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SRS X-RAY DETECTOR SYSTEM SURVEY, RESULTS AND CONCLUSIONS

by

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SRS X-Ray Detector System Survey

Results and Conclusions

Rob Lewis 1993

Abstract

The results of a survey conducted during the autumn of 1992 on the requirements of SRS x-ray users for detection systems are reported. There are two main conclusions. Firstly, inadequate x-ray detection systems are a major factor limiting progress in research projects currently taking place using the SRS and secondly, that the remarkable degree of commonalty in the requirements for widely different applications has implications for the development of future detectors.

1. Aims and Objectives

The experimental work being carried out on the SRS is constantly changing with ever more complex experimental facilities being required to perform leading edge science. Much of the time it is the lack of adequate instrumentation that is the single largest obstruction to the progress of research. Within the field of synchrotron radiation research there has always been a major mismatch between the ability of machine builders to produce photons and the ability of detection instrumentation scientists to design and construct detectors that detect them with sufficient accuracy. Such a mismatch means that the potential of synchrotron radiation sources is not fully exploited in many areas of research. The problem is exacerbated by the fact that improvements in instrumentation for one type of experiment may take a long time to propagate into other areas of work where they may be applicable.

A questionnaire was sent to all registered SRS x-ray users in autumn 1992. The aim of the survey was firstly, to find out from x-ray users what is limiting progress in their research, and secondly, to determine the specifications of the x-ray detection systems that they require. From the results it was hoped that potential areas of cross fertilisation could be identified where developments in detector technology for one field may be used to advantage in others.

2. Results and Discussion

Approximately 130 replies were received. Whilst the quality of the majority of replies were of a very high standard, it should be noted that many SRS users are not instrumentation experts and there was therefore a smattering of replies containing somewhat contradictory combinations of answers to the questions. The data from these replies have therefore been closely scrutinised and inconsistencies adjusted on the basis of the consensus of the replies of other users in the same category.

Much of the data has been broken down into 5 user groups based on the techniques and stations used. These are;

1. Non crystalline diffraction.
2. Protein crystallography
3. EXAFS
4. Powder diffraction
5. Surface and crystalline diffraction and diffraction physics.

The first part of the analysis has been directed at finding out what is limiting users from making further progress in their research activities.

2.1. Limits on Research Progress

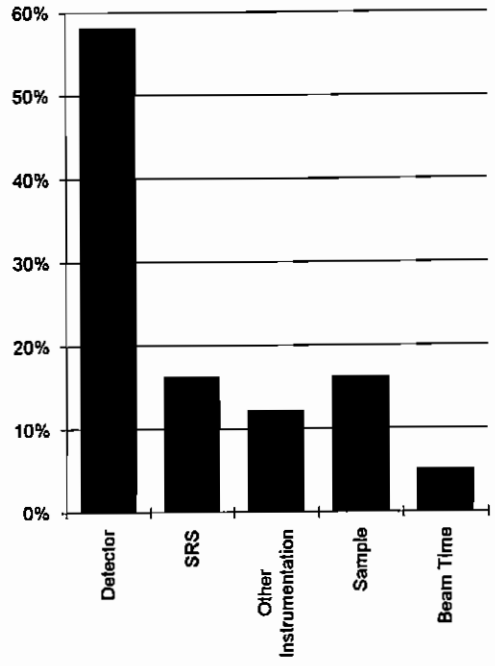

Figure 1. The major factors limiting the research of SRS x-ray users.

The questionnaire contained a question asking what was the major technical factor limiting progress in the research project. Replies to this question have been grouped into five categories which are;

1. detector problems;
2. inadequacies in the SRS, including flux, brilliance and stability;
3. other instrumentation problems;
4. difficulties in sample preparation or handling;
5. lack of beam-time.

The fact that this was a questionnaire specifically about detector systems is certain to have biased these results towards showing the need for improved detection systems. Nevertheless it is clear from the results shown in figure 1 that lack of adequate detectors is a major factor limiting progress in many research projects involving the SRS. Detector problems were mentioned more than 3.5 times as often as the next most quoted limitations.

