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The OSIRIS diffractometer and polarisation analysis spectrometer at ISIS: New developments and ^{3}He spin-filter polarisation analysis

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Abstract

OSIRIS combines a long-wavelength powder diffractometer with a polarisation analysis backscattering spectrometer. The diffractometer can access wavelengths up to 70 Å with a resolution of better than 1% Δd/d. The very high counting-rate at shorter wavelengths is ideal for in-situ, real-time and parametric experiments. The spectroscopy section incorporates an array of graphite crystals arranged in near-backscattering to give a high counting rate with 25 μeV energy resolution. The incident beam is polarised using a supermirror bender and the scattered beam is polarisation-analysed by a ^{3}He spin-filter in the process of being constructed. The spin-filter system consists of a fibre laser, a peristaltic pump and a wide-angle banana-shaped quartz cell in a continuous-flow setup. The scattered beam passes twice through the spin-filter cell, thus doubling the optical path length in the cell. The aim is to achieve 70% nuclear polarisation with no variation in time.

1. Introduction

The OSIRIS project [1] aims to explore the possibilities of cold neutrons and polarisation techniques at a pulsed source. The instrument combines a long d-spacing diffractometer with a polarisation analysis backscattering spectrometer. OSIRIS shares a beamport with its sister instrument IRIS, viewing the liquid H_2 moderator through a curved m=2 supermirror guide. This provides a high flux of cold neutrons with a time-structure appropriate for high-resolution measurements. A converging m=3.6 supermirror guide focuses the beam down to a 20×40 mm sample size at a distance of 34 m from the moderator. Immediately before the converging guide, the Polariser Interchanger allows the insertion of a polarising supermirror bender and current-sheet flipper in place of a section of straight guide.

2. Diffraction

The use of a supermirror guide significantly enhances the neutron flux at all wavelengths [2], but at a price in beam divergence, which increases substantially as a function of wavelength. On OSIRIS, this is compensated for by placing the diffraction detector in near-backscattering, where beam divergence does not dominate the instrumental resolution. A position-sensitive scintillator detector covers the full range of scattering angles between 150° and 171°, providing a total solid angle coverage of 0.67 steradians. Two disk choppers at 6.3 and 10 m from the moderator select the wavelength range of the measurement and prevent frame overlap. Neutron wavelengths of up to 70 Å can be cleanly selected and used for diffraction experiments. Figs. 1 and 2 show the incident beam flux. It is seen that the inevitable reduction in flux at long wavelengths is partly compensated for by the λ^4 form factor which applies to powder Bragg peak intensities. At a wavelength of 70 Å, Intensity×λ^4 is down by just 2 orders of magnitude from the peak flux.

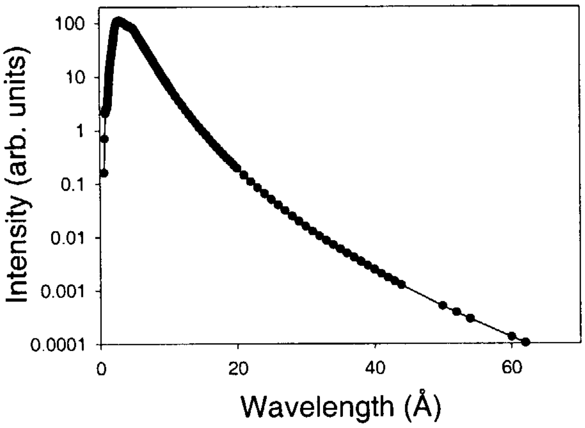

Fig. 1
Measured beam flux on OSIRIS as a function of neutron wavelength.

