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POLI: Polarised hot neutron diffractometer

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Abstract: POLI, which is operated by the Institute of Crystallography, RWTH Aachen University in cooperation with JCNS, Forschungszentrum Jülich, is a versatile two axes single crystal diffractometer with broad field of applications. Mostly dedicated to the investigation of magnetic structures in single crystals using neutron spin polarisation, POLI is also used for classical structural investigations under extreme conditions. High intensity hot neutrons flux makes it attractive also for the other applications like study of parity violations phenomena in nuclear physics or BNCT (boron neutron-capture therapy) in medicine.

1 Introduction

The using of the separate non-polarising variably focussing monochromators and optimised polarisers allows the structural investigations using polarised and non-polarised neutrons with short wave length and high resolution. Two standard options are currently implemented on POLI:

- Zero-field **s**pherical **n**eutron **p**olarimetry (SNP) using third generation polarimeter CRYOPAD;
- Non-polarised diffraction under special conditions using heavy and bulky sample environments and out-of-plane lifting counter.

A third measurement method named ipping-ratio is under development and planned to be operationalusing a new 8 T magnet in 2016.

SNP allows distinguishing between the depolarisation and polarisation rotation occurring during the scattering in the sample. X, Y, Z components of the scattered polarisation are measured for each orientation of the incoming polarisation and hence a polarisation matrix of 9 elements for an individual Bragg reflection can be found. Determining the relationship between the directions of incident and scattered polarisations gives access to the 16 independent correlation functions involved in the most

Figure 1: Instrument POLI with SNP setup.

general nuclear and magnetic scattering processes. Generally, this leads to the direction's determination of the magnetic interaction vector of magnetic structures. For those structures coinciding nuclear and magnetic re ections in reciprocal space, SNP leads to the amplitude's determination of the magnetic interaction vectors, and hence to the magnetisation distribution. SNP could also be employed to study the magnetic domain distribution.

Actually, polarised ^{3}He spin filters are used on POLI in order to produce and to analyse neutron polarisation. This method offers best performance in the polarising of hot neutrons. Tuning the pressure of ^{3}He in the filter cell it is possible to optimise the polariser's performance depending on wave length or experimental needs. The automatic correction of the time-dependent polarisation is applied. Because of the ^{3}He filters' sensitivity about non-homogeneous magnetic fields, a dedicated solid state supermirror bender will be used in the future for experiments with high magnetic fields.

Non-polarised diffraction under extreme conditions e.g. very low temperatures (< 3 K), magnetic and electric fields, high pressures, high temperatures, etc. using dedicated sample environments could be performed on POLI using out-of-plane lifting counter. The available vertical opening is -4.2° - 30° and in many cases this permits data collection sufficient large for the precise structural determination. Beside the fact that use of the hot neutrons allows access to the large Q range, it is also advantageous in order to reduce the absorption and extension corrections. It can be especially attractive for investigation of the strongly absorbing rear-earth compounds.

2 Typical Applications

- Complex commensurate and incommensurate magnetic structures studied in ground state (zero-field) – very useful especially for superconductors.
- Studies of magnetic or magneto-electric domains using SNP on samples cooled in zero-field as well as in external magnetic field (up to 7.5 T).
- The combination of magnetic and electric fields applied on the sample – important for the studies on multiferroic materials.
- Determination of magnetic form factors (sometimes also in antiferromagnets).
- Structural and magnetic phase transitions, phase diagrams.

