GOVERNMENT OF INDIA

CRYSTAL SPECTROMETERS AT TROMBAY

January 1964

Indian Nuclear Data Group
Nuclear Physics Division
Atomic Energy Establishment Trombay
Bombay-74, India

1. Single Crystal Spectrometer

1. Organisation responsible for design, construction and operation	: Nuclear Physics Division, Atomic Energy Establishment Trombay.
2. Location	: Apsara Reactor, Atomic Energy Establishment Trombay, Bombay-74, India.
3. Main purpose of apparatus	: Cross section measurements (both scattering and absorption measurements) and spectra from crystals for studying high order contamination etc.
4. Status	: Year of first operation 1957
5. Scientist in charge of experimental programme	: K.R. Rao, Nuclear Physics Division, Atomic Energy Establishment Trombay
6. Number of staff employed	: Three to four
7. Available reference for more detailed description	: Nil
8. Literature on research already accomplished	: 1. V.P.Duggal, K.R.Rao, C.L.Thaper and V.Singh, Proc. of Nucl. Phys. Symposium, Waltair, (1960), published by Department of Atomic Energy, Bombay. 2. V.P.Duggal, K.R.Rao, C.L.Thaper, and V.Singh, Proc. Ind. Acad. of Sc. Vol. LIII, No. 2, 59 (1961) 3. V.P.Duggal Nucl. Sc. and Engg. 6, 76 (1959) 4. V.P.Duggal and C.L.Thaper Rev. Sci. Instr. 33, No. 1, 49(1962) 5. V.P.Duggal and C.L.Thaper, Proc. of Nucl. Phys. Symposium, Madras, (1962), published by Department of Atomic Energy, Bombay.

6. K.R. Rao and C.L.Thaper, Proc. of Nucl. Phys. Symposium, Bombay (1963), published by Department of Atomic Energy, Bombay.

9. Programme in progress : The spectrometer is being used at present for studies or resonant absorption and resonant scattering in Iridium and its compounds

10. Future programme : Along similar lines

11. Special specifications:

- Type : Single crystal, plane crystal
- Collimator : Cross section area of the collimator sometimes 1 mm x 5 cms, sometimes 5 mm x 5 mm
- Crystals available: Various crystals have been used from time to time Be(11$\bar{2}$2), Ge(111), Al(111), NaCl(200), KCl, etc.
- Energy range: With Be(11$\bar{2}$2) max. energy 3 ev., 0.005 ev to 3 ev.
- Sample : Useful area 5 cm x 5 cm.
- Specifications: Distance for crystal to detector 150 cms.
- Other details: Accuracy in angular position is 1 minute.

2. Double Crystal Spectrometer I

1. Organisation responsible for design, construction and operation : Nuclear Physics Division, Atomic Energy Establishment Trombay

2. Location : Canada India Reactor, Atomic Energy Establishment Trombay Bombay 74, India.

3. Main purpose : Crystal structure analysis

4. Status : First year of operation 1961

5. Scientist in charge of experimental programme : R.Chidambaram, Nuclear Physics Division, Atomic Energy Establishment Trombay.

6. Number of staff employed : Five

7. Available reference for more detailed description : Nil

8. Literature on research accomplished :
   1. R.Chidambaram, A.S.Sequeira and S.K.Sikka, Submitted for publication to Jour. of Chemical Physics.
   2. R.Chidambaram, A.S.Sequeira and S.K.Sikka, Submitted for publication to Nuclear Instr. and Methods.

9. Programme in progress : Study of crystal structure of $K_2Zn(CN)_4$, $BeSO_4$, $4H_2O$.

10. Future programme : Study of crystal structure of hydrogen bonded crystals and cupric complexes. When the Double Crystal Spectrometer II goes into operation, this spectrometer will be modified for low temperature work

11. Special specification:

- Crystals and planes available: lead (200)
- Incident energy variable or fixed: Fixed
- Range of scattering angle : 0° - 100°
- Steps in which scattering angle can be changed : 6'
- Accuracy of counter setting: 1'
- Collimators (location, size, and divergence)
  i) inpile, soller type - 1" x 1¾" x 24", 5/8° (F/HM)
  ii) between monochromator and sample, 5/8" x 1¾" x 24", 1½°(F/HM)
  iii) between sample and counter, soller type - 1" x 1¾" x 24", 5/8° (F/HM)
  (divergence of (iii) to be increased to about 1° shortly)
- filters: Polycrystalline bismuth 4" long
- Other operational features: Half angling by belt drive
  Spectrometer operation automatic
  Each reflection requires separate - setting.

