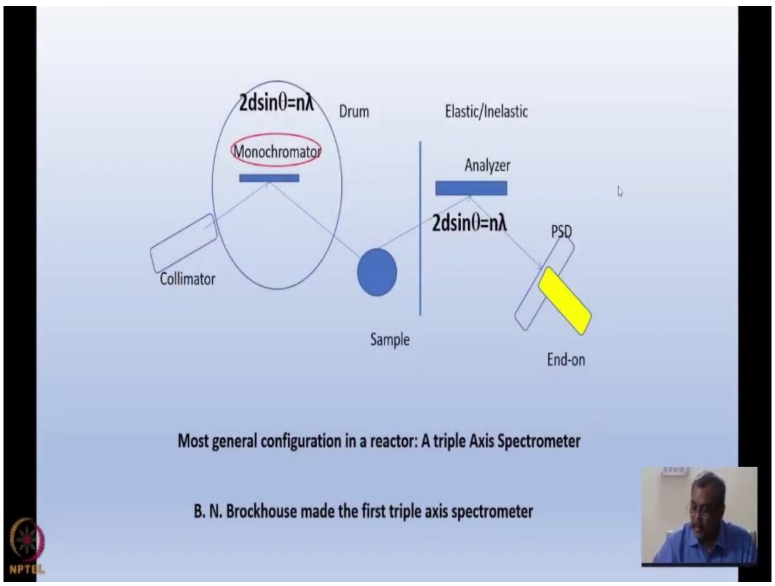
Neutron Scattering for Condensed Matter Studies
Professor Saibal Basu
Department of Physics
Homi Bhabha National Institute
Week 04 Lecture 10B

(Refer Slide Time: 00:13)

Keywords: Triple Axis Spectrometer, Diffractometer, Position Sensitive Detectors, Monochromator drum, Analazer, Goniometer



Let me show you the actual Triple Axis Spectrometer at Dhruva. This is used for inelastic neutron scattering. I will come to this later again when I discuss specific techniques related to neutron, but here I just wanted to show the photograph. Here this large drum is a monochromator drum. It contains a monochromator at the center of it. You can see the monitor detector here, which I discussed with you earlier and this is the collimator after the monochromator. This is a goniometer you can see on the sample table. because, if you have a single crystal sample, then you should be able to align that. After that there is a further collimator.

The detector rotates around the analyzer crystal with the analyzer crystal rotating around its own axis. You can see the bottom yellow arm that allows the rotation of the analyzer around the sample. This is the upper arm, that allows the rotation of the detector around the analyzer crystal, which detects the neutron finally with its energy and direction.

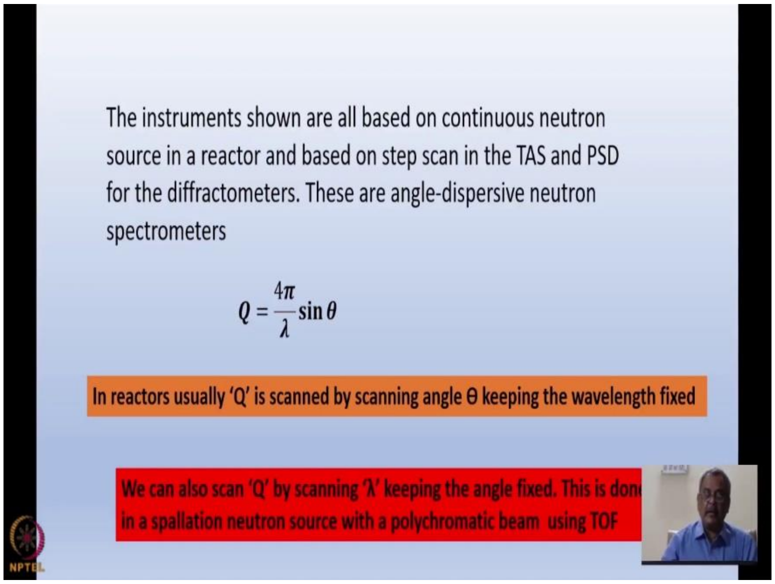
This red drum is a beam catcher, which is in line with the beam coming from the monochromator drum. It is in line (with the direct beam) so that anybody walking over here, do not get any unwanted radiation (exposure). This is a typical triple axis spectrometer at Dhruva. Such spectrometers are plenty and almost every major neutron source will have this kind of triple axis spectrometer. I told you earlier that B N Brockhouse was the person who first introduced this concept of triple axis spectrometer and he was a Nobel Prize winner for his studies on inelastic neutron scattering.

(Refer Slide Time: 02:29)

For diffractometers the geometry is much simpler. In the picture, I have shown two powder diffractometers of Dhruva. The green table and the blue arc that you see have position sensitive detectors inside them. There are no moving parts in these diffractometers. The beam falls on a sample and then the diffracted beam goes into these fixed detectors.

