Thermal neutron three-axis spectrometer with polarisation analysis IN20

Applications

• Magnetic fluctuations and quantum critical points
• Spin waves and their coupling to lattice modes
• Crystal field excitations
• Spin canting in amorphous magnets
• High resolution line-width studies (TASSE)

Selected examples

Phonon-magnon coupling in CMR manganates

Despite large differences in their Curie temperatures, different ferromagnetic manganese perovskites exhibit very similar dispersions with marked zone-boundary magnon softening and broadening due to a strong coupling to optical phonons. Polarisation analysis provides an ultimate tool to separate unequivocally the magnetic part from the rest of the neutron response. The data displayed in the figure were collected with a 2 cm$^3$ single crystal of La$_{0.7}$Ca$_{0.3}$MnO$_3$ using the 4T horizontal cryomagnet and a "half-polarised" setup (Heusler 111 monochromator and PG 002 analyzer) (Fig. 1).

Anisotropy of the magnetic incommensurate fluctuations

The unconventional superconductor Sr$_2$RuO$_4$ is isostructural with the high-$T_c$ superconductor La$_{2-x}$Sr$_x$CuO$_4$ (LSCO) but exhibits an unusual triplet (p-wave) spin-pairing. Polarisation analysis on IN20 provides a tool to probe theoretical models requiring the presence of (quasi-)ferromagnetic or highly anisotropic antiferromagnetic fluctuations in the neutron response. The present IN20 results confirm the latter scenario qualitatively, with incommensurate fluctuations (similar to those observed in LSCO), whose anisotropy between the in-plane ($x_\parallel^a$) and out-of-plane ($x_\perp^a$) components and energy dependence are weaker than predicted for p-wave pairing (Fig. 2).

Phonon anharmonicity in Ge

The transverse acoustic phonons at the X point in Si, Ge and some III-V semiconductors (GaAs, InSb ...) exhibit a negative Gruneisen parameter and are responsible for the anomalous negative thermal expansion coefficients at low temperatures. The IN20 spin-echo (TASSE) measurements on an isotopic crystal of $^{74}$Ge have revealed their metastable character (line-width close to zero) below 100 K, confirmed by subsequent $ab$ initio calculations: the phonons required by the only possible difference process of decay are not thermally populated at such low temperatures. This behaviour is qualitatively different from that of optical phonons at the centre of the Brillouin zone, the only ones accessible to line-width measurements by Raman spectroscopy (Fig. 3).
IN20 is a thermal beam three-axis spectrometer equipped for inelastic scattering experiments with 1D and 3D (CRYOPAD) polarisation analysis and for high-resolution studies using the thermal beam spin-echo technique (TASSE). This instrument was upgraded as a part of the ILL’s Millennium Programme.

**Instrument description**

IN20 is installed at the H13 thermal beam tube (Ø 170 mm) in the reactor hall. Both the primary and the secondary spectrometer employ a monochromatic horizontal focusing geometry. A heavy input slit of an adjustable size, placed in the casemate, serves as a virtual source, providing a large solid angle for the monochromatic beam, while reducing, together with a sapphire filter window, the fast neutron background. The neutron energy is selected either by a double focusing polarizing Heusler 111 monochromator (230 x 150 mm² x h) or by an unpolarised Si 111 monochromator (elastically bent crystals, 195 x 200 mm² x h) free of higher-order contamination in the incident beam at wave-numbers \( k_i > 3 \) Å¹. The analysis of the energy and polarisation state of the scattered neutrons is effectuated by a similar horizontally focusing Heusler crystal analyzer. Further PG 002 and Si 111 analyzers are available for occasional unpolarised work.

The energy transfer range accessible in the present configuration of IN20 extends to 100 meV with maximum incident neutron energies reaching 150 meV. The typical energy widths (FWHM) measured with a reference vanadium sample at the graphite filter wave-numbers \( k_i = 2.66 \) Å¹ and 4.1 Å¹ are 0.82(3) meV and 3.05 (15) meV respectively.

Polarisation analysis can be performed in combination with the standard ILL 2.5 T and 6 T vertical-field and 4 T horizontal-field cryomagnets as well as with a set of Helmholtz coils generating a guide field (about 15 Gauss), which automatically follows the direction changes of the scattering vector. This coil set can receive the standard ILL cryostats and furnaces. The overall beam polarisation is about 90% (flipping ratio 20) in most of the spectrometer configurations. Thanks to the recent upgrade a single crystal volume of 0.1 – 1 cm³ is sufficient for investigations of most systems of current interest.

**Instrument layout**

**Instrument Data**

** Reactor hall, thermal beam H13 beam tube H13 Ø 170 mm²**

<table>
<thead>
<tr>
<th>monochromator</th>
<th>crystal</th>
<th>( d_h0l (\text{Å}) )</th>
<th>( k_f (\text{Å}^{-1}) )</th>
<th>flux (10¹⁷ n cm⁻² s⁻¹)</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>polarised</td>
<td>Heusler 111 230x150 mm²</td>
<td>3.437</td>
<td>2.662</td>
<td>1.05</td>
<td>virtual source D = 40 mm sapphire filter horizontal focusing and vertical fixed</td>
</tr>
<tr>
<td>unpolarised</td>
<td>Silicon 111 190x200 mm²</td>
<td>3.135</td>
<td>3.0</td>
<td>11.0</td>
<td>horizontal and vertical focusing</td>
</tr>
</tbody>
</table>

| analyser      | polarised | Heusler 111 | 3.437 | horizontal focusing |
|               | unpolarised | PG 002 | Silicon 111 | 3.355 | horizontal focusing and vertical fixed |

| detector      | \(^{3}H_{e} 5 \text{ bar} \) | \( 4 \times 10 \text{ cm}² \) | vertical |
| beam cross-section | 20 x 20 cm² |

web: [www.ill.fr/YellowBook/IN20/](http://www.ill.fr/YellowBook/IN20/)