Deflector Development

at the Cooler Synchrotron COSY/Jülich

October 2, 2012 | Ralf Gebel

Institute for Nuclear Physics (IKP-4/COSY)

ECT* 2012, Trento, October 1-5, 2012
Outline

• Overview
• COSY extraction
• RF spin manipulation
• Ion sources and beam transport
• Cyclotron extraction
• Options for improving performance
• srEDM deflector Prototype
• Outlook
Deflectors at COSY

(1) Extraction of COSY beams
(2) rf devices
  • Solenoid
  • Dipole(s)
(3) Ion sources
  • pol. Source: 90° extraction
  • Beam line: 135° to polarimeter
  • (Extraction at high voltage)
(4) Cyclotron
  • Extraction of pos. and neg. ions
  • Injection
COSY Extraction Septum

- Grounded septum foil (0.1 mm Mo)
- Max. 200 kV on cathode (Ti)
- Max. 120 kV/cm (3.3 GeV/c)
- In situ bakeable to 300°C
- Moveable electrodes (r, r’)

G.Krol

500 mm
RF Deflectors for Spin Manipulations

Helmholtz dipole (2002)

Parameter range:
- 250 to 1450 kHz
- 0.2 - 1 T mm

Ferrite dipole (2003 – ‘07)

Solenoid (2007 - )

Plan for 2013+
- Dipole + combined E/B
- A.Lehrach’s talk
RF Amplifier for the Spin Flipper

RF system (A. Schnase et.al.)

- Provides up to 1 kW RF power (resonant, up to 10 kV\(_p\) and 20 A\(_p\))
- Locked to the COSY RF and timing
- System will be copied, enabled for \(E \sin(\omega t) + B \sin(\omega t + \phi)\) operation
Ion Sources and Beam Transport

Spherical beam deflectors for ion beams

- 90° / 135°
- Low fields
- Low aberrations

90° deflector for pol. ions 135° deflector

Study for ELENA/CERN

ECT* October 1-5, 2012
Ralf Gebel | IKP-4
Cyclotron Extraction

AEG design (RFQ: 1961)
1st internal beam: 1968

Pole diameter 3.3 m -> 700 t iron
\(<B>_{\text{max}} =1.35 \, \text{T}, \ B_{\text{hill}} = 1.97 \, \text{T} \)
RF 20 – 30 MHz (h=3, 100 kW_{\text{peak}})
22.5-45 MeV/A light ions
2-4.5 keV/A injection

3 ion sources (2 multicusp + pol. CBS)

Extraction channel starts with E-Septum

40 kV for 75 MeV d / gap: 0.35 cm

E-Field: > 115 kV/cm
B-Field: ~ 1 T
Cyclotron Extraction

Summary of septum operation

• Positive ions with negative voltages: okay
• $\text{H}^-$ with positive voltages: developing since 1995
• $\text{D}^-$ operation: pulsed operation since 2000
Septum Features

- FC77 cooling for HV parts (mineral oil before 2000)
- Ti septum
- Water cooling for anti septum
- Position control

Treatment
- Material selection (Ti)
- Diamond paste polishing (DPP)
- Electro chemical polishing
- Oxygen processing

Operational issues:
- Conditioning (rev. Voltage)
- Accept mA dark current
- Pulsed operation
Cyclotron Septum

Before 2000:
No spares
no long term D⁻ operation possible

Since 2000: continuous improvement
2 spare septa
exchange rate: about 1 / year
Deflector Preparation

- Mechanical production and polishing with different grits
- DPP: Diamond paste or spray polishing
- BCP/ECP: Buffered/electro chemical polishing
- HPR: High Pressure Rinsing (not at FZJ)
- Ultra sonic cleaning
- Acid-, Alkali- cocktails, ...
- Vacuum / plasma annealing

Up to now: Long term D− only in pulsed operation possible.

