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ANL/APS/CP-4

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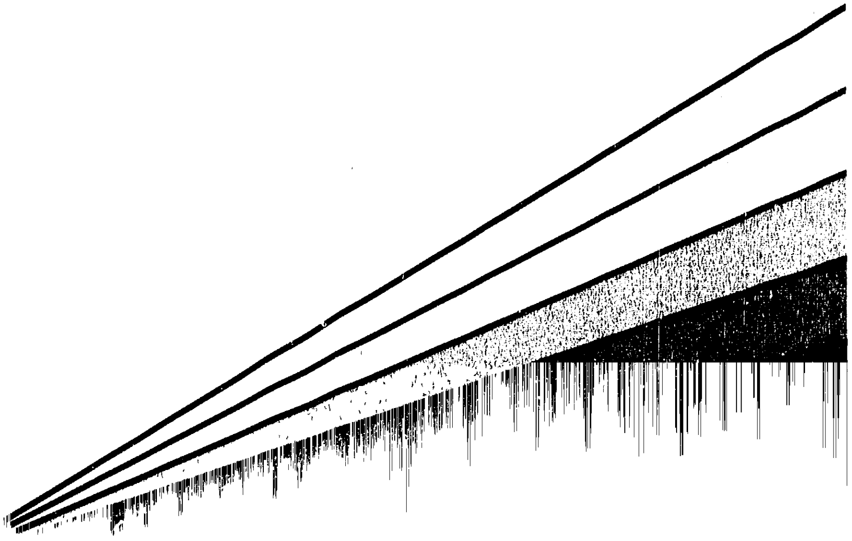
Proceedings of the Fourth Users Meeting for the Advanced Photon Source

held at Argonne National Laboratory
May 7-8, 1991



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Argonne, Illinois 60439

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ANL/APS/CP-4

PROCEEDINGS OF THE FOURTH USERS MEETING FOR THE ADVANCED PHOTON SOURCE

Held at Argonne National Laboratory
May 7-8, 1991

February 1992

work sponsored by
U.S. DEPARTMENT OF ENERGY
Office of Energy Research

MASTER

Foreword

With the Advanced Photon Source (APS) ground breaking a year in the past and commissioning still several years in the future, the Fourth Users Meeting focused on facility issues relevant to beamline planning and innovative science possibilities. More than 200 participants, representing at least 70 different institutions in the U.S., Canada, and Japan, attended the two-day conference sponsored by the APS Users Organization (APSUO), the Argonne National Laboratory Division of Educational Programs, and The University of Chicago.

The presentations included overviews of the status of the project in both R&D and construction, six invited talks covering advances in synchrotron radiation applications, a session on user issues covering both facility and activity plans, tours of either the APS site or staging areas, and an APSUO business meeting. Six new members were elected to the APSUO Steering Commitee. The current membership of the Steering Committee is shown below:

APSUO Steering Committe

Paul Horn, *Chairman* (IBM)
Stephen Durbin, *Vice Chairman* (Purdue)

Robert Broach (UOP)
Haydn Chen (Univ. of Illinois)
Roy Clarke (Univ. of Michigan)
Peter Eisenberger (Princeton)
Doon Gibbs (BNL)
Samuel Krinsky (NSLS)
Keith Moffat (The Univ. of Chicago)
Paul Sigler (Yale Univ.)
William Thomlinson (NSLS)
Keith Watenpaugh (Upjohn)
Bob Batterman, *ex-officio* (CHESS)
Arthur Bienenstock, *ex-officio* (SSRL)
Denis McWhan, *ex-officio* (NSLS)
Walter Trela, Past Chairman, *ex-officio* (LANL)

Program Committee for the Fourth Users Meeting

Robert Broach
Roy Clarke
Keith Moffat

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Proceedings of the Fourth Users Meeting for the Advanced Photon Source

Abstract

The Fourth Users Meeting for the Advanced Photon Source (APS) was held on May 7-8, 1991 at Argonne National Laboratory. Scientists and engineers from universities, industry, and national laboratories came to review the status of the facility and to look ahead to the types of forefront science that will be possible when the APS is completed. The presentations at the meeting included an overview of the project; critical issues for APS operation; advances in synchrotron radiation applications; user perspectives, and funding perspectives. The actions taken at the 1991 Business Meeting of the Advanced Photon Source Users Organization are also documented.

