NEUTRON SCATTERING FACILITIES AT THE TOHOKU UNIVERSITY ELECTRON LINAC

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In 1967 the Tohoku University 300 MeV electron linear accelerator was constructed. Since 1971 available pulsed neutrons have been supplied through nine horizontal and one vertical neutron beam tubes installed in the 2.5 m thick biological concrete shield. The length and cross section of the beam tubes are shown in Table 1.

The electron linear accelerator is usually operated at the acceleration energy of 250 MeV with the peak beam current of 60 mA and at the pulse duration of 3 μs with the repetition frequency of 115 pps. Therefore an electron beam of 5 kW mean power is irradiated to the multiplate tungsten target to provide the thermal neutron peak flux of 1×10^{12} $n/cm^2/s$ at the surface of the moderator. The specification of the target and moderator assembly is summarized in Table 2 and its arrangement is shown in Figure 1.

At the moment the nine neutron beam holes are occupied by various types of spectrometers and the one by a television monitor camera. The schematic layout of the neutron facilities in Tohoku electron LINAC is illustrated in Figure 1.

A medium size computer OKITAC-4500 plays the central function in the on-line data acquisition from the nine spectrometers. Each raw data collected is independently displayed and monitored on CRT. Necessary data can be recorded by a line-printer, paper-tape puncher and graphic copier. The whole system of data acquisition used is shown in Figure 2. The software and interface were totally developed by neutron users themselves.

Time Focusing Crystal Analyser Spectrometer

A time focusing energy-loss spectrometer with a reasonably good energy transfer resolution is installed at the H-1 beam hole to measure local modes of the hydrogen atom motion in transition metal hydrides in the crystalline and glassy state. The pyrolytic graphite crystal is used as an analyser in the inverted geometry at the expense of momentum transfer resolution. The beryllium filter of 15 cm in thickness is located in front of He-3 counters (1/2" diameter) without cooling it. The energy resolution achieved is 2.2 to 3.6 % over the energy transfer range of 50 to 600 MeV.

Rotating Crystal Inelastic Scattering Spectrometer

An inelastic scattering spectrometer with a pair of stationary and rotating pyrolytic graphite crystal plates is installed at the H-2 beam hole. Monochromatic pulsed neutrons with a desired wavelength from 1.5 to 4.5 are effectively chosen by adjusting the Bragg angle of the stationary crystal and tuning the delay of the firing time of the electron LINAC relative to the angular position of the rotating crystal. The neutron path is evacuated to avoid air scattering. Eight He-3 counter banks are arranged over the scattering angle from $2\theta = 10$ to $90°$ at the

position of 1.8 m apart from the sample. The momentum resolution is 20-7 % over the range of the momentum transfer from 0.2 to 4.5 A^{-1}, and the average energy resolution is 0.3 MeV over the range of the energy transfer from 0.3 to 100 MeV, respectively. The spectrometer has been used so far to measure the quasielastic neutron scattering due to the concentration fluctuation in Tl_2Te-Tl liquid, the diffusional motion of hydrogen atoms in $NbH_{0.32}$ single crystal and the Brownian motion in polystylene polymer-CH_2Cl_2 solution.

Magnetic Mirror Diffractometer

A magnetic mirror diffractometer is installed at the H-3 beam hole as an application of polarised pulsed neutrons to the structure study of magnetic substances. The magnetic mirror used is $Fe_{45}Co_{55}$ alloy evaporated on the OPP polymer film surface in 1 kOe magnetic field. The performance of the mirror shows the high polarisability of 90 % with the reflectivity of more than 85 % for the neutron of its wavelength longer than 2.5 A. This diffractometer is a prototype of the TOP spectrometer in KENS.

Liquid Total Scattering Spectrometer

The liquid total scattering spectrometer is installed at the H-4 beam hole to measure the structure factors of liquids and amorphous solids over a wide range of the scattering vector from 0.1 to 50 A^{-1}. The incident neutron beam size is defined to 10 mm wide × 50 mm high by a B_4C window and inner-beam tube collimator. Scattered neutrons are detected at six scattering angles (2θ = 3, 15, 30, 60, 90 and 150°) by He-3 detector (1/2" diameter × 20" length) banks placed symmetrically on each side of the incident beam. He-3 counters at the 60, 90 and 150° scattering angles are arranged in the time-focusing geometry with large apertures. Therefore B_4C nose cones coated with Gd_2O_3 paint are located between the He-3 counter box apertures and a sample chamber to prevent the He-3 counters from finding neutrons scattered from anything except for the sample. The sample chamber is evacuated to avoid air scattering and has the collimators extended from the nose cones in it. Incident neutron flight path length is fixed at 4.359 m, while scattered ones are variable from 0.40 to 0.50 m for 2θ = 15 to 150° and fixed at 1.509 for 2θ = 3°. The resolution of the scattering vector varies from 20 to 1 % according to the change in the scattering angle from 2θ = 5 to 150°.

