The ISOLDE RILIS in 2018

Shane Wilkins

CERN | EN ENGINEERING DEPARTMENT

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  - The team in 2018.
- Laser systems:
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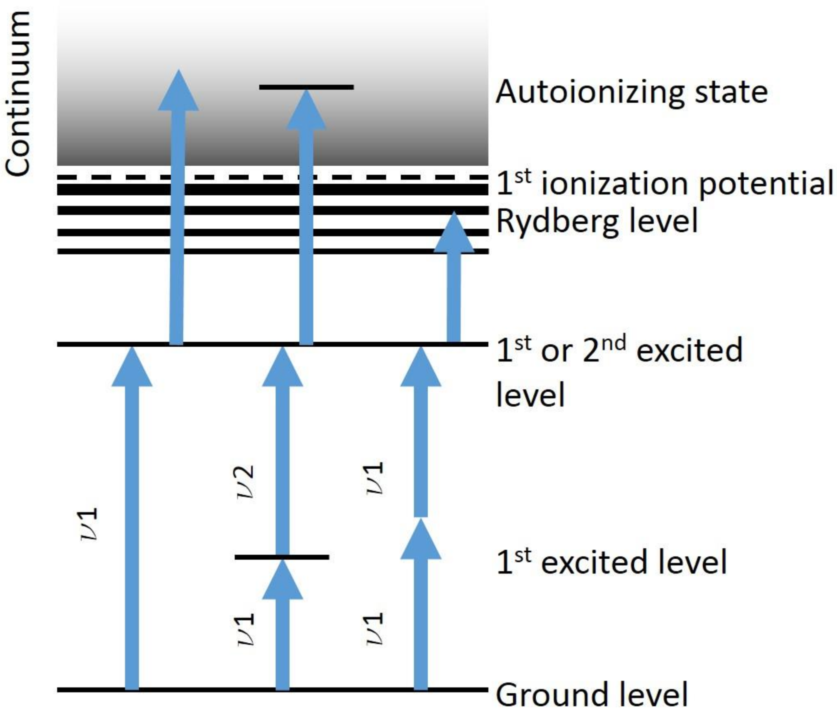
- New laser laboratories.
  - Offline 2.
  - MEDICIS.
- Towards two-photon spectroscopy.
- Outlook for LS2.

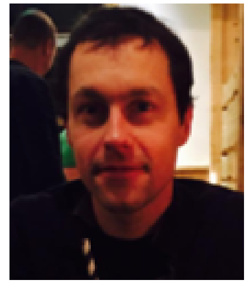
The ISOLDE RILIS

- Utilizes resonance ionization to ionize atoms of interest inside hot cavity.
- Each element has a unique 'fingerpint'.
- High efficiency and selectivity.
  - Isotope selectivity in combination with mass separator.
  - Isomer selectivity in exceptional cases.



RILIS team in 2018

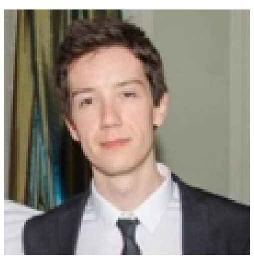
Valentin Fedosseev
Section leader EN-STI-LP



Bruce Marsh
Staff member EN-STI-LP

Camilo Granados
CERN fellow since
Apr. 2017

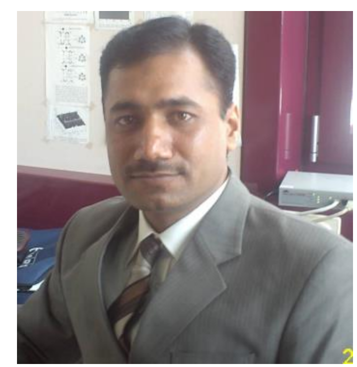
Katerina Chrysalidis,
PhD student since Oct. 2016



Shane Gary Wilkins
CERN fellow since
Oct. 2017

& Support from PNPI: Dima Fedorov, Pavel Molkanov, Maxim Seliverstov

Rizwan Ahmed, Associate (NCP, Pakistan) since April 2018



Eduardo Granados (new Staff member STI-LP)

InnoLas Nanio

RILIS

- Looking for alternative Ti:Sa pump lasers.
  - Continued issues with current lasers and chillers.
- Tested a loan laser from InnoLas.
- Model: 532-18-Y
- Power: 18 W.
- TEM_{00} beam, $M^2 < 1.3$.
- <40-ns pulse width at 10 kHz.
- Modular design.
- ‘In-field’ maintenance/repair.

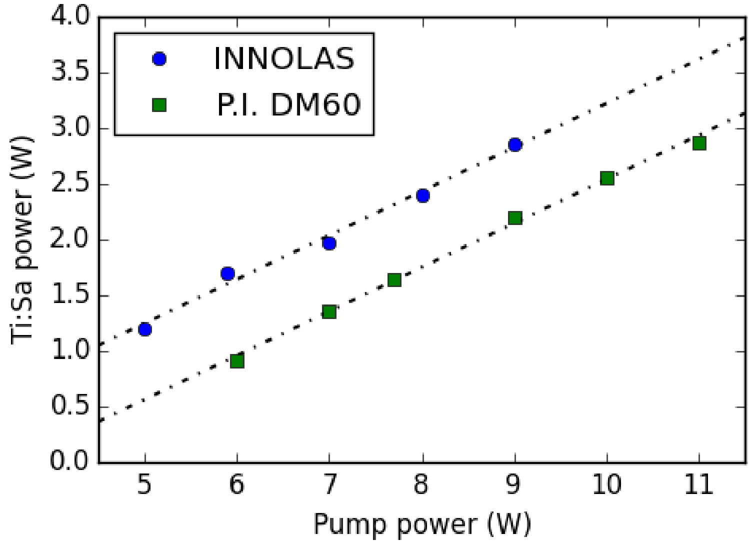
InnoLas Nanio

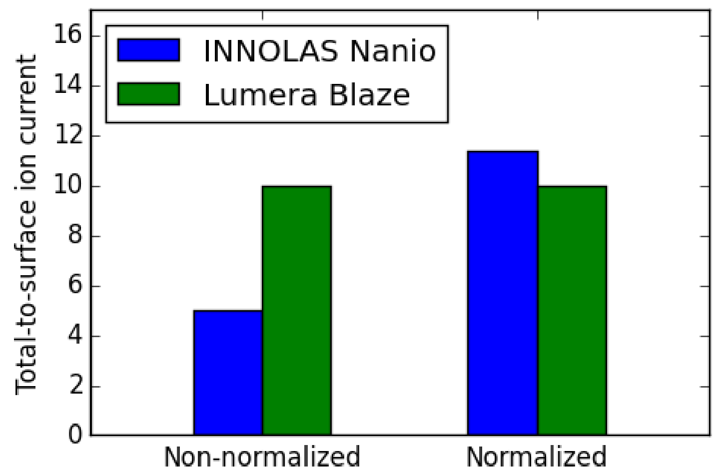
- Z-cavity Ti:Sa pumping:
- Better per-watt performance compared to Photonics Industries DM60.

- Non-resonant ionization:
- Similar performance compared to Blaze (when power normalized).
- Confirms excellent beam quality.

- System is versatile.

- Loan laser system purchased as part of combined deal with MEDICIS pump laser acquisition.





