NEUTRON SCATTERING FOR CONDENSED MATTER STUDIES

PROF. SAIBAL BASU
Department of Physics
IIT Bombay - HBIN

PRE-REQUISITES : M.Sc in Physics or Chemistry/bachelor's in Material Science. The course is a stand-alone course for application of neutron scattering to condensed matter problems.

INTENDED AUDIENCE : Ph. D. students and researchers in condensed matter physics

INDUSTRY SUPPORT : Some characterization tools like Diffraction, SANS and PNR are often used by industry

COURSE OUTLINE :

The short-range strong interaction of neutron with matter and the inherent magnetic moment of neutron, makes neutron scattering a unique probe in condensed matter research. An important advantage of neutrons is that they carry no charge and can penetrate the bulk of materials. They interact via strong force with the nuclei of the material and the scattering cross section varies randomly between various elements and even between two isotopes of the same element. This allows one to observe light atoms such as hydrogen in the presence of heavier ones and distinguish neighbouring elements in the periodic table easily. Notably, hydrogen and deuterium have large contrast with respect to neutrons. One can exploit isotopic substitution and contrast variation methods in such studies. Since neutron also carries a magnetic moment of -1.91μN, it also interacts with magnetic moment in atoms, making it a unique probe for determination of microscopic magnetic structure. Wavelength and energy of thermal neutron match with the lattice spacing and excitations in condensed matter and makes it an indispensable tool to study both structure and dynamics in condensed matter. Using neutron scattering techniques with varying momentum transfer and energy transfer range and resolution one is capable or understanding structure and dynamics in materials at various length and time scales.

ABOUT INSTRUCTOR :

Prof. Saibal Basu retired as Head, Solid State Physics Division, Bhabha Atomic Research Centre, Mumbai. He was a Raja Ramanna Fellow and a senior professor at Homi Bhabha National Institute (HBNI). He has been working in condensed matter research using neutrons for nearly four decades. His field of research has been, neutron scattering, development of neutron spectrometers and development of cold neutron sources. He was the leader of neutron beam research at Bhabha Atomic Research Centre as Head of Solid State Physics Division. He developed the first Polarized Neutron Reflectometer in the country for characterization of thin films. His special interest had been thin films as novel components of material science. Prof. Basu had worked as a Research Reactor Specialist at International Atomic Energy Agency (IAEA), Vienna during 2001. He was also a visiting scientist at National Institute for Standards and Technology's reactor centre during 2005-2006. Prof. Basu has more than hundred publications and a large number of presentations in National and International conferences. He had delivered invited talks in large number of International symposia. Several students have worked under the guidance of Prof. Saibal Basu towards their doctoral thesis at HBNI. Prof. Basu had initiated several international collaborations in the field of neutron beam research and neutron beam instrumentation. He was part of a Coordinated Research Project (CRP) under IAEA on production of cold neutrons. Prof. Basu was a board member of Asia Oceania Neutron Scattering Society. Presently he is a member of the editorial board of an Elsevier journal, Heliyon

COURSE PLAN :

Week 1: Properties of neutron, Comparison with other probes: optical rays, x-rays, electrons, Nature of interaction between neutrons and matter at microscopic length scale
Week 2: Neutron Sources: Reactors and Accelerator based sources, Neutron Scattering Instrumentation for condensed matter studies vis a vis neutron sources, Neutron detectors.
Week 3: Principles of Neutron Scattering under Born approximation, Scattering Laws, coherent and incoherent scattering, Principle of detailed balance, correlation functions.
Week 4: Neutron diffraction at different length scales: microscopic to mesoscopic.
Week 5: Neutron diffraction from powders, single crystals, liquid and amorphous systems
Week 6: Magnetic structure using neutron diffraction
Week 7: Small Angle Neutron Scattering (SANS) from precipitates and inhomogeneities
Week 8: Polarized Neutron Reflectometry (PNR) from magnetic thin films
Week 9: Back to Born approximation and scattering law. Inelastic and Quasi-elastic neutron scattering for dynamics in condensed matter.
Week 10: Inelastic neutron scattering from phonons. Experiments to determine phonon dispersion relations using single crystals and phonon density of states from powders. Magnons.
Week 11: Quasi-elastic neutron scattering to determine stochastic dynamics like diffusion in solids and liquids
Week 12: Detailed discussion on available neutron sources and spectrometers at nuclear reactors and spallation neutron sources for experiment design with examples.