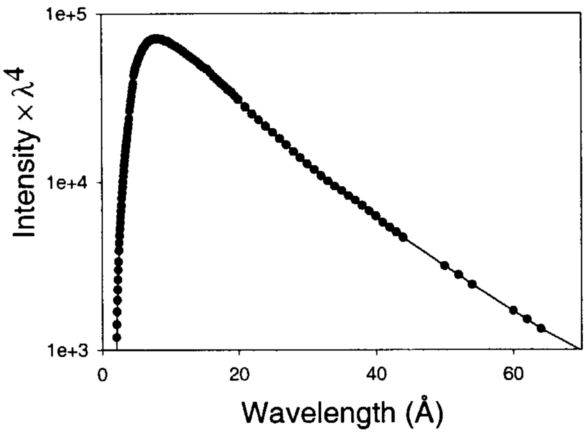

Fig. 2
Beam flux multiplied by λ^4, which is proportional to the Bragg peak intensities in a powder diffraction experiment.

At Δd/d down to 0.25%, OSIRIS provides similar resolution to the HRPD 90° bank with the same counting rate and resolution as on the GEM high-angle bank. OSIRIS can reach d-spacings in excess of 35 Å with high resolution, but can not access d-spacings below about 0.8 Å, due to the short-wavelength cut-off of the curved guide.

3. Spectroscopy

OSIRIS will use pyrolitic graphite crystals for energy analysis of the scattered beam; a 40 cm high array of graphite crystals, covering a continuous range of scattering angles from 10° to 150° at a distance of 90 cm. The analyser array will be cooled to a temperature of around 10 K to reduce thermal diffuse scattering. The energy-analysed neutrons will be detected in an array of 42 ^{3}He gas tubes arranged in a ring below the sample position. The energy resolution is expected to be 25 μeV (FWHM) for the PG (002) reflection. Installation of the graphite crystals and their associated detectors will take place in March 2001.

4. Polarisation Analysis

Polarisation analysis will be performed by means of a ^{3}He spin-filter, being developed in-house and shown schematically in fig. 3. A 10 W fibre laser will be used for the metastable pumping of the low-pressure ^{3}He gas. The gas polarisation will be monitored using an optical polarimeter, examining the polarisation of the 668 nm discharge. After the optical pumping cell, the gas will be compressed using a peristaltic pump to a pressure of the order of 1 bar. The compressed, polarised gas will then be fed into a wide-angle spin-filter cell, covering the entire solid angle of the crystal analyser. The scattered neutron beam travels twice through the spin-filter cell, once before and once after being monochromated at the graphite analyser. In this way, the effective optical thickness of the cell is doubled. At the opposite end from the inlet of the spin-filter cell, the ^{3}He gas is slowly leaked out, fed back into the optical pumping cell and repolarised. This continuous flow system is designed to maintain a high level of ^{3}He polarisation with no variation in time.