3. Double Crystal Spectrometer II

1. Organisation responsible for design, construction and operation : Nuclear Physics Division, Atomic Energy Establishment Trombay

2. Location : Canada India Reactor, Atomic Energy Estsblishment Trombay, Bombay 74, India.

3. Main purpose of apparatus : Crystal structure analysis

4. Status : Scheduled for completion March 1964

5. Scientist in charge of experimental programme : R.Chidambaram, Nuclear Physics Division, Atomic Energy Establishment Trombay.

6. Number of staff employed : Five

7. Available reference for more detailed description : Nil

8. Literature on research accomplished : Nil

9. Future programme : Study of crystal structures of hydrogen bonded crystals and cupric complexes

10. Special specifications:
    - Crystals and planes available : Lead (200)
    - Incident energy variable or fixed : fixed
    - range of scattering angle : 0° - 120°
    - Steps in which scattering angle can be changed : 6'
    - Accuracy of counter setting: 1'
    - Collimator (location, size, and divergence)
        i. Inpile
        ii. between monochromator and sample, $\frac{1}{4}$" x $\frac{1}{2}$" x 36", 0.4° (FWHM)
        iii. between sample and counter, tapered collimator of length 15" tapering from $\frac{1}{4}$" x $1\frac{1}{2}$" to $1\frac{1}{2}$" x $1\frac{1}{2}$" on the counter side

- filters : Polycrystalline bismuth 4" long
- Other operational features: Half angling by belt drive; automatic operation; twenty reflections in one layer can be scanned with one initial setting.

4. Double Crystal Spectrometer III

1. Organisation responsible for	
a. design and construction	: M/s John Curran Co. Ltd., Cardiff, U.K.
b. Operation	: Nuclear Physics Division; Atomic Energy Establishment Trombay
2. Location	: Canada India Reactor, Atomic Energy Establishment Trombay, Bombay 74, India
3. Main purpose of apparatus	: Magnetic scattering studies
4. Status	: First operated at Apsara Reactor in the year 1959. Transferred to Canada India Reactor in January 1960
5. Scientistsin charge of experimental programme	: N.S.Satyamurthy, Nuclear Physics Division, Atomic Energy Establishment Trombay.
6. Number of staff employed	: Four
7. Available reference for detailed description	: P.K.Iyengar, N.S.Satyamurthy,and B.A. Dasannacharya; Proc. of the Symposium on Inelastic Scattering of Neutrons in Solids and Liquids, International Atomic Energy Agency, Vienna (1961).
8. Programme in progress	: Study of magnetic structure and properties of iron-tin, iron-germanium, and magnesee~~t~~in systems
9. Future programme	: Along similar lines

10. Special specifications:

- Crystals and planes available: Al(111)
- Incident energy fixed or variable : fixed
- Range of scattering angle: -30° to 130°
- Steps (smallest) in which the scattering angle can be changed : 1/12°
- Accuracy of counter setting: 1'
- Collimators (location, size and divergence)
  i. inpile, 2" x 2" x , 1½°(FWHM)
  ii. between monochromator and sample, soller type - 2" x 2" x 24", 0.6°(FWHM)
  iii. between sample and counter, 2" x 2" x 12", 1.2° (FWHM)
- filters : polycrystalline bismuth 4" long
- Other features: sample half angling is by belt drive mechanism, operation of spectrometer automatic; facilities are available to heat samples and cool them down to liquid helium temperatures; fields upto 45 kOe can be applied on the sample.

5. Polarized Neutron Spectrometer

1. Organisation responsible for design, construction and operation : Nuclear Physics Division, Atomic Energy Establishment Trombay
2. Location : Canada India Reactor, Atomic Energy Establishment Trombay Bombay-74, India.
3. Main purpose of apparatus : To study spin densities in magnetic crystals
4. Status : Scheduled for completion April, 1964.
5. Scientist in charge of experimental programme : N.S.Satyamurthy, Nuclear Physics Division Atomic Energy Establishment Trombay
6. Number of staff employed : Four

7. Special specifications:

- Crystals and planes available: Co-Fe(111), (200)
  Magnetite (220)
- Incident energy fixed or variable : Fixed. For normal operation a wavelength of about 1 Å will be employed, but the monochromator and shielding are designed for a wavelength range of 0.8 Å to 1.5 Å.
- Details of field applied on monochromator : The monochromator is mounted between the pole pieces of 3000 Oe permanent magnet with a 2" air gap
- Details of guide field : The guide field has a 3" square section and is 36" long. The value of the guide field is approximately 100 Oe.
- Spin flipper, type and details : radio frequency type, made of 14 gauge copper wire, is 10" long and 1½" in dia.
- Range of scattering angles:
- Smallest step in which scattering angle can be changed: 1/8°
- Accuracy of counter setting: 1'
- Other features: A special feature of the spectrometer is an additional thrust bearing independently mounted above the sample table. An electromagnet producing fields upto 15 KOe can be mounted on this bearing. The magnet can be stationary or can be coupled to rotating with the sample table. Half angling is by a belt drive.