Candidates for improvement:
- Laser cleaning
- Gas conditioning (PT cyclotrons; Oxygen, Jefferson Lab: Krypton)
Cleaning with pulsed IR Laser Light

- Application samples:
  - Extraction electrode
  - Tungsten ionizer, disk
- Speed: several cm²/s
- No chemistry, less waste (vapour only)

Rapid pulsed laser beam scans across treated surface

Target coating/contaminant is vaporized & residue is captured

Cleaning process stops when target material is removed

20 mm

Clean-Lasersysteme GmbH
Applikation
Dornkaulstr. 6, DE 52134 Herzogenrath
T +49 (0)2407 9097-0
F +49 (0)2407 9097-111
E applikation@cleanlaser.com
http://www.cleanlaser.de
More power, continuous operation

Laser polished samples (Inconel 718)

Polishing results for selected metals

<table>
<thead>
<tr>
<th>METAL</th>
<th>PROCESS VARIANT</th>
<th>INITIAL ROUGHNESS RA</th>
<th>ROUGHNESS AFTER LASER POLISHING RA</th>
<th>PROCESSING TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>tool steels e.g.</td>
<td>macro</td>
<td>1 - 5 µm</td>
<td>0.05 - 0.15 µm</td>
<td>&gt; 60 s/cm²</td>
</tr>
<tr>
<td>1.2343, 1.2344, 1.2316, 1.2365</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.3344</td>
<td>micro</td>
<td>0.5 - 1 µm</td>
<td>0.3 µm</td>
<td>3 s/cm²</td>
</tr>
<tr>
<td>Titanium,</td>
<td>micro</td>
<td>3 µm</td>
<td>0.5 µm</td>
<td>10 s/cm²</td>
</tr>
<tr>
<td>TiAl6V4</td>
<td>micro</td>
<td>0.3 - 0.5 µm</td>
<td>0.1 µm</td>
<td>3 s/cm²</td>
</tr>
<tr>
<td>Bronze</td>
<td>macro</td>
<td>10 µm</td>
<td>1 µm</td>
<td>10 s/cm²</td>
</tr>
<tr>
<td>Stainless steel</td>
<td>macro</td>
<td>1 - 3 µm</td>
<td>0.2 - 1 µm</td>
<td>60 - 120 s/cm²</td>
</tr>
<tr>
<td>1.4435, 1.4571</td>
<td></td>
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Polarized Electron Source “Musts”

Good Electron Gun

- Ultrahigh vacuum
- No field emission
- Maintenance-free

Good Laser

- Niobium
  - Capable of operation at higher voltage and gradient?
  - Buffer chemical polish (BCP) much easier than diamond-paste-polish

Good Photocathode

Conventional geometry: cathode electrode mounted on metal support structure

Replace conventional ceramic insulator with “Inverted” insulator: no SF6 and no HV breakdown outside chamber

BCP Niobium vs Stainless Steel

Field Emission Current (pA) vs Voltage (kV)

With permission of M. Poelker, from his talk at SPIN2012 (Dubna, 2012, September 16-22)
Field Emission from Niobium

With permission of M. Poelker, from his talk at SPIN2012 (Dubna, 2012, September 16-22)
See also: PhysRevSTAB.15.083502
Surface Analysis

Stainless steel

Fine grain Nb

Large grain Nb

Single-crystal Nb

With permission of M. Poelker, from his talk at SPIN2012 (Dubna, 2012, September 16-22)
See also: PhysRevSTAB.15.083502 (optical profilometer images)
An iron free deflector

R.Talman’s design proposal

- Landau-Lifschitz:
  - analytic model
  - Numerical model
  - Prototype

- Technical issues
  - Field quality
  - Thermal load, cooling
  - Precision

Figure 10: Iron-free, all current, uniform field magnet. The current configuration starts from an example in Landau and Lifshitz, *Electrodynamics of Continuous Media.*
Development steps from Landau Lifschitz towards a real magnet
A first prototype

Magnet parameter
104 mm length
22 mm hole
Max. 5 A -> 1.5 mT
0.7 mm wire (22 W)
Outlook

• Deflector development
  • E/B spin manipulator test in 2013

• Application of new methods
  • laser clean cell available soon
  • check gas processing for both polarities
  • Tests with Nb (RRR300 samples available at FZJ)

• Magnet optimization
  • Improvement of srEDM deflector model

Thank you for your attention!