Conclusions concerning NSE

Michael Monkenbusch, IFF, FZ-Jülich, E-mail: m.monkenbusch@fz-juelich,de
Katia Pappas, BENSC, HMI Berlin, E-mail: pappas@hmi.de
Bela Farago, ILL, Grenoble, E-mail: farago@ill.fr

The following statement is based on a memorandum which was issued by Bela Farago and myself (M. M) in preparation of the meeting at Heathrow. At the meeting I discussed the topic with Katia Pappas. Here is a summary of these inputs.

Source requirements

Neutron scattering is not a new technology. While it can not be excluded that something fundamentally new will be proposed (like NSE was in the seventies) breakthrough can be expected only if there is an improvement of at least one or two orders of magnitude in the output quality or quantity similar to that of synchrotron vs standard Xray sources. **Intensity coupled with state of the art instrumentation** is as crucial for neutron scattering as it is for synchrotron radiation.

As stated in the report by F. Mezei (ESS reference moderator characteristics… 4-12-00) the time averaged flux of the “coupled long pulse” source is superior to all other sources and at all cold neutron wavelengths by a factor ˜ 10. The coupled long pulse cold hydrogen source is expected to deliver the same average flux as a cold source at the ILL and this should hold for all pulse frequencies and widths as long as the average power remains the same (5 MW).

In the following we will show that NSE can benefit from the high brilliance of the “coupled long pulse” source and we will point out that a low repetition rate is essential for reaching reasonable gain factors and for taking advantage of the pulsed source characteristics.

A typical length for NSE instruments (transmission polarizer + precession coils + analyser) is about 10 m. Taking into account the heavy protection of the source, the space needed for frame overlap choppers (~3 m) and a device to reduce the T_0-pulse, we estimate the detector to source distance to be about L_D˜ 20m.

The estimated pulse width of the “coupled long pulse” source is dt =2msec and the period for a repetition rate of 16 Hz is T_{rep}~60msec.

This leads to a maximum band width, set by frame overlap, of :

$$l_{max} - l_{min} = 3.960 \cdot T_{rep} / L_D \approx 12 Å$$

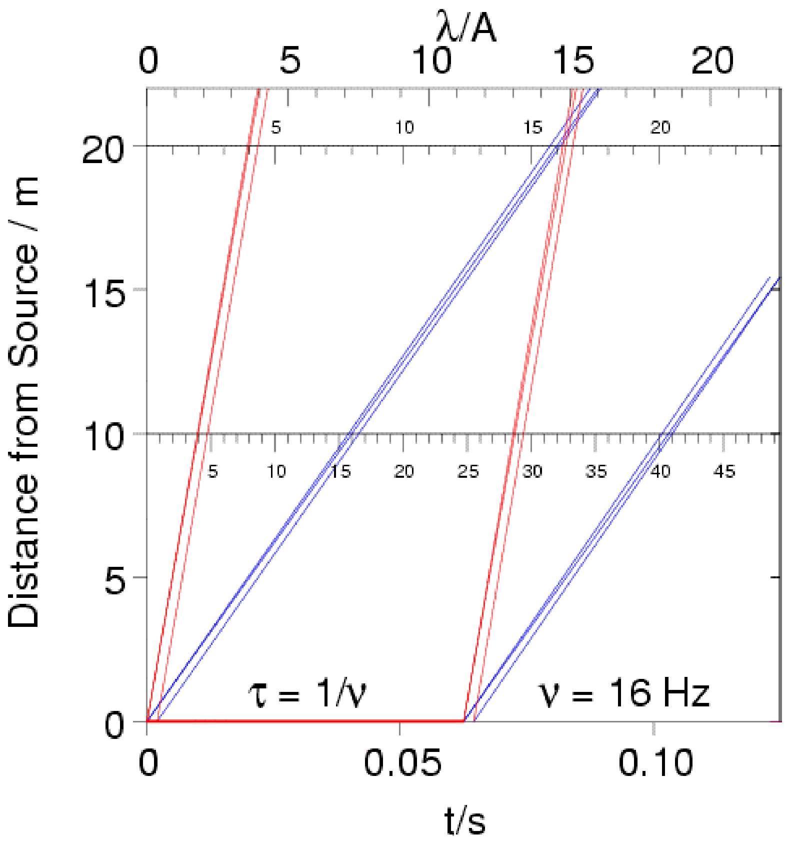
and a monochromatization of :

$$dl / l = 3.960 \cdot dt / L_D l \approx 0.4 / l$$

see the figure below for the visualization of both effects.

