The Resonance Ionization Laser Ion Source at CERN-ISOLDE
Expanding limits of selectivity, intensity, spectroscopy

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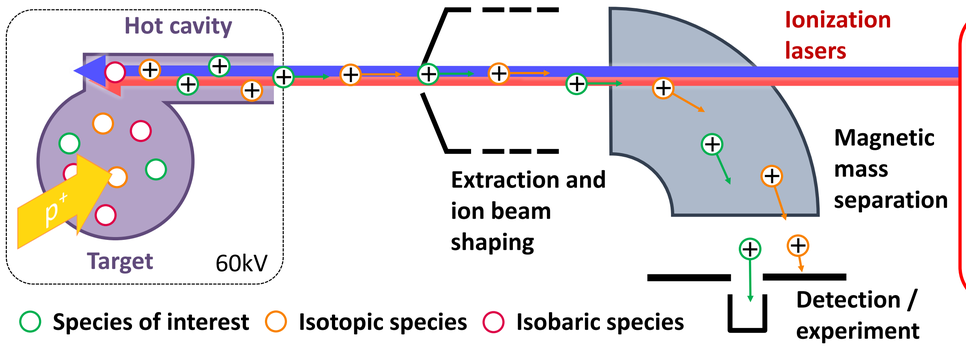
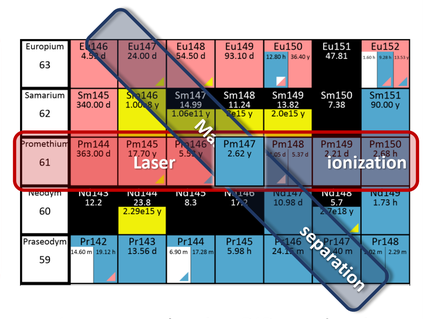
Element-selective radioactive ion beam production: **RILIS**

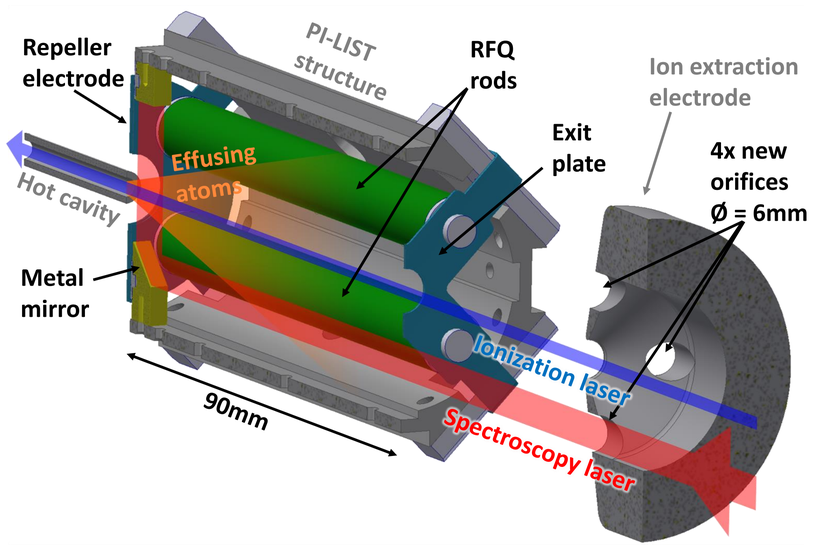
Resonance ionization laser ion sources (RILIS) [1] provide high selectivity and efficiency in the production of isotopically enriched **radioactive ion beams (RIBs)** at on- and off-line facilities such as CERN – ISOLDE [2]. Wavelength-tunable lasers are used to address fingerprint-like electronic shell transitions to subsequently excite and detach an electron of the element of choice while leaving other species unaffected.





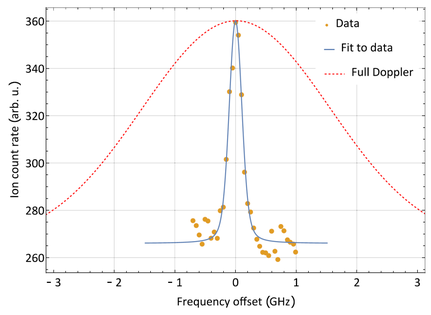
Isotope-selective RIB production

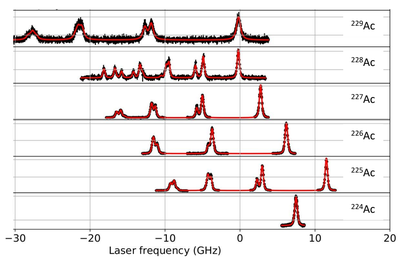
"Sub-Doppler" in-source laser spectroscopy: **PI-LIST**



CAD model of the PI-LIST as installed at ISOLDE [3]

