Actinium Laser Ionization and Spectroscopy

TRILIS / TRIUMF


1.2.2012 - Science Forum
• Motivation for Ac spectroscopy
• Ti:Sa Laser system
• Development of ionization scheme
• Laser ionization of Ac @ TRIUMF
• Laser spectroscopy
General remarks

Laser spectroscopy for

- nuclear properties
  - Isotope shift
  - $\Delta r^2$
  - Hyperfine splitting
  - $\mu$, $Q$, $I$

- Atomic properties
  - Atomic energy levels
  - Ionization potentials
  - Ionization schemes

### Pulsed Ti:Sa-Laser System

#### Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repetition rate</td>
<td>10 kHz</td>
</tr>
<tr>
<td>Wavelength range (fundamental)</td>
<td>690 – 960 nm</td>
</tr>
<tr>
<td>doubled (2v)</td>
<td>350 – 480 nm</td>
</tr>
<tr>
<td>trippled (3v)</td>
<td>233 – 320 nm</td>
</tr>
<tr>
<td>quadrupled (4v)</td>
<td>205 – 232 nm</td>
</tr>
<tr>
<td>Tuning range (conventional)</td>
<td>300 GHz</td>
</tr>
<tr>
<td>grating-Resonator</td>
<td>135 THz</td>
</tr>
<tr>
<td>Intensity</td>
<td>3 W</td>
</tr>
<tr>
<td>doubled (2v)</td>
<td>0.5 W</td>
</tr>
<tr>
<td>trippled (3v)</td>
<td>100 mW</td>
</tr>
<tr>
<td>quadrupled (4v)</td>
<td>100 mW</td>
</tr>
<tr>
<td>Spatial beam quality, $M^2$</td>
<td>&lt; 1.2</td>
</tr>
<tr>
<td>Spectral bandwidth</td>
<td>3 – 5 GHz (⇒ 20 MHz)</td>
</tr>
<tr>
<td>Temporal pulse duration</td>
<td>30 – 50 ns</td>
</tr>
</tbody>
</table>

Good coverage of **infra-red to visible-red & blue to ultra-violet** range.
In-Source Ionization

MABU (Mainz Atomic Beam Unit)

- Channeltron detector
- Quadrupole massfilter
- Ion trajectory
- Ion optics
- Quadrupole deflector
- Furnace

Laser

Laser ion source & laser in-source spectroscopy
resolution limited to Doppler broadening and laser bandwidth
• In-Source spectroscopy in Mainz - $^{227}$Ac ($T_{1/2} = 21.8$ a)


  – First hyperfine structure
Ionisation of Ac @ ISAC

Sept. 2011: Test of ionization scheme on irradiated UC\textsubscript{x} target without p\textsuperscript{+}

\textsuperscript{225}\textit{Ac} (T\textsubscript{1/2} = 10 d) requested for \textsuperscript{221}\textit{Fr} experiments

- Yield: up to \(10^7\) ions / sec (Dec. 2011)
- Factor 100 laser enhancement higher than expected - IP of Ac: 5.4 eV similar to Li
- Stable signal over days
Ionisation of Ac @ ISAC

Sept. 2011: Test of ionization scheme on irradiated UC\(_x\) target without p\(^+\)

\(^{225}\text{Ac} \ (T_{1/2} = 10 \text{ d}) \) requested for \(^{221}\text{Fr} \) experiments

\(^{212,213}\text{Ac}\)
Gascell (IGISOL)

\(^{197}\text{Au}(^{20}\text{Ne}-145 \text{ MeV},4-5n)^{212,213}\text{Ac}\)
\(\sigma: \ 2.3 \text{ mb for } ^{212,213}\text{Ac}\)

ISOL !!

\(\alpha\)-spectrum Yield station

Ac spectroscopy

Scan SES 720-920 nm

- Signal from ISAC Channeltron detector
- Attenuated beam

• 20 high lying atomic levels identified
• 22401 cm\(^{-1}\) transition does not fit

High lying atomic levels in Ac

- 20 high lying atomic levels identified
- 22401 cm\(^{-1}\) transition does not fit

Transitions starts from thermal 2231 cm\(^{-1}\) level

→ Reliability of atomic data?

Isotope Shifts

First rough measurement of isotope shifts

About 0.2 cm\(^{-1}\) (6 GHz) isotope shift \(^{227}\)Ac-\(^{225}\)Ac measured

laser optimized for spectroscopy - high power and spectral broadband
Outlook

• Atomic lines still under evaluation

• Atomic spectroscopy mostly done
  – Few spectra missing due to break of target

• HFS & IS Spectroscopy
  – Has to be measured precisely
  – Which isotopes are feasible
Thanks

• J. Grüneisen (B. Eng.)
  Thesis on *Grating laser control*

• Th. Quenzel (B. Eng.)
  Thesis on *Automated doubling crystal tracking*

• Special thanks to
  – ISAC Operators
  – Yield station support
  – Joe Mildenberger - Safety
  – John Behr

Thanks for your attention