By using frame overlap choppers, which will be needed in any case and would be positioned somewhere between the spectrometer and the source, a very broad wavelength band can be selected: eg 4-16 Å or 12-24 Å. If we allow for some reduction in the transmission of the polarizing and analyzing devices, the wavelength range can be extended down to 2 Å. Such a broadband operation mode would drastically reduce the number of different magnetic settings required for covering a large Fourier time range and would enable an operation with superconducting magnets.

Using the part of the spectrum from say 4 up to 10 Å the worst monochromatization is already 10%, which is significantly better than the one commonly used (15-18%) on NSE spectrometers. As this extra monochromatization comes for free, without any intensity losses, it is a welcome feature in Q resolution improvement.



The above considerations clearly show that neither the time structure nor the high repetition rate of a short pulsed source would be of advantage for NSE. A short pulse would improve beam monochromatization with only marginal advantages for NSE operation. The high repetition rate (50 Hz) of a short pulsed source would, however, prevent broadband operation unless frame overlap choppers reduce the repetition rate with a consequent cutback in neutron flux. When it comes to choosing between the two low repetition rate options (short pulse, 10 Hz, 1 MW or long pulse, 16 Hz, 5 MW) it becomes clear that NSE can only benefit from the high neutron flux of the long pulse source. We note that these considerations are based mainly on the source-detector distance and should hold equally well for NSE as for resonance NSE instruments.

We conclude that the “coupled long pulse” source is the choice par excellence for NSE.

Gains - Losses

With the “coupled long pulse” source the time averaged flux is estimated to be nearly the same as that of the ILL. This simplifies comparisons. Instead of the 15% FWHM monochromatization, used at the NSE spectrometers of ILL, we might be able to use a broad wavelength band from 4 to 16 Å with a repetition rate of 16 Hz. This would lead to a plain gain factor of ln(16/4)/0.15=9.2, under the condition that the polarizers and analyzers will cope with such a wavelength range. Most probably an operation mode with two different frame settings, say 2-6 Å and 6-18 Å, would be more appropriate.

Whether a broad wavelength band will be used completely or not will depend on the physical problems. In the past years the NSE spectrometers at the ILL (IN11 and IN15) were often operated in the SANS range, where the physical problems are especially well suited to broad wavelength operation. The advantages are twofold :

for a fixed scattering angle there is a favorable compensation between the λ^{-n} decay of the incoming spectrum and the typical $Q^{-m} \sim \lambda^{+m}$ intensity dependence of small angle scattering and the NSE Fourier time (resolution) increases with the third power of lambda matching the typical exp(-Q^nt) (n = 2-4) dependence of the dynamics. Operation of NSE at pulsed sources should also lead to other slightly different criteria depending on the samples and the required informations.

Other physical problems might profit less from the wide wavelength band. In extremis, when measurements at only one Q are required, the spectrometer would be equivalent to the ones at the ILL. With inferior choice of moderator the instrument will be consequently inferior. The “loser” would be inelastic NSE. There seems to be no possibility to implement it at a pulsed source unless by using the source as a steady one.

Possible realizations of NSE spectrometers

A high resolution SANS - NSE spectrometer, which would benefit the most from a broad band operation should be placed as close as possible to the source, typically at a distance of 20 m. Superconducting coils with very low stray fields should reduce magnetic interference with the shielding of the source and the surrounding spectrometers to a minimum. Such a spectrometer would be ~10 m long and would operate in the SANS range. For that reason it should be relatively compact and should be easily placed in the “crowded” region next to the shielding of the source.

For NSE measurements at high Q a wide angle NSE spectrometer (like SPAN at BENSC but with improved energy resolution) would be needed, which should be placed at a larger distance from the source, typically at 40 m. This large distance is dictated by the space requirements (diameter of 8-9 m) of the spectrometer and should also allow for reducing magnetic cross talk with other instruments. From the equations above it is clear that the long distance from the source would restrict the wavelength band by a factor of two (λ_{max}-λ_{min}~ 6 Å) compared to the band available at 20 m from the source. This, however, should not have a dramatic cutback in neutron flux because, as already mentioned, the transmission of the polarizing and analyzing devices also restrict the wavelength range usable in a single frame set-up. With different settings for the polarizers and analyzers and for the frame overlap chopper it would then be possible to cover the ranges of either 2-8 Å or 8-14 Å. The long distance from the source would therefore restrict the wavelength band mainly at long wavelengths. This cutback should then be compensated by the particularly large solid angle (up to 0.27 strad) over which simultaneous NSE measurements will be possible. The long distance from the source would also lead to an improved monochromatization and Q-resolution, which would then be a welcome feature of this configuration. Indeed no wide angle NSE spectrometer with good Q-resolution exists at the moment although this is required by several NSE experiments at high scattering angles. For this reason IN11 has the option of mounting a graphite monochromator in front of the detectors.