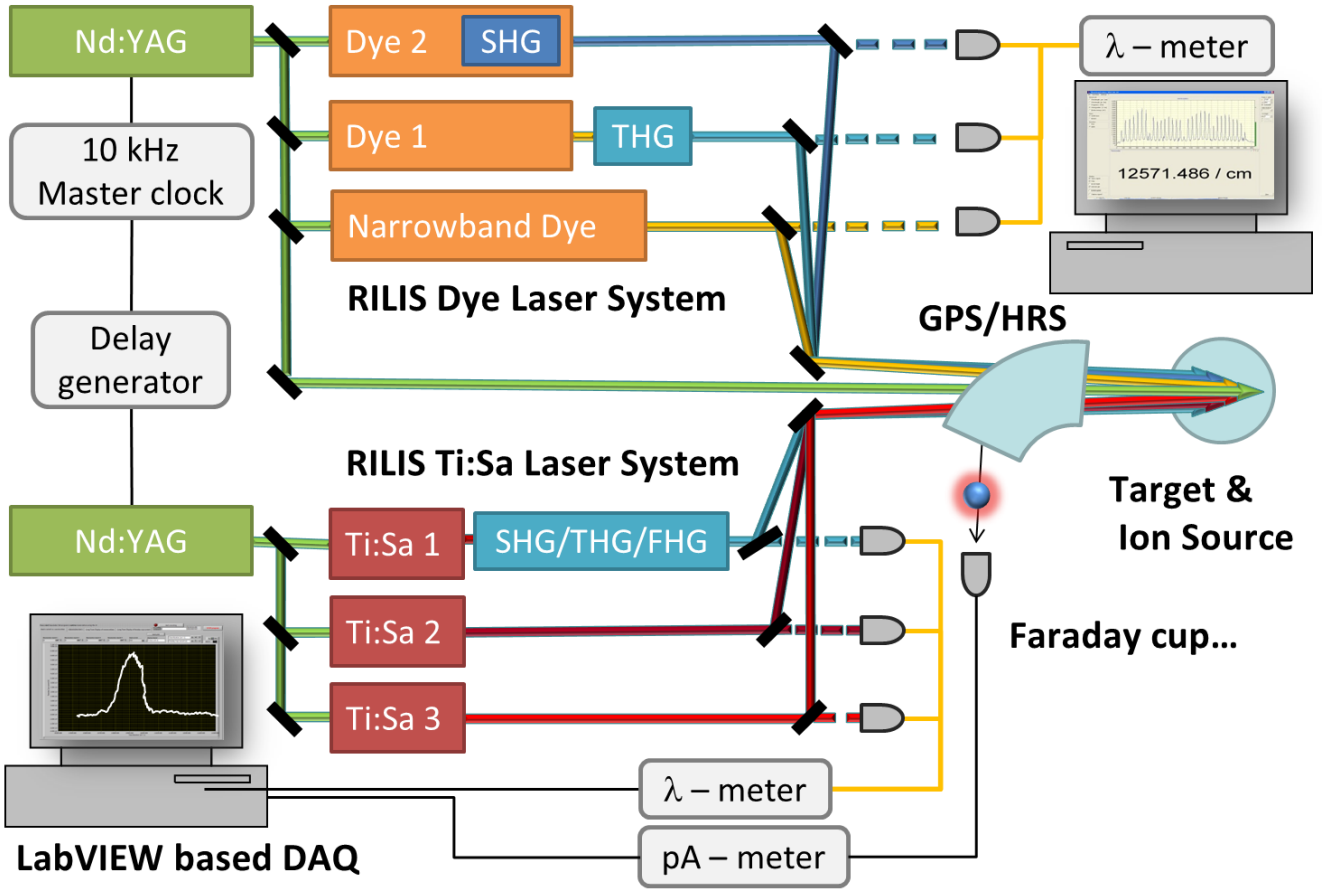
The addition of new lasers to the RILIS at ISOLDE necessitates a re-evaluation of the current ionization schemes:

- Have existing schemes been adversely affected or can they be improved upon?
- Are new elements now accessible?

This talk will explore:

- The principles of ionization scheme development
- Elements of particular interest for re-evaluation
- The equipment and methods available for scheme development