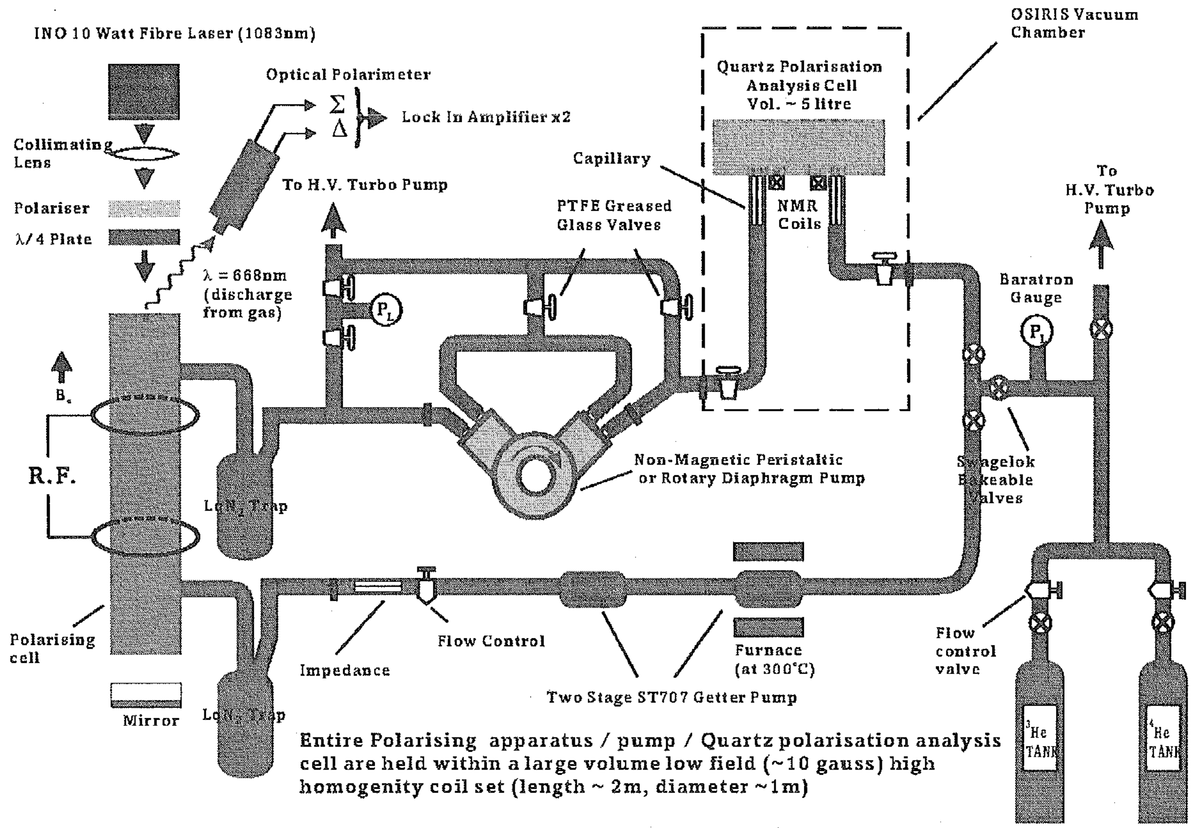

Fig. 3

Schematic layout of the OSIRIS polarised ^{3}He circuit, described in the text.

The entire spin-filter setup will be placed in a high-homogeneity magnetic field to minimise nuclear depolarisation effects due to field inhomogeneities. A peristaltic pump [3], designed at the University of Nottingham (U.K.) to pump spin-polarised ^{3}He gas, is being modified to reduce polarisation losses. The possibility of using a rotary diaphragm pump is also being examined. The spin-filter cell is being designed and constructed in collaboration with the ILL polarised-^{3}He group who have considerable experience in producing cells with long relaxation times, in excess of 100 hours [4]. The cell will be constructed of silica glass, coated on the inside with Cs to minimise ^{3}He depolarisation via interactions with the silica glass wall.

Fig. 4 shows a standard figure of merit, defined as neutron transmission (of the right spin-state) times beam polarisation squared for standard supermirror-based polarisation devices (hatched area) and various 3He spin-filters optimised for the PG002 reflection on OSIRIS. It is seen that the ^{3}He spin-filter becomes competitive with supermirror-based devices at a nuclear polarisation level between 60 and 70%. The aim on OSIRIS is to achieve 70% nuclear polarisation with no variation in time. Off-beamline testing of the OSIRIS circuit will start in December 2000 and continue during 2001. Installation and gradual optimisation on the instrument is expected to take place from 2002.