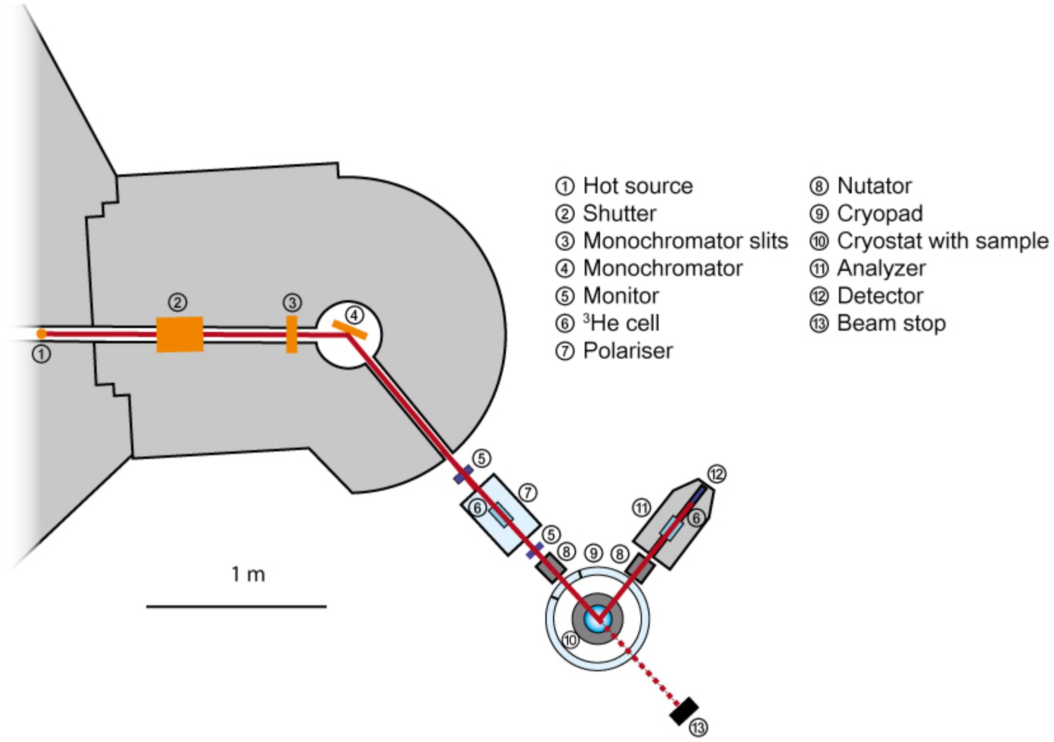

Figure 2: Schematic drawing of POLI.

3 Sample Environment

- Standard closed-cycle cryostat (4 K – 425 K)
- Variox LHe cryostat (1.5 – 300 K)
- Lower temperature inserts on request
- 2.2 T HTS magnet / 7.5 T magnet on request
- 8 T dedicated magnet planned from 2016
- Electric field up to 10 kV

4 Technical Data

4.1 Primary beam: SR-9a on hot source

- Focussing monochromators

Crystal	λ (Å)	flux (n cm^{-2} s^{-1})	λ (Å)	flux (n cm^{-2} s^{-1})
Cu (220)	0.55	$4 \cdot 10^6$	0.9	$2.4 \cdot 10^7$
Si (311)	0.7	$7 \cdot 10^6$	1.15	$2.8 \cdot 10^7$

4.2 Neutron polarisation: ^{3}He spin filter

- ^{3}He polarisation: 0.75 – 0.7
- Typical Neutron polarisation: 0.93 – 0.8
- Cell holding time: 2 days
- Cells replacement time: 5 – 10 min

4.3 Diffractometer angles

with Cryopad	without Cryopad
-10° $< 2\theta <$ 120°	-30° $< 2\theta <$ 130°
-180° $< \omega <$ 180°	-180° $< \omega <$ 180°
-4° $< \xi_1 <$ 4°	-5° $< \xi_1 <$ 5°
-4° $< \xi_2 <$ 4°	-5° $< \xi_2 <$ 5°
ν =0	-4.2° $< \nu <$ 30°

4.4 Cryopad (zero-field polarimeter)

- Precision in polarisation control: better 1°
- Low background / low absorption
- LHe autonomy: 10 days
- LN_2 refill (automatic): daily
- Space for closed cycle cryostat or orange type cryostat