genes and to preserve genetic diversity within this breed, the team of scientists at NRCE have taken up a project to cryopreserve the embryos of this breed through which elite genetics can be preserved. Until now, the team has successfully cryopreserved 15 Marwari horse embryos. This achievement will help us envisage the feasibility of equine embryo transfer in India. Embryo transfer technology in equines will bring new dimensions to our efforts to produce quality indigenous horse breeds. Also, the farmers will benefit from this advanced reproductive technology, which will lead to future stability of indigenous horse breeds that are fast declining.

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Assured access to neutron and muon sources at RAL, UK under the DST–STFC collaboration

The DST-RAL project is a collaborative agreement between the Department of Science and Technology (DST), India, and the Science and Technology Facility Council (STFC), the United Kingdom, representing a cutting-edge initiative to enhance and streamline access to neutron and muon facilities at the Rutherford Appleton Laboratory (RAL), UK. This project is dedicated to advancing research in nanoscience and technology, focusing on quantum materials, energy, advanced engineering and healthcare. The main objectives of this project are to nurture researchers, enhance instrumental resources, and foster collaborations in neutron and muon techniques.

On 16 January 2015, the Government of India and STFC partnered to benefit the latter's ISIS neutron and muon facility, and India's Nano Mission. ISIS is acknowledged as a world-class centre for research in the physical and life sciences. Figure 1 shows various neutron and muon instruments situated at target stations 1 and 2. A few other facilities in India offer similar research capabilities. Under this agreement, scientists involved in India's Nano Mission will be given dedicated access to ISIS instruments.

The Director of STFC's ISIS, Robert McGreevy, and C. N. R. Rao, Chair of India's Nano Mission, officially established the partnership through a letter of intent. The Nano Mission is dedicated to advancing material studies on a nanoscale, aiming to deepen our understanding of science on this level. The acquired knowledge will be used for the development of technologically important materials, such as steel for household appliances or polymers for drug-delivery systems, with practical applications in the real world.

The inaugural phase of this five-year undertaking has yielded substantial scientific contributions, which have been published in renowned journals. These contributions span various subjects, including energy materials, carbon dioxide capture, nanomaterials, biomaterials and quantum materials. Researchers from many research and academic institutions in India have had the opportunity to utilize these state-of-the-art facilities. Notably, close to 100 Ph.D. students actively participated in experiments conducted at RAL. This initiative has played a pivotal role in supporting the professional development of researchers and post-doctoral fellows. Through workshops and training programmes, it has also facilitated extensive scientific collaboration and knowledge exchange among researchers in India. It is worth noting that this project, overseen by the Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR), Bengaluru is slated for completion by 31 December 2023. A proposal for the next phase of this project is under consideration by DST.

Techniques available at RAL

Neutron diffraction

Neutron diffraction experiments are helpful in uncovering the atomic or magnetic arrangement within a material. This method involves elastic scattering of neutrons from the material. It is somewhat akin to X-ray diffraction, but offers complementary insights because it employs a different type of radiation. To perform a neutron diffraction experiment, a sample is positioned in the path of a beam of either thermal or cold neutrons. The neutron diffraction pattern of the sample provides details about the atomic arrangement. Neutrons interact directly with the nucleus, and the contribution to the intensity of the diffracted neutrons differs for each isotope. For instance, hydrogen and deuterium have distinct effects. Even though neutrons are electrically neutral, they possess spin which interacts with magnetic moments, including those created by the electron cloud surrounding an atom. Consequently, neutron diffraction can unveil the microscopic magnetic configuration of a material.

Target systems: Crystalline solids, gases, liquids, thin films and amorphous materials.

Instruments: Engin-X, GEM, HRPD, INES, NIMROD, PEARL, Polaris, SANDALS, SXD and WISH.

Neutron spectroscopy

Inelastic neutron scattering is a technique that measures how a neutron's energy changes as it interacts with a sample. This method serves as a versatile tool for investigating a broad spectrum of physical

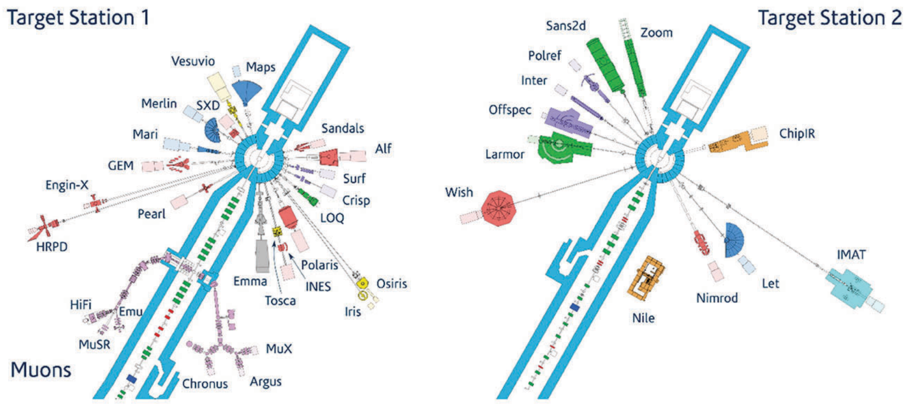

Figure 1. Various neutron and muon instruments at target stations 1 and 2. Courtesy: STFC website.

phenomena, including the movements of atoms such as diffusion and hopping, the rotational behaviour of molecules, sound waves, molecular vibrations, motion in quantum fluids, magnetic and quantum excitations, and even shifts in electronic states.