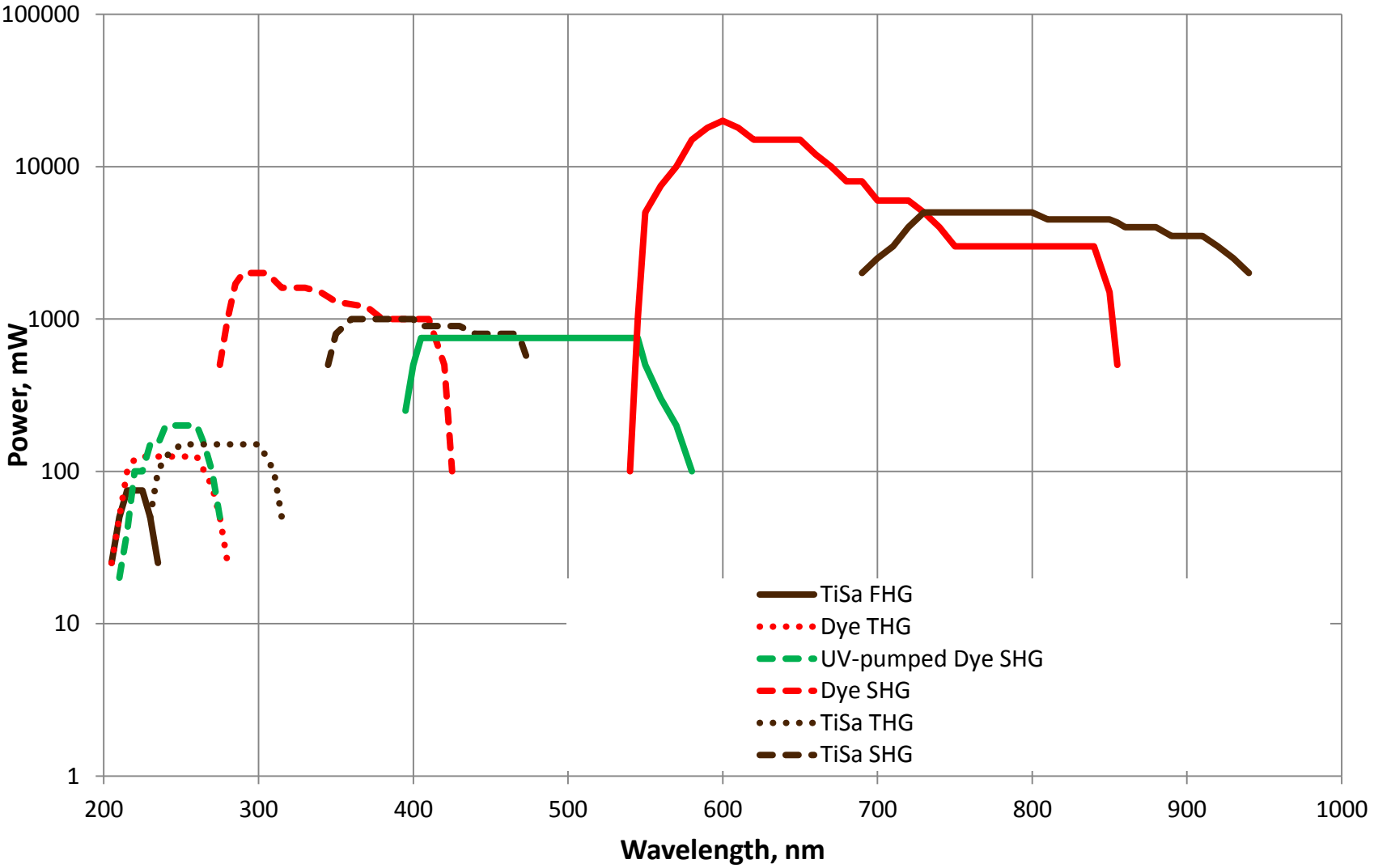
New Laser Setup



Fedosseev et al. 2012

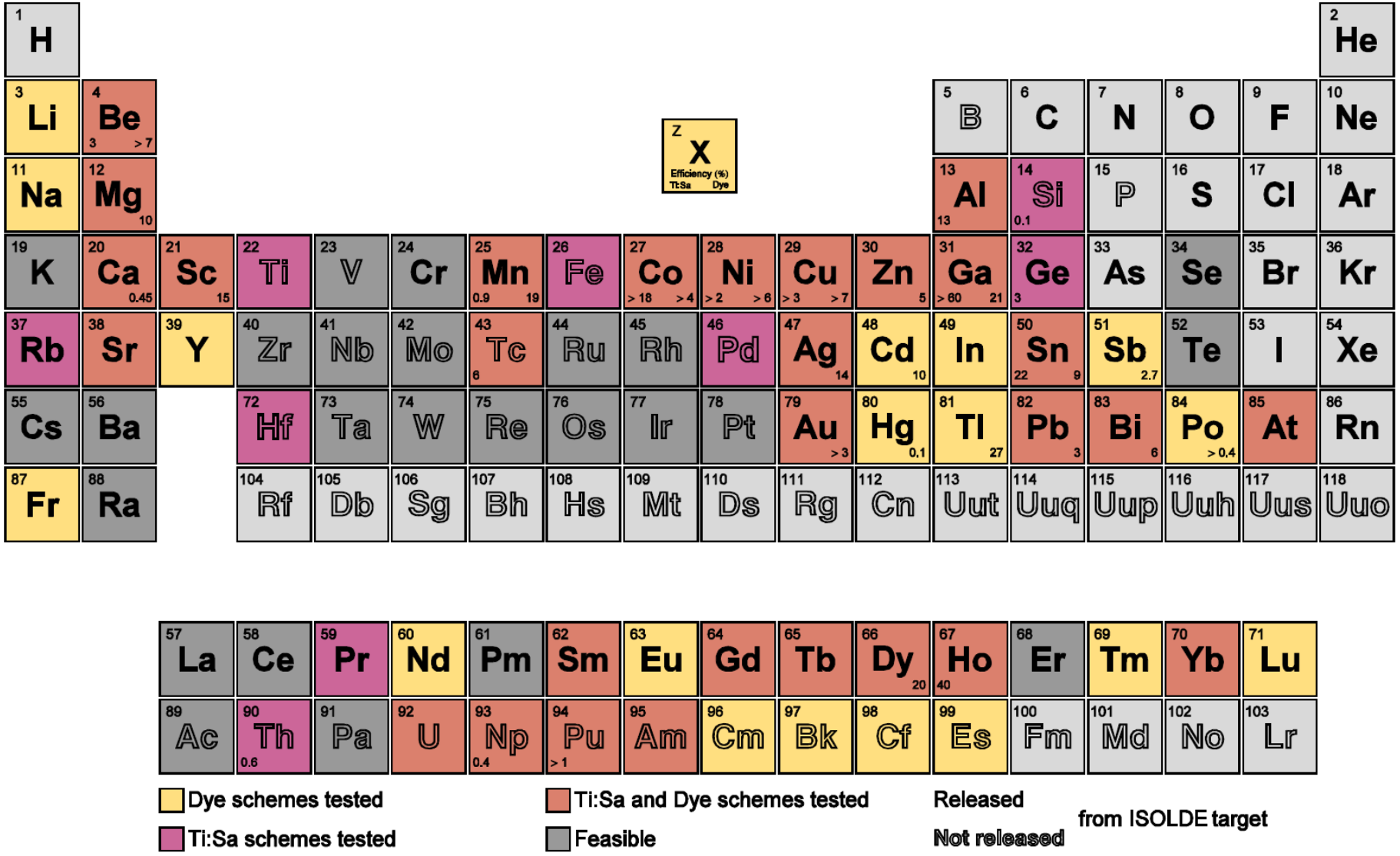
The previous RILIS laser setup consisted of 3 dye lasers pumped by 2 copper vapour lasers.

