BT-7 Triple-axis Spectrometer

https://www.ncnr.nist.gov/instruments/bt7_new/
Neutron Basics

• $E = \text{energy}$
  
  $E = \frac{\hbar^2 k^2}{2m_n} \propto \frac{1}{\lambda^2}$

• $k = \text{wavevector (momentum)}$
  
  $k = \frac{2\pi}{\lambda}$

• $\lambda = \text{wavelength}$

• BT-7 uses “thermal” neutrons
  
  Temperature $\sim 300\text{K}$
  
  Energy peak $\sim 30\text{meV}$
  
  Wavelength $\sim 1.8\text{Å}$

• Most common:
  
  $E = 14.7\text{ meV}$
  
  $k = 2.66\text{ Å}^{-1}$
  
  $\lambda = 2.35\text{ Å}$

• SPINS MACS uses “cold” neutron

• Most common:
  
  $E = 5\text{ meV}$
Bragg's Law

\[ n \lambda = 2d \sin \theta \]

\(n=\)positive integer

https://en.wikipedia.org/wiki/Bragg%27s_law
Real Space vs. Reciprocal Space

Fourier transformation

Space-time \((r,t)\) \hspace{1cm} \rightarrow \hspace{1cm} \text{Energy-momentum} \ (Q, \ hw)

Real space \hspace{1cm} Q\text{-space} \hspace{1cm} \text{Time space} \hspace{1cm} \omega\text{-space}

Elastic scattering – static structures \hspace{2cm} \text{Inelastic scattering} – dynamics

\[ 2\pi/a \]
Triple-axis Spectrometer

Monochromator: a1/a2
2 out of 3 axes: $k_i$ & $k_f$

$n \, 2\pi/ \, k_i = 2d_M \sin(\theta_M)$
$m \, 2\pi/ \, k_f = 2d_A \sin(\theta_A)$
$n, m = 1, 2, 3…$

$E_i = \hbar^2 k_i^2 / 2m_n$
Controlled by $a_1/a_2$

$E_f = \hbar^2 k_f^2 / 2m_n$
Controlled by $a_5/a_6$

Sample: $a_3/a_4$
Analyzer: $a_5/a_6$
Monochromator: $a_1/a_2$
3rd axis : Sample

Q = k_f - k_i

ℏω = E_i - E_f = 0 (elastic)

Alignment

a4 : angle between ki/kf  a3 : rotation of reciprocal space

Bragg peak!  No peak...  No peak...
When $k_i$ and $k_f$ aren't equal...

$$Q = k_f - k_i$$

$$\hbar \omega = E_i - E_f \neq 0 \text{ (inelastic)}$$

- Phonon
- Spin wave
- and etc
Velocity Selector and Filter

\( n \lambda = 2d \sin \theta \)

\( n = \) positive integer

Pyrolytic Graphite (PG)

\( E_i = 14.7 \text{ meV} \)

http://www.neutron.ethz.ch/research/resources/graphite-filter-transmission.html

https://www.ncnr.nist.gov/instruments/bt7_new/VelocitySelector.html
Sample Environment

- Low temperature (50mK)
- Magnetic field (15T)
- Pressure (1GPa)
- Furnace (1600°C)
- Electric field (5000V)