The ILL Millennium Programme - a Bridge to ESS

CENSC, Budapest 7-11 April 2003

Alan Hewat, ILL Grenoble, FRANCE
European Neutron & Synchrotron Sources
ILL & ESRF Grenoble

- World’s most intense neutron source
- 1280 visiting scientists each year
- 300+ scientific papers each year
- physics, chemistry, biology, materials

ILL member countries are shown in green

Alan Hewat, CENSC, Budapest 7-11 April 2003
The ILL Millennium Programme in Diffraction

- New 10 year ILL extension contract just signed
- Millennium Programme -> ILL machines by x10 to x20
- New detector and neutron optic technology
- ILL seeking participation of more European countries
New Diffraction Instruments:

- D3c - He3 neutron spin filters and magnetic polarimetry
- Strain Scanner - mapping strain in engineering components
- VIVALDI - Laue Diffractometer with Neutron Image Plate
- D19 - a very large 2D PSD for protein/fibre diffraction
- D2B - high resolution powder diffractometer with linear PSDs
- DRACULA - Diffractometer for RApid Acquisition over Ultra Large Areas
Molecular magnets

- Molecular magnets can be light, transparent, magneto-optic, bio-compatible etc...
- Neutrons are unique for mapping the magnetisation density on an atomic scale
- The first organic ferromagnet (left) - the magnetic density is on nitrogen & oxygen

E. LeLievre-Berna, E. Ressouche, J. Schweizer (ILL & CENG)
D3 – Polarised Neutron Diffractometer

- Complex magnetic structures
- Magnetisation density

The field arrangement is shown for spin down transmission.
- Up guide field
- Down guide field
- Longitudinal guide field

Alan Hewat, CENSC, Budapest 7-11 April 2003
D3c – He³ neutron spin filters & magnetic polarimetry

- helium flow cryostat
- Inner Meissner shield
- outer Meissner shield
- Incident coll
- Incident nutator
- Eulerian cradle
- outgoing nutator
- turnabout coil
- detector
- LHe
- µ-metal
- motors
- ³He neutron spin filter

D3C - Cryopad
Tensile stress can produce cracks

Compressive stress toughens materials

Neutrons can penetrate deep inside materials (~10cm) and measure stress by changes in atom spacings

The compressive stress (blue) deep inside a VW crankshaft

Design of stronger, lighter engines

T. Pirling, G. Bruno (ILL & Manchester)
Elastically-bent Si-monochromator
- Bending radius: 5 - 10 m
- Take off angle 55-125°
- Wavelength 1.3-4.5 Å
- $\Delta 2\Theta \sim 0.1°-0.5°$ ($\Delta d/d \sim 2 \times 10^{-3}$)
SALSA - Strain Analysis of engineering components

- 1 Mio EPSRC grant to build a new high flux strain scanner “SALSA”
- 1.6 Mio EPSRC grant to set up an engineering support lab “Fame38”
SALSA - Strain Analysis of engineering components

“Hexapod Platform” - Large x, y, z displacements of heavy components
- Large angular range of rotations
Nature (1997) Cover showing LADI data (LAue Diffractometer with Image plates)
LADI Neutron Image Plate LAue Diffractometer

- Neutron guide
- Band of neutron energies
- View reciprocal space
- In-situ laser readout
- Unique survey of P/T
- Phase T/Ns, superstruct.

Dean Myles with LADI and cryo-refrigerator on thermal guide H22
5-fold symmetry axis in ZnMgY quasi-crystal - De Boissieu et al.

T-LADI neutron image plate photo courtesy of G. McIntyre
Neutron Image Plate Superstructure in $\text{La}_2\text{Co}_{1.7}$

$\text{La}_2\text{Co}_{1.7}$ on T-LADI showing incommensurable superstructure
Neutron Image Plate Superstructure in La$_2$Co$_{1.7}$

- 6-domain ring of (122)$^-$ superstructure

La$_2$Co$_{1.7}$ on VIVALDI showing incommensurable superstructure
New very large 2D resistive wire detector (D19)

- 400 mm high resistive wires (2D), very large solid angle - 30° x 120°
- Medium resolution, 0.2° in both horizontal and vertical directions
Water in A-DNA Fibres on D19

- B-DNA sheets, but A-DNA fibres
- 100 individual DNA fibres in D$_2$O
- Diffuse fibre diffraction patterns from D19 used to locate water
- 4 distinct water sites located along double helix backbone
Why can’t we do it with X-rays?
Density of water in co-enzyme B12

D19 Neutron data

Synchrotron data
Super-D2B high resolution 2D linear wire detector

High resolution neutron powder diffractometers - D2B at ILL

Strong peaks at high angles give high precision structures of materials

Counts

4000
3500
3000
2500
2000
1500
1000
500
0

20 40 60 80 100 120 140
2θ in degrees

CALIBRATION YIG

Alan Hewat, CENSC, Budapest 7-11 April 2003
Super-D2B high resolution 2D linear wire detector

- 128 x 300 mm high resistive wire detectors, high resolution collimators
Super-D2B high resolution 2D linear wire detector

- 128 x 300 mm high resistive wire detectors, high resolution collimators
Super-D2B high resolution 2D linear wire detector

First Neutrons
3 April 2003
Applications of large fast detectors

D20 - high intensity medium resolution ($4 \times 10^{-3}$) PSD; runs ~secs

- Very large monochromator and micro-strip detector (printed circuit)
- Extremely fast (300 msec real time expts) but only medium resolution
Sue Kilcoyne, Bob Cywinski et al.
Crystallisation of amorphous alloys $Y_{67}Fe_{33}$ with increasing temperature

Complete diffraction pattern in minutes or seconds, scan through temperature
DRACULA, a super-D20 2D resistive wire detector

• Order of magnitude faster than D20
• Extremely fast reactions
• Extremely small (e.g., isotopic) samples and extreme conditions (high P)

Alan Hewat, CENSC, Budapest 7-11 April 2003
Advantages of continuous neutron sources


* Efficiency for a given resolution = time averaged flux on the sample
  * sample volume
  * detector solid angle

- As on pulsed sources, reactor machines will increase the detector solid angle

- Reactor machines already have an advantage, with high flux at the sample
Example: A proposal for a new ILL high flux powder diffractometer DRACULA (Diffractometer for Rapid Acquisition over Ultra-Large Areas)

<table>
<thead>
<tr>
<th></th>
<th>ILL-D20</th>
<th>ISIS-GEM</th>
<th>ILL-DRACULA</th>
<th>ESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>time averaged sample flux</td>
<td>$&gt;5 \times 10^7$</td>
<td>$\sim 2 \times 10^6$</td>
<td>$&gt;5 \times 10^7$</td>
<td>$\sim 10^8$</td>
</tr>
<tr>
<td>detector solid angle</td>
<td>0.5 sr</td>
<td>3.5 sr</td>
<td>3.0 sr*</td>
<td>3.0 sr</td>
</tr>
</tbody>
</table>

* Based on new D19 detector: R=730 mm, h=400 mm, 800 linear resistive wires covering 160°
• The ILL Millennium Programme will improve the efficiency of many ILL-Grenoble instruments by more than an order of magnitude.

• This is a cost-effective way of meeting the challenge of the new US and Japanese spallation neutron sources in the next 10 years.

• The time averaged neutron flux on the sample at the ILL reactor will remain competitive with these new sources.

• For powder instruments it remains to increase the size of detectors and use more efficient monochromators.

• New ILL machines Super-D2B and DRACULA are proposed.