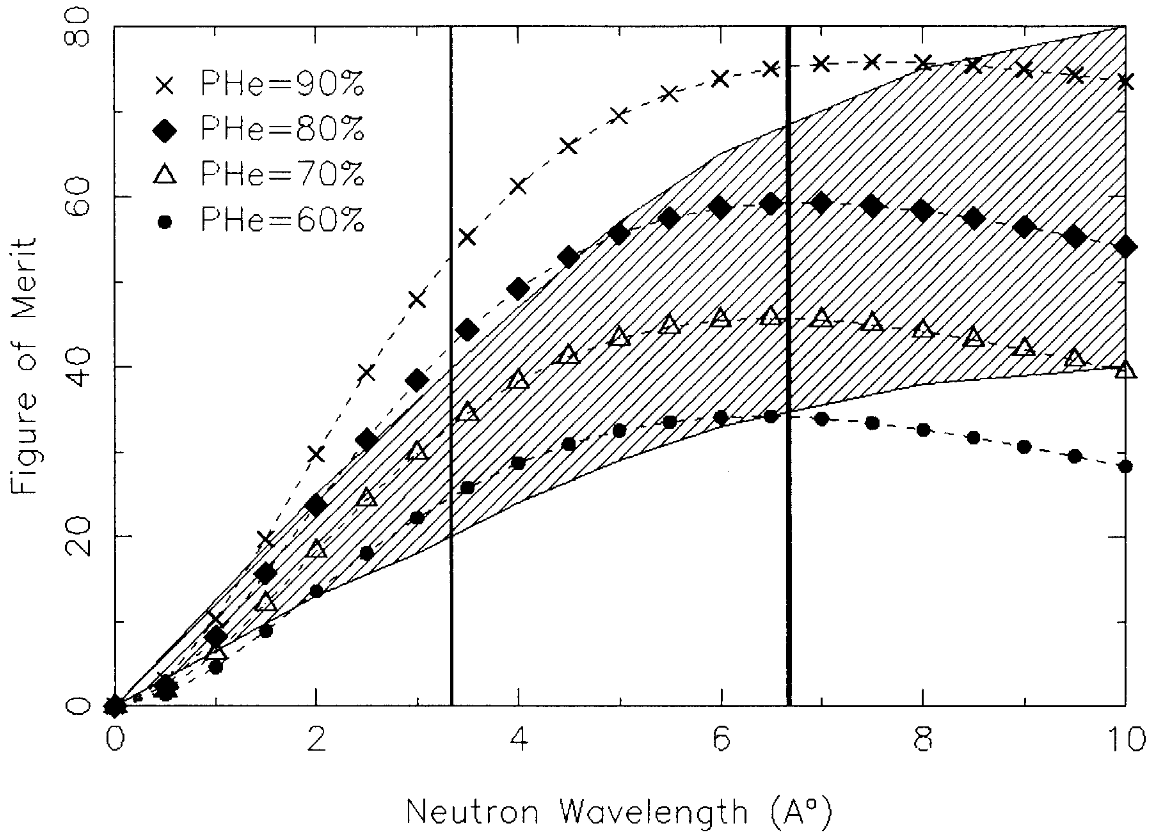

Fig. 4
Figure of Merit (P^2T) versus neutron wavelength The hatched area shows the performance of typical supermirror-based polarisation devices. The two vertical lines indicate the wavelengths used on OSIRIS, corresponding to the PG 002 and 004 reflections.

5. Summary

OSIRIS is a third-generation pulsed-source instrument, on which many new ideas and techniques are being implemented, some for the first time at a pulsed source. As a long d-spacing diffractometer it offers an unrivalled combination of resolution, counting rate and d-spacing range. As a spectrometer, it will utilise the well-established combination of cooled graphite crystals with a resolution matched to the time-structure of the moderator pulse. The high flux on the sample combines with the large solid-angle coverage to give a very high counting rate with an energy resolution of 25 μeV. OSIRIS is on target to become the first wide-angle instrument on a pulsed source with full polarisation analysis. The development of a continuously circulating ^{3}He spin-filter using metastable optical pumping is under way. The instrument specifications are summarised in Table I.

Table I. Instrument Specifications

Diffractometer Specifications	
Solid angle	0.67 steradians
Scattering angles	$150° < 2\theta < 171°$
Resolution	$2.5\times10^{-3} < \Delta d/d < 6\times10^{-3}$
d-spacings	0.8 Å < d < 35 Å
Spectrometer Specifications	
Solid angle	1.09 steradians
Scattering angles	$10° < 2\theta < 150°$
Momentum transfers	0.3 Å^{-1} $< Q <$ 1.8 Å^{-1}
Energy resolution	25 μeV
Bragg reflection	PG002 ($83° < \theta < 87°$, $\langle\lambda\rangle = 6.69$ Å)
^{3}He Spin-filter Specifications	
Polarisation method	metastable optical pumping
Laser output	10 Watts, 3 GHz bandwidth
Gas compression	peristaltic pump, continuously circulating
Spin-filter cell	Cs-coated quartz, 8 litres at 800 mbars

References

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