WELCOMING REMARKS

Paul Horn
Chairman, APS Users Organization

On behalf of the APSUO Steering Committee, I would like to welcome all of you here today to the Fourth Users Meeting for the Advanced Photon Source. Before we begin our comprehensive program, I'd like to take just a few minutes to reflect on the role of users at the APS and remind us all again of the "user-centered" philosophy that underscores all aspects of this facility. From the beginning, prospective users made contributions by identifying their needs, which has greatly influenced the technical design of the APS, as well as the planning for user-support buildings and services. Users also markedly influenced the development of policies for user access, as we discussed in detail at our last Users Meeting. But the real mark of the APS commitment to serving users is the enthusiasm we see daily in the APS management and staff and their willingness to receive our ideas and incorporate them into designs and plans.

The last few months have seen considerable activity in the synchrotron users community as proposals to establish Collaborative Access Teams (CATs) at the APS were being prepared. We look at this activity with pleasure as another sign of the partnerships that will be established between the user community and the APS. At our Business Meeting tomorrow, I'll talk more about the activities of the APSUO for the past 18 months and share with you some of our challenges and successes. However, before I turn to Bill Oosterhuis, who will be welcoming you in his new role as Program Manager for the Material Sciences Division, office of Basic Energy Sciences for the Department of Energy, I'd like to thank the many individuals who made my term as Chair of this APSUO so rewarding. Walter Trela, past APSUO Chair, David Moncton, Associate Laboratory Director for the APS and his staff, members of the APSUO Steering Committee, and the Directors of our other U. S. synchrotron radiation facilities, have all contributed to the efforts of this organization. I have enjoyed working with all of the individuals and have very much appreciated their help and counsel.

And now, let's focus on the future, looking at plans for APS construction, ongoing APS research and development, and the types of science that will become possible when the APS begins operation.

Greetings to APS Users on Behalf of DOE

William T. Oosterhuis
Solid State Physics and Materials Chemistry
Division of Materials Sciences
U. S. Department of Energy

I would just like to say that 16.5 years ago when I joined the NSF, I was assigned the SSRP and Wisconsin SRC projects, which had a total annual budget of about $1.5M. The total number of users was about 50-100.

In 1978, we began an ambitious program to create the second generation of synchrotron light sources with construction budgets of about $10M (over 3 years) at NSF and $24M (for NSLS) at DOE. The total number of users at that time was about 1000.
Now the third generation light sources are under construction with a total price tag that may approach $1B. The cost of a beamline may exceed $5M! The total number of users is about 3000.

We have come a long way.

But we have a long way to go - the tasks are large, BUT NOT IMPOSSIBLE. By working together — scientists, engineers, technicians, faculty and students, industry and even government — we can accomplish much.

There will be barriers and detours as we walk down this path, but the goals are clear. Keep your eyes on them.

I would like to welcome you on behalf of the DOE, I hope to interact with you today and tomorrow, and I wish us all well in this undertaking.

Thank you.

STATUS REPORT ON THE ADVANCED PHOTON SOURCE - SPRING 1991

by

David E. Moncton
Associate Laboratory Director for the Advanced Photon Source
Argonne National Laboratory

Opening Remarks

I would like to welcome you to the Fourth Users Meeting for the Advanced Photon Source (APS). We are all very happy to have you here, and we look forward to the time when you will be at Argonne National Laboratory (ANL) on a daily basis rather than once every year. I would also like to welcome Bill Oosterhuis, who has recently joined the Department of Energy (DOE) as Program Manager for the Office of Basic Energy Sciences. Bill is a long-standing friend of synchrotron radiation research. We hope that Bill's appointment signals a trend toward bringing in new people to help do a job that has become increasingly difficult, given the tight budget climate.

This meeting marks the end of Paul Horn's term as Chairman of the APS Users Organization. Paul has done an excellent job during the last year and a half, particularly in helping to support user interests in areas such as proposed user fees and others. He has been willing to listen to the difficulties we face and take real action to help when we needed the support. We all truly appreciate his efforts.