Resulting Wavelength Range



Fedosseev, V. N., Fedorov, D. V, Fink, D., Losito, R., Marsh, B. A., S.Rothe et al. (2012). *Upgrade of the RILIS at ISOLDE; Rev. Sci. Inst 83*(2), 02A903. doi:10.1063/1.3662206

Viable Schemes at ISOLDE's RILIS



Goal of Ionization Scheme Development

To find the most efficient method of ionisation whether by:

- Exciting to the continuum
- Exciting an autoionizing resonance
- Ionization from a Rydberg level

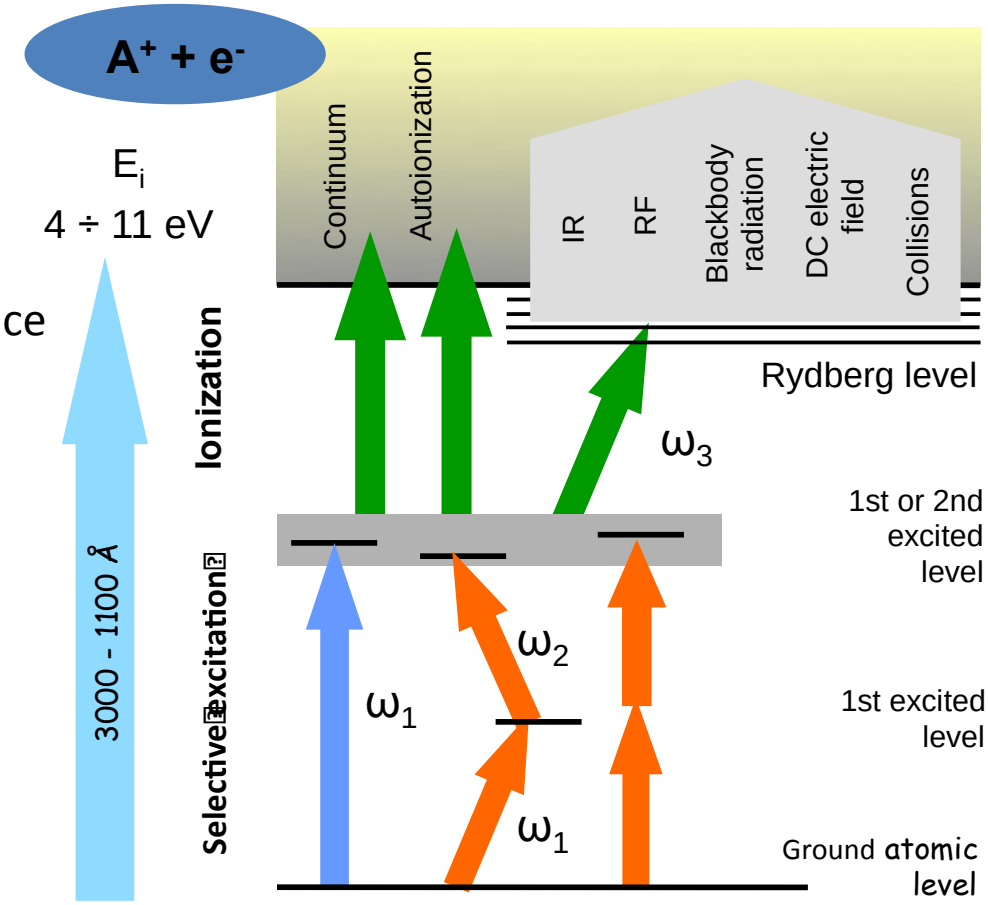


Image by V.I. Mishin

Factors Affecting Scheme Efficiency

Scheme efficiency is determined by a number of things:

- Transition strengths
- Statistical weights (J value)
- Thermally populated lower levels
- Width of the resonance or splitting of the lines (hyperfine structure)
- Photon flux (up to saturation)
- Laser pulse duration Vs Lifetime of excited levels

Technical aspects also affect efficiency:
(laser pulse synchronization, delay, overlap, beam transport efficiency, stability, reliability)

Potential Scheme Developments for ISOLDE's RILIS

The scope for ionization scheme development for ISOLDE's RILIS falls into five categories:

1. Feasible but a suitable ionization scheme has yet to be developed:
   Cr, Se, Te, B, Ra, La, Ce, Pm, Er

2. RILIS enhancement low due to surface ionization, so needs an efficient scheme and/or surface ionization suppression:
   K, Cs, Li, Na, (Ba), (Ra)

3. Existing scheme using non-resonant ionization for the final step, AIS desired:
   Mg, Sc, Co, Zn, Ga, Y, Ag, Cd, In, Sb, Tl, Pb, Bi, Po, At, Dy

4. Suboptimal schemes or laser configurations:
   Hg

5. Refractory metals, requires further development of targets and ion sources:
   V, Zr, Nb, Mo, Ru, Rh, Ta, W, Re, Os, Pt, Ar, Pa

Basic Formula for Scheme Development

1. **Literature search and use of databases**
   (Kurucz and NIST) to determine resonant steps.