Laser failures

- Photonics DM-60:
- PX3 self-immolated in **Nov 17** – sent to Nexlase for post mortem.
- Replacement (PX4) arrived **May 18**.
- PX4 broke after Q-switch malfunction in **Jun 18** – occurred during IDS Cu run.
- Sent for repair and received system back in **Aug 18**.
- Not tested due to missing key and interlock connector.

Laser failures

- Edgewave INNOSLAB:
- Installed in **2017**.
- 30% loss in power measured in **Apr 18** – hotspot inside resonator killed Nd:YAG crystal.
- System sent for repair and returned in **Jul 18**.
- Total failure in **Sep 18** – during ISS Hg run.
- Replaced with old Edgewave system.
- System at company – no news on cause of failure or return date.

Laser failures

- INNOLAS Nanio:
- Loan system (Nanio 1) laser cavity flooded **Jun 18**.
- Replacement system (Nanio 2) arrived a week later.
- Nanio 2 failed **Oct 18** – due to some electrical failure.
- System sent for repair.

Laser failures

RILIS

- INNOLAS Nanio:
- Loan system (Nanio 1) laser cavity flooded **Jun 18**.
- Replacement system (Nanio 2) arrived a week later.
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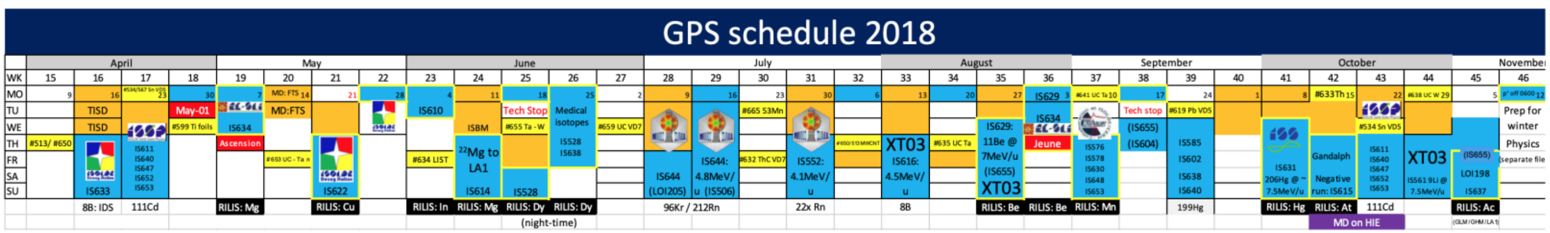
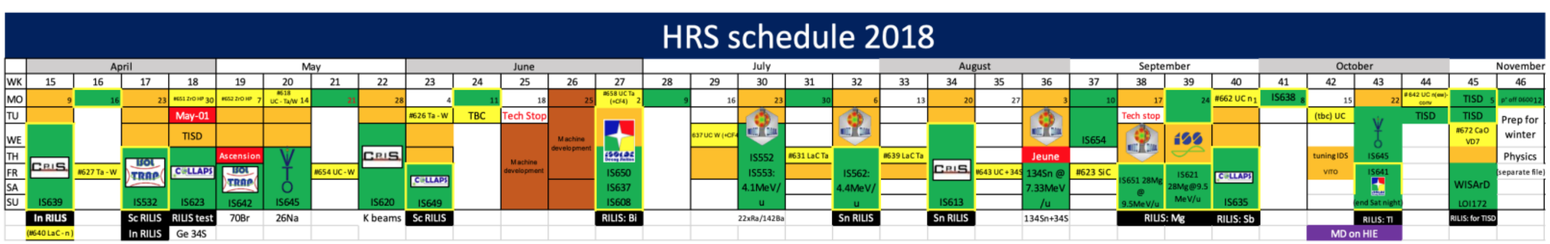
2018 On-line period statistics

RILIS

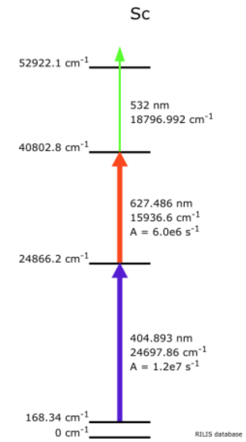
- **14** elements:
  - In, Sc, Mg, Cu, Dy, Bi, Sn, Be, Mn, Mg, Sb, Hg, Tl, Ac, Al.
- **21** separate on-line runs (not including TISD).
- **3** elements for TISD over 2 days:
  - Ga, In, Zn.
- **>50 %** of ISOLDE beams in 2018.

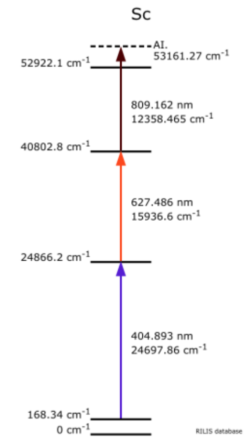


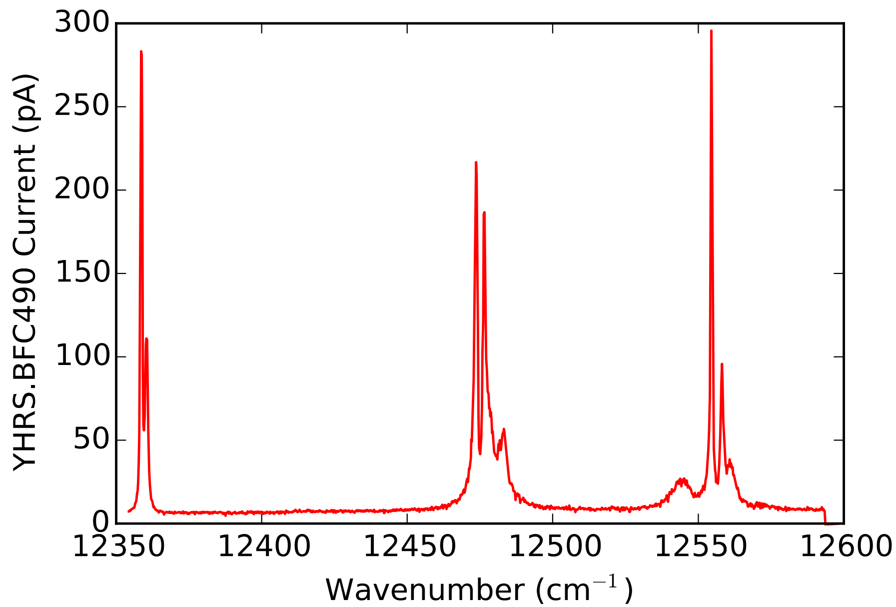


Sc scheme development

- First Sc runs in 2018 for ISOLTRAP and COLLAPS.
- Compare 2 previously used schemes.
  - Non-resonant final step vs transition to auto-ionizing state (AI).
- AI scheme **3x** more efficient.
- Found a slightly more efficient AI at 12554.5 cm^{-1}.
- Search stopped after target vent.

