The application of laser resonance ionization inside FEBIAD-type ion sources for ISOL facilities.

Bruce Marsh, CERN EN-STI-LP
RILIS LASERS

~10 cm

> 20 m optical path
3 mm diameter ion source

Proton beam from PSB
Drawbacks of hot-cavity laser ion sources

- Surface ionized contamination
  - long standing issue but no universal solution has been found
- Limited ion capacity (~ 1 uA)
  - possible issue for EURISOL, ISOL@MYRRHA etc.
- Not currently suitable for liquid targets
- Limited scope for non-standard RILIS applications
Using a FEBIAD as a laser/atom interaction region

- Normally used for non surface-ionizing elements
- Ar or Xe plasma with 130 eV electrons

**FEBIAD series:**
- MK5
- MK7

**VADIS series:**
- VD5 is identical to MK5 FEBIAD
  - but with Mo components to reduce contaminants

3D VADIS drawing taken from Alberto Andrighetto’s talk
Cathi Meeting
Sept ‘14
WP1: coupling of the IRENA radial-FEBIAD device and the laser ion source

<table>
<thead>
<tr>
<th>Partners</th>
<th>Requested budget</th>
<th>Responsable Labo</th>
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<tr>
<td>CERN</td>
<td>0 k€</td>
<td>B. Marsh</td>
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<tr>
<td>IFJ (Poland)</td>
<td>25 k€</td>
<td>R. Misiak</td>
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<td>IPNO</td>
<td>210 k€</td>
<td>C. Lau</td>
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<tr>
<td>LNL-INFN</td>
<td>60 k€</td>
<td>A. Andrighetto</td>
</tr>
<tr>
<td>SLCJ (Poland)</td>
<td>25 k€</td>
<td>J. Choinski</td>
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Work Package

Project coordination

WP1: IRENA device for the RILIS
WP2: Beam extraction
WP3: Physicochemical alteration
WP4: Material for selective regulation

C. Lau et al., EURISOL-NET, CERN 27 June 2011
RILIS R&D setup at ISOLDE off-line separator

Ionization scheme for gallium
First Off-line test

Modified (2.5 mm diameter entrance aperture) VADIS + Ga mass marker

Optional pulsed ANODE @ laser rep rate
1 --> 100 μs, 0 - 200 V pulses synchronized with lasers, with DC offset
1) RILIS efficiency is comparable to VADIS efficiency
2) FAST switching between RILIS / VADIS modes
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Laser pulse repetition rate of 10 kHz!
2) FAST switching between RILIS / VADIS modes
3) Long residence time of ions wrt. hot cavity

Modified VADIS + Ga mass marker
3) Long residence time of ions wrt. hot cavity

Modified VADIS + Ga mass marker

CPO simulation of the internal electrical field distribution

- With electrical charges (1 passage through the volume)
- Active volumes (in color): (132V; 149.8V) for MK7; (130V; 149.8V) for MK5

Th diffusion:

The difference in active volumes can justify the efficiency difference.

Hot-cavity RILIS

RILIS mode in VADIS

Total generated currents:
- Electrons: 15 mA (150 eV)
- Ions: 2.5 μA (0.2 eV)
3) Long residence time of ions wrt. hot cavity

Modified VADIS + Ga mass marker

Hot-cavity RILIS

<table>
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<tr>
<th>Counts</th>
<th>5 kHz</th>
<th>10 kHz</th>
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<tr>
<td>150</td>
<td></td>
<td></td>
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<tr>
<td>100</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
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RILIS mode in VADIS

<table>
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<th>gallium ion counts on MCP</th>
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<tbody>
<tr>
<td>1500</td>
</tr>
<tr>
<td>1000</td>
</tr>
<tr>
<td>500</td>
</tr>
<tr>
<td>0</td>
</tr>
</tbody>
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VADIS "active" volume

Total generated currents:
- Electrons: 15 mA (150 eV)
- Ions: 2.5 μA (0.2 eV)

CPO simulation of the internal electrical field distribution

- With electrical charges (1 passage through the volume)
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L. Penescu, R. Catherall, J. Lettry, and T. Stora

Development of high efficiency Versatile Arc Discharge Ion Source at CERN ISOLDE

Citation: Rev. Sci. Instrum. 81, 02A906 (2010); doi: 10.1063/1.3271245
View online: http://dx.doi.org/10.1063/1.3271245
First On-line test

Standard VADIS + liquid Pb target @ ISOLDE

The first RILIS ionized isotopes from a liquid target

Tom Day Goodacre (CERN, Manchester) – PhD work
Establishing modes of operation
Establishing modes of operation

ANODE:
- 120 V
- 10 V
- 120 V
- 120 V

Hg alpha count rate

178Hg alpha count rate

Alphas per second (counts s⁻¹)

