INEL5— Single-Crystal Chopper Spectrometer —Reference Instrument WBS 1.7.12
Technical Note ANL/SNS/98-10
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1 Instrument Description

1.1 Overview

INEL5 is designed for the study of relatively high energy cooperative excitations in single crystals. Figure 1 provides a schematic representation of INEL5, and Table 1 gives the parameters for this instrument. The use of linear position sensitive detectors provides good vector Q resolution, and the coverage of a large solid angle at low scattering angles permits sampling of the necessary regions of reciprocal space to follow the dispersion of these excitations. The instrument is optimized for studies with relatively high incident energies (tens to hundreds of meV) but can also be used with incident energies as low as 10 meV. Provision is made to allow addition at a later date of a detector bank at higher scattering angles in order to enhance the capabilities for the lower energy transfer studies.

Fig. 1. Schematic plan view of the single-crystal chopper spectrometer INEL5.

Work supported in part by the U. S. Department of Energy, BES, contract No. W-31-109-ENG-38.

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Table 1. Parameters for the single-crystal chopper spectrometer INEL5

Component	Parameter	Value
Moderator	Beam line	18BU
	Moderator	Liquid-H ₂ O decoup, pois
Geometry	Source-sample distance	15.0 m
	Sample-detector distance	4.0 m
T ₀ chopper	Type	Vertical-axis T ₀
	Chopper radius	100 mm
	Distance from moderator	7.0 m
	Frequency	≤180 Hz
	Beam width at chopper	80 mm
	Wavelength range to open or close	0.35 Å @ 180 Hz
E ₀ chopper	Type	Fermi
	Chopper radius	50 mm
	Distance from moderator	14.0 m
	Frequency	≤600 Hz
	Beam width at chopper	50 mm
Collimation and beam line	Upstream	Standard apertures
	Before E ₀ chopper	Variable aperture
	After E ₀ chopper	Soller collimator
	Beam line, distances <4.5 m	He-filled beam tube
	Beam line, distances >4.5 m	Evacuated to <10 ⁻² torr
Beam-line shielding	Steel radial thickness around beam	0.7 m
	Paraffin radial thickness around steel	0.2 m
	Channel for beam tube	0.2 m × 0.2 m
	Length	6.5 m
Beam stop	Steel	1.6 m × 1.6 m × 2.6 m
	Paraffin radial thickness around steel	0.2 m
	Re-entrant hole in steel	0.2 m × 0.2 m × 0.5 m
Sample	Width (maximum beam size)	50 mm
	Height (maximum beam size)	50 mm
Linear position sensitive detectors	Type	³ He proportional
	Diameter	25 mm
	Length	900 mm
	Position resolution	20 mm
	Angular coverage, horizontal	~0° to ±30°
	Angular coverage, vertical	~0° to ±30°
	Number	500
	Solid angle coverage	0.7 sr
Data acquisition		Standard system

Table 6.3-10 (continued)

Component	Parameter	Value
Scattering chamber	Geometry	Irregular
	Width	2.5 m
	Length	4.0 m
	Height	1.5 m
	Filling	Evacuated to $<10^{-2}$ torr
	Shielding, top and bottom	Fixed
	Shielding, sides	Removable
	Shielding thickness and composition	TBD
Sample chamber	Depth	~0.6 m
	Diameter	~0.3 m
	Filling	Evacuated to 10^{-6} torr
Resolution	$\delta E/E_{\text{incident}}$	~0.01 fwhm

1.2 Source

A poisoned decoupled ambient temperature water moderator provides a polychromatic beam of neutrons to the instrument. The design documented here assumes a fwhm pulse width of $\delta t \approx 25 \mu\text{s}$ at $10 \text{ \AA}$, $\delta t \approx 24 \mu\text{s}$ at $5 \text{ \AA}$, $\delta t \approx 22 \mu\text{s}$ at $3 \text{ \AA}$, and $\delta t \approx 10 \mu\text{s}$ at $1 \text{ \AA}$.¹ This moderator was selected for INEL5 because of its high intensities at short and intermediate wavelengths, coupled with adequate timing resolution. Beamline 18BU was chosen for this instrument because this beamline views the poisoned ambient temperature water moderator BU which provides these characteristics.

1.3 Choppers

A T_0 chopper is used to cut out the prompt pulse to reduce background. An E_0 Fermi chopper near the sample allows only a very narrow band of wavelengths to reach the sample, thus effectively monochromating the incident beam as well as providing a reference starting time for time-of-flight measurement of the scattered neutron energies. The T_0 chopper is a relatively massive vertical-axis chopper designed to stop the faster neutrons as well as the slow ones. This chopper is essentially a Fermi chopper without the slit package, and it is closed most of the time to further reduce the background.

Preliminary optimization of the chopper locations and speeds was done using a spreadsheet to evaluate the wavelengths for which the chopper system is fully open and the wavelengths for which one or more of the choppers is opening or closing. Table 2 shows the parameters assumed for the choppers, and Table 3 shows the opening and closing wavelengths for each of these choppers for several different choices of chopper phases. Appendix A of Reference 2 gives the equations used for these calculations.

