## Title
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Workshop on Detectors for Synchrotron Radiation

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What would have been the result if high energy physicists had not spent a significant fraction of their budget on the huge detectors associated with their accelerators? They probably would not have made as many exciting discoveries or been awarded as many Nobel prizes. Unfortunately, this hypothetical situation for HEP may be the real situation for users of synchrotron radiation. There is a widening mismatch between the well-demonstrated ability of beamlines at synchrotron sources to deliver abundant photon fluxes to samples in advanced end stations and the inadequate ability of detectors to record the results.

As a direct consequence, forefront experiments in many scientific areas for which synchrotron sources provide sufficient flux are nonetheless hindered because detectors cannot collect data fast enough, do not cover sufficiently solid angle, or do no have adequate resolution. Overall, the synchrotron facilities, each of which represents collective investments from funding agencies and user institutions ranging from many hundreds of millions to more than a billion dollars, are effectively significantly underutilized. While this chronic and growing problem plagues facilities around the world, it is particularly acute in the United States, where detector research often has to ride on the coat tails of explicitly science-oriented projects.

As a first step toward moving out of this predicament, scientists from the U.S. synchrotron facilities held a national workshop in Washington, DC, on October 30-31, 2000. The Workshop on Detectors for Synchrotron Research aimed to create a national “roadmap” for development of synchrotron-radiation detectors. The roadmap will, it is hoped, lead to a “national initiative” for funding immediate upgrades of existing beamlines with state of the art detectors and, most important, for long-range strategic research leading to new detector technologies. One goal of the proposed initiative will be to identify critical-mass groups in key detector areas, and to propose the creation of such groups for areas in which they do not already exist by forming collaborations or otherwise. These groups would be funded to develop technology in their defined areas and also to disseminate results and technology to the whole community,

The process for implementing this national research initiative continues to be under active discussion following the workshop, but there are two central themes. First, new programs would be focused in a relatively small range of key areas for which the scientific opportunities are the highest, and second, the selection of these new focused programs would be by a national peer-reviewed competition. An umbrella group to be named DetectorSync, following the practice of consortia in other areas of synchrotron research in the U.S., is being formed to take on the responsibility of shepherding the detector roadmap and the resulting initiative through the intricacies of the federal funding process.

The Washington detector workshop came at a timely moment. While the “coat-tails” approach has worked well for funding the acquisition of existing technology, it has proved to be ineffective in funding long-term strategic research in new detector technology. In particular, one of the problems facing the U.S. community is the sub-critical size of many detector research groups. The special problem that has evolved in the U.S. can be seen by contrasting the number of people working on detectors at European and U.S. synchrotron sources. Perhaps the starkest contrast is with the CLRC Daresbury Laboratory in the United Kingdom, which including support from the CLRC Rutherford Appleton Laboratory  has nearly as many personnel devoted to detector research as the whole U.S. synchrotron community. The result is that in several areas such as time resolved solution scattering the Synchrotron Radiaton Source (SRS) at Daresbury is leading the way, even though the source is now dated compared to third-generation machines.

In addition to the lack of a tradition for supporting research specifically leading to advanced detectors, several factors are converging in today's fast-moving world that make it obligatory to transform detector development into a more focused activity with its own funding base than it has been in the past. Many of these trends appeared first in the world of elementary particle physics, where detectors have long played a key role. The importance of detectors in this field is well signified by the award to Georges Charpak (CERN) of the 1992 Nobel Prize in Physics "for his invention and development of particle detectors, in particular the multiwire proportional chamber," a technology that subsequently spread to other fields of research.

One emerging trend is that synchrotron experiments are becoming ever more sophisticated, demanding detectors with high count rates and good spatial resolution over large areas, for example. Such detectors will also be expensive. A state-of-the art CCD camera for macromolecular crystallography now costs more than $1 million, and the day of highly sophisticated detectors costing as much as $10 million is foreseeable. Moreover, the microelectronics technology that has played such a key role in particle tracking and other functions in the massive devices installed around colliding-beam storage rings built for studying elementary particles is now seen to be applicable to synchrotron-radiation detector systems, as well. Finally, the complexity of detector systems with the required capabilities is outgrowing the ability of single investigators or small research groups to develop them, and a more coordinated approach involving teams of specialists looks certain to be the future mode of operation.

Under development in both the U.S. and Europe, silicon pixel detectors for macromolecular crystallography and other applications in some ways exemplify the opportunities and challenges of advanced detectors. In these devices, each image pixel has its own electronics integrated into an application-specific silicon chip that is bonded to the chip containing the detecting elements. A high-speed, large-area, position-sensitive detector is then assembled from modules built up from these chips. Prototypes have been demonstrated, but development of complete devices that fully utilize the power of microelectronics requires a coordinated effort over many years with substantial and consistent funding. Future generations of detectors that add energy and/or time resolution are well beyond the ability of today's detector efforts but their development would enable multi-dimensional experiments with extraordinary sensitivity.

The two-day Workshop on Detectors for Synchrotron Radiation in Washington was organized with the financial support of the U.S. Department of Energy, Office of Basic Energy Sciences. The organizing committee was drawn from the U.S. synchrotron-radiation community and consisted of Al Thompson (Advanced Light Source, ALS), Denny Mills (Advanced Photon Source, APS), Steve Naday (Argonne National Laboratory), Josef Hormes (Center for Advanced Microstructures and Devices, CAMD), Sol Gruner (Cornell High Energy Synchrotron Source, CHESS), Peter Siddons (National Synchrotron Light Source, NSLS), John Arthur (Stanford Synchrotron Research Laboratory, SSRL), Ralf Wehlitz (University of Wisconsin Synchrotron Research Center, SRC), and Franco Manfredi (University of Pavia).

