Osiris guide upgrade

The replacement of the current 25-year-old guide by a modern guide will deliver at least a fivefold increase in flux to facilitate studies of battery materials, correlated electron dynamics and diffusion in catalysts. The guide design will increase flux and sensitivity, and will also provide a natural next step to the current secondary spectrometer upgrade which will equip Osiris with an additional high-resolution silicon analyser. The guide project will make Osiris a highly competitive and versatile neutron spectrometer.

Summary of physical changes

The existing primary spectrometer will be replaced by a novel supermirror guide with a more favourable geometry and high m-values to increase the transported neutron flux decisively. Osiris shares the same beam port as the Iris spectrometer, so the shutter section and the insert section within the target station wall are common to both instruments and will be replaced by new components. No further work will be done on Iris in this project. The new guide will comprise of three sections: an elliptical defocusing section, a curved section and a final elliptic focusing section (that terminates close to the sample position). The existing bandwidth-defining choppers at 6.3 m and 10 m will also be replaced with new choppers, adapted in size to the increased beam profile in the guide and integrated into the guide vacuum.

Science justification

Osiris is a highly competitive and successful cold-neutron indirect geometry near-backscattering spectrometer for quasielastic neutron scattering (QENS) and low energy spectroscopy. The science covered by the Osiris spectrometer is broad and ranges from energy materials, catalysis, life science to quantum magnetism. The combination of high resolution (25 μeV) with a signal to background ratio of better than 10^4 has resulted in high profile publications in the recent past.

The high energy resolution combined with a wide momentum transfer range makes Osiris ideal for studying microscopic origins of diffusional processes, for example, ions in novel battery materials or molecular transport in porous materials and catalysts of industrial relevance. The ultimate performance of fuel cells, batteries and electrolytes are all rooted in the transport properties of moving ions including hydrogen, lithium or oxygen. Increasingly, the mobile particle of interest is non-hydrogenous (e.g. Li, Na, Mg in batteries; CO_2, NO_x, SO_x in zeolites), which provides severe challenges for revealing the microscopic details of the important motions. There is a trend to study more dilute systems, such as diffusing particles in catalytic environments, which needs increased sensitivity.

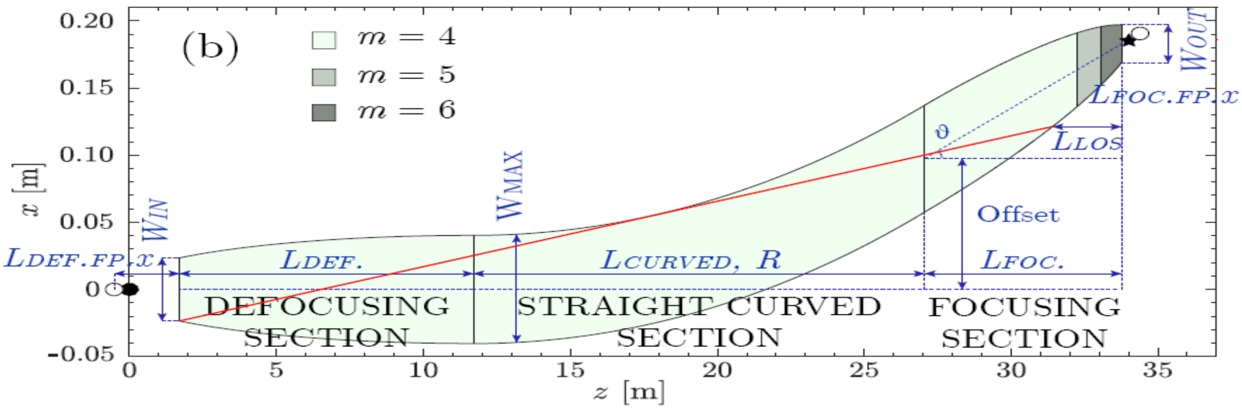
A significant part (~30%) of the program on Osiris is the study of low energy magnetic excitations. There is currently a great deal of interest in quantum phase transitions, which occur at zero temperature when the ground state of a system changes fundamentally upon changing an external parameter, such as pressure or magnetic field. Such transitions are driven by quantum fluctuations and key issues include the properties of the quantum critical fluctuations and how elementary quasiparticles transform upon crossing critical points. Low-dimensional magnets can also be considered as model systems for high-T_c superconductors, to explore in detail the subtle connection between superconductivity and magnetism. The elliptic focusing guide geometry will provide focusing directly onto a smaller sample area and hence all experiments, in particular the single crystal ones, will benefit from higher flux on a smaller sample spot.

Business case

There exists a strong business case for QENS and low energy spectroscopy at ISIS: demand for beam time on Osiris consistently exceeds availability. There is increasing use of QENS to study molecular transport in nanoporous materials for catalysis, work primarily carried out in collaboration with the UK Catalysis Hub at the Harwell Research Complex. Studies related to non-hydrogenous ion mobility in battery materials from both academic and industrial stakeholders are growing and the Faraday Battery Challenge will further increase activity in this area. The condensed matter physics community uses Osiris to observe low energy excitations. All these communities will benefit from the enhanced performance of Osiris brought about by this project. The flux gain, in combination with the installation of the silicon analyser (currently in progress), will keep Osiris competitive with the most modern spectrometers (BAsisat SNS, IN5 at ILL, Miracles at ESS) in this field for the foreseeable future.

Summary of current status

Extensive Monte Carlo simulations have been performed for the design and optimisation of the new guide system. Amongst several guide geometries assessed, a curved guide with elliptical defocusing and focusing sections performs best. The estimated gain in intensity is a factor of 5–6 at the sample position. The elliptic geometry results in a smaller beam spot, which will particularly benefit small samples.



The optimised design of the Osiris guide.

The project is subject to the physical constraint that the sample position remains unchanged i.e. the secondary spectrometer will not be modified. The project will require significant effort from the Design and Detector Groups, at a time when there is heavy demand for their services. The guide requirements associated with this project are well within the current technology, so pose no risk. The major technical issue of the project are the new, significantly larger, choppers. A feasibility study is being carried out to assess the effects these will have on Iris. Installation of the guide and choppers will require either a long shutdown or a short shutdown to install the shutter and insert sections and both Osiris and Iris unavailable for at least one cycle as the main shutter will have to be locked closed.