Table 2. Assumed chopper parameters for INEL5.

T ₀ chopper diameter (mm)	200.00
T ₀ chopper distance (m)	7.00
beam width at T ₀ chopper (mm)	80.00
E ₀ chopper diameter (mm)	100.00
E ₀ chopper distance (m)	14.00
E ₀ chopper blade spacing (mm)	1.00
beam width at E ₀ chopper (mm)	50.00
distance to sample (m)	15.00
sample-detector distance (m)	4.00
ratio scattered/incident wavelength	0.45

Table 3a. Opening and closing times for INEL5.

frame	1
t _{max} (μs)	16667
T ₀ freq (Hz)	180.0
T ₀ Δt (μs)	707
E ₀ freq (Hz)	600
E ₀ Δt (μs)	2.8

Table 3b. Accessible wavelengths for INEL5.^a

frame	1
t _{max} (μs)	16667
T ₀ freq (Hz)	180.0
T ₀ Δλ (Å)	0.40
E ₀ freq (Hz)	600
E ₀ Δλ (Å)	0.0007
λ _{inc-max} (Å)	2.76

^a Assumes scattered wavelength is 222% of the incident wavelength.

1.4 Collimation

The massive variable aperture collimator before the E_0 chopper is used to define the beam to the approximate size of the sample. The Soller collimator after the E_0 chopper eliminates background from neutrons scattered by that chopper.

1.5 Detectors

Linear position sensitive detectors are used at all scattering angles to provide the good vector Q resolution required to study coherent excitations in single crystals.

2 Performance

2.1 Resolution

For INEL5 the resolution in both Q and E are of interest.

$$Q = 2\pi \left\{ \frac{1}{\lambda_{inc}^2} + \frac{1}{\lambda_{scat}^2} - \frac{2}{\lambda_{inc}\lambda_{scat}} \cos 2\theta \right\}^{1/2} \quad (1)$$

$$\frac{\delta Q}{Q} = \left\{ \frac{\left(\frac{2}{\lambda_{inc}^2} - \frac{2 \cos 2\theta}{\lambda_{inc}\lambda_{scat}} \right)^2 \left[\left(\frac{\delta t_{inc}}{t_{inc}} \right)^2 + \left(\frac{\delta L_{inc}}{L_{inc}} \right)^2 \right] + \left(\frac{2}{\lambda_{scat}^2} - \frac{2 \cos 2\theta}{\lambda_{inc}\lambda_{scat}} \right)^2 \left[\left(\frac{\delta t_{scat}}{t_{scat}} \right)^2 + \left(\frac{\delta L_{scat}}{L_{scat}} \right)^2 \right]}{\left[\frac{1}{\lambda_{inc}^2} + \frac{1}{\lambda_{scat}^2} - \frac{2}{\lambda_{inc}\lambda_{scat}} \cos 2\theta \right]^2} + \frac{\left[\frac{2 \sin 2\theta}{\lambda_{inc}\lambda_{scat}} \delta 2\theta \right]^2}{\left[\frac{1}{\lambda_{inc}^2} + \frac{1}{\lambda_{scat}^2} - \frac{2}{\lambda_{inc}\lambda_{scat}} \cos 2\theta \right]^2} \right\}^{1/2} \quad (2)$$

$$E = \frac{81.787}{\lambda_{inc}^2} - \frac{81.787}{\lambda_{scat}^2} \quad (3)$$

$$\frac{\delta E}{E_{inc}} = 2 \left\{ \left[\frac{\delta t_{inc}}{t_{inc}} \right]^2 + \left[\frac{\delta L_{inc}}{L_{inc}} \right]^2 + \left[\frac{\lambda_{inc}^2}{\lambda_{scat}^2} \frac{\delta t_{scat}}{t_{scat}} \right]^2 + \left[\frac{\lambda_{inc}^2}{\lambda_{scat}^2} \frac{\delta L_{scat}}{L_{scat}} \right]^2 \right\}^{1/2} \quad (4)$$

Table 4 shows the resolution calculated at different scattering angles for this instrument.

Table 4. Resolution and dynamic range for INEL5.^a

2θ	$\delta Q/Q$	$\delta E/E_{inc}$	$Q (\text{\AA}^{-1})$
2°	0.36	0.016	0.28
30°	0.025	0.016	4.16

^a Calculated for $E_{inc}=E_{scat}=50$ meV, and $\delta L_{inc}=\delta L_{scat}=1$ cm.

2.2 Bandwidth and Dynamic Range

Only the first frame is needed. This provides access to incident wavelengths up to 2.76 Å with the scattered wavelength equal to 222% of the incident wavelength (incident energies down to 10.7 meV with the scattered energy equal to 20% of the incident energy).

Table 4 shows the dynamic range at different scattering angles with these wavelength ranges.

2.3 Data Rates

Data rate estimates for this instrument will be provided in a later Technical Note.

References

1. SNS Conceptual Design Report values for poisoned decoupled ambient water moderator.
2. Technical Note ANL/SNS/98-1