Electron Cooling at GSI and FAIR - Status and Latest Activities
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- Overview GSI/FAIR
- CRYRING : Latest Activities
- Recent ESR operation
- HVDC measurements at the ESR electron cooler
- Outlook
CRYRING@ESR

CRYRING injection

cooler cage
HV power supplies

electron cooler

Beam

Circumference = 54 m

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### Typical operation parameters

**ESR/CRYRING electron coolers**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>ESR</th>
<th>CRYRING</th>
</tr>
</thead>
<tbody>
<tr>
<td>e- energy (HV)</td>
<td>2-220 keV (± 1 eV)</td>
<td>up to 6 keV</td>
</tr>
<tr>
<td>e- current</td>
<td>0-1 A</td>
<td>up to 0.15 A</td>
</tr>
<tr>
<td>cathode diameter</td>
<td>2 inch</td>
<td>0.16 inch</td>
</tr>
<tr>
<td>guiding magnetic field (no expansion option)</td>
<td>0.02-0.1 T</td>
<td>(adiab. expansion)</td>
</tr>
<tr>
<td>cool. section length/circumference</td>
<td>2%</td>
<td>up to 4 T</td>
</tr>
<tr>
<td>vacuum</td>
<td>10^{-12} - 10^{-11} mbar</td>
<td>up to 0.3 T</td>
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</tbody>
</table>

**CRYRING**

- **e- energy**: up to 6 keV
- **e- current**: up to 0.15 A
- **cathode diameter**: 0.16 inch
- **guiding magnetic field (adiabatic expansion)**: up to 4 T
- **gun (sc solenoid)**: up to 4 T
- **cool. sect.**: up to 0.3 T
- **cool. section length/circumference**: 2%
- **vacuum**: 10^{-12} - 10^{-11} mbar

**Very cold e- beam for recombination studies!**

- Adiabatic expansion factor: 10-100
- Typically: gun to cool. section magnetic field 3 T to 0.03 T
  (e- beam diameter 4 mm to 40 mm)

**Sweden experience:**

- $kT_{\text{transv}} = 1.5$-3.5 meV
- $kT_{\text{ion}} = 0.05$-0.20 meV (//→// relaxation)
CRYRING Electron cooler
ESR operation with protons at 400 MeV

- **Proton beam**: $1.3 \times 10^{19}$
- **Shottky signal suppression**
- **Electron current**: 100 mA
- **Electron current**: 500 mA

- Resonant shottky pickup at 245 MHz (span=50kHz)

**Motivation**
 feasability tests for antiprotons (possible future option at FAIR)

**Electron cooling**
$I_e=250$ mA

resonant shottky pickup at 245 MHz (span=200kHz)

For same initial beam quality, $10^{18}$ protons → Notch filter stochastic cooling in 8 s !
final rms $\delta p/p \times 10$ higher than e- cooling
ESR operation: instability of cooler voltage

longitudinal frequency spectrum of the beam in ESR ± 5 kHz at 245MHz

\[ \Delta f/f = \eta \Delta \rho / \rho = \eta \gamma / \gamma + 1 \Delta V/V \]

\[ \Delta V/V = \pm 10 \uparrow -4 \]

→ Variations independently confirmed with precise HV divider measuring the HV output of cooler power supply

\[ \pm 20 V \text{ at } 200 \text{ kV}! \]
ESR electron cooler: High Voltage power supply

Heinzinger
HNCs 320000 – 10 neg
-320 kV 10mA (18-bit i.e. ± 1.2 V)
SF6 pressurized vessel
year of manufacture: 1988

HV cascade each module 30kV

output and regulation resistors tank

internal diodes damaged (discharges → failure)
refurbished before beamtime
ESR electron cooler: High Voltage power supply

old HV resistors

damaged by:
- aging
- mechanical stress

output and regulation resistors

tank:

new HV resistors: power supply stable as specified
ESR electron cooler: Precise High Voltage DC dividers

- Ohmlabs HV divider
  HVS
  250kV 250MΩ
  accuracy: \(10^{-4}\)
  PTB calibrated

- PTB HV divider
  HVDC2.1
  200kV 2000MΩ
  accuracy: \(1.3 \cdot 10^{-5}\)!
Outlook

- Integration of improved HV measurement equipment (HVDC dividers) to the ESR electron cooler for next beamtimes
- Also planned for low-energy range < 20 kV at ESR & CRYRING
- Final work on CRYRING electron cooler installation
- CRYRING electron cooler commissioning in early 2016