High Magnetic Field Facility for Neutron Scattering

Project HFM-EXED

NHMFL:

EPFL-CRPP:
P. Bruzzone, R. Wesche

HZB:
P. Smeibidl, A. Daske, H. Ehrmer, C. Fritsche, J. Heinrich, M. Hoffmann, S. Kempfer, R. Wahle
What is Helmholtz?

What is HZB?
What is Helmholtz?

What is HZB?
Investigation of Structure and Dynamics of Complex
Materials and Material Systems with Neutrons

Atoms within crystal

Neutron scatters at the lattice

Magnetism

Detector area

Neutron reflection

Diffraction picture

Scattering Angle

Neutrons
Identification of different vortex phases
(lattice, liquid, disentangled, entangled, decoupled)

Method:
diffraction / inelastic scattering / SANS

B/T phase diagram of underdoped YBCO
Le Boeuf et. al., Nature Physics 9 (2013) 79
Magnet Systems for n-Scattering at HZB

Continuous Field
max. ~15T- split pair configuration
Present Cryomagnets for N-Scattering Experiments

Limitations

Sample chamber

Vertical Field

Horizontal Field

SANS SC-Magnet
Monochromatic

Triple-Axis Instrument

Split-Coil-Magnet
(vertical field)

Magnetic Structures

Single Crystal Measurements

Inelastic Measurements

Broad Wavelength Band of Neutrons

TOF-Instrument

Tapered Solenoid
(horizontal field)

Powder Diffraction

Single Crystal Measurements (restrictions!)

SANS with \( B \parallel k_i \)

Inelastic Measurements (flux reduction!)
Neutron Guide Hall-I

Neutron Guide Hall-II

Exp-Hall

Cold Source

Neutron Guide (Ni coated)

Super Mirror

Thermal Neutrons

Cold Neutrons
Invited presentation 3OrCB_01 given at MT24; Seoul, Korea, October 18 to 23, 2015.

- Resistive Magnet or
- Superconducting Magnet or
- Series-Connected-Hybrid Magnet (SCH)

Hybrid data:
Max. Field:
- > 25 Tesla (4 MW)
- > 30 Tesla (8 MW)
(conical opening: 30°)

Multi Purpose Instrument:
- Diffraction
- Small Angle Neutron Scattering
- Spectroscopy
Magnets for n-Scattering Experiments

Future

25 T – 31 T Hybrid Magnet (Solenoid)
Geometry and power of resistive coil determine maximum field
Why not a Superconducting Magnet?

Current Density Across Entire Cross-Section

Plot maintained by Peter Lee at: http://magnet.fsu.edu/~lee/plot/plot.htm
Central Field | > 25 T (> 30) T
---|---
Bore | 50 mm horizontal
Opening Angle | 30°
Power Resistive Insert | 4 MW (8 MW)
Field Homogeneity | < 0.5% (15 mm x 15 mm Vol.)
Operating Current | 20 kA
Magnetic Field of Resistive Insert | 13 T – 18 T (4 MW / 8 MW)
Magnetic Field of Supercond. Coil | 13 T
Height | ~ 5 m
Total Weight | ~ 25 t
Cold Mass | ~ 6 t
Simplified Electrical Circuit

Coil Protection

- 400V DC
- 20kA Power Supply

Breaker

SCH

Supercon. Coil
197 mH

3.3 kΩ

Resistive Coil
2.45 mH
10 mΩ

Thyristor Crowbar

100 mΩ Dump Resistor

Reverse Diode
### Superconducting Outsert Coil

**Nb₃Sn Strand and 3 Types of Superconductor**

<table>
<thead>
<tr>
<th></th>
<th>High Field</th>
<th>Mid Field</th>
<th>Low Field</th>
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<tbody>
<tr>
<td><strong>Cable Pattern</strong></td>
<td>4x3x3x3x3=324</td>
<td>5x4x4x3=240</td>
<td>4x4x4x3=192</td>
</tr>
<tr>
<td><strong>N sc strands/Cu strands</strong></td>
<td>324/0</td>
<td>120/120</td>
<td>64/128</td>
</tr>
<tr>
<td><strong>Strand diameter</strong></td>
<td>0.81mm</td>
<td>0.81mm</td>
<td>0.81mm</td>
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<tr>
<td><strong>Jc-nocu (12T,4.2K)</strong></td>
<td>&gt;2100A/mm²</td>
<td>&gt;2100 A/mm²</td>
<td>&gt;2100 A/mm²</td>
</tr>
<tr>
<td><strong>Type of strand : Nb₃Sn</strong></td>
<td>RRP</td>
<td>RRP</td>
<td>RRP</td>
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<tr>
<td><strong>Strand coating</strong></td>
<td>Chrome plating</td>
<td>Chrome plating</td>
<td>Chrome plating</td>
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<tr>
<td><strong>Void fraction</strong></td>
<td>29+/-1%</td>
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- **Cu transition piece (to current lead)**
- **4 K He piping**
- **50 K He inner bore shield**
- **Potential break**
- **Interlayer joint**
- **Tie rod**
- **Endplates**
Resistive Insert Coil

Horizontal
Superconducting Outsert Coil

Final Assembly
Superconducting Oilsat Coil

Final Assembly
Superconducting Otsat Coil

Final Assembly
Sample Environment

- Sample
- $^4$He Evaporator
- $^3$He Evaporator
- Closed Cycle Refrigerator as precooling stage
Operation:

- $400\,\text{V} / 20\,\text{kA}$ DC power supply
- Helium refrigerator for CICC coil, radiation shields and current leads
- High pressure, high purity cooling water
- 4 / 8 MW cooling power for resistive coil
Control System - Hybrid Magnet

Combine Controls for:
Magnet +
Power Supply +
Water Cooling +
Helium Refrigerator +

Data monitoring and safety procedures

User Terminal
Commissioning Hybrid Magnet

- Aug 2015: Start of cooldown of superconducting coil
- 16 Oct 2014: First successful magnet test at 20 kA (26 T)
- 12 Dec 2014: Relocation of magnet system from HFM technics building to Neutron Guide Hall
- Jan. 2015 to Feb. 2015: Installation of magnet on neutron instrument EXED
- 07 Apr 2015: Start HFM/EXED commissioning
- Successful test on instrument 20 kA (26 T) for 3 hours