Single Crystal Diffractometer

A single crystal diffractometer with a goniometer is installed at the H-5 beam hole. The goniometer has simultaneously four He-3 counters at different four scattering angles. The sample can be tilted within ± 10° on the goniometer. The sample and scattering angle are stepped with the accuracy of 0.05°. Using this diffractometer, it has been so far found that the magnetic spin in cubic Mn_3Si single crystal has the double helical structure along the <111> direction and the solid solution of Mn_3Si and Fe_3Si (simple ferromagnetic) shows the magnetic phase transition of double helical → simple antiferro → canted ferro → simple ferro with increasing Fe_3Si content.

Glass Scintillator Total Spectrometer

A new total scattering spectrometer with glass scintillation detectors is scheduled at the H-6 beam hole with a 6.0 m incident neutron flight path length. Li-6 enriched glass scintillation counters are

arranged at the scattering angle 2θ = 4 to 10°. At the moment the four scattering angles of 2θ = 150, 90, 45 and 26 ~ 22° have He-3 counter banks. In near future the He-3 counters will be replaced with the glass scintillation detectors to obtain much higher counting efficiency for epithermal neutrons. Furthermore all counters take the geometric and electric focusing arrangement. The estimated resolution of the scattering vector is between 0.1 and 1.0 A^{-1} over the range of the scattering vector from 0.2 to 60 A^{-1}. Several different samples are simultaneously mounted in the vaccum chamber which has high temperature furnace and helium cryostat.

Time-of-Flight Position Sensitive Detector Diffractometer

This diffractometer installed at the H-7 beam hole is a time-of-flight(TOF) single crystal diffractometer combined with a position sensitive detector(PSD). The one-dimensional PSD can provide the two-dimensional representation of the reciprocal lattice space when the TOF detection is used. Therefore the TOFPSD diffractometer is a quite promising and powerful instrument to measure the complicated intensity distribution in the reciprocal space. This diffractometer has been so far used for the observation of the thermal diffuse scattering and the rapid collection of many Bragg reflections from Cu_3Mn and NaCl single crystals. The positional resolution of the PSD used is 1.4 cm at 1.3 kV bias voltage. The scattering angle is set between 2θ = 15 and 120° by the goniometer, which mounts the PSD with the accessible aperture angle of about 30°. The two-dimensional data size is a 64 ch(position) × 250 ch (time). The channel width is variable from 2 to 32 μsec. The data collecting rate of the TOFPSD diffractometer is improved 100 times better than that of a conventional single counter diffractometer.

Vertical Beam Tube Diffractometer

A time-of-flight neutron diffractometer using the vertical incident beam tube (V-1) has been constructed to observe the medium resolution powder diffraction pattern ($\Delta d/d$ = 3%) as well as liquid and amorphous solid ones. This diffractometer consists of eight He-3 counters arranged at the scattering angles 2θ = 160, 130, 110, 90, 70, 50, 30 and 15°. Each detector is mounted inside a can filled with B_4C powder. The whole assembly of the detector array and sample are housed in a shielded box constructed from slabs of borated wax 10 cm thick. The sample is located at the position of 300 cm apart from the target and the detectors 25 cm from the sample. It is expected to use the diffractometer for a variety of simple experiments: crystalline powder patterns, determination of the Debye-Waller factor as well as the static displacement of lattice atoms and short-range structure of amorphous solids such as fluoride glasses.

Table 1 Distance between moderator and exit of beam tube, and its cross sections

Beam tube	Distance (cm)	Entrance cross section (cm)	Exit cross section (cm)
H-1	524.4	$10^W \times 10^H$	$20^W \times 7^H$
H-2	378.1	$10^W \times 10^H$	$8^W \times 8^H$
H-3	314.5	$8^W \times 8^H$	$5^W \times 5^H$
H-4	348.9	$6^W \times 6^H$	$6^W \times 6^H$
H-5	478.5	$10^W \times 10^H$	$5^W \times 10^H$
H-6	470.0	5.2 ϕ	5.2 ϕ
H-7	319.5	$5^W \times 5^H$	$5^W \times 5^H$
V-1	240.0	15 ϕ	20 ϕ

