Inelastic X-ray scattering from Phonons at the ESRF

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Outline

Introduction

Highlights from “standard” experiments

Recent developments
  - Phonon density-of-states
  - Phonons at surfaces
  - Polycrystalline materials -> single crystal properties
  - IXS and (thermal) diffuse scattering

Outlook
Inelastic Scattering from Phonons

Thermal neutrons:

\[ E_i = 25 \text{ meV} \]
\[ k_i = 38.5 \text{ nm}^{-1} \]
\[ \Delta E/E = 0.01 - 0.1 \]

large beam

Brockhouse (1955)

Hard X-rays:

\[ E_i = 18 \text{ keV} \]
\[ k_i = 91.2 \text{ nm}^{-1} \]
\[ \Delta E/E \leq 1 \times 10^{-7} \]

small beam

Burkel, Dorner and Peisl (1987)

The instrument INELAX at the HARWI wiggler line of HASYLAB.
Scientific themes (I)

Disordered systems: Explore new Q-E range

- Interplay between structure and dynamics
- Structural and other relaxations
- Excess of the VDOS (Boson peak)
- Nature of sound propagation and attenuation
Scientific themes (II)

Crystalline systems: small samples, high pressure

- correlated electron systems
  - actinides, superconductors, CDW systems
- novel materials
- “old” materials at very high pressures
- minerals relevant in Earth science

$V = 10^{-4} - 10^{-5} \text{ mm}^3$

Diamond anvil cells

Thin films and surfaces
Phonon dispersion of PuCoGa$_5$

- Sample: $^{242}$Pu from Ga flux method (ITU Karlsruhe)
- Main effect: softening of some phonon frequencies in relation with $U > 0$

$\Rightarrow$ Sensitivity of phonon spectrum to 5f charge distribution
OH-stretching vibrations in diaspore

AlOOH, orthorhombic H-bond of intermediate strength

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<th>$E_{\text{exp}}$ [meV]</th>
<th>$E_{\text{theo}}$ [meV]</th>
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<tbody>
<tr>
<td>(2.5 0 -1)</td>
<td>374</td>
<td>375</td>
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<tr>
<td>(2.5 0 0)</td>
<td>357</td>
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IXS at very high pressures

Pressure measurement by frequency shift of ruby fluorescence