1.5.4 JRA 4 - NSF

Coordinator: 8 - ILL
Partner: 1 - STFC, 4 - FZJ, 9 - CEA DSM, 11 - FRM-II, 13 - HMI
Observers: IUCF, NIST, SNS, KEK, Michigan University

Project objectives

The project consisted of developing neutron spin filters with the aim of opening new research areas at European neutron facilities. The partners have improved the production of polarised ^{3}He gas using both the spin-exchange (SEOP) and metastability-exchange (MEOP) optical pumping techniques and spread the exploitation of the spin filters with improved containers and new magnetostatic cavities necessary for the slow decay of the ^{3}He polarisation.

At the beginning of the project, the ISIS and FZJ facilities were producing polarised ^{3}He with the SEOP technique and ILL was starting its MEOP station. From the collaboration established with the observers, we have learned how to replace conventional lasers with external cavity diode lasers and develop many techniques to diagnose the SEOP processes. Motivated by the anticipated results, ILL has decided to launch a SEOP programme and collaborated with ISIS and FZJ. In 3 years, the maximum ^{3}He polarisation has raised from 32 to more than 70% in these European facilities. The partners and observers have carried out together an experiment at ILL for understanding the limits of the SEOP technique when it is employed to polarise the gas continuously on a neutron beam. They have discovered that the ^{3}He polarisation decreases with increasing neutron flux. This discovery will probably have a great impact in the future.

In parallel, ILL has built a set of electronics, tested new optical elements and worked on the electrodes used to polarise the gas with the MEOP technique. This work has led to huge improvements: the gas is now polarised twice as fast as before and the maximum polarisation available on a neutron beam has risen from 68 to 80%. The success is such that ISIS has decided to purchase a MEOP station to ILL and that the number of instruments using spin filters on a regular basis has grown from 2 to almost 10 at ILL.

The ^{3}He polarisation decreases in time and this raises a number of difficulties for exploiting spin filters on neutron beams. From the experience gained by the observers in the USA, the partners have changed their recipes and now produce cells regularly featuring very long relaxation times, i.e. greater than 200 hours. HMI has also shown that magnetic fields have a big impact on the lifetime of the gas in the containers and this has helped people understand some of the irregularities encountered during experiments. Today cells are regularly demagnetised and this has solved a number of problems.

ILL which was facing troubles for transporting the polarised gas to the instruments at the beginning of the project, has developed a magnetostatic cavity which is easy to handle and which screens the stray magnetic fields encountered during the transports. After this successful development, ILL has added a radiofrequency coil to this cavity that permits to flip the ^{3}He polarisation. This has greatly enhanced the motivation of scientists in using spin filters because it simplifies a lot the use of the filters on polarised beams. 12 copies of this box have been produced and distributed to the partners and observers.

The progress made with the MEOP technique has enabled the production of large quantities of polarised gas and ILL has built large cells covering large solid angles with the aim to improve the instruments efficiency. From finite element calculations, ILL has also successfully built an apparatus producing a magnetic field that can be rotated on the instrument while maintaining the field homogeneity and therefore the ^{3}He polarisation. For instruments using high magnetic fields, a special magnetostatic cavity made from superconducting and soft-magnetic materials able to host a ^{3}He container in front of a cryomagnet has also been built and tested very successfully. A further step has even been accomplished with the exploitation of filters when ILL has demonstrated that a filter could be maintained at a constant polarisation by repolarising small quantities of gas in pulsed mode using a special magnetic capillary.

Methods

The exchange of information between the Observers located in the USA and the Partners has been very important, in particular for developing the SEOP technique and improving the preparation of containers in Europe.

The main deliverables have been produced by the largest European facility (ILL) thanks to the motivation and synergy existing between the scientific and technical divisions and to the investment injected in this project. The collaborations with the other partners has facilitated the testing of the new devices. Indeed, the neutron beams are heavily demanded at ILL and it is a little easier to get beam time at the other facilities.

Impact

Today, the world's leading technique for polarising ^{3}He remains MEOP in Europe but the SEOP community is making big progress and the European facilities have acquired most of the knowledge which has been developed in the USA.

The number of instruments taking advantage of the spin filters has increased very rapidly during the project. For example, the quantity of polarised gas produced for scheduled experiments has been multiplied by 3 at ILL. In most cases, the use of spin filters has increased the performance of instruments: better flux and/or resolution, less background, easier data analysis. It has also opened new possibilities, for example the investigation of magnetic nano-scale samples on powder diffractometers and the exploitation of polarised beams at spallation sources.

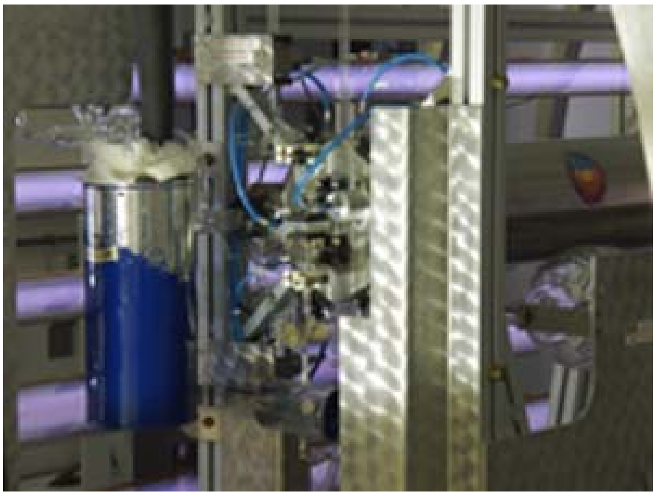

Fig J4: The world's best MEOP filling station for neutron scattering located at ILL, Grenoble (France). In this photo, we see the head of the non-magnetic piston used to compress the polarised gas. In the back, we also see the light emitted by the plasma of ^{3}He obtained by applying a discharge. The whole apparatus is about 2m diameter and 3m long. A very homogeneous magnetic field of 8 Gauss is applied in the whole system.