2. **Resonance ionization spectroscopy**
   Laser frequency scans across regions of interest whilst observing the ion current

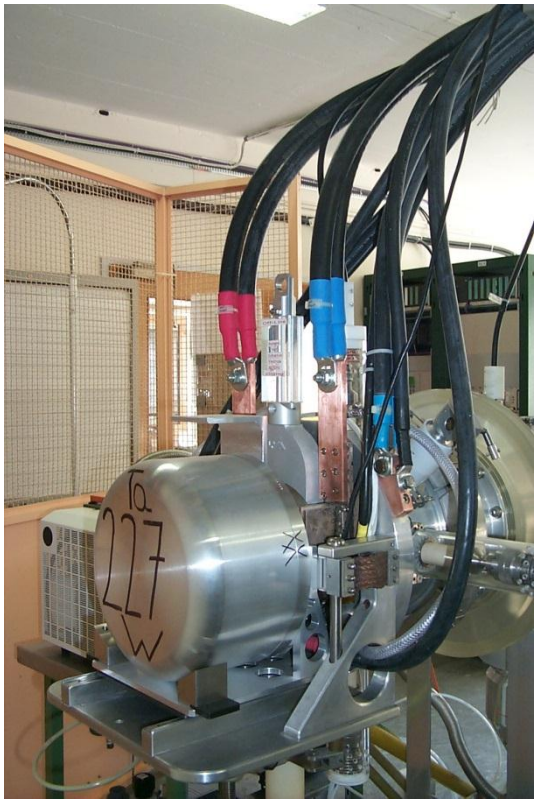
3. **Saturation measurements**
   Determine if efficiency gains can be achieved from an increase of power.

4. **Efficiency measurements**
   Total evaporation of the sample (of known mass) and integration of the ion current.

Methods of Ionization Scheme Development for RILIS 1

Dedicated off-line experiment using a target and mass marker

- Enables optimization of RILIS specific parameters
- Efficiency can be measured
- Requires dedicated separator use + target preparation and setup (limited to 1-2 weeks/yr)
- Limited to stable isotopes



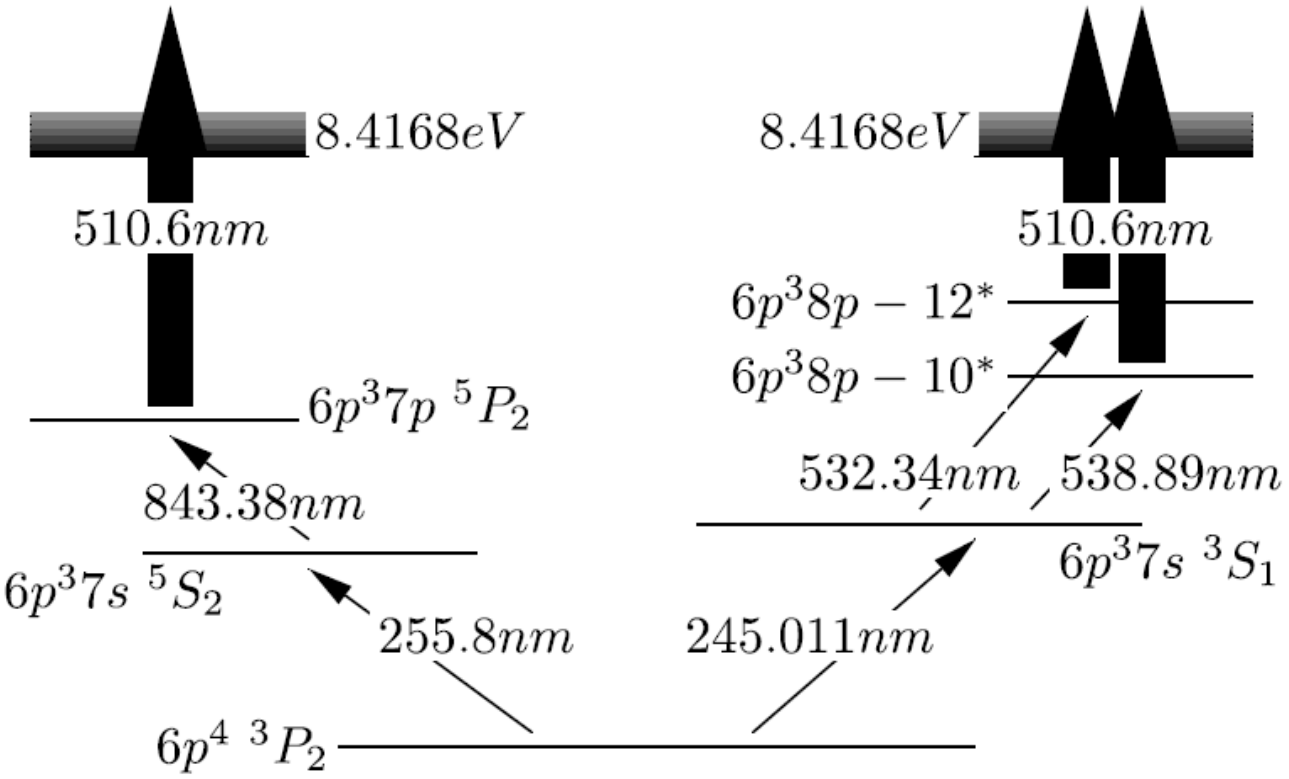
Images from Julien PARRA-LOPEZ

Methods of Ionization Scheme Development for RILIS 2

Dedicated on-line experiment using a target and radiogenic isotopes:

- The only method for scheme development of exclusively radioactive isotopes (Po, At)