6. Triple Axis Spectrometer I

1. Organisation responsible for design, construction and operation : Nuclear Physics Division
   Atomic Energy Establishment Trombay
2. Location : Canada India Reactor,
   Atomic Energy Establishment Trombay,
   Bombay-74, India.
3. Main purpose of apparatus : Study of inelastic scattering of slow neutrons from solids and liquids.

4. Status : Year of first operation 1962

5. Scientist in charge of experimental programme : P.K.Iyengar, Nuclear Physics Division, Atomic Energy Establishment Trombay

6. Number of staff employed : Five

7. Available reference for more detailed description : P.K.Iyengar et al., Proc. of the Symposium on Inelastic Scattering of Neutrons in Solids and Liquids, (Chalk River), Vol. II, I.A.E.A.(1963)

8. Literature on research accomplished : 1. P.K.Iyengar et al., Proc. of Symposium on Inelastic Scattering of Neutrons in Solids and Liquids, (Chalk River), Vol.II, I.A.E.A. (1963)

2. P.K. Iyengar et al., Proc. of International Conference on Lattice Dynamics, Copenhagen (1963) - under publication

9. Programme in progress : Study of phonon spectrum in iron

10. Future programme : Study of dispersion relations for phonons in various crystals

11. Special specifications:

- Crystals and planes available as monochromator: Al(111), (200)
- Incident energy fixed or variable: Fixed
- Range of scattering angle: 0° - 90°
- Steps in which scattering angle can be changed: 1/16°
- Accuracy of scattering angle setting: 1'
- Steps in which sample orientation can be changed: 3'
- Accuracy of setting sample orientation: 1'
- Crystals and planes available as analyser: Al(111)
- Outgoing energy fixed or variable: Continuously variable
- Steps in which analyzing spectrometer can be moved: 1/8°(2θA)
- Range of analyzing spectrometer: 70°(2θA)
- Accuracy of positioning of analyzing spectrometer: 1'

- Collimator (location, size, and divergence) : i. Inpile, 2" x 2" x , $\frac{3}{4}^{\circ}$(FWHM)
  ii. between monochromator and sample, 2" x 2" x 24",
  iii. between sample and analyser soller type - 2" x 2" x 12" $1\frac{1}{4}^{\circ}$ (FWHM)
- filter: polycrystalline, bismuth 4"
- Other operational features: Sample orientation drive is by a motor cum reduction gear system; scattering angle drive is by a motor cum belt system, analyzing spectrometer by a motor operated belt system; spectrometer is operated automatically by an electro-mechanical drive control The control can be programmed for "constant momentum transfer" operation of the spectrometer. Motor movements are unidirectional in a given programme

7. Triple Axis Spectrometer II

1.	Organization responsible for design, construction and operation	: Nuclear Physics Division, Atomic Energy Establishment Trombay
2.	Location	: Canada India Reactor, Atomic Energy Establishment Trombay, Bombay-74, India
3.	Main purpose	: Study of lattice dynamics and atomic motions in liquids
4.	Status	: Scheduled for completion in March 1964
5.	Scientist in charge of experimental programme	: K.R.Rao, Nuclear Physics Division, Atomic Energy Establishment Trombay
6.	Number of staff employed	: Three
7.	Proposed programme	: Study of atomic motions in liquid Krypton

8. Special specifications:

- crystals and planes available: Pb and Cu(200), Al(111)
- Incident energyfixed or variable: continuously variable
- range of monochromator angle ($2\theta_M$) : 20° - 90°
- steps in which $2\theta_M$ can be changed: 1/8°
- Accuracy of $2\theta_M$ = : 1'
- Range of scattering angle: 0° - 110°
- Steps in which scattering angle can be changed: 1/8°
- Accuracy of scattering angle: 2'
- Steps in which sample orientation can be changed: 1/8°
- Accuracy of sample orientation: 2'
- Outgoing energy fixed or variable: Can be varied in steps of 10°
- Filters: a)polycrystalline bismuth (7")
  b)provision has been made for introducing quartz single crystal filters if necessary
- Other features: Monochromator and scattering angle drives are motor operated belt drives.
  is driven by a motor cum reduction gear system
  Operation of the spectrometer is automatic and non-linear increments can be achieved by means of paper tape instructions