These data on technical limitations have been broken down into user groups and the results illustrated in figure 2. It shows that in all but one of the groups, the detector limited users outnumber those limited by all other problems put together. Even for the EXAFS group where the limitations are distributed more evenly, detector problems are the largest single factor at 33% of replies.

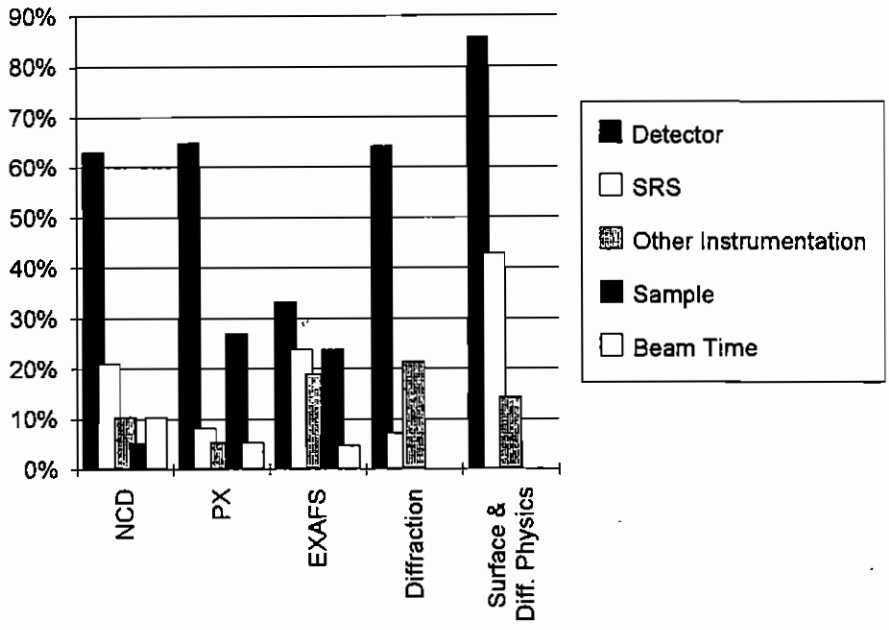

Figure 2. The major technical factors limiting SRS user's research broken down into user groups.

2.2. Ideal Detector Specifications

In order to determine the specifications required by experimenters, the questionnaire contained questions with multiple choice answers for most detector parameters. The replies have been analysed for each of the user groups defined above and the requirements averaged to yield a set of specifications for each user group.

A set of specifications for detectors for each of the user groups has been derived by calculating the weighted

mean of each detector parameter for each user group. Great care should be taken in interpreting this data since different users will have had different types of detection systems in mind when compiling their replies. For example several types of work may be performed either by scanning a single detector, or by using a position sensitive device. Alternatively as in the case of EXAFS, the experiment may be performed using either an energy resolving device, or a position sensitive detector, depending on the experimental technique. It is unfortunately difficult to separate such requirements as many users have combined all their requirements for different experiments on one form. Nonetheless some overall parameters emerge from the data.

The results of this analysis are shown in table 1. It is a striking feature that despite the enormous range of SRS x-ray experimental techniques, many of the desired specifications are the same. In particular almost all users require a detection system with a quantum efficiency in excess of 50% coupled with a dynamic range of 3 to 5 decades and signal to noise ratios in the range 1000 to 10000. These specifications represent a desire for data of extremely high quality as might be expected when one considers that it is often only the most demanding experiments that are performed using synchrotron radiation.

		NCD	*PX*	*EXAFS*	*Diffraction*	*Surface & Diff. Physics*
Active Diameter (mm)		100-250	100-250	50-100	50-100	50-100
Spatial Resolution (um)	(full width 50% max)	100-500	25-50	50-100	50-100	50-100
	(full width 1% max)	100-500	50-100	>500	25-50	50-100
Angular Aperture (degrees)		5-20.	20-45	45-90	45-90	5-20.
Quantum Efficiency		>80%	>80%	>80%	>80%	50-80%
Signal to Noise Ratio		1e3-1e4	1e3-1e4	1e3-1e4	1e3-1e4	100-1e3
Dynamic Range		1e4-1e5	1e4-1e5	>1e5	1e3-1e4	1e3-1e4
Global Counting Rate Limit (cts/s)		1e6-2e7	1e6-2e7	1e6-2e7	1e5-1e6	1e6-2e7
Local Counting Rate Limit (cts/s/mm2)		1e4-1e5	1e5-1e6	>1e6	1e3-1e4	1e3-1e4
Spectral Resolution (fwhm)		20-10%	10-1%	<1%	<1%	10-1%
Time Resolution		1-100ms	1-100ms	1-100ms	100ms-10s	1-100ms
Number of time frames		100-1000	100-1000	10-100	10-100	100-1000