Po

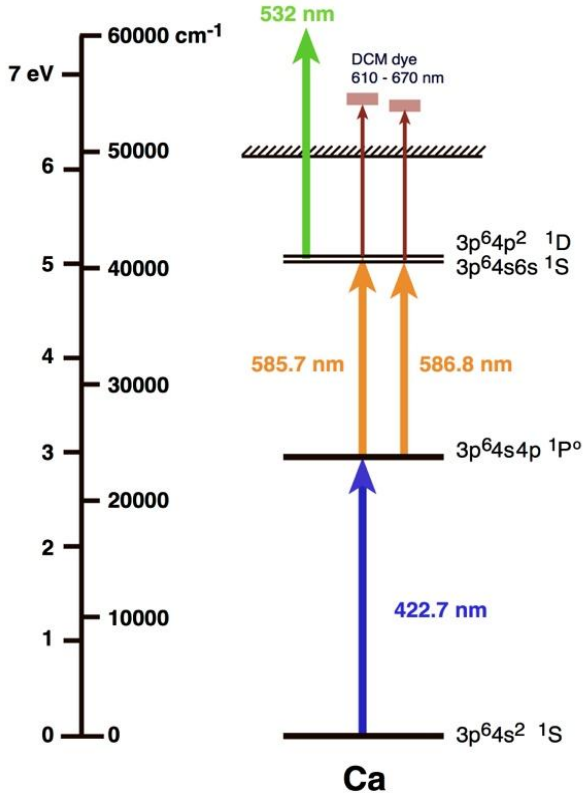


Cocolios and Marsh et al. 2008

Methods of Ionization Scheme Development for RILIS 3

Opportunistic scheme development during an on-line RILIS run:

- Use any available tuneable laser to search for alternative ionization schemes (e.g. Ca)
- Only possible due to the Dual-RILIS set-up
- Time and laser availability limits the scope of this method.



Daniel Fink PhD work

Factor of 4 improvement!

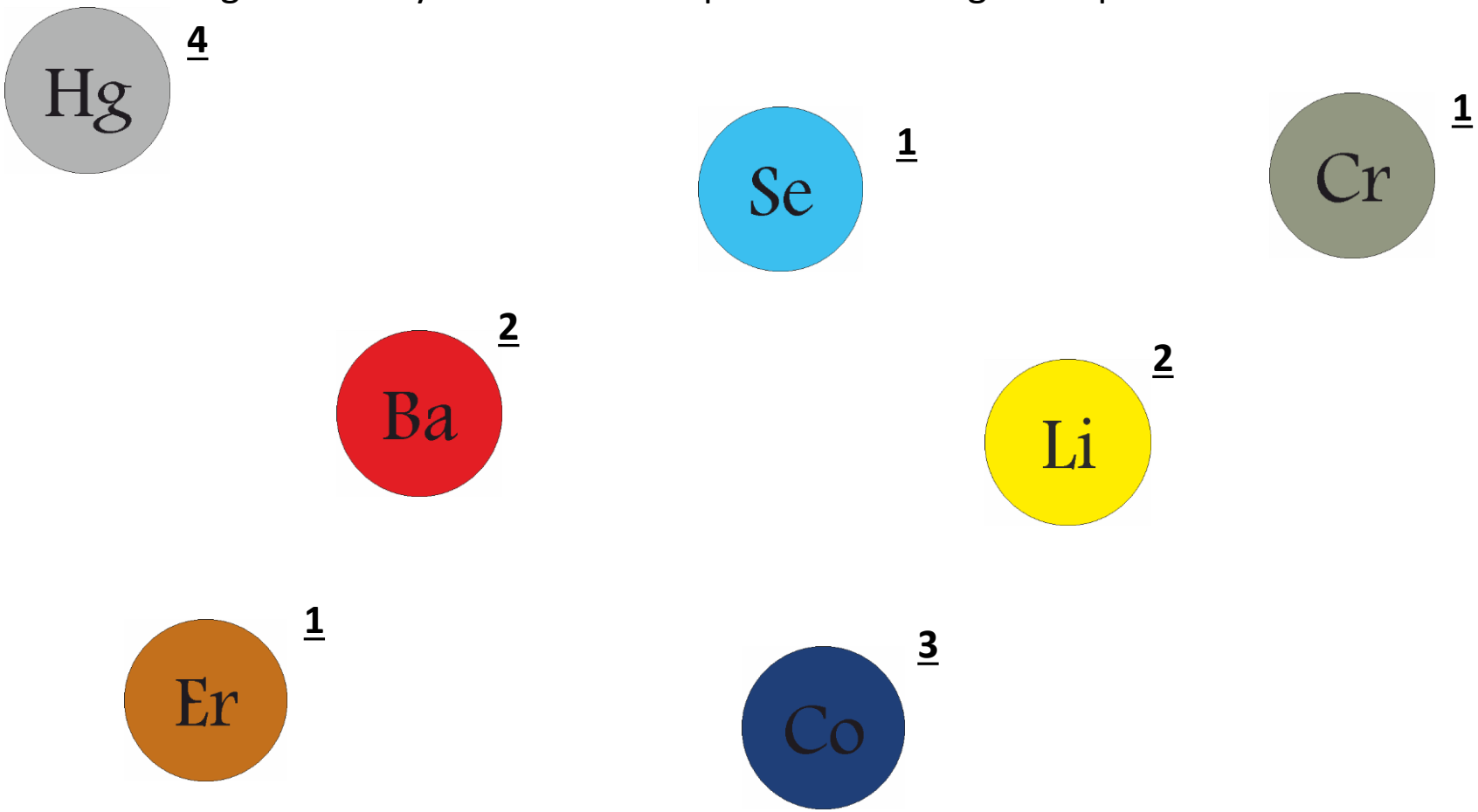
Methods of Ionization Scheme Development for RILIS 4

Scheme development using an independent reference cell

- A thermal atomic beam unit, developed by Tobias Kron at the University of Mainz will be installed in the RILIS room scheme development for stable elements using the RILIS lasers.