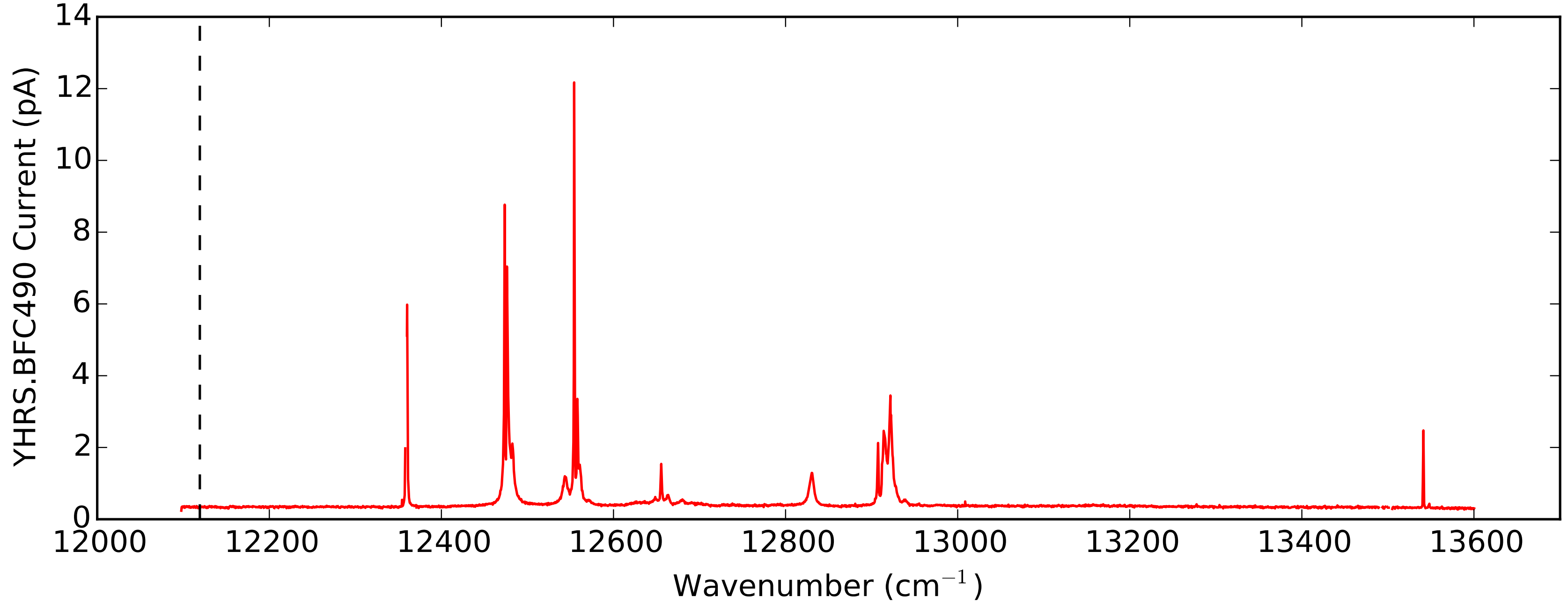






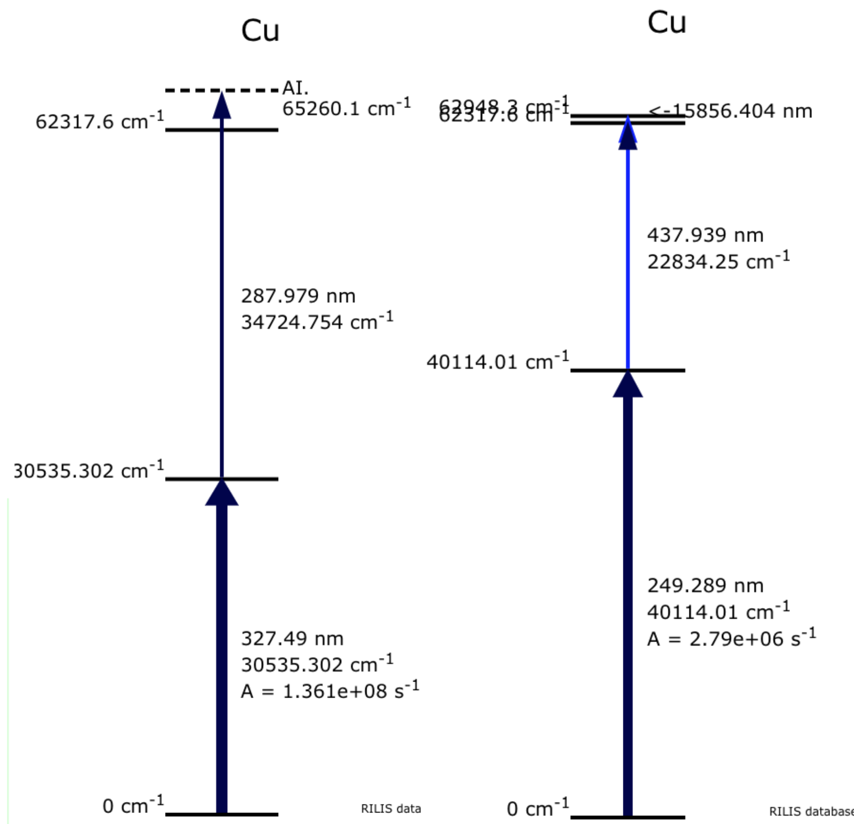
Sc scheme development

- Before COLLAPS beamtime:
- More time to search for AIs.
- Scanned from IP – using grating Ti:Sa.
- Found 1 new AI – not as efficient as previously used transition.



Ti:Sa-only Cu scheme

- Usual scheme uses 2 dye lasers.
- 2nd step requires high-power UV step.
  - Requires frequent maintenance.
  - Dye changes, cleaning of optics after UV generation.
- TRILIS scheme avoids high-power UV step and dye lasers altogether.
  - J. Lassen (private communication).
- Ti:Sa scheme **2.5x** efficient.
- Used for IDS experiment until pump laser failure forced a switch back to the dye scheme.



Ti:Sa-only Sb scheme

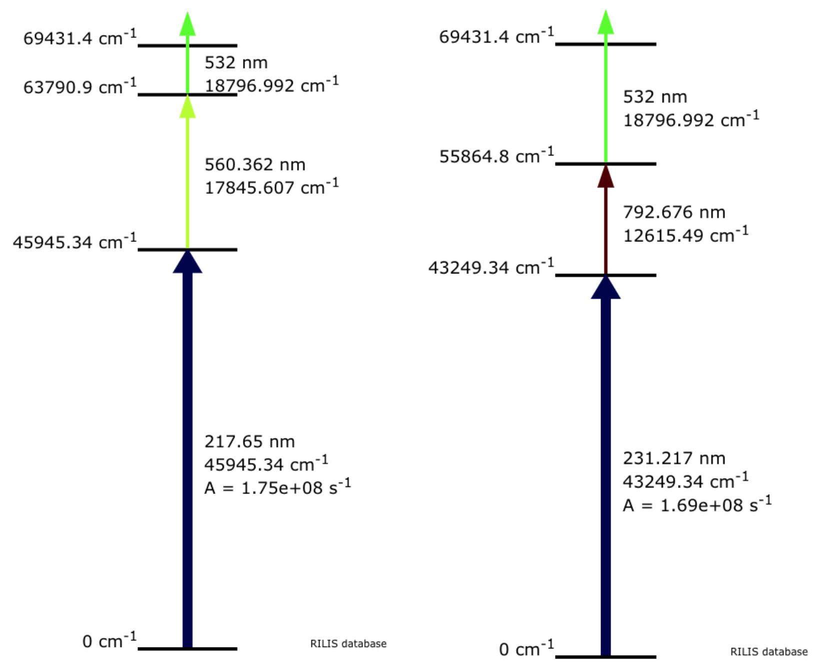
RILIS

- Original scheme developed a long time ago.
- Non-resonant ionization forces excited atoms far above continuum.
- Tested TRILIS scheme.
- **~2x** as efficient as dye scheme.
- Ti:Sa scheme used in successful COLLAPS beamtime.

