A European Network for Neutron Instrumentation

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Abstract

A research proposal is described which has recently received EC funding. The proposal involves 7 European laboratories: HMI (Berlin), University of Rome, ILL (Grenoble), The Delft University of Technology, The Risø National Laboratory, EMBL (Grenoble) and RAL (Oxford, co-ordinator). The aim of the research is to provide the basis for improvements in neutron instrumentation in 3 areas: neutron detectors, neutron polarisation and data verification and visualisation.

Introduction

The network described here was conceived during a planning meeting for a next-generation neutron source, the ESS, held in 1992 at The Cosener's House, Abingdon. Although a new generation of neutron sources may be planned, the provision of new sources has a long lead time (10-20 years), and there is a need to improve the existing infrastructure of neutron instruments in the intervening period. The aims of the network are therefore twofold:

- to improve the instrumentation of European neutron facilities
- to train young scientists in the techniques of neutron instrumentation

It will achieve these aims by undertaking research in 3 key areas:

- detectors
- polarisation devices
- visualisation software

Each of these areas was chosen because of the major impact it will have on neutron instrumentation, and because in each area there are new ideas and techniques that require development. These 3 areas underpin the current development of neutron instrumentation and the overlapping expertise of each partner will result in an effective network of 7 leading European laboratories (see Table 1).

Detectors

Because of the high cost of neutron detectors, many existing facilities are equipped with less than their optimal detector complement. One of the central aims of this programme will therefore be the development of cheaper neutron detector technologies, together with improvements in their performance.

The programme on detectors will be the largest activity in the network, drawing together the expertise from 6 of the participating laboratories. Three key areas have been identified which will be studied:

- novel solid state detectors
- new scintillators/converters
- neutron image plate development

At the Instituto Nazionale di Fisica della Materia (INFM) in Italy the exciting possibilities of using amorphous silicon as a neutron detector will be explored. Amorphous silicon diode material, when coated (or doped) with a suitable neutron converter offers the promise of both fast and inexpensive neutron detectors. This possibility has recently been demonstrated by American research workers, although much work remains to be done in optimising both the materials and signal processing for such devices. The programme that will be followed in Italy will include:

- Studying the performance of position sensitive detectors based on a-Si:H diodes using various neutron-ionising converters. In this research, particular care will be devoted to developing position sensitive detectors (PSDs) with good efficiencies over a wide energy range.

- Investigating the possibility of building PSDs which are built up not by a single diode but by a stack of diodes. This solution is very important because it will allow, for example, the use of very thin boron coating so to accomplish both a high neutron absorption and high probability for α particle emission from the converter. In this way a PSD could be made with a high efficiency over a wide neutron energy range.

At Delft, in the Netherlands, new ideas on scintillator detectors will be pursued. In particular new inorganic neutron scintillators and techniques for the position sensitive detection of light will be explored.

Studies will be made of glasses and crystals containing Li and/or B, in low atomic-number scintillators to keep the background gamma ray efficiency small. Luminescence will be based on fast transfer of the excitation energy, produced by the neutron interaction in a host material, to low concentration rare earth ions. The intensity depends strongly on the host material as the efficiency of the transfer is governed by;

- the presence of competitive nonradiative processes that may occur in the host material and,
- the position of the 5d level of the rare earth ion in relation to the energy levels (bands) of the host material.

The main research task will be to find an optimal combination.

For emission in the UV region below 220 nm it is possible to use wire chamber technology or gas amplification micro strip detectors for the position sensitive detection of light (for which the response can be very fast). We will work on the development of the last type of detector since wire chamber technology is sufficiently understood.

At the Institut Laue-Langevin (ILL) in France, the detector programme will focus on the development of a neutron image plate. This is a neutron-sensitive analogue of the image plate which is increasingly being employed in X-ray diffraction. In order to use these image plates as neutron detectors, a scintillator is necessary to convert neutrons to electromagnetic radiation. A comprehensive experimental study to include the choice of scintillator materials, the production of special phosphors suitable for neutron diffraction and their characterisation using neutron beams will be pursued.

The considerable expertise of the Risø Laboratory and the Rutherford Appleton Laboratory (RAL), based on long standing programmes in neutron detectors, will be used to assist these programmes.

Polarisation

Polarised neutrons are crucially important in the study of spin dependant processes, such as occur in magnetism. Existing polarising devices (crystals, mirrors and super-mirrors) become increasingly inefficient below 3Å. The use of polarised ^3He filters is an alternative approach, which could revolutionise the field of polarised neutron spectrometry. It could provide vastly improved intensities, particularly for polarisation analysis at thermal neutron wavelengths (1-3Å). Small filter units using this technique have been tested but there remains a variety of technical/physical problems to be solved, before a system of this kind could be of practical use. The research will focus on one of the schemes of optical pumping ^3He, (i.e. via the exchange scattering on Rb vapour). The first goal is to set up a high power, stable laser facility on a neutron beam, in order to test and optimise various ^3He cells. The goal of the test is to find the optimal efficiency and stability of working polarising filters of this kind, and to gain operational experience, a prerequisite for actual utilisation.

Data Visualisation and Visualisation Software

Four host laboratories (Table 1) will be involved, with an RA being employed at the Rutherford Appleton Laboratory in the UK. The objective of this research is to design software able to handle efficiently the complexity of data now being produced by neutron instruments.

Many spectrometers now employ large, positive sensitive detectors and routinely produce data sets of between 5-20 Mbytes. On some instruments, particularly those on white-beam pulsed sources, such data sets may be produced in minutes rather than hours. While raw computing power has increased significantly over recent years, there has not been a corresponding improvement in the software necessary to 'visualise' complex data. The efficient guiding of resource-limited neutron experiments requires specialised software, tailored closely to the instrument's and experimenter's needs. An example of such successful software is in the 'GENE' language developed at RAL for manipulating 2-d spectra (e.g. I vs. momentum transfer Q, or energy ω).

An equivalent language for 3-d (I vs. Q_x, Q_y), 4-d (I vs. Q) and 5-d (I vs. ω,Q) intensity maps is now required and the research will concentrate on:

- selecting suitable visualisation techniques for the problems described above;
- defining the data analysis language;
- producing selective software prototypes.

The related problem of automatic data fault recognition (data verification) will also be investigated, since this now plays an important part in maintaining the efficient throughput of neutron experiments. A number of avenues will be explored. Many instruments now contain hundreds of individual detectors (e.g. MARI, SANDALS at ISIS) and manual surveys of the data are impractical. Such surveys are important since individual detector errors may be missed when the data is merged with that from other detectors. Instruments vary widely in their data rates and data 'profile'. Thus a different technique will be required to detect errors in sparse data than in intense data, for example. Suggested methods for testing, in increasing order of complexity, are:

- comparing total counts
- comparing information content
- comparing 'shape' using statistical or neural network techniques

The possibility of using neural networks to 'learn' normal data analysis patterns is being explored elsewhere, and could prove an effective tool for diagnosing error conditions within faulty neutron instrumentation.

Table 1

Institute	Detectors	Polarisation	Visualisation
Delft (NL)	•		
HMI (DE)		❷	•
ILL (FR)	•	•	
INFM (I)	❷		•
Risø (DK)	•		•
RAL (GB)	•		❷
Symbol:	• = participation	❷ = 2yr RA	

The total network, encompassing the interlinked areas of neutron instrumentation described above, will therefore employ 3 RAs. They will receive excellent training, in the techniques and technologies described at leading research centres throughout Europe. It is also clear that, resources permitting, further fellows could build upon this foundation and, following the creation of the network, will be bid for individually.