The goal of the meeting was to produce a collective vision of how to develop next-generation detectors to solve critical experimental problems and to guide U.S. funding agencies in implementing this vision for the next decade. Two stages of information gathering laid the foundation for the workshop. First, in order to adequately portray the extensive and diverse research community, representatives at each of the seven U.S. light sources polled those involved in detector use and in research and development to determine their detector needs. The second stage comprised meetings at several of the synchrotron facilities. For example, as part of the ALS users meeting in Berkeley (see pp. xx-yy), a Forum on Detectors for Synchrotron Radiation was held on October 18, 2000 with short presentations by ten speakers followed by an active discussion period. A similar meeting was held at the APS on September 20, 2000, where APS users and staff alike had the opportunity to voice opinions and concerns related to their detector needs.

The meeting was attended by more than 70 internationally renowned experts in detector technology and by users and staff from each of the U.S. synchrotron sources, as well as representatives from government funding agencies. It began with an introduction by

Thompson, who outlined the issues facing development of detectors for synchrotron radiation, the goals for the workshop, and what needed to be accomplished to achieve the goals. The workshop program (available on the Web at http://xraysweb.lbl.gov/esg/wdsr.html) was divided between formal presentations (first day) and working groups (second day).

Talks on the first morning emphasized requirements for improved detectors in various areas of research in both hard and soft x rays, including spectroscopy and atomic-structure determination (Charles Fadley, University of California, Davis, and Lawrence Berkeley National Laboratory), diffraction characterization of materials (Sean Brennan, SSRL), microscopy of heterogeneous materials (Mark Rivers, University of Chicago), structural measurements with EXAFS (Steve Heald, Pacific Northwest National Laboratory), ultrafast dynamics in solids (Roger Falcone, University of California, Berkeley), macromolecular crystallography (Bob Sweet, Brookhaven National Laboratory), x-ray scattering and fluorescence (Chi Chang Kao, NSLS), fourth-generation sources (John Arthur, SSRL), and infrared research (Larry Carr, NSLS).

The focus in the afternoon shifted to reviews of advanced detectors. Rob Lewis of the CLRC Daresbury Laboratory provided an overview of the process of developing new detectors. He gave as an example the latest ultrahigh-speed two-dimensional wire detector, which now gives Daresbury a lead in several scientific areas such as time-resolved scattering from biological systems. He pointed out that it took a decade of intensive effort to bring this detector from the laboratory to the experimental floor. Without the strategic vision that this was a core technology needed to enable research in new scientific areas, this detector could not have been built. This theme was emphasized by many participants at the meeting.

After Lewis, Graham Smith (Brookhaven National Laboratory) reviewed gas detectors; Kent Irwin (National Institute of Standards and Technology, NIST) surveyed superconducting bolometer arrays with high energy resolution, and Steve Naday (Argonne National Laboratory) examined CCD detectors for crystallography. The afternoon then continued with more detailed discussions of silicon pixel detectors for crystallography and other applications with talks on analog systems (Sol Gruner, CHESS), digital systems (Christian Brönnimann, Swiss Light Source), integrated systems (Jacques Millaud, Lawrence Berkeley National Laboratory, and a perspective from the high-energy physics community by Erik Heijne (CERN).

Following the pixel-detector session, there were several presentations about multi-element Si(Li), Ge, and CdZnTe detectors for EXAFS (Gareth Derbyshire, CLRC Rutherford Appleton Laboratory), silicon-drift detectors and active-matrix silicon detectors (Pavel Rehak, Brookhaven National Laboratory), avalanche photodiodes (Alfred Baron, Spring-8), and sub-picosecond streak cameras (Jean-Claude Kieffer, University of Quebec). The day concluded with short reports on detector needs by representatives of the synchrotron facilities and the formation of working groups for the next day.

Working groups (chairs in parentheses) were established for diffraction and scattering (Sol Gruner), spectroscopy (Peter Siddons), imaging (Mark Rivers), crystallography (Bob Sweet, Andy Howard and Ed Westbrook), timing (John Arthur) and infrared (Larry Carr). Time was divided between listening to input from workshop attendees, discussion, and writing working-group reports, including recommendations. The working-group reports will be one of the principal inputs (along with papers based on the science and detector presentations) to a report that will represent one of the two main outputs of the workshop (the other being the formation of DetectorSync) and will become a roadmap for detector research for synchrotron experiments for the next decade

In his introduction, Thompson argued that to secure future funding for detector research and development, it will be crucial to show that (1) the needs of the synchrotron-radiation community have been accurately determined, (2) new detectors will actually have a significant impact on specific scientific programs, (3) any proposed research program will have realistic goals that are closely coupled to demonstrated experimental needs and (4) that the research program is focused and cost effective. It is the job of the workshop report to demonstrate all of these. To disseminate, as well as authenticate, the findings, the report will be submitted for peer review and publication in a special issue of the *Journal of Synchrotron Radiation*. The organizers expect the full report to be available by spring 2001.

All in all, the workshop organizers have taken on a huge challenge, but the benefits to the U.S., as well as international, synchrotron-radiation community will be enormous if they succeed.

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[figure and captions]

[Figure 1]

The timing group (foreground) and diffraction group (background) are two of the working groups into which attendees at the detector workshop split for in-depth discussions and report writing.

[Figure 2]

Jean-Claude Kieffer (University of Quebec), Gerd Rosenbaum (University of Georgia), Christian Brönnimann (Swiss Light Source) and Sean Brennan (Stanford Synchrotron Radiation Laboratory) at a seafood dinner, which provided a break from the workshop deliberations.