ELSEVIER
Spectrochimica Acta Part B: Atomic Spectroscopy
Volume 128, 1 February 2017, Pages 36-44

Laser resonance ionization spectroscopy of antimony

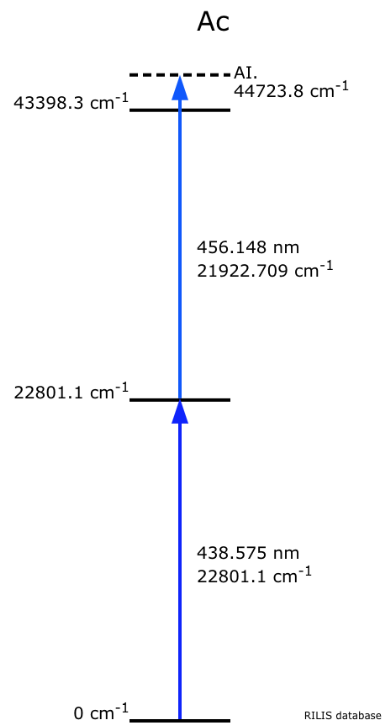
R. Li [a], J. Lassen [a, b, c], J. Ruczkowski [d], A. Teigelhöfer [a, b], P. Bricault [a]

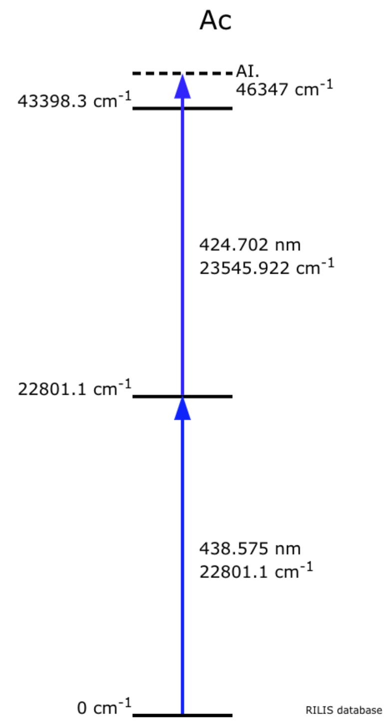


First laser-ionized Ac at ISOLDE

RILIS

- New RILIS element at ISOLDE.
- Ac experiments during last week of protons.
- Tested two schemes – transitions to different AIs.
  - Hot-cavity scheme (TRIUMF).
  - Gas-cell/jet scheme (LISOL).
- Schemes equally efficient.





Hyperfine Interactions
April 2013, Volume 216, Issue 1–3, pp 33–39 | Cite as

In-source laser spectroscopy developments at TRILIS—towards spectroscopy on actinium and scandium

Authors | Authors and affiliations

Sebastian Raeder, Marik Dombsky, Henning Heggen, Jens Lassen, Thomas Quenzel, Marica Sjödin, Andrea Teigelhöfer, Klaus Wendt

nature COMMUNICATIONS

Article | OPEN | Published: 22 February 2017

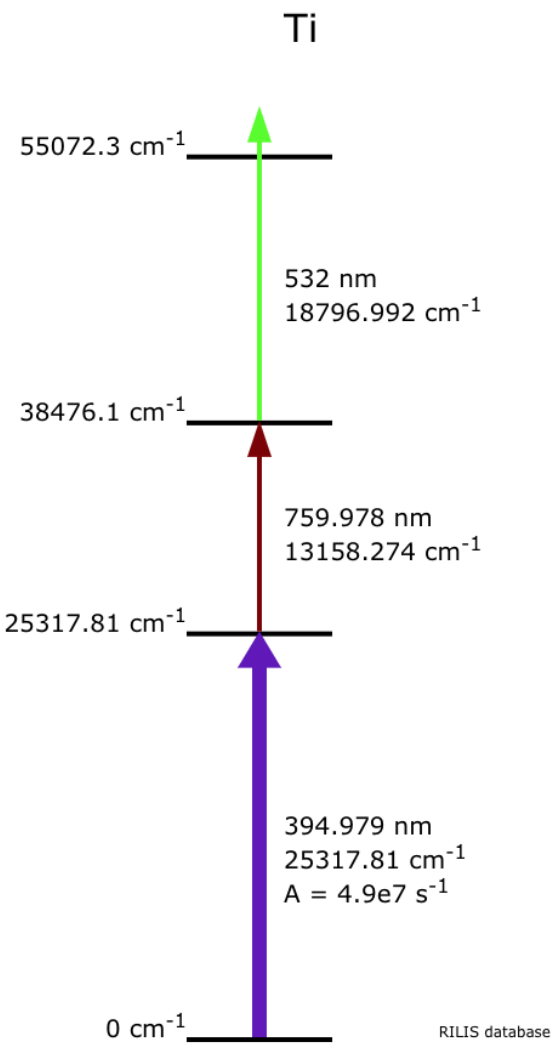
Towards high-resolution laser ionization spectroscopy of the heaviest elements in supersonic gas jet expansion

R. Ferrer, A. Barzakh [...] A. Zadvornaya

Nature Communications 8, Article number: 14520 (2017) | Download Citation

Ti scheme efficiency

- Request for Ti RILIS efficiency measurement for ^{44}Ti run.
- Two calibrated mass markers (**560 nAh**, **5600 nAh**).
- Efficiency measurement from small Ti sample: <**6.4 %**.
- Line failure during big sample measurement – current return for mass markers through line.
- Big mass marker could have released Ti through heating small marker.
- Plan: surface ionization efficiency measurement at Offline 1.
- Use known laser/surface ratio at line temperature to show RILIS efficiency.