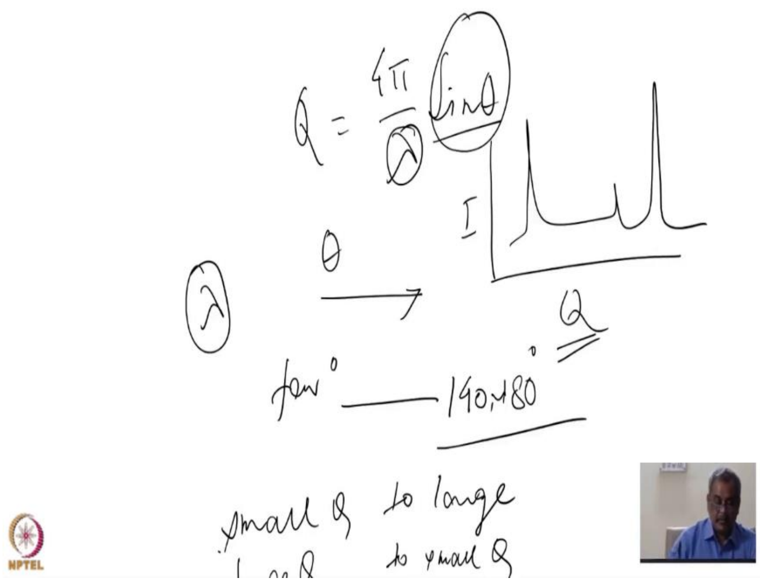
The Q-ranges actually depends on the (neutron) wavelength and the angular range (covered). $\Delta d/d$ gives us the resolution. You can see they have got a very similar Q-range while the Powder Diffractometer-III has slightly better resolution. This spectrometer is a magnetic powder diffractometer and is maintained by an organization known as UGC DAE CSR. The other one, Powder Diffractometer-II, is run by the solid-state phase division scientists in Bhabha Atomic Research Center.

(Refer Slide Time: 04:00)



This brings me to the fact that in a diffraction experiment or in any experiment, one important thing is that we need to know the outgoing wave vector, so that we know the wave vector transfer $Q = \frac{4\pi \sin\theta}{\lambda}$. In case of inelastic experiment along with that we also want to know the $\hbar\omega$ so that we know the energy transfer between the neutron and the system. Hence, we need to know the incoming energy and outgoing energy. For diffraction we do need to know this incoming energy and but not outgoing energy and we need to know Q.

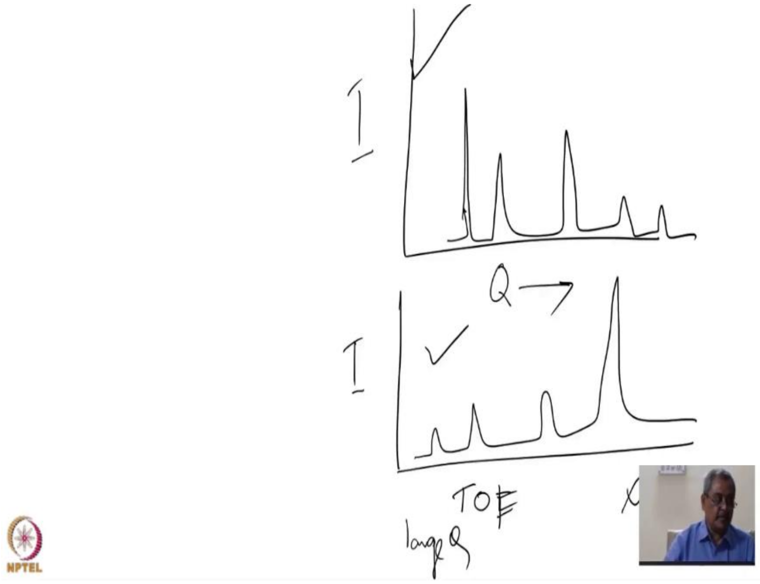
(Refer Slide Time: 04:46)



I am doing a Q scanning, because my aim is to get intensity as a function of Q in this experiment. That is why even the diffractometer showed that Q-ranges (in its description). How do I scan Q? In case of a monochromatic beam, wavelength (λ) is fixed, I keep changing the angle (θ). θ can go from few degrees to150° (often). In back scattering it can even go close to 180° as is the case of high-resolution powder diffractometers in many spallation sources. This is scanning by changing θ.

