millennium programme

First neutrons on SALSA

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At the beginning of August 2004 SALSA, the Strain Analyser for Large and Small scale engineering Applications, saw its first neutrons. Although provisional, the configuration used allowed testing the instrument under real conditions.
This initial operation of the instrument was the result of more than three years of dedicated design, development, manufacture and assembly by many groups, both within and outside the ILL. The project is one of the first five of the ILL's Millennium Programme, which started in the year 2000 [1]. SALSA enjoyed the joint financial and manpower contribution from both, the Manchester Materials Science Centre (Prof. P.J. Withers), funded by the EPSRC, and the ILL.

The idea of the instrument was introduced in 2000, and optimisation studies were performed in collaboration with Jan Šaroun from the Nuclear Physics Institute, Řež near Prague [2,3] for the neutron guide and the monochromator, and with J.P. Merlet, INRIA Sophia-Antipolis for the hexapod sample stage. The main output was i) a monochromator, using bent perfect crystals, in combination with a super mirror guide of m=2 would give optimum performance, ii) a parallel kinematic hydraulic robot would meet all the specifications for sample manipulation. The output excavation of the site started in 2001 and provided the necessary floor to beam axis distance to achieve the specified z-movement range. In 2002, the new 9 m long and 30 x 200 mm^2 section super mirror guide between D1A/D1B and SALSA was installed. During 2003, a newly conceived exit assembly was delivered and positioned. Finally, in 2004, the last instrument parts were delivered, tested and installed: they included the monochromator from Missouri University Research Reactor (USA), the hexapod sample stage from Ölhydraulik Elemente Hagenbuch, Ebikon, Switzerland, the motorised slit system from Swiss Neutronics and the base Δ-table.

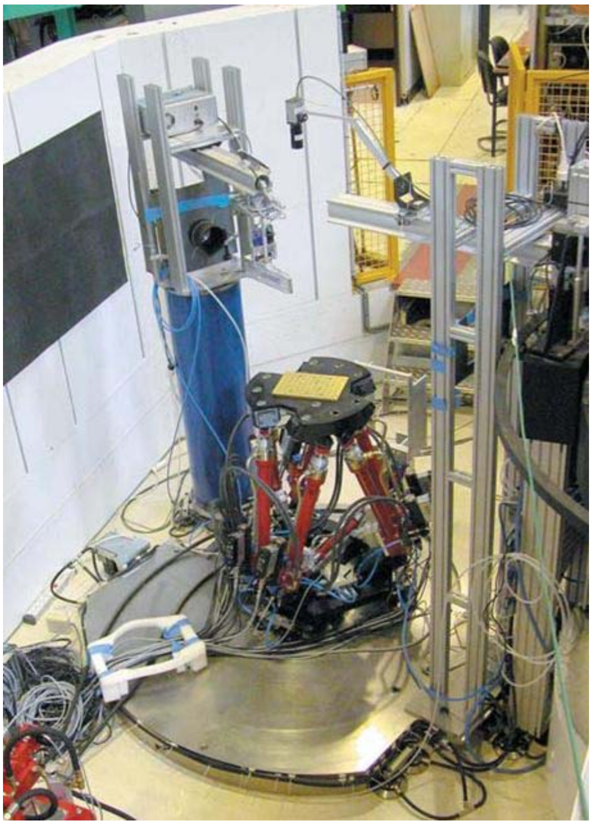

Figure 1: SALSA as set-up for the first tests. The optics, detector and hexapod are linked by the delta-table. An omega rotation and a translation of the hexapod increase the work space for large samples. The connections and the optics support are still provisional.

The list of specifications, assembled with international experts, included sample weights over 250 kg, sample dimensions up to more than 1 meter and positioning precision of 50 µm. A further demand was the ability to measure big samples of any shape, i.e. wing sections from airplanes, without the need of special sample preparation (in particular cutting), to pursue the use of a non-destructive technique. Variable wavelength was demanded to enable measurements in different materials, such as metals, alloys and composites. Finally, quick, reproducible and automated sample alignment and user-friendly operation as well as reliable data analysis completed the specifications.

A lot of effort was put into the development of the sample stage. This was important because a strain imager has to deal with a big variety of sample shapes and weights. At the same time the orientation of the sample in the beam is crucial. The scattering vector defines the direction in which the strain is being measured. Therefore tilt *and* position of the specimen have to be adjusted at the same time. A sample stage that allows such flexibility is a hexapod or Stewart-Platform (see figure 1). This is a robot with parallel kinematics and six degrees of freedom. The advantage of the hexapod conception for SALSA's sample stage is the flexibility of movements, the high precision and its high stiffness. The final design allows a tilt range of ± 30° and a translation range of ± 300 mm. The nominal payload is 500 kg and the upper limit lies at 1000 kg.