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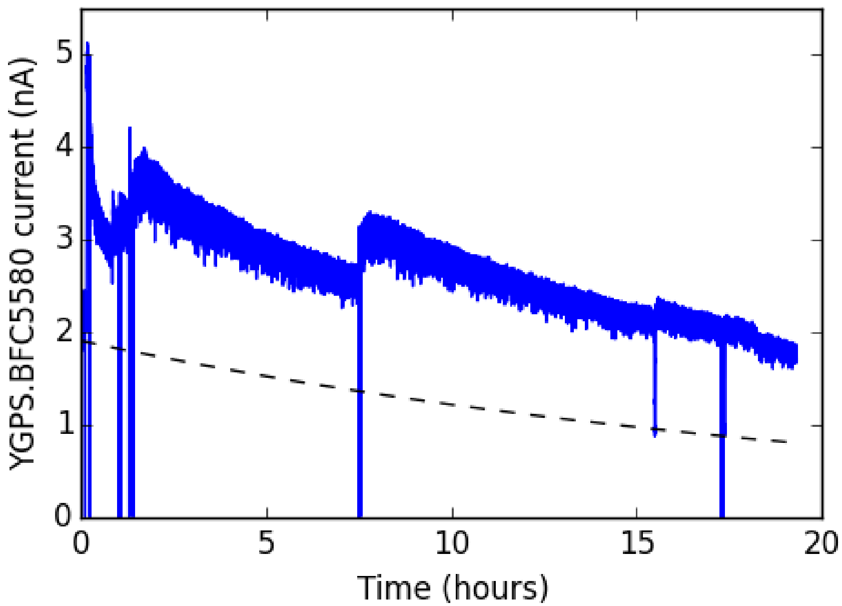
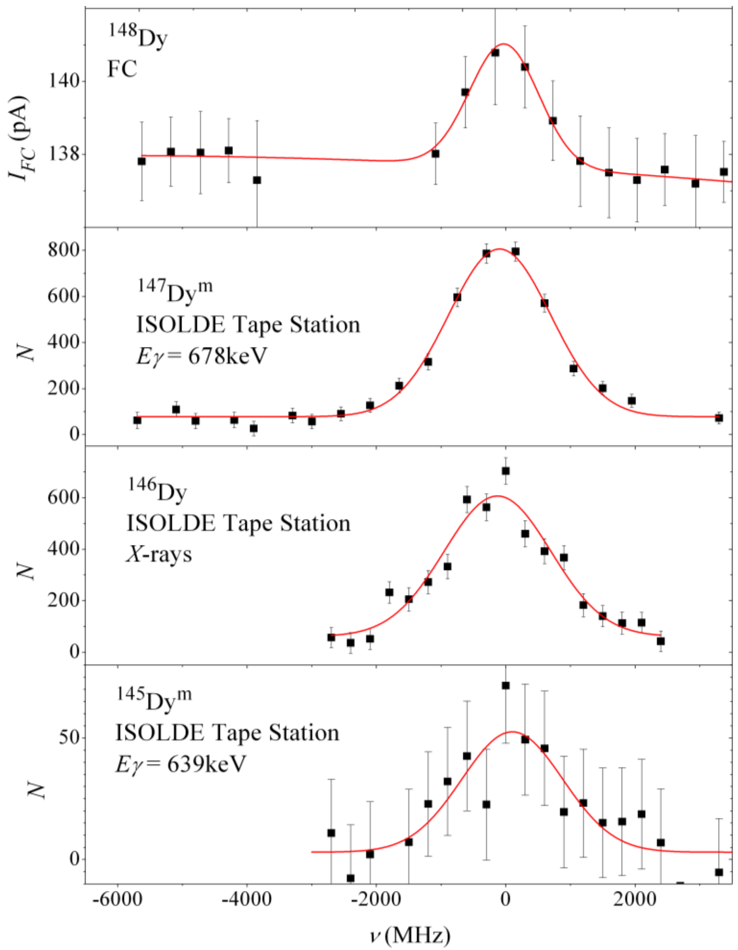


In-source spectroscopy of Dy and Bi

- Continuation of IS608 for Bi (Z=83).
- First in-source measurements of Dy (Z=66).
- First on-line use of narrowband intracavity-doubled grating Ti:Sa.
- Motivation: to measure changes in mean-square charge radii below N=82.
- Combination of Faraday cup/tape station scans.

- Results will be published in EMIS proceedings by K. Chrysalidis.



A. Barzakh

In-source spectroscopy of Dy and Bi

RILIS

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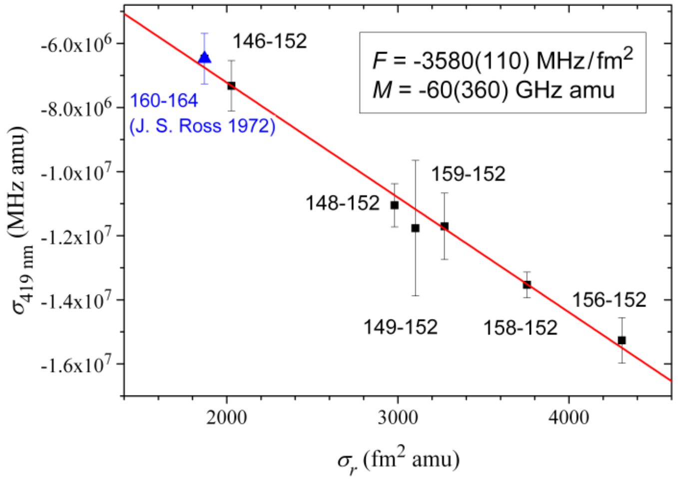
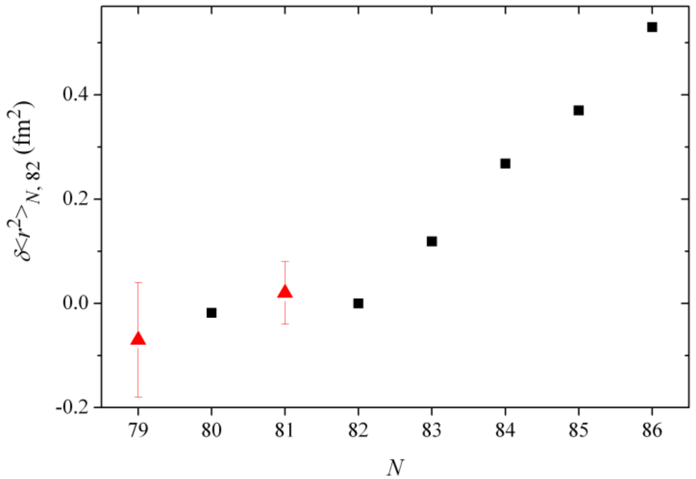




A. Barzakh

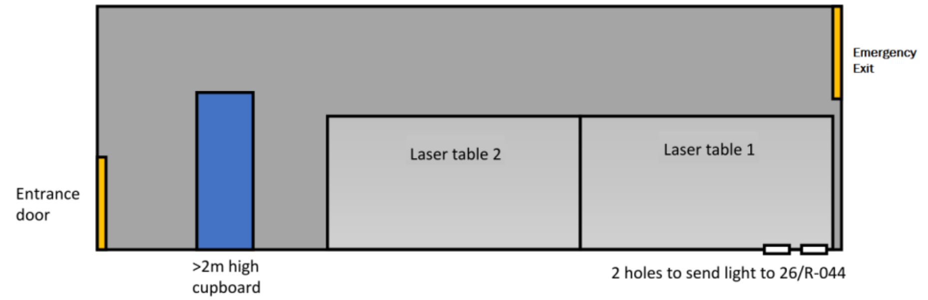
Lasers for GANDALPH

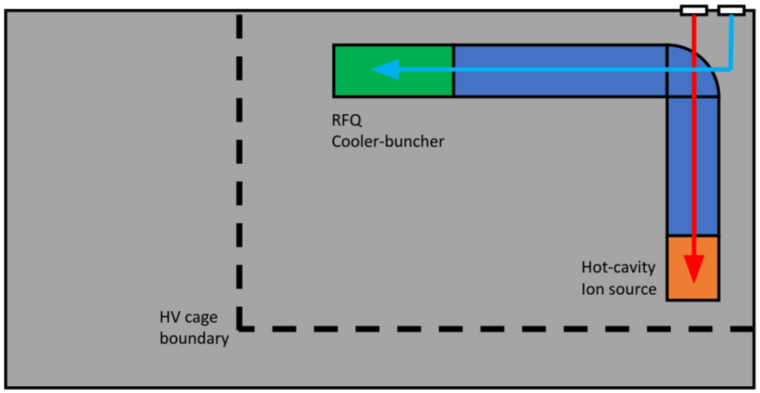
RILIS

- Collaboration with GANDALPH for electron photodetachment of negative ions.
- Laser light sent to GLM for I, At, Cl experiments.
- See talk by D. Leimbach (directly after this talk!).

