Opportunities in Laser Spectroscopy of Exotic Nuclei

Jon Billowes
Isotope shift and Hyperfine Structure

Isotope shift of atomic transition

Analysis yields the change in nuclear mean square charge radius

Nuclear size, static and dynamic deformations

Hyperfine structure of atomic transition

(Isotope shift found using centroids of hyperfine multiplet)

Nuclear spin I
Magnetic moment $\mu$
Quadrupole moment $Q_s$
Present

**JYFL**
Laser spectroscopy with cooler-buncher
Development of resonance ionization techniques

**ISOLDE**
RILIS – in-source laser spectroscopy
- RF Quadrupole Cooler
- Reduces energy-spread of ion beam
- Improves emittance of ion beam
- Trap and accumulates ions – typically for 300 ms
- Releases ions in a 15 µs bunch

Light collection region
(Laser resonance fluorescence)
Sensitivity gains using the RFQ ion-cooler

**BEFORE**

8000 ions/sec
5.3 hours

**AFTER**

2000 ions/sec
48 minutes

Photons from laser-excitation of radioactive $^{88}\text{Zr}$
Fission fragment spectroscopy

Fission product yields at IGISOL (25 MeV p + $^{238}$U)

V. Rubchenya
Yttrium (fission)

$I=0$  $I\neq 0$  Prolate
<table>
<thead>
<tr>
<th>Mass Number</th>
<th>Lifetime</th>
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</thead>
<tbody>
<tr>
<td>102</td>
<td>(1091s)</td>
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<tr>
<td>101</td>
<td>(60s)</td>
</tr>
<tr>
<td>100</td>
<td>(128s)</td>
</tr>
<tr>
<td>99</td>
<td>(36s)</td>
</tr>
<tr>
<td>98</td>
<td>(g:24s, m:120s)</td>
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<tr>
<td>97</td>
<td>(72s)</td>
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<td>96</td>
<td>(48s)</td>
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<td>95</td>
<td>(10s)</td>
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<tr>
<td>94</td>
<td>(184s)</td>
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<tr>
<td>93</td>
<td>(71s)</td>
</tr>
<tr>
<td>92</td>
<td>(457s)</td>
</tr>
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</table>
The collinear-beams resonance ionization method

Atom bunch
50 Hz delivery rate, synchronized with laser pulse

- All atoms from the ion source have a chance to be ionized
- Resonance located by ion counting (not photon counting)
- Doppler-broadening free

Off-line tests with $^{27}\text{Al}$

50 Hz repetition rate lasers

Ionization limit
532 nm
308 nm
Comparison with low-flux bunched beams

Photon counting (12 minutes)

Ion counting (4 minutes)

Sensitivity:
1 resonance ion per 30 atoms within 1 µs time window
(compared with 1 photon per 50,000 atoms)
Ti:Sapphire lasers
Nd:YAG 100W, 10 kHz

Pulsed dye lasers
Copper vapour laser 45W, 10kHz

cw dye laser

cw pump laser
LIST: Laser ion source trap

Method being developed by FURIOS collaboration at JYFL

Applications:

* Production of high isobaric purity isotope or isomer beams
* In-source laser spectroscopy

IGISOL

Pulsed laser beams
Present ..... and next 5 years

**JYFL**
- Laser spectroscopy with cooler-buncher

**ISOLDE**
- RILIS – in-source laser spectroscopy
- ISCOOL cooler-buncher from 2006
The RFQ cooler-buncher project at ISOLDE

Design & Project Management: Ivan Podadera (Doctoral Student)
Ari Jokinen
Mats Lindroos
Tim Giles

Construction: Mainz
Munich
Orsay

Physics programme - Letter of Intent:
“Laser spectroscopic studies with an RFQ cooler-buncher”

Manchester, McGill (COMPLIS), Birmingham, Jyväskylä,
Mainz (COLLAPS), Orsay (COMPLIS), ISOLDE
Location beam section at ISOLDE layout

- After the HRS final focus
- Up to existing beam diagnostics box after the beam gate focus
stable isotopes
nuclear ground states
isomer only
off-line spectroscopy
10 years and beyond

JYFL

ISOLDE

GSI-FAIR Laser spectroscopy on the LEB

EURISOL
The GSI future facility FAIR
The low energy branch LEB
Laser Spectroscopy at the LEB
New Opportunities at the LEB

Isotopes with small production rates at ISOL facilities

Heavy neutron-rich isotopes

Laser spectroscopy at the dripline