1.5.5 JRA 5 – PNT

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Partners: 2 – GKSS, 7 – ATI, 8 – ILL, 9 – CEA LLB, 9 – CEA DSM, 11 – FRM-II, 13 – HMI, 18 – TUD, 21 – PNPI, 23 – BNC-RISP
Observers: Riken, SNS, ISIS, JINR, LANL, NIST, MPI Stuttgart, Uni. Brest, JAERI, TU Taiwan, ANSTO

Project objectives

The development of new superconductors, molecular magnets, spin electronic and magnetic nanostructures are at the forefront of condensed matter research. Polarized neutron scattering provides exceptional possibilities for detailed understanding of the mechanisms involved. Measurement of the vector properties of the neutron polarization provides a unique way of recovering the significant directional and phase information lost when only neutron intensities are measured. The changes in the direction of the neutron spin that take place on scattering by a magnetic dipolar field are highly dependent on their relative orientations and can be measured very precisely using neutron polarimeters. On the other hand, the Larmor precession of neutron spin in magnetic field allows attachment a “Larmor clock” to every neutron. Such a Larmor labelling opens the possibility for the development of “unusual” neutron scattering techniques, where the energy (momentum) resolution does not require the initial and final states to be well selected. This decoupling results in an extremely high energy (momentum) resolution that is not achievable in conventional neutron spectroscopy (diffraction) because of intolerable intensity losses.

Three main objectives of this PNT JRA are:

- Develop and make widely available a new generation of key tools used for a precise handling of neutron polarization vector.
- Develop a new generation of neutron scattering instruments, methods and devices based upon the Larmor labelling of neutrons.
- Develop interdisciplinary contacts and establish hand-on facilities that will allow for scientists from different field of physics to learn powerful polarized neutron scattering technique.

JRA partners undertook research and activities in three key areas: 3-dimensional neutron polarimetry, Larmor precession based neutron scattering instrumentation and training program for people interested in polarized neutron scattering theory and practice. The following work has been carried out and allows us to practically completely reach the project’s objectives:

1. Development of non-cryogenic zero-field polarimeters for diffraction and reflectometry – MUPAD.
2. Development of polarimetric neutron spin echo technique.
3. New correction elements for high –resolution NSE spectrometers
4. Development of the NRSE-TAS method towards neutron energies up to 50 meV and a maximum tilt angle of 70°.
5. Developments of NRSE technique towards the simultaneous data acquisition over a high solid angle.
6. Development of SESANS towards resolution of 20 micrometers. Development of magnetic SESANS
7. New alternative NSE techniques
8. Development of an adiabatic broad wavelength spin flipper for $\lambda > 0.4$ Å.
9. New Larmor precession devices for reflectometry and GISANS.
10. Development and test of methods of neutron magnetic spin tomography.
11. Development and test of dynamical neutron polarization technique.

Methods

The whole spectrum of approaches ranging from the most modern technological possibilities to the sophisticated analytical calculations, simulations and software development have been used during the realisation of tasks of this JRA. Beside many others one should mention final element based calculations of magnetic field distributions around complicated current distributions carried out by one of the most powerful in the world CRAY computers and the use of latest developments in the cryogenic techniques.
All achievements of this project are absolutely on the front line of modern polarized neutron scattering and constitute its state-of-the-art.

Impact

The results of the project already have a strong impact on the European scientific community. SESANS method is becoming an established neutron scattering technique. More institutes are now considering building a SESANS-instrument. It is now being applied to all kind of questions where structures on length scales of microns have to be resolved. The techniques we have developed during this JRA show great potential for reflectometry. Using this knowledge we have constructed the spin-echo components for the instrument OFFSPEC that is being built at the second target station at ISIS.
State-of-the-art Spherical Neutron Polarimetry can now be combined with Neutron Spin Echo spectroscopy without any reservations at the expense of some intensity loss due to the additional polarizer device. We are confident that Polarimetric Neutron Spin Echo will be developed further and become the method of choice for a deeper understanding of chiral and other complex magnetic phase transitions.
The energy resolution of neutron scattering instruments is greatly enhanced by the use of Larmor labelling techniques. Measurements of the life time of phonon excitations in crystals become possible with the unprecedented accuracy. An extremely slow diffusion of polymer chains becomes detectable.