Offline 2

- New offline lab for research and development.
  - Home for RILIS developments during LS2.
- Completed:
  - Laser interlock design and installation (BE-ICS).
  - Laser tables installed.
  - Optical table layout designed.
- To be completed:
  - Air-conditioning and water cooling circuit installation (EN-CV) - **Ongoing**.
  - Move and install spare RILIS hardware – **Jan-Feb 19**.



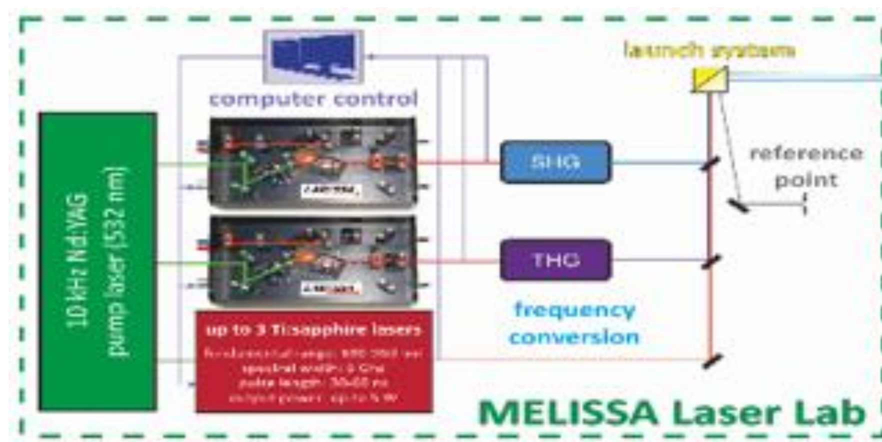


MELISSA at MEDICIS

RILIS

- Completed:
- AC installation.
- Laser tables moved in.

- To be completed:
- Install lasers - **Jan 19**.
  - 2x InnoLas Nanio arrived and tested at CERN.
  - Ti:Sa cavities assembling.
- Laser interlock installation - **Jan 19**.
- Beam path to MEDICIS - **Jan 19**.
- Ready for commissioning in **Jan/Feb 19** – Sm.
- Laser operation for **Tb Mar 19**.

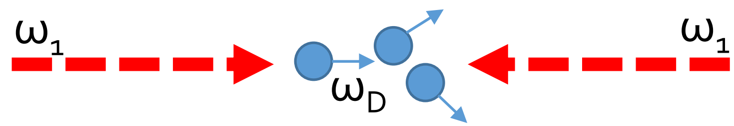


V. Gadelshin and K. Dockx

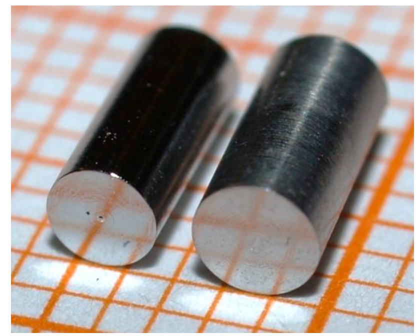
Two-photon in-source spectroscopy

- Doppler broadening limits applicability of in-source spectroscopy to heavy elements.
- Doppler-free two-photon spectroscopy offers route to high-resolution in-source spectroscopy.
- Developments required:
  - Narrowband pulsed laser (< 100 MHz).
  - Reflective surface inside ion source.
  - Examples of Mo surface on right.

$$(\omega_1+\omega_D)+(\omega_1-\omega_D)=2\omega_1$$

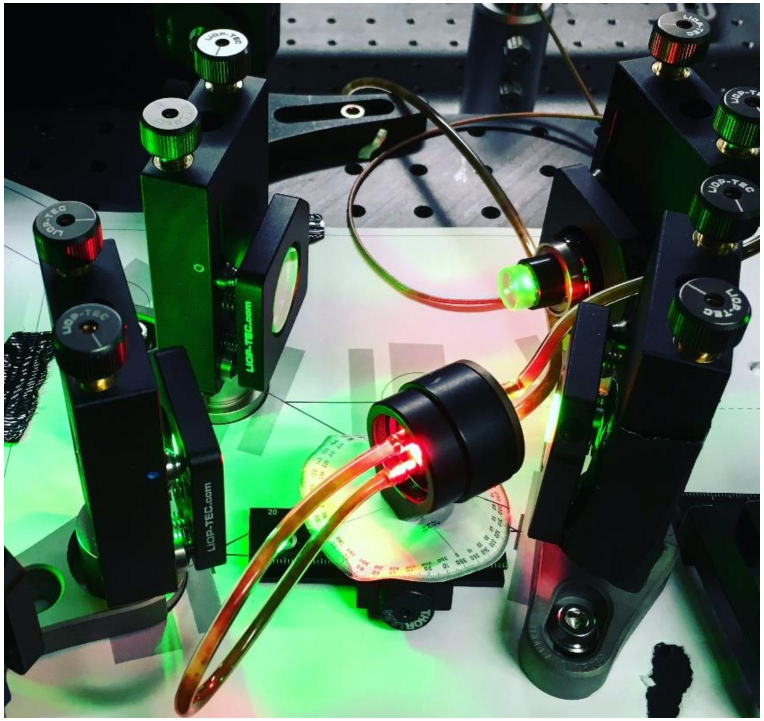


K. Chrysalidis



Injection-seeded Ti:Sa

- Bow-tie cavity geometry designed and 'printed' onto breadboard.
  - Design made by D. Studer (Mainz).
- Compatible with current Z-cavity Ti:Sa mirrors.
- Seed laser light provided by CRIS (SolsTiS/Matisse) through 50-m fibre.
- Piezo-actuated mirror locks cavity to seed.
- Commissioned and operational.
- 2nd system built and installed in CRIS lab.