Ion Sources

VADIS
RILIS
VADIS + Blaze
RILIS + VADIS

ANODE: 120 V 10 V 120 V 120 V

Gα Ion Signal (pA)

RILIS Mode
VADIS Mode

Ion Current (A)

No VADIS Ionization

Anode Voltage (V)

Anode Voltage (V)
Establishing modes of operation

These measurements were obtained with a standard VADIS under normal operating conditions - lots of room for optimization!
EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
Proposal to the ISOLDE and Neutron Time-of-Flight Committee

In-source laser spectroscopy of mercury isotopes
October 10, 2014


1KU Leuven, Belgium; 2CERN-ISOLDE, CH; 3The University of Manchester, UK; 4The University of York, UK; 5PNPI, Gatchina, Russia; 6CENBG, Bordeaux, France; 7Johannes Gutenberg University of Mainz, Germany; 8GSI, Darmstadt, Germany; 9Ernst-Moritz-Arndt Universität Greifswald, Germany; 10Max-Planck-Institut für Kernphysik, Heidelberg, Germany; 11Comenius University, Bratislava, Slovakia; 12CSNSM-IN2P3-CNRS, Orsay, France; 13Technische Universität Dresden, Germany.

Abstract: This proposal follows on from the Letter of Intent, I153. The neutron-deficient mercury isotopes are one of the prime examples of shape coexistence anywhere in the nuclear chart. Wide-ranging and complementary experimental and theoretical approaches have been used to investigate their structure over the last few years, however mean-square charge radii are unknown for isotopes with \( A < 181 \). It is proposed to measure the isotope shift (IS) and hyperfine structure (HFS) of the 253-nm transition in \(^{177}\text{Hg} \) in an attempt to study the propagation of the famous odd-even staggering behaviour. At the other end of the chain, no information exists on the optical spectroscopy of Hg isotopes beyond the \( N = 126 \) shell closure. There is a well-known “kink” in mean-square charge radii beyond this point in the even \( Z = 82 \) elements. It is proposed to measure the IS of \(^{207,208}\text{Hg} \) in order to provide the first information on this effect below \( Z = 82 \).

Requested shifts: 16 shifts, (in a single run)

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Contact person: Bruce Marsh [Bruce.Marsh@cern.ch]
Introducing new RILIS + FEBIAD opportunities

- **New option for surface ion reduction**
  - Easy and fast ‘switch on/off’ of non-selective ionisation / electron impact effects
  - Immediately compatible with liquid targets
  - Greater ion capacity is expected (> 100 uA) - High-power target application?
  - New opportunity for 2-photon spectroscopy
  - RILIS ionized non metals and noble gases?
  - Ideal 2+ RILIS ionization environment?
  - Towards RILIS ionized refractory metal beams at thick-target facilities?

ANODE grid = surface ion repeller

Low work-function anode material: no surface ionized contaminants
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Modified ANODE grid

\[ \text{Molybdenum mirror} \]

50% reflectivity for all wavelengths
- increased efficiency
- **2-photon spectroscopy feasibility?**

CATHODE (LINE)
- \( < 330 \text{ A} \)
- \( T \sim 2000 \text{ C} \)

ANODE
- \( > +100 \text{ V}: \text{VADIS + RILIS ions} \)
- \( < +5 \text{ V}: \text{RILIS ions only} \)

Hg atoms

Hg ionization scheme
- RILIS TiSa + dye + Nd:YAG (Blaze)

GND

50%
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- New opportunity for 2-photon spectroscopy
- RILIS ionized non-metals and noble gases or optical pumping of ions?
- Ideal 2+ RILIS ionization environment?
- Towards RILIS ionized refractory metal beams at thick-target facilities?

RILIS lasers overlap with ‘trapped’ ions

Synchronized laser + **anode** pulsing operating cycle

Background-free RILIS ionization

**Background-free RILIS ionization**

**electron impact**

(molecular breakup, ionization, excitation of metastable atomic levels)
Introducing new RILIS + FEBIAD opportunities

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[Graph showing the relationship between temperature and intensity for different gas conditions (argon) and current settings.]

Liviu Penescu
ICIS 2009, Gatlinburg, September 2009
Outlook

• RILIS inside a standard VADIS/FEBIAD works extremely well
• RILIS, VADIS and VADLIS operating modes are tested on-line
  • This open the doors for promising new R&D for many RILIS applications
  • Much more needs to be understood about the ion dynamics inside the VADIS cavity - Simulations (CPO and VORPAL)
  • So far we have only tested ‘standard’ FEBIAD cavities: we can expect that there is a lot of room for improvement through optimisation of the cavity design for RILIS use.
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In-source laser spectroscopy of mercury isotopes
October 10, 2014

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