One of the key applications of inelastic neutron scattering is to delve into the vibrational motion of atoms. This motion, either entirely or in part, plays a crucial role in defining various characteristic properties of a material. These properties encompass heat capacity, thermal conductivity, optical and dielectric characteristics, and electrical resistance. Furthermore, by studying atomic vibrations using this technique, researchers gain direct insights into the nature of atomic bonds in a material.

Target systems: Powder and single crystals, liquids and thin films.

Instruments: Iris, LET, MAPS, MARI, Merlin, Osiris, Tosca and Vesuvio.

Reflectometry

Neutron reflectometry is a method used to examine the structure of thin films, with diverse applications ranging from materials science to soft matter and bioscience. In this, an extremely collimated neutron beam is focused on a flat surface and the variation in the reflected intensity is measured with respect to changes in incident angle or neutron wavelength. A detailed information about the thickness, roughness, density of the thin films layered on a substrate can be extracted from the shape analysis of reflectivity profile.

Target systems: Thin films with magnetic and non-magnetic interfaces, air/liquid, liquid/liquid, air/solid and liquid/solid interfaces.

Instruments: Crisp, Inter, Offspec, POLREF and Surf.

Small angle scattering

Small-angle neutron scattering (SANS) is a neutron-based method that allows examination of structures within a size range spanning approximately 1 nm to over 100 nm. Small-angle scattering (SAS), is an umbrella term encompassing various techniques, including SANS small angle, X-ray (SAXS), and small angle light (SALS or LS) scattering. In each of these methods, radiation is scattered elastically when it encounters a sample, and the resultant scattering pattern is analysed to extract information about the dimensions, configurations and orientations of specific components within the sample.

Target systems: Biological materials, polymers and magnetic materials.

Instruments: Larmor, Loq, Sans2d and Zoom.

Imaging

The ISIS instrument IMAT is a specialized tool that offers a unique combination of neutron imaging and neutron diffraction techniques. IMAT is tailored to meet the needs of a wide spectrum of materials science applications where non-destructive and *in situ* testing is essential. This instrument provides neutron radiography, tomography, strain scanning and texture analysis capabilities. It is poised to facilitate research in various fields, from engineering sciences to earth sciences, archaeology, heritage science, soft matter and biomaterials.

Target systems: Soft matter, engineering materials and biomaterials.

Instrument: IMAT.

Muon spectroscopy

Muon spectroscopy is a powerful tool for looking deep into the atomic structure of materials. This technique is employed to explore diverse subjects, including magnetism, superconductivity, how charges move around, the behaviour of molecules, chemical investigations, and even the intricate study of how hydrogen behaves within materials like semiconductors and proton conductors. Additionally, it can be used for detailed elemental analysis. Muon spectroscopy is a versatile microscope for the atomic world, helping researchers uncover the mysteries of various materials and their properties.

Target systems: Magnetic materials, superconductors, molecular materials, polymers and semiconductors.

Instruments: ARGUS, CHRONUS, EMU, HiFi, MuSR, MuX and Super-MuSR.

Accessing these facilities

There are different routes to access these facilities, which require writing and submitting a scientific proposal to the online submission system. The submitted proposals will go through peer review by corresponding facility access panels.

Direct access

Direct access is suitable for all ISIS experiments. Proposals are submitted during two annual calls, due on the third Wednesday of April and October. The ISIS Facility Access Panels review these proposals approximately six weeks after the deadline. The allocated beamtime is typically scheduled by ISIS scientists within 3–8 months, depending on run cycles. Under the DST–RAL project, proposals can be submitted through a separate Indian access route.

Rapid access

If beamtime is urgently required, one can write rapid access proposals. These proposals can be submitted any time of the year and will be peer-reviewed by Facility Access Panels members. The allocated time will be scheduled as soon as possible. It is important to discuss your rapid access proposal with the relevant ISIS scientist before submission to ensure beamtime availability and experiment feasibility for rapid access.

Xpress access

The Xpress proposal is ideal for simple and short-duration measurements, which do not require any complex sample environment and can be done by instrument scientists. It is best suited for one-time crystal structure determination, sample suitability assessment or completing a single measurement. No advance peer review or a science case is necessary. Samples are sent to ISIS for measurement, and fully processed, high-quality data are received for analysis with minimal assistance from ISIS. While Xpress access is theoretically available on any ISIS instrument, it is advisable to consult the relevant ISIS scientist before submitting an Xpress request to ensure suitability.

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