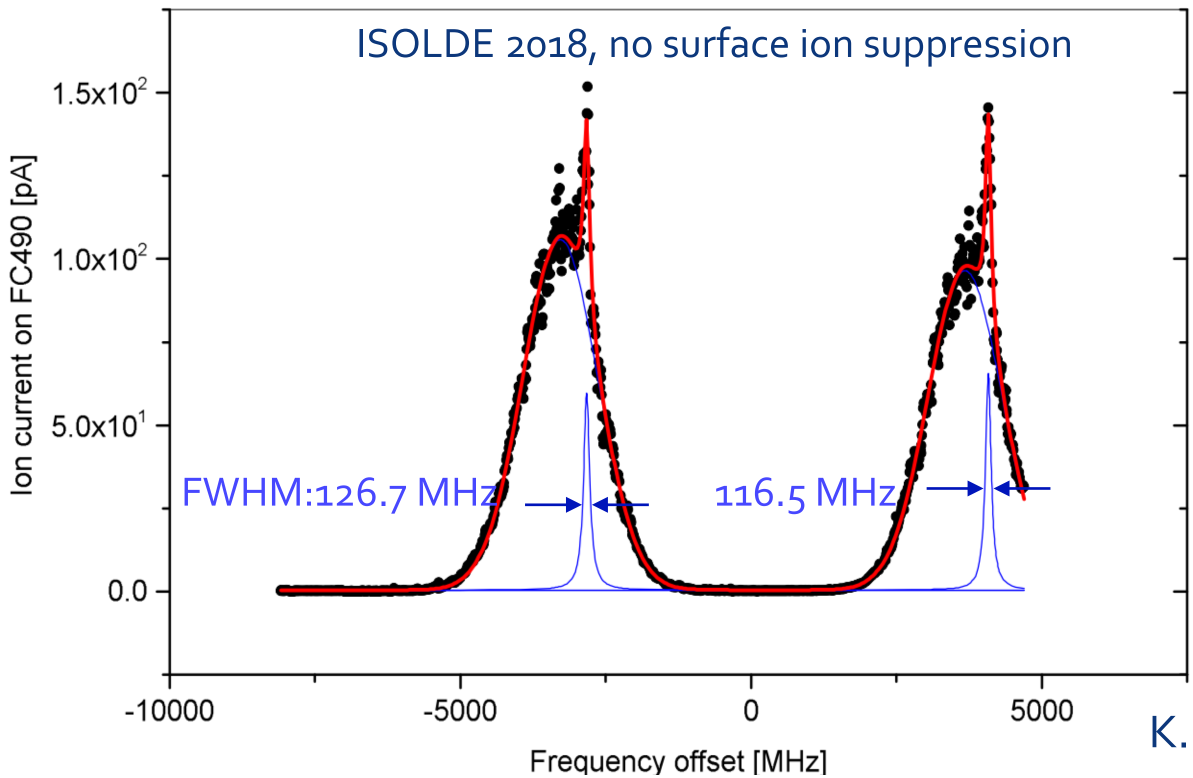


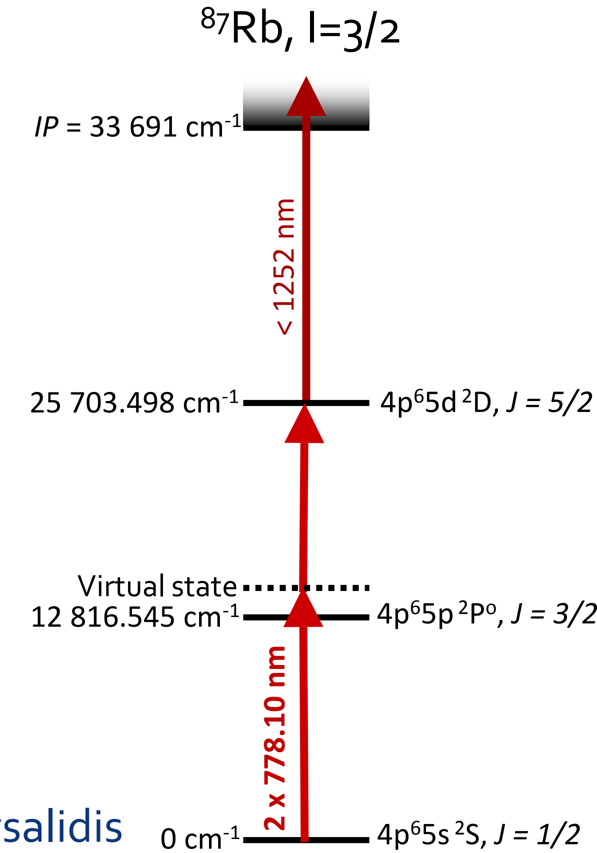
K. Chrysalidis

First measurements at ISOLDE

RILIS

- Measurement of 5s-5d transition in 87Rb.
- Results will be published in EMIS proceedings by K. Chrysalidis.
- Optimization of mirror geometry during LS2.

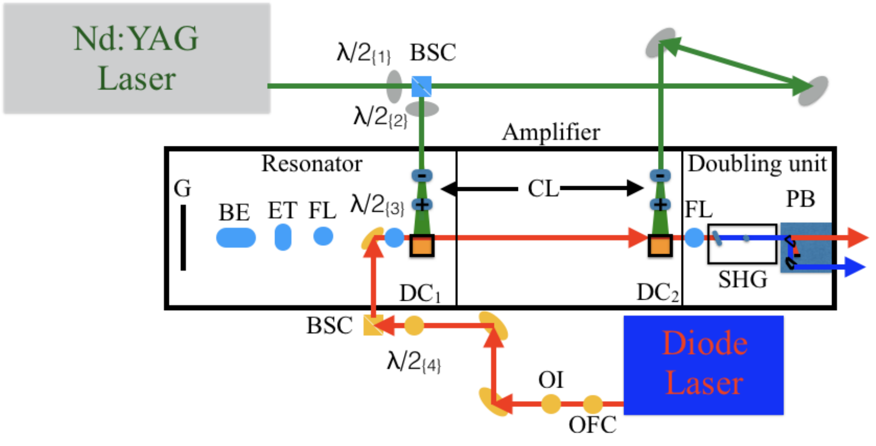




K. Chrysalidis

Pulsed-dye amplifier

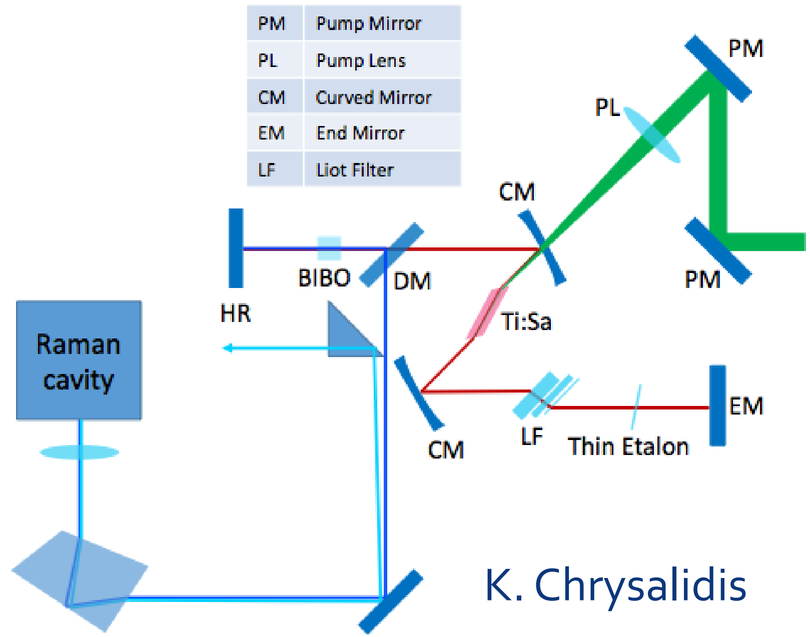
- Complementary system to injection-seeded Ti:Sa.
- Seed laser light provided by continuous-wave dye laser.
- Narrowband amplified light produced.
- Characterization of system through offline spectroscopy in reference cell in coming months (PISA).



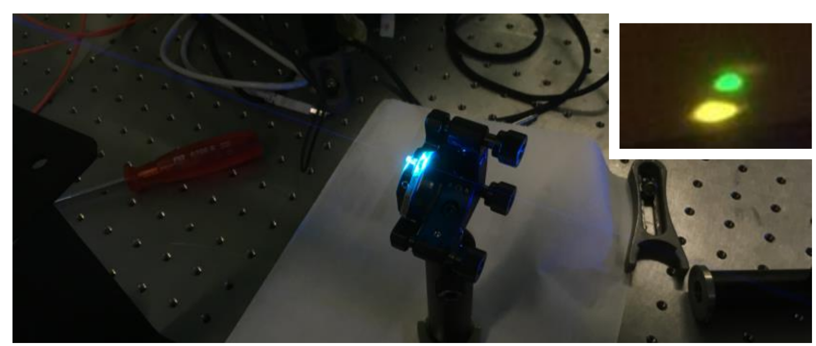
C. Granados

Solid-state Raman laser for RILIS

- Attempt to bridge gap between blue TiSa and dye range.
- Collaboration with E. Granados (EN-STI-LP), R. Mildren (Macquarie University).
- Use blue Ti:Sa to pump diamond Raman laser.
- Promising results already obtained.
- Additional funding under discussion with Knowledge Transfer.
  - Dedicated student(s) during LS2.