Schemes of Interest

Priorities are governed by ISOLDE user requests or the degree of potential interest:



Schemes of Interest

Hg

Efficiency ≈1%

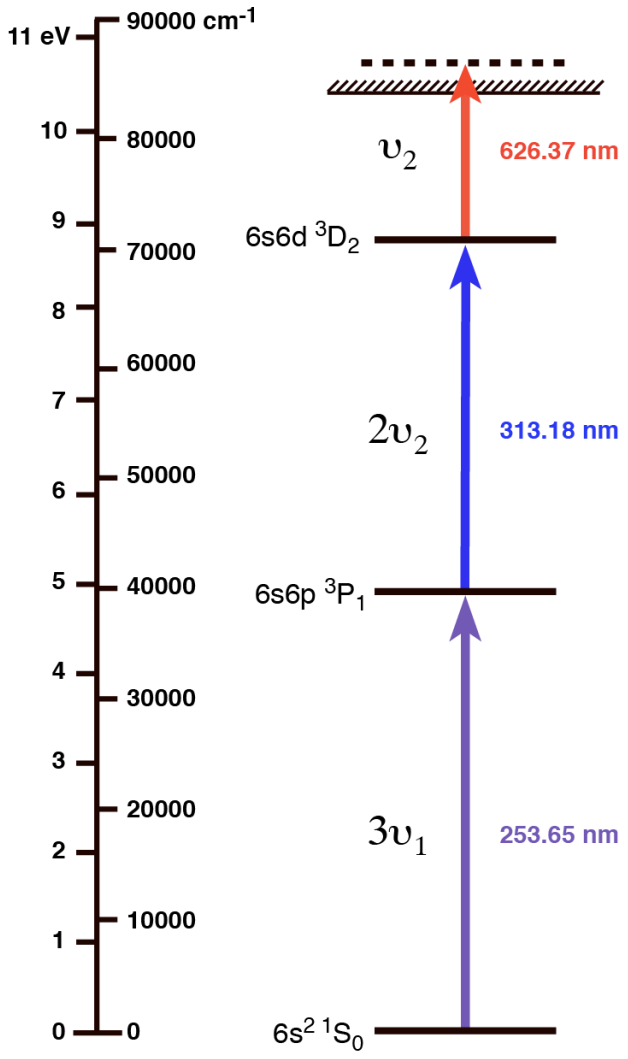
Low efficiency because of a weak first step and power had to be split between 3 dye lasers.