8. Beryllium Detector Spectrometer

1. Organization responsible for desing, construction operation : Nuclear Physics Division Atomic Energy Establishment Trombay

2. Location : Canada India Reactor, Atomic Energy Establishment Trombay Bombay-74, India

3. Main purpose of apparatus : Study of molecular vibrations and torsional oscillations in molecular compounds; study of lattice dynamics

4. Status : Year of first operation 1961

5. Scientist in charge of experimental programme : P.K.Iyengar, Nuclear Physics Division, Atomic Energy Establishment Trombay

6. Number of staff employed : Five

7. Available reference for more detailed description : 1. G.Venkataraman et al., Proc. of the Symposium on Inelastic Scattering of Neutrons in Solids and Liquids, (Chalk River), I.A.E.A. (1963)

   2. P.K.Iyengar, Nucl. Instr. and Methods) (under publication)

8. Literature on research : 1. G.Venkataraman et al., Proc. of the Symposium on Inelastic Scattering of Neutrons in Solids and Liquids, (Chalk River), I.A.E.A. (1963)
   2. G.Venkataraman et al., Solid state Communications 2 (1964)

9. Programme in progress : Study of phonon spectrum in magnesium by use of window filter techniques

10. Future programme : Along similar lines

11. Special specifications:

    - Crystals and planes available: Al(111) and Cu(111)
    - Incident energy fixed or variable: Variable
    - Range of monochromator angles: 0° - 27° (θ_M)

- Steps in which monochromator angle can be changed: 1/8° (in θ_M)
- Accuracy of monochromator setting: 0.01°
- Range of scattering angle 0° - 110°
- Steps in which scattering angle can be changed: $\frac{1}{4}$°.
- Accuracy of scattering angle setting: 1'
- Steps in which sample orientation can be changed: 4'
- Accuracy of setting sample orientation: 1'
- Analysers available: a) Polycrystalline Beryllium filter
  b) Polycrystalline beryllium oxide filter
  c) Window filter employing a Be-BeO combination
- filter details: a & b) 2" x 4" cross section and 4" long cadmium wrapped
  c) 7 beryllium pieces, $\frac{1}{4}$" x 2" x 8" inter leaved with cadmium and one 2" x 2" x 4" beryllium oxide piece
- detector details: a & b) one 2" dia 6" long BF_3 counter placed broadside on
  c) A ring of 12 counters 1" dia, 12" long arranged to see back scattered neutrons from BeO
- Collimators (location, size and divergence): i) inpile, 2" x 2" x , $\frac{5}{4}$°
  ii) between monochromator and sample, soller type - 2" x 2" x 24", 5/8°
- Inpile filters : Polycrystalline bismuth 4"
  provision has been made to introduce quartz filters if necessary.
- Other features: Monochromator drive is by a motor operated belt dri Counter drive is by similar means. Sample orientation variation effected by a motor cum reduction gear system. Operation of the spectrometer can be programmed for "constant momentum transfer" operation. Such programmes are used for study of phonons by the window filter technique.

9. Rotating Crystal Spectrometer

1. Organisation responsible for design, construction and operation : Nuclear Physics Division, Atomic Energy Establishment Trombay

2. Location : Canada India Reactor, Atomic Energy Establishment Trombay

3. Main purpose of apparatus : Study of cold neutron scattering from liquids and solids

4. Status : Year of first operation December 1963

5. Scientist in charge of experimental programme : G.Venkataraman, Nuclear Physics Division Atomic Energy Establishment Trombay

6. Number of staff employed : Four

7. Proposed programme : Study of atomic motions in liquid methane

8. Special specification:
   - Filter details: 2 inches of lead single crystal
     6 inches of quartz single crystal
     4 inches of beryllium
   - Rotor: aluminium single crystal
     spherical (2" dia) in shape reflecting from (111) plane
   - wavelength: 4 Å
   - Distance between sample table and crystal: 25"
   - Pulse width at sample table
   - Flight path : 3 meters
   - Neutron detector: A bank of 6 BF_3 counter 2" dia 18" long filled to 60 cms of Hg with 90% enriched gas
   - Time analyser: Number of channels 100 channel widths available 8 usec, 16 usec and 32 usec.
   - Resolution at incident energy : $\frac{\Delta\lambda}{\lambda}$ ~3%
   - Range of scattering angle: 0° - 100°