K. Chrysalidis

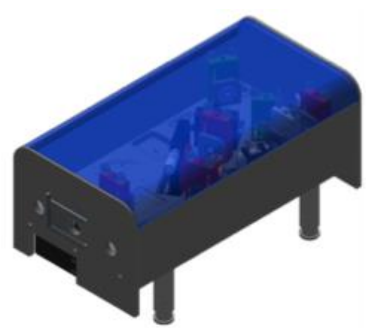


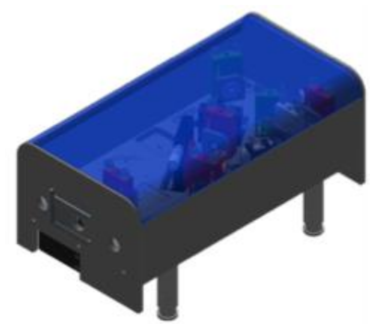
RILIS hardware consolidation

RILIS

- Completed:
- Dye pump laser replacement.
- New Ti:Sa cavities.
- Alternative Ti:Sa pump laser.
- High-resolution laser systems.

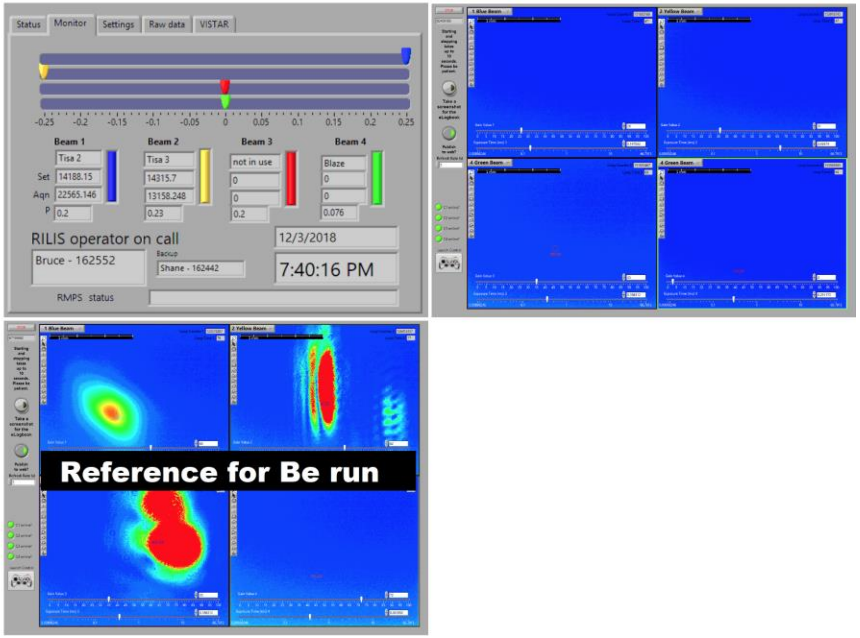
- Planned:
- ~~Spare Blaze laser.~~
- Test/purchase replacement Blaze laser.
- Test picosecond laser for molecular breakup.
- Replace dye lasers.





Dual-separator RILIS operation

- Upgraded laser beam observation and stabilization system.
  - Allow beams from both separators to be stabilized.
- Reduced setup time and faster switching between elements and separators.
- Re-arrange optical layout with compact telescopes and additional optics/optomechanics to facilitate dual-separator operation.



Summary

- 14 elements for 21 separate on-line runs + TISD week, >50% of ISOLDE beams in 2018.
- Scheme development/testing on Sc, Cu, Sb.
- Ti RILIS efficiency: <6.4 %.
- Ac established as a new RILIS element.
- First 2-photon in-source measurements at ISOLDE.
- Development and commissioning of high-resolution systems.
- Progress on constructing and equipping new lasers labs at Offline 2 and MEDICIS.
- Outlook for LS2.

Acknowledgements

The RILIS team

Dima, Maxim, Pavel at PNPI

In-source spectroscopy collaboration

ISOLDE technical teams:
Target group, operators, workshop technicians

CRIS, COLLAPS

LARISSA group, Mainz

Thank you for your attention!

ENGINEERING DEPARTMENT

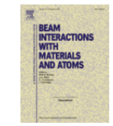
Ion source developments

- VADLIS:
- Variable extraction voltage as standard for on-line operation.
  - 3x increase in RILIS efficiency.
- Further optimization for RILIS-mode operation.

ELSEVIER

Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms

Volume 431, 15 September 2018, Pages 59-66



Enhancing the extraction of laser-ionized beams from an arc discharge ion source volume

Y. Martinez Palenzuela [a, c], B.A. Marsh [a], J. Ballof [a, b], R. Catherall [a], K. Chrysalidis [a, d], T.E. Cocolios [c], B. Crepieux [a], T. Day Goodacre [a, e, f], V.N. Fedosseev [a], M.H. Huyse [c], P.B. Larmonier [a, g], J.P. Ramos [a], S. Rothe [a], J.D.A. Smith [h], T. Stora [a], P. Van Duppen [c], S. Wilkins [a]

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https://doi.org/10.1016/j.nimb.2018.06.006

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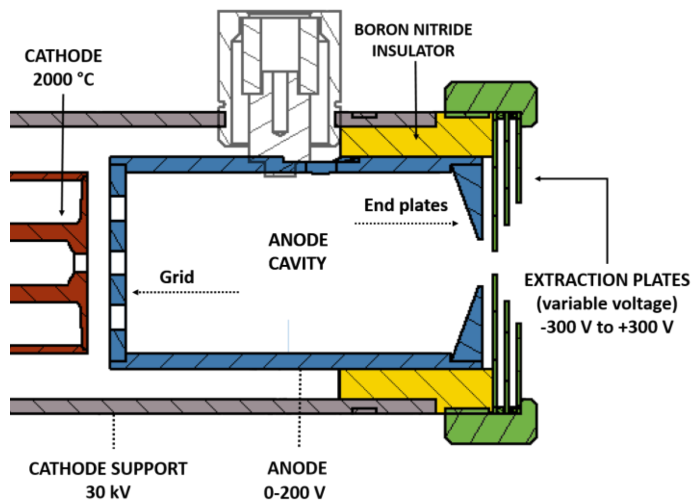

- LIST:
- Compatibility with HRS and GPS.
- ToF-LIS:
  - Fast beam gate at time focus of laser ion bunches.
  - Improvement in selectivity.

High-resolution in-source techniques

- 2-photon:
- Optimization of mirror geometry.

- PI-LIST:

- Isomer selectivity for

- 2-photon ionization for new RILIS elements.
  - Phosphorus,

Molecular breakup

- Could provide access to atomic form of refractory elements.
- Extract as volatile element, breakup and then ionize element.
  - VADIS ionization of molecule not selective.
- Breakup requires multiple photons.
- Need very high peak powers for this to be efficient.
- Systems to test:
- Lumera Blaze – **0.2 MW**
- InnoLas FEMTO – **4 – 30 MW**.
- Edgewave FX - **>800 MW**.