AIS was reached using the fundamental output of the 2nd step dye laser

1st step Ti:Sa then 2 independent dye lasers

Saturate transitions

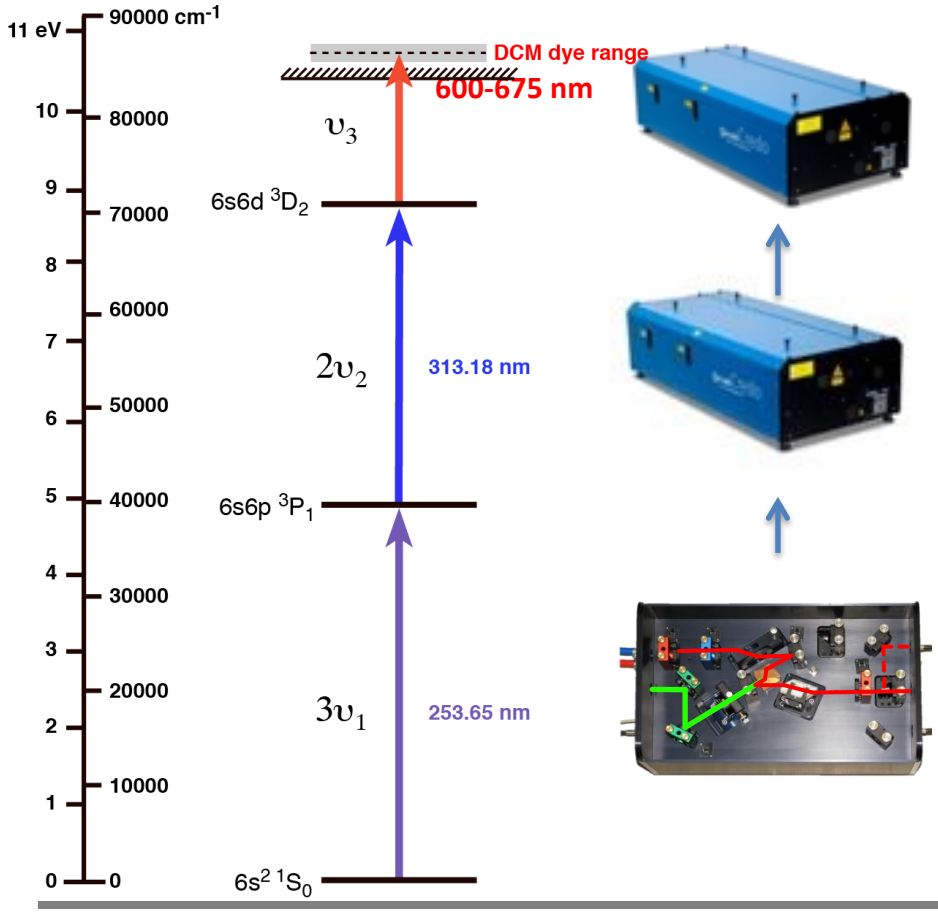
Locate peak of the AIS



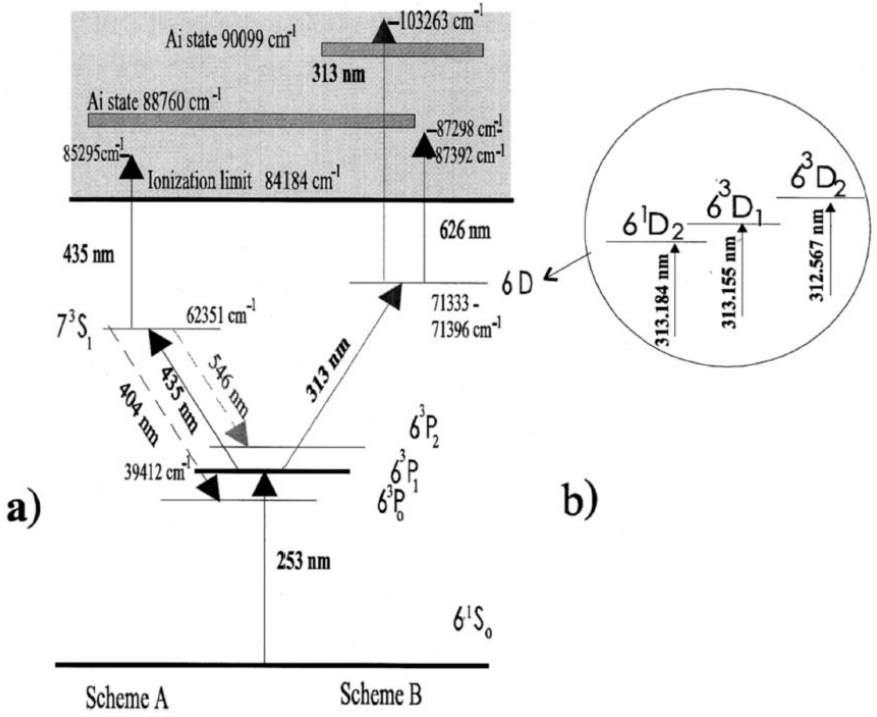
Hg – 2 stages

Hg

1)
- 1st step provided by a frequency tripled Ti:Sa laser
- Dye laser for the 2nd step will require ~30 W of the ~90 W Edgewave pump power.
- ~ 60 W pump power available for second dye laser to scan across the region of the AIS.



2) Investigate the ionization schemes and AIs identified by Podshivalov et al. 1999.



Development at LARIS

Equipped for:

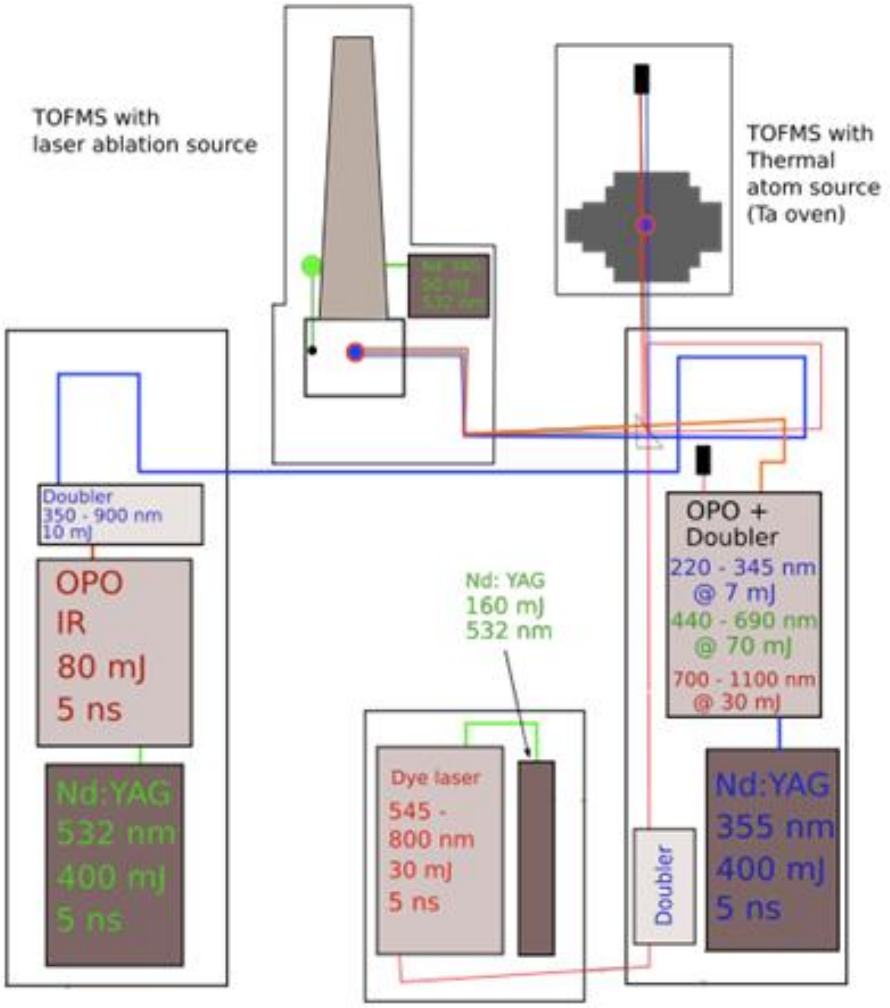
- Atomic or molecular spectroscopy,
- Determination of ionization potentials and hyperfine structure measurements of stable isotopes.

Three tunable lasers operating at 10 Hz**:**

- Nd:YAG pumped dye laser
- 2nd harmonic Nd:YAG pumped OPO
- 3rd harmonic Nd:YAG pumped OPO
- 3 frequency doubler/tracker units
- Frequency tripling without tracking.