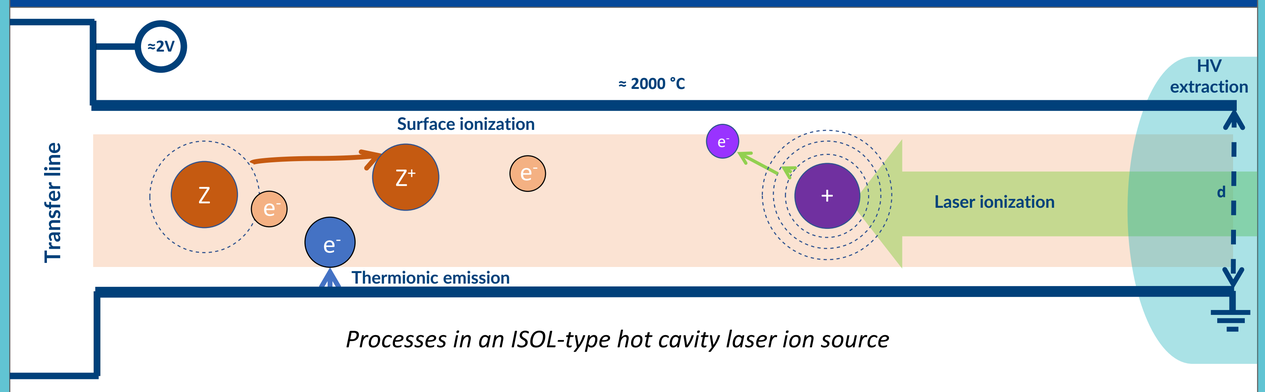
- Experimental resolution in hot cavity laser source limited by **Doppler broadening to the order of several GHz**
- **PI-LIST** (Perpendicularly Illuminated Laser Ion Source and Trap) provides **crossed laser / atom beam environment** to address lateral velocity classes
- Successful ISOLDE integration in 2022 [3]
  - Resolution gain of one order of magnitude: **100 – 200MHz**
  - Efficiency in the order of **0.01 %** (Standard RILIS: 10%)
  - Nuclear structure investigation on neutron-rich actinium within **EU network LISA (Laser Ionization and Spectroscopy of Actinides)**
- Versatile ion source with in-situ mode change:
  - *Ion guide*: High efficiency, resembling RILIS
  - *LIST* [4]: Contamination suppression, reduced efficiency
  - *PI-LIST*: Laser spectroscopy and *isomer-pure* RIB production



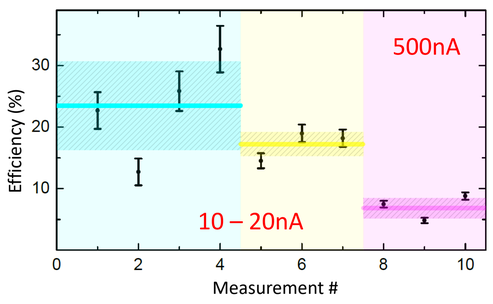


Resolution comparison [3] and actinium laser spectroscopy results

High intensity beams: **Ion confinement**

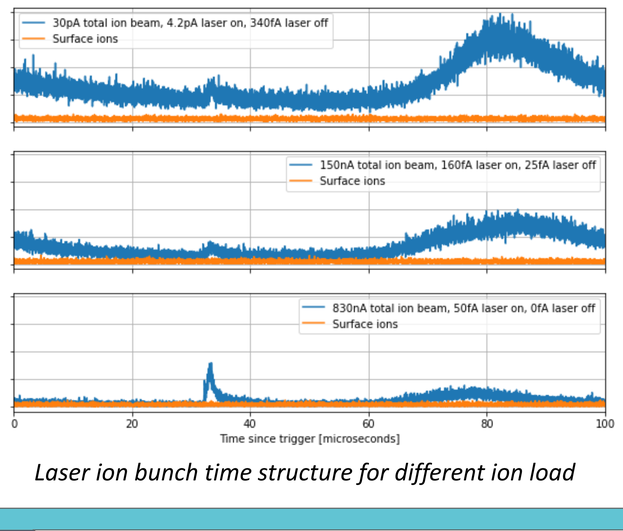


Processes in an ISOL-type hot cavity laser ion source

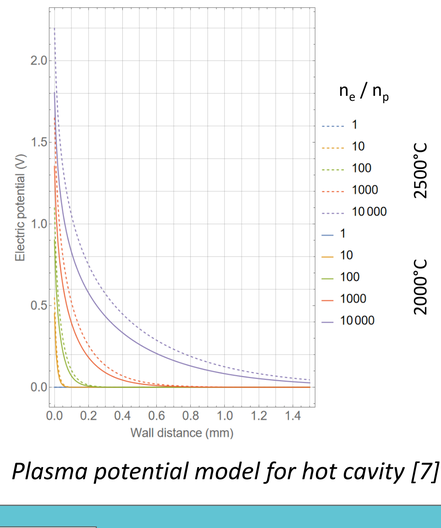


Manganese efficiency vs extracted beam intensity [5]

- Efficiency of laser ionization and ion beam extraction process depends on **total ion load** in the hot cavity interaction volume
- Specifically important for off-line **medical isotope extraction** (e.g. MEDICIS [6]): Time-critical collection times
- Reason: Breakdown of **ion-confining plasma** potential for surplus of positive charges
- Systematic investigations via pulsed laser ion bunch **time structures and simulations**

