Neutrons for society, continued

The 50th anniversary of the Institut Laue–Langevin marks a time for celebration, and for reflection on the future of Europe's neutron-scattering landscape.

After James Chadwick's discovery of the neutron in 1932, physicists were quick to try using them as scatterers for studying materials, similar to the successful exploitation of X-ray photons and, to some extent, electrons. However, whereas X-ray sources suitable for diffraction experiments were relatively easy to construct and manage, producing a reasonably intense neutron flux seemed a hopeless undertaking, until Enrico Fermi's demonstration of a controlled, neutron-producing chain reaction in 1942. Following Fermi's experimental proof of principle, a full-scale nuclear reactor was constructed in Oak Ridge, USA. At the end of the Second World War, Ernest Wollan equipped it with a diffractometer and managed to obtain the very first neutron diffraction patterns (of NaCl, H_2O and D_2O) in 1946[1].

In the decades that followed, more reactors for neutron scattering experiments were constructed, but nowadays the focus is on a limited number of high-flux neutron sources. Of these, the Institut Laue–Langevin (ILL) in Grenoble, France, is widely recognized as the leading facility. Founded in 1967, its current neutron flux of 1.5×10^{15} cm^{-2} s^{-1} makes it the world's most intense continuous source.

The hassle of a nuclear reactor such as the one at the ILL — the imperative to make it safe and secure — is worth the trouble. Thermal neutrons have a mean wavelength of 1.8 Å, just what you need for diffraction from a typical solid. Moderating with hot graphite or liquid hydrogen extends the wavelength range to about 0.4–20 Å, providing access to all kinds of condensed matter. Neutrons scatter from nuclei, enabling isotopic labelling; they possess a magnetic moment, providing a handle on magnetic properties of solids; and through inelastic scattering they make dynamical processes within materials accessible. In short, as a probe, neutrons are a winner.

The results produced by the ILL over the past 50 years, described in a whopping 21,000 papers, are testimony to the value of neutrons as condensed-matter probes. Some of the highlights include the first structural characterization of a natural biological membrane[2], the observation of magnetic-monopole behaviour in spin ice[3] and, more recently, a matter–wave interferometer experiment demonstrating the 'quantum Cheshire Cat' effect[4]. The highest accolade so far went to Duncan Haldane: in 1981, while a post-doc in the ILL's theory group, he found that one-dimensional antiferromagnets of integer spin behave entirely differently to those of half-integer spin, a discovery that contributed to his share of last year's Nobel Prize in Physics (Haldane's original manuscript is available at http://go.nature.com/2kqsiHd). Experimental evidence of the predicted 'Haldane gap' was obtained with several of the ILL's inelastic neutron scattering instruments[5,6].

Two factors in particular have contributed to the ILL's on-going success. From the very beginning, the project was met with great scientific enthusiasm and exceptional political goodwill. The idea of a joint Franco-German neutron-scattering facility was pitched to the French and German ministries of research during the third Atoms for Peace conference in Geneva in 1964 — the decision to build not only a high-flux source, but also a materials research centre around it, was made then and there. Formalization of the agreement followed on 19 January 1967, with the initial momentum getting an additional boost when the UK, a country with a rich expertise in neutron science, joined in 1973 as an associate member.

The other pillar of the ILL's success is its innovative resolution, from the very start, to operate as a user facility[7]. Rather than relying exclusively on the — admittedly invaluable — research activities of the institute's local scientists, making the instruments available to the wider scientific community was a visionary decision of the ILL's founders. Nowadays, user programmes are an essential aspect of many large facilities, with neutron-scattering centres and synchrotrons being the prime examples. Every year, the ILL typically welcomes 2,000 users from 30 countries, totalling to about 800 experiments based on proposals that have been approved by a review panel.

With the ILL having turned 50, it's inevitable to be thinking about the institute's future. A status report on Europe's neutron-facility landscape by an international expert group[8] warns that it would be dangerous to see the European Spallation Source (ESS), currently under construction in Lund, Sweden, as a like-for-like replacement for the ILL. Yes, when switched on in 2020 the ESS will be the brightest neutron source in the world, but full specification will — if everything goes according to plan — only be reached in 2028, with far fewer instruments than the ILL's current suite of 40.

With the imminent closures of two important European medium-flux sources (at the Laboratoire Léon Brillouin and the Helmholtz-Zentrum Berlin), it is crucial that France, Germany and the UK renew the intergovernmental agreement for the ILL when it expires in 2023 (and thankfully, this issue is separate from the impending Brexit negotiations[9]). Premature closure of the ILL would lead to a disastrous loss of European neutron-scattering expertise: the scientific culture and technical excellence developed and nurtured in Grenoble would be extremely difficult to replicate elsewhere. There are no technical reasons for the ILL not to operate beyond, say, 2030 — it is currently preparing to obtain a ten-year licence for nuclear operation until at least 2028.

In addition to its world-leading neutron-scattering studies of condensed matter, the ILL is home to an esteemed nuclear and particles physics research unit. Producing and studying radioisotopes for clinical applications, researching fundamental constants, understanding nuclear-fission processes, and experimenting with ultracold neutrons to find the answer to cosmological questions are but a few of the lines of research pursued at the ILL — research that cannot be done elsewhere.

Neutroniciens — the French term feels untranslatable — in Grenoble and elsewhere will surely agree: early retirement of the ILL would not be good for science. ❒

References

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