Two complimentary atomic beam sources:

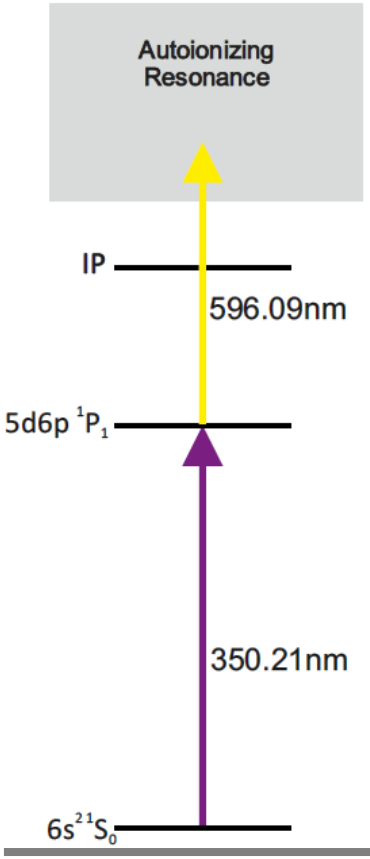
- Rotating rod laser ablation source with gas extraction and TOFMS -refractory elements.
- Tantalum oven atom source with residual gas analyser and TOFMS.



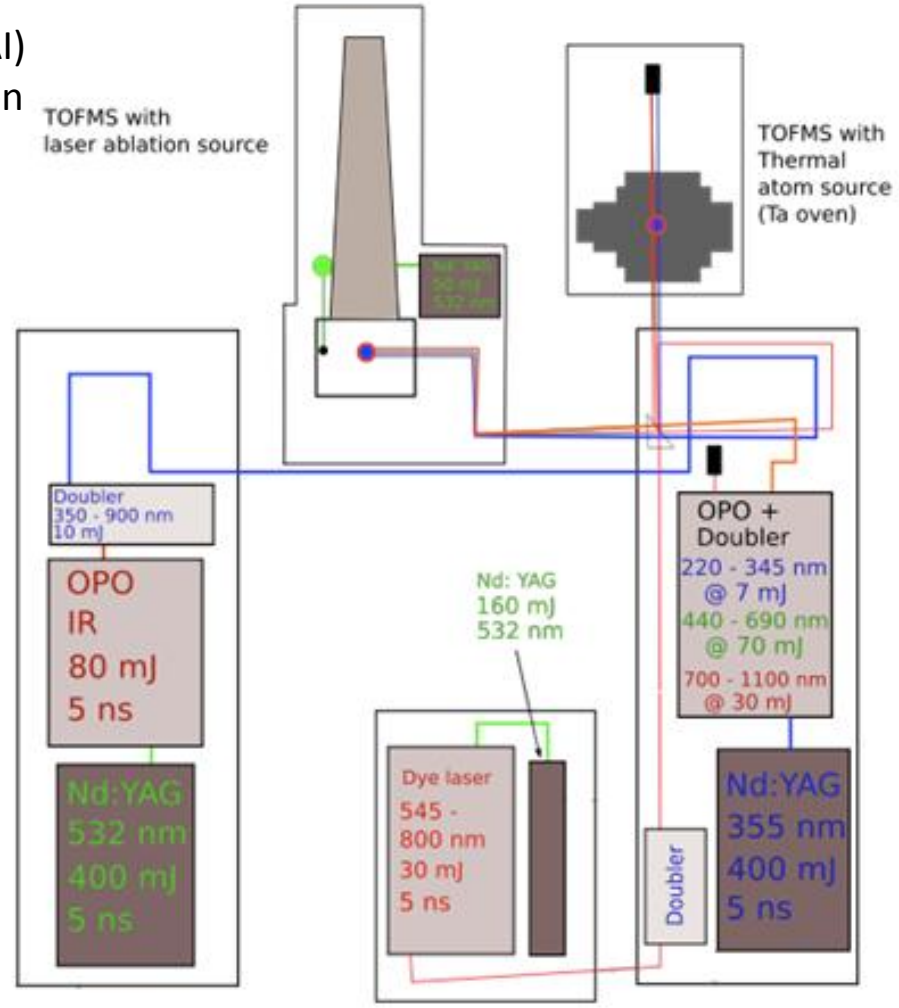
Development at LARIS

On going work at the LARIS lab:

- Development of ionisation schemes for Zr and Hf atoms + molecular breakup of fluorides (Nobu IMAI)
- Plan for scheme development of Nd in collaboration with LAL at ORSEY for enrichment.
- Scheme Development of Ba



- Scan an autoionizing resonance identified by M.A. Kaylar et al. 2009.
- First step frequency doubled dye
- Fundamental of the OPO for the Second



Summary

Additional lasers allow for old schemes to be re-evaluated and new ones developed

Development will take place at both ISOLDE's RILIS and in the LARIS lab

Priorities for development are determined by user requests

Collaboration for Scheme Development

RILIS elements database developed by Martin Klein and Sebastian Rothe:

The idea of this database is to be a communal resource for all RILIS (not just ISOLDE's) schemes.

In addition to inputting successful schemes there is the hope that unsuccessful AIS searches could be recorded in the notes: saving everybody's time!

Fully functional but still in the testing phase so recommendations are more than welcome!

http://riliselements.web.cern.ch/riliselements/index.php

Acknowledgements

Valentine FEDOSSEEV[1], Daniel FINK[1,2], Nobuaki IMAI[3], Tobias KRON[4], Bruce MARSH[1], Ralf Erik ROSSEL[5], Sebastian ROTHE[1], Maxim SELIVERSTOV[6],

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Thank you for your attention!