Final 10/1/04

Cross-cut Review
Science with Microbeams

Wednesday, January 21, 2004
Advanced Photon Source, Bldg. 402 Auditorium

Overview: Background and Purpose

In his opening talk, APS Director Murray Gibson described the following as purposes of the review:

- It will provide an important view as to where are we now from the perspective Scientific Advisory Committee (SAC) members and invited experts.
- It differs from the SAC's individual sector reviews in that it focuses on a single area across APS beamlines.
- It advises APS on strength and opportunities in this specific area.
- It should provide an opportunity for a healthy information exchange.

The following criteria were used in the development of the day's program:

- Only talks describing current research with x-rays focused below 10 microns were included.
- Each beamline where research in this category is being conducted was asked to describe its best science
- In general, only one presentation per sector was requested.
- Sectors to present were selected on the basis of the amount of microbeam research conducted at their beamlines.
- The final overview presentation by Eric Isaacs dealt with the future for nanoscience.

Overall Review Comments:

Since this was the first cross-cut review at APS, this report begins with a few general remarks on the process. If the intent was to survey the "best" science in the area of microbeams being carried out at the APS, then the talks were suitable, but the results were very mixed. However, if this was the intent, then an appropriate response from the review panel is difficult to develop. A ranking of each talk by the panel is of little use as it does not advise the APS on appropriate allotments of time or funding. The majority of presenters described their own work, without providing any wider context such as the relationship of their work to that at other APS sectors or at other national and international facilities. In addition, the talks were not structured in a way that would allow the panel to judge the quality of the APS instrumentation and facilities for carrying out excellent science.

With regard to the quality of the science presented (which often included proposed future research), it ranged from outstanding and very high to mediocre (in a very few cases). Eric Isaacs' overview was excellent and presented a clear roadmap for the future. It was an inspiring and ambitious vision for the APS/CNM nanoprobe and just what the APS and the CNM should be doing. This type of presentation, focusing on science fields, commonalities and differences around the ring, which puts the results and technical achievements into a broader picture, should be the approach for the next cross-cut review.

Such a review can also help to develop more integration of research activities at APS, creating science/technique-oriented synergy among all of the different users. In addition, it will open the dialogue to initiate and drive coordinated efforts in technical R&D, e.g. for software/real-time data analysis, detector development, real-time instrument controls, and efficient user interfaces. It could also help to make the best of the present situation at APS with various methods and similar experiments scattered around the ring.

The overall quality of the work presented was high. In the few cases of less than satisfactory presentations, it seemed to be a case where the individual carrying out the work was not sufficiently competent in the field where the available x-ray techniques were being applied. In other words, these are cases where knowing the x-ray physics is not sufficient to produce good science; bringing in expertise in the field would be advisable. Although this will be difficult, the APS needs to facilitate cooperation in such cases to assure the best scientific output for the facility.

An overall technical observation is that the brightness of the APS makes it possible to create microbeams of very small size and exceptionally high flux density. This provides the capability to add high spatial resolution to just about every kind of x-ray technique, including diffraction, fluorescence, EXAFS, XANES, circular and linear dichroism, reflectivity, as well as imaging (i.e., microscopy) using absorption, luminescence, fluorescence, dark field, or phase contrast. Coherence-based applications also depend directly on the brightness of the source.

A lot of excellent work is going on. Nevertheless there are two specific areas that could be improved:

1. Most of the microbeams at the APS are formed with K-B mirrors. These have the advantage that they are achromatic. The best of the K-B mirrors have demonstrated focal spot sizes in the sub-100 nm range. In routine use at the APS, they are often used with a focal spot size of 2-10 microns, and in only a few cases in the sub-micron regime. When the larger spot size is designed to capture more flux or to create a more parallel beam, then this is clearly justified. However, in some of the presentations stability, difficulty of alignment, and vibrations were mentioned as reasons for relatively poor performance. An additional issue with K-B mirrors is the fraction of the beam that is outside the focus, which adds to the diffuse background illumination of the sample. Where zone plates are used (as in Sector 2), the spatial resolution is generally higher.

2. Some of the instruments are not optimized for maximum throughput. The problem tends to be either the frequent change of apparatus requiring time-consuming alignment or the lack of optimized software for data acquisition.

Overall, it was somewhat surprising that many of the applications presented did not use, nor seem to demand, submicron spatial resolution.

Usually, new science is enabled by superior instrumentation and capabilities, and the APS was build with expressly that goal. However, when one focuses on the highest spatial resolution work, the technical picture is not entirely positive, as was mentioned for his field by Cev Noyan during his presentation. The APS appears to provide excellent beams, but more effort may need to be put into optimizing the end station instrumentation.

Overall, the APS microscopy programs seem to be missing some cutting-edge developments, such as coherent imaging techniques. The APS needs to first of all attain world leadership in straightforward microprobe applications, but other methods should be pushed as well.

It is also suggested that the APS put more emphasis on instrumentation at lower energy. Traditionally, there has been a clear separation between the third-generation national facilities, each having its own energy "turf". Clearly, the emphasis of the APS program should remain at the >2 keV range. However, all facilities have some local character when viewed from the actual user base, and the rationale is shifting to integrated sophisticated infrastructure (e.g., the Nanotechnology Centers). It will therefore be beneficial to make state-of-the-art soft x-ray instrumentation available, complementing the present hard x-ray methods.