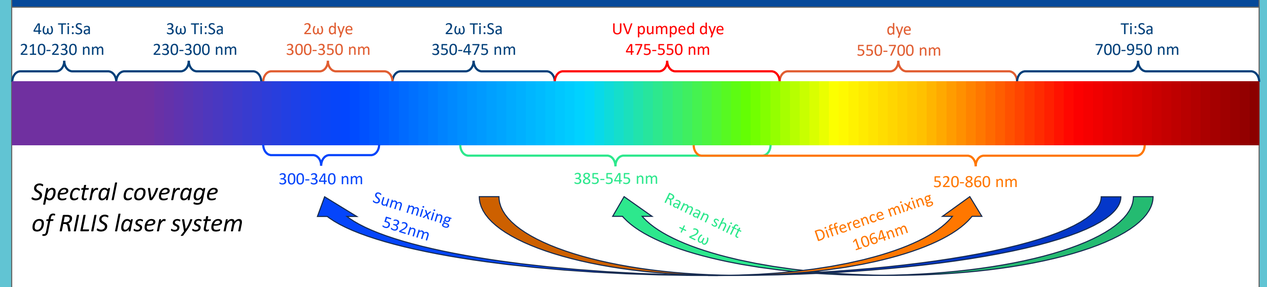


Laser ion bunch time structure for different ion load



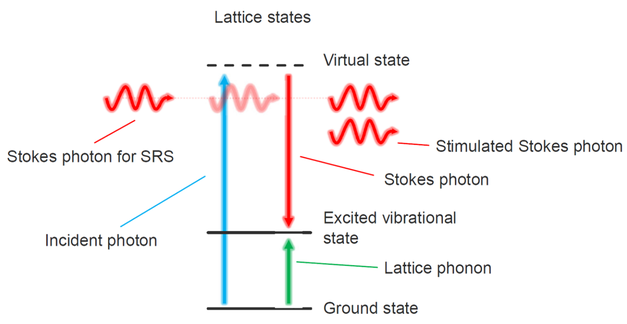
Plasma potential model for hot cavity [7]

VUV to IR in solid state: **Laser development**



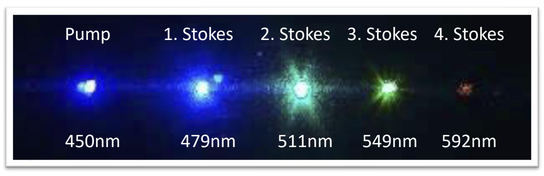
Spectral coverage of RILIS laser system

- Solid state laser technology offers **low-maintenance 24/7 facility operation**
- State-of-the-art **Titanium:sapphire (Ti:Sa) lasers** [8] developed in collaboration with RIB facilities world-wide
- Use of various photonics techniques to **enhance spectral coverage** of fundamental infrared Ti:Sa output



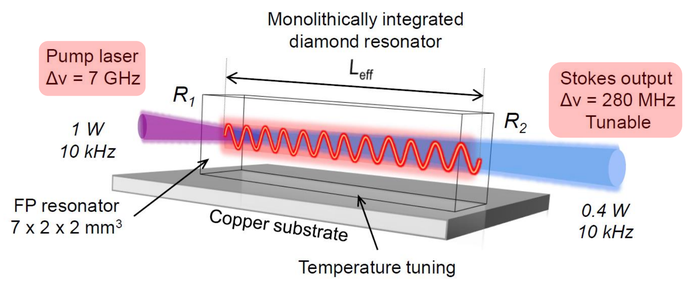
Principle of Stimulated Raman Scattering (SRS)

- **Stimulated Raman Scattering** for frequency red-shift
- Shift for diamond: 0.17 eV
- **Cascading** for subsequent shifts

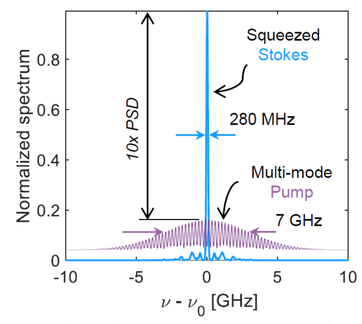


Cascading of Stimulated Raman Scattering [9]

Spectral squeezer: Single-mode narrowband Raman converter



Single mode operation: diamond as Fabry-Perot resonator [10]



Simulated spectral in-/output [10]

Contact & Refs.

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Conclusion & Outlook

- RILIS as workhorse ion source at RIB facility CERN-ISOLDE: **22 elements for 55% of experiment shifts in 2022**
- First time implementation of PI-LIST for in-source high resolution spectroscopy: Ongoing programs in **actinide and lanthanide** section of nuclear chart
- Cross-facility program to investigate high throughput ion source efficiencies: Experimental and simulation campaign with **ion source designs from ISOLDE, SPES (Italy), SCK CEN (Belgium)**
- Implementation of **fixed design conversion units** in laser setups for spectral coverage extension
- Narrow bandwidth laser light generation: Essential component for high-resolution spectroscopy