Table 1. The averaged detector requirements for the five x-ray user groups

Note: The table above gives a general outline of experimental requirements and does not necessarily represent the ideal detector specifications for all applications. e.g. conventional step mode EXAFS does not demand 1% fwhm energy resolution. Also it must be remembered that the data is an average requirement and these specifications may not be sufficient to fulfil the requirements of the most demanding experiments.

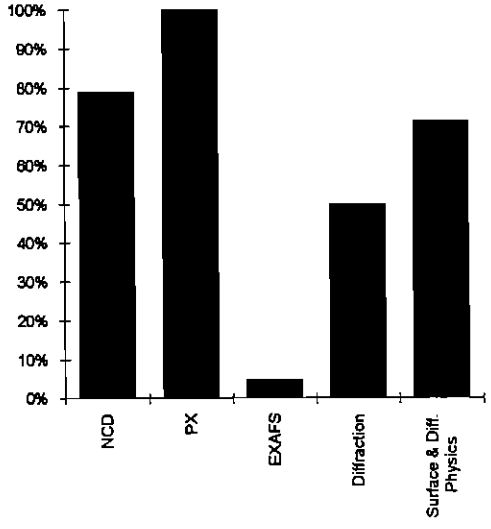

Figure 3. The fraction of users by user group requiring two dimensional detectors.

One of the major demands that emerged was for two dimensional imaging detectors with two thirds of all users requesting them. Figure 3 clearly shows that in the four diffraction based user groups there is a major need for two dimensional detectors. Even in fields such as powder diffraction and surface science which have traditionally used scanning detectors, more than 50% of the replies indicated that more and better research would be possible with two dimensional position sensitive detectors. Just under 20% of EXAFS users requested position sensitive detectors for energy dispersive work but this is generally restricted to a single dimension.

Since some users had position sensitive detectors in mind when determining specifications, whilst others required only a simple single channel detector the average of the active diameter figures leads to a misleading value which is too small for a useful imaging device and too large for a non position sensitive detector. The specification from almost all users who did not wish position sensitivity was a diameter less

than 10mm. The active area given in table 1 therefore, is the average of those replies requesting a position sensitive detector.

Referring to table 1 it can be seen that there are major similarities in the detector requirements for all four diffraction based techniques. Protein crystallography, non-crystalline diffraction and x-ray diffraction coupled with surface diffraction and diffraction physics all require large area two dimensional position sensitive detectors with spatial resolutions of ~0.1 mm and capable of high count rates. The lack of interest in two dimensional detectors coupled with the absence of large active areas tends to separate the needs of EXAFS users from those of all the other user groups. This is not at all surprising since all the other techniques are based on diffraction whilst EXAFS is based on spectroscopy.

3. Conclusions

As has been mentioned previously it would be very dangerous to read too much detail into the results of a survey such as this, however several general conclusions can be made.

1. A great deal of research using x-rays on the SRS is seriously limited by the available detection systems.
2. In order to pursue 'leading edge' research, SRS users are demanding at least 'state of the art' detection systems or in many cases even more.
3. There are strong similarities between the position sensitive detection requirements of all those users utilising x-ray diffraction based techniques.

The cost and difficulty of developing detection systems that can realise the potential offered by even a second generation synchrotron radiation source such as the SRS requires that resources be pooled and detector developments directed at more than one experimental technique. Given the similarity, albeit with some notable variations, there is considerable scope for detector developments to be applied across the different x-ray diffraction user groups.