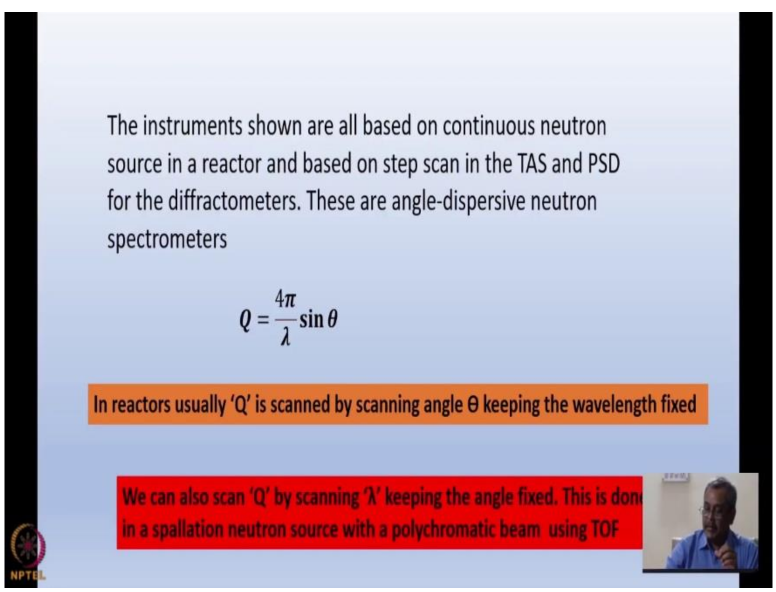
Now, we can also do the same scanning by keeping theta (θ) fixed and changing wavelength (λ). Usually, in case of pulsed sources like a spallation neutron source, the scanning is done by using a polychromatic beam. So, wavelength is changing and the detectors are all fixed, so theta is fixed.

(Refer Slide Time: 06:55)

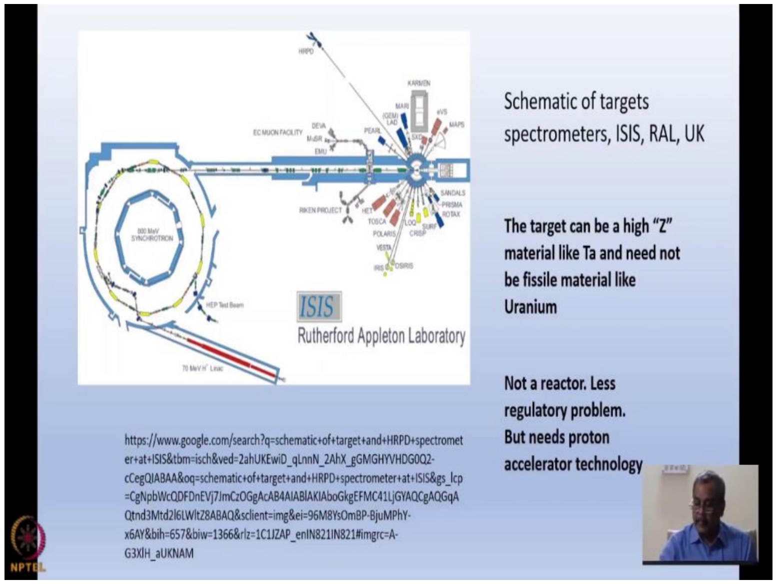


$I(Q)$ vs Q looks like this in case of a reactor source while in case of spallation source it looks different because it is the time of flight (x-axis). So, when the time of flight is less neutron is more energetic, and ToF spectrum in case of spallation source will be a mirror image of the intensity spectrum in a reactor source.

(Refer Slide Time: 08:03)



(Refer Slide Time: 08:13)



Here, I have shown a schematic of a major spallation neutron source. This is at Rutherford Appleton Laboratory. The general concept is that there is a proton beam here of 70 MeV from a Linac which feeds 800 MeV synchrotron where the proton gets accelerated to 800 MeV and hits the target. There are instruments all around the target. There is one instrument which is HRPD (High Resolution Powder Diffractometer), I will come to HRPD later, known as high-resolution powder diffractometer in backscattering geometry.

A spallation neutron source has the advantage that it is not a reactor. A reactor actually uses fission to produce neutrons and then it is a critical assembly which means, generation to generation the number of neutrons remains same for safe reaction. If it does not happen and if it (number of neutrons) keeps increasing then it becomes a bomb. On the other hand, if the multiplication factor is less than 1 then the reactor will stop working and it will be sub-critical. So, there are situations when reactor is sub-critical, critical or (even) super-critical. We are always working in the critical region. But you have to remember that there are lots of regulations we have to follow.

In case of spallation neutron source, the target need not be uranium. It can be a high *Z* material like tantalum, zirconium which need not be fissile material. Of course, the yield maybe more in uranium, because after spallation it can be followed by more fission by the neutrons which are produced in spallation.

But generally, in many places, for example, in RAL they use high *Z* materials like tantalum. This is not a reactor like situation and regulations are much relaxed and much easier to handle. But at the same time, this needs a very high-end technology like producing a proton beam of 800 MeV or almost 1 GeV energy. So, that is the challenging part. And India proposes to have spallation neutron source in future.

(Refer Slide Time: 11:16)

I will get back to polarizers and time of flight angle dispersive scattering comparisons in the next lecture. Thank you.