Translations, tilts or even oscillations of the specimen around the gauge volume are possible.

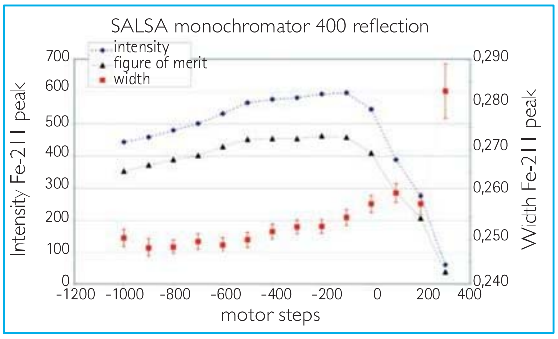

Figure 2: Optimisation of the curvature of the monochromator crystals. The radius of curvature is decreasing towards positive motor sreps (=more bending). The figure of merit shows a flat maximum between -500 and -100 motor steps. A curvature of 5.4 m is achieved at -350 motor turns. This is the optimum for 2θ = 840.

Preliminary tests allowed determining the repeatability of positioning to 3 μm with the smallest displacement width at 5 μm under the conditions of zero load as well as 940 kg. Further tests for the determination of the absolute positioning accuracy will follow. The mathematical model gives a maximum positioning error of 50 μm.

The hexapod is moving freely on a platform, the Δtable. This is a thick steel plate, which links the variable take-off, the hexapod and the detector. It is large enough to allow a full 360° rotation around the diffractometer omega axis and an additional translation of up to 700 mm. This option increases the workspace and allows measurements on the extremities, even of samples up to 1.4 m in length.

The rotation around the omega-axis of the diffractometer enables the typical 90° turns for the measurement of two perpendicular strain components with only one set-up.

Moreover, the Δtable provides the ability to vary the take-off angle between 55° and 125°. It also supports the beam optics. This is a key issue, because the same alignment is kept while changing the take-off angle and no re-calibration is needed. Figure 1 shows all these components in an instrument overview [4].

Similarly, the casemate exit assembly is a novel design. Control is greatly simplified and safety increased.

The double bent, variable horizontal focusing monochromator takes advantage of the divergence of the neutron beam providing high intensity, without loss in resolution. Unlike common flat perfect crystal or mosaic monochromators, it allows finding an optimum resolution at each 2θ angle.

The MURR monochromatorw - designed and built by Mihai Popovici - contains 36 stacks of 5 mm high slices of Silicon crystals, cut in the (400) plane and arranged to have a fixed vertical curvature. The horizontal curvature is variable in order to optimise intensity and resolution. Figure 2 shows the optimisation curve of the monochromator during the tests in August. The horizontal curvature of the crystals was changed while recording intensity and peak width of the Fe(211)-reflection from a powder. The wavelength was 0.16 nm and the scattering angle 84°.

Figure 2 shows that the flatter the crystals, the higher the resolution, but the lower the intensity. With greater curvature the diffracted intensity I_d increases until it reaches a maximum. One way to find the optimum settings for an experiment is to use a figure of merit f, putting weight on resolution σ, defined as the peak width (Gaussian standard deviation): $f = \frac{I_d}{\sigma^2}$

In fact, figure 2 shows a flat maximum of the figure of merit between -500 and -100 motor steps.

A nose-shaped slit system allows automated selection of the horizontal and manual choice of the vertical size of the gauge volume. It also allows remote control of the sample-slit distance and the reproducible mount of oscillating collimators or even mixed collimator-slit configurations.

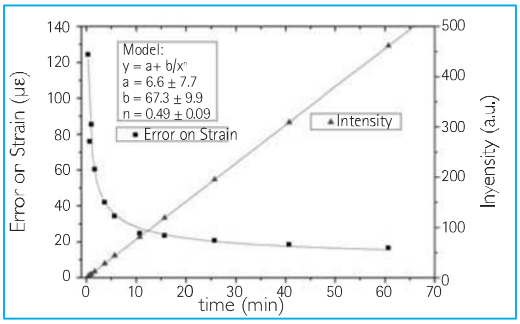

Figure 3: The time evolution of the error on the strain follows the inverse square root law foreseen by both Webster [5] and Withers [6]. The stabilisation occurs after 10-15 min counting time.

First test with neutrons

The same Fe powder peak was measured for different counting times. The results shown in figure 3 imply that: a) the error in strain is about 25 με and b) the convergence of both the lattice parameter value and the measurement error occurs after 10-15 min.

The final assembly of the instrument was completed in 2004. Alignment, optimisation of hard- and software parameters, and testing of all components will take place during the first reactor cycle in 2005. The second cycle will be used for commissioning experiments, and for the third cycle SALSA will finally become a scheduled public ILL instrument.

The SALSA team is confident that the new instrument will go beyond the original specifications and become a world-class instrument.

References:
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