Table 2 Specification of target and moderator assembly

Target	Tungsten
	$30\times30\times2^{mm^3}$ (5 pieces)
	$30\times30\times5^{mm^3}$ (3 pieces)
	$30\times30\times9^{mm^3}$ (1 piece)
Moderator	water
	$115^{mm\phi}\times115^{mm}$
	height cylinder

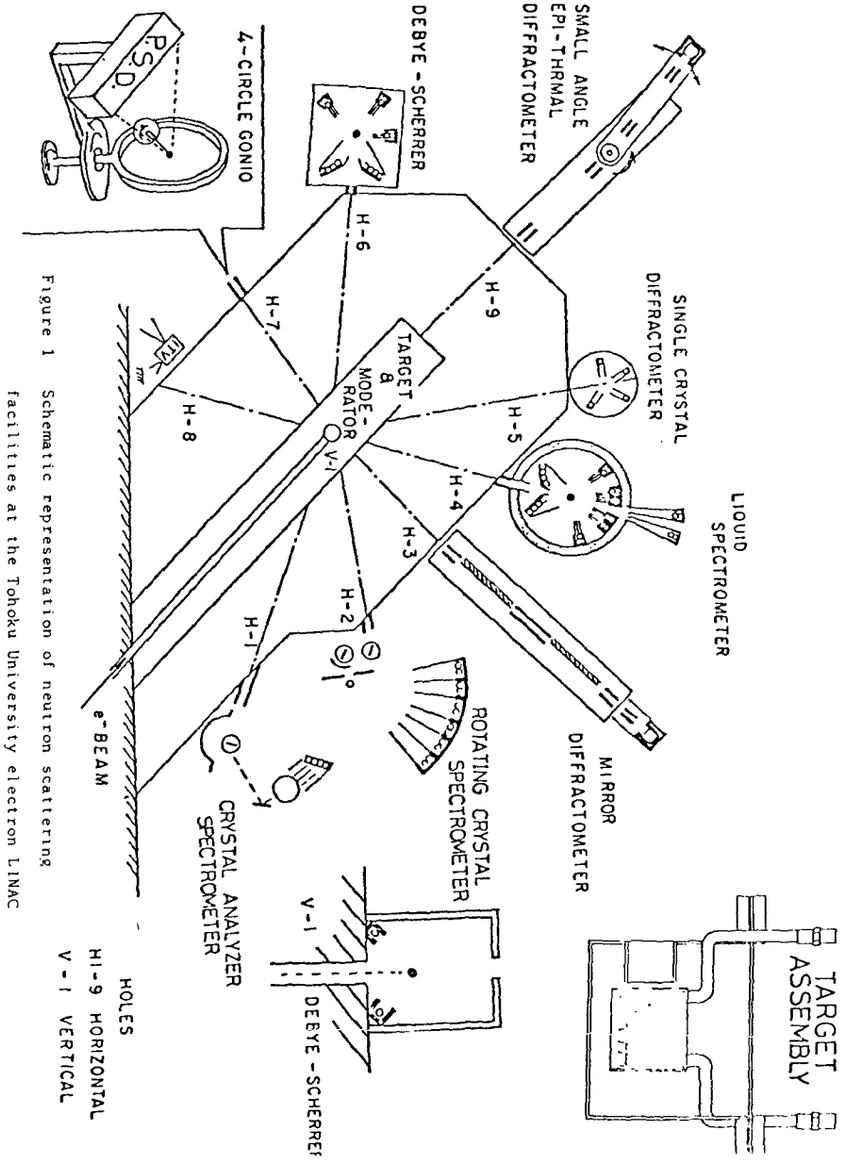

Figure 1 Schematic representation of neutron scattering facilities at the Tohoku University electron LINAC

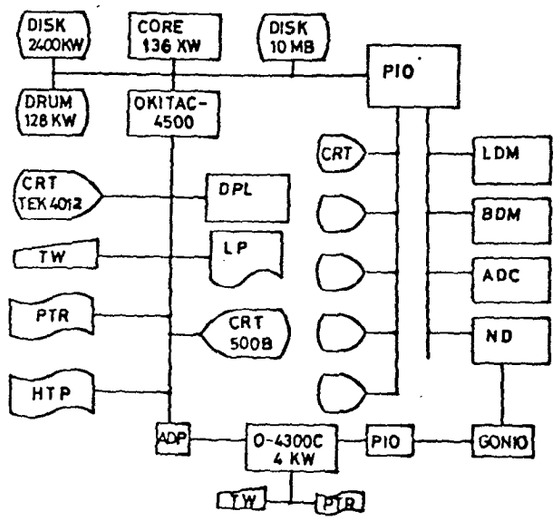

Figure 2 Block diagram of data acqusition system