Detectors and what we use them for at ELISA

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Low Current, Low Energy Beam Diagnostics, November 25, 2009
Electrostatic Ion Storage ring in Aarhus (ELISA)
Elisa data

Ring design:
- 8.3 m in circumference
- 160° deflectors
- 10° deflectors
- Stores ions with energies up to 22 keV per charge

Beam diagnostics:
- 4 horizontal pickups
- 4 vertical pickups
- Scrapers
- MCP detectors
ELECTROSTATIC ION STORAGE RING AARHUS (ELISA)


ELISA = ELectrostatic Ion Storage ring Aarhus

Commissioned in 1999

**ENTIRELY ELECTROSTATIC**

*Advantages:*

- Store ions of fixed charge and energy with arbitrary mass
- Useful for study of heavy ions: fullerenes, biomolecules and other macromolecules

Combined with an electrospray ion source and a multipole ion trap to accumulate the ions for injection into ELISA.

Two others are operating in Japan, rings in Stockholm, Frankfurt and Heidelberg are under construction.
Three pieces of information

Lifetimes with respect to dissociation

At what wavelengths ions absorb light

Daughter ion masses
Electrospray ion source

- ESI needle
- Tube lens
- Skimmer
- Octapole
- Lenses
- Acceleration tube
- Heated capillary
- Rotary pump
- Turbo pump
- Turbo pump
- 1 mbar
- 10⁻³ mbar
- 10⁻⁵ mbar
- 10⁻⁶ mbar
- Fused silica capillary
- Iontrap
22-pole ion trap
E* = E_0 + h\nu

Beam storage time scale
\sim 10 \text{ s}

Revolution time
\sim 100 \mu\text{s}

Counts
\sim 100 \mu\text{s}
LASER EXCITED IONS

Decay due to gas collisions

Laser excited ions

Intensity

Time
Lifetimes for statistical dissociation of photoexcited ions

Channeltron detector
LIFETIME SPECTRA OF C$_{60}^{2-}$ WITH RESPECT TO ELECTRON LOSS

\[ C_{60}^{2-} \rightarrow C_{60}^- + e^- \]

Decay yield vs. Time (ms) graph showing the lifetime spectra of C$_{60}^{2-}$ with respect to electron loss at different temperatures: 58 °C, 20 °C, and -70 °C.
SPECTROSCOPY OF $\text{C}_{60}^{2-}$ STATES

Resonance states with very short lifetime

Coulomb barrier for emission of $l=1$ electron from $\text{C}_{60}^{2-}$

Photon induced tunneling
ABSORPTION SPECTRA OF C$_{60}^{2-}$ AFTER DIFFERENT STORAGE TIMES
Glass plate detector / secondary electron detector.

Neutrals make secondary electrons when they hit the glass plate while most of the laser light is transmitted. Works down to the UV-range.
Momentum imaging of ions stored in ELISA
Momentum imaging of ions stored in ELISA

Detector for neutrals

Magnet

Ion source

Laser

\[ \Delta r \text{ and } \Delta t \text{ detection} \rightarrow E_{\text{kin}} \]
\[ E_{\text{kin}} = \frac{1}{2} \mu \left[ (\Delta r)^2 + (\Delta t v_b)^2 \right] \left( \frac{v_b}{L} \right)^2, \]
ELISA: A new scheme for daughter ion mass spectrometry
ELISA: A new scheme for daughter ion mass spectrometry

Ring element voltages

- Parent ion storage
- Daughter ion storage
- Fast switch of all ring voltages (µs)
- Dump of daughter ion on MCP

Time

- $t_1$
- $t_2$
- $10^\circ$ deflector

MCP detector
Signal in MCP detector as a function of scaling parameter $x$ and storage time $t_1$

Time-resolved fragmentation mass spectrometry on the $\mu$s to ms time scale
1) Molecule was stored in the ring

2) After 1.1 ms, ring voltages were switched to store daughter ion

3) After 1.15 ms of storage, the daughter ion was dumped in the MCP detector
Consideration for switching times, type of switches..

Switch times faster than 1 μs
Voltages up to 3 kV
Vertical needs to be bipolar
Injection and dump switch – 3 levels.
Horizontal deflectors:
16 new solid state switches with power supplies

Vertical deflectors:
Replaced by fast amplifiers (bipolar).

All is integrated into the control system.
Photodissociation of protoporphyrin ions in ELISA with 390-nm light

Neutrals from collisions with residual gas

Laser pulse fired after 12.4 ms.

Daughter ion mass spectra were recorded right after ($t_{1A}$) and after 190 µs ($t_{1B}$) of storage.
High-energy CID spectrum (50-keV collisions) recorded at another instrument

ELISA switch at $t_{1A}$:
Fragmentation due to both one-photon and two-photon absorption

ELISA switch at $t_{1B}$:
Fragmentation due to one-photon absorption since all ions that have absorbed two photons have decayed.

“A new technique for time-resolved daughter ion mass spectrometry on the microsecond to millisecond time scale using an electrostatic ion storage ring,”

ELISA experiments

- Collisional cross sections (geometrical size of molecule)
- Radiative cooling (emission from infrared active vibrations)
- Lifetimes after photon absorption:
  - statistical decay processes
  - excited state lifetimes, e.g., triplet states
- Electron autodetachment lifetimes
- Absorption spectroscopy
THE GROUP

Principal investigators:
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Klaus Eriksen

FNU    Lundbeckfonden    Carlsbergfondet    Villum Kann Rasmussen
Heating by photon absorption
Energy distribution changes in time

![Graph showing energy distribution changes over time](image)

- **g(E)**: Internal energy (eV)
- **t**: Time points: t=0 (red), t=10 µs (green), t=1 ms (blue), t=100 µs (black)
- **Energy distribution** changes over time.
Very sharp distribution

Exponential decay

Very broad distribution

$1/t$ decay
Table 1  
Design parameters for ELISA

<table>
<thead>
<tr>
<th>General parameters</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Injection energy</td>
<td>25 keV</td>
</tr>
<tr>
<td>Circumference</td>
<td>6.28 m</td>
</tr>
<tr>
<td>Revolution time</td>
<td>2.9 μs (p), 77 μs (C_{60})</td>
</tr>
<tr>
<td>Betatron tunes (Q_H, Q_V)</td>
<td>1.206, 1.439</td>
</tr>
<tr>
<td>Chromaticities (ξ_H, ξ_V)</td>
<td>−1.7, −1.3</td>
</tr>
<tr>
<td>Momentum compaction (ζ_p)</td>
<td>0.50</td>
</tr>
</tbody>
</table>

### 160° spherical deflectors

| Electrode radii                   | 235 and 265 mm |
| Nominal voltages                  | ±4.0 kV       |

### 10° deflectors

| Plate distance                    | 50 mm       |
| Plate length                      | 100 mm      |
| Nominal voltages                  | ±2.2 kV     |

### Electrostatic quadrupoles

| Inscribed radius                  | 26.2 mm     |
| Electrode length                  | 50 mm       |
| Nominal voltages                  | ±0.43 kV    |

### Chopper and inflector

| Rise/fall time                    | <200 ns.    |
Standard single trace

Example for double trace

- Voltage [div]
- Time [ns]

experiment
full fit