We have also benefited from the counsel of a number of external advisory groups. It is appropriate to thank all of these people for the work they've done over the years and continue to do. William Brinkman chairs the committee that has a management oversight function and reports to the ANL Board of Governors. The Accelerator Advisory Committee has been in place for some four years. Don Edwards was its original chair, and Ewan Paterson now holds that title. Argonne has an internal APS Safety Review Committee, chaired by Bruce Brown, which is very active in evaluating safety features of APS prototype facilities, as well as designs for interlocks and controls systems. The Advanced Photon Source Users Organization Steering Committee is chaired by Steve Durbin. The Proposal Evaluation Board (PEB), chaired by Mike Knotek, has been very active over the past year, evaluating, first, Letters of Intent, and then proposals.

Project Status

Facility modifications

Since our last meeting 18 months ago, some significant conceptual changes have been made to the APS Project. The injector facilities, while not altered technically, have been relocated slightly counterclockwise on the Experiment Hall infield. The radio-frequency buildings, which had been in two places on the storage ring, have been eliminated. The rf cavities and their associated power supplies and klystrons have been consolidated into a single location near the 12 o'clock position on the Experiment Hall. The result of that change has been a much more effective use of space. The two "shadow" areas (where no beamlines could be used for synchrotron radiation) created by the rf components are now one area amounting to about 30,000 ft^2 of space. In addition, the injection line from the booster to the main storage ring follows back to the four straight sections that are reserved for rf. Taken together, these modifications have created five straight sections in a row where there are no insertion devices, and that shadow can be used for a variety of other activities. The most immediate activity has given that space its name: the Early Assembly Area (EAA), where initial assembly of the storage ring girders will take place. Magnets, power supplies, and the vacuum system will be constructed in various buildings in the ANL 360 area away from the APS site, then brought together and assembled on girders in the EAA.

The Control Center, the Central Laboratory/Office Building (CLO), and the Multi-use Building have been reconfigured to lie in the path of the shadow area. This new arrangement will ensure that there is absolutely no radiation in that area to require nonradiation workers to have film badges. Access to office buildings, conference rooms, and libraries will be completely open, requiring no interlock procedures. We believe that it is important to have an open facility in that sense.

Conventional-facilities construction

Work on the APS conventional facilities is moving ahead rapidly. The detailed design phase for almost all technical buildings (with the exception of the CLO and the user modules around the periphery of the ring) is nearly complete. Conventional-facility construction began in July 1990 following ground breaking in June 1990. Site-preparation activities were conducted in the late summer and early fall of that year. A large contract was awarded in late fall 1990 for the removal of two pockets of soils unsuitable for support of the Experiment Hall and replacement with engineered material.

Contracts totaling nearly $40 million are to be awarded during FY1991. In April of this year, a subcontractor began pouring the 274 concrete caissons that are the support footings for the Experiment Hall. Also in April, work began on the Utility Building, the first structure to be erected on the site, with completion scheduled for spring 1992. Other subcontracts recently awarded include those for the cooling tower, site grading, and site utilities. The contract for the first of the technical facilities, the Linac/Injection Wing structure, was awarded at the end of April, and work will begin shortly, with beneficial occupancy set for April of 1992. Fiscal year 1992 will also see beneficial occupancy of the synchrotron building (December 1992). Having the storage ring available for commissioning in June of 1995 will allow us to provide some early beams for users by the late summer or early fall of that year. Various beamlines will come on over time, with the official designation of project completion scheduled for late 1996.

Technical components

Fiscal Year 1991 will see completion of the detailed design for critical storage-ring components such as the rf cavities, the vacuum system, the storage-ring quadrupole magnet system, and the beam position monitors (BPM). The R&D

program is very well advanced; many prototypes exist, and some of the actual components for the facility have already been procured.

1. Vacuum system

The APS vacuum system prototype is equivalent to a full sector (1/40th) of the machine. Five vacuum chamber segments made of extruded aluminum 6063T5 alloy are connected by bellows and conflat flanges. This permits complete testing of the manufacturing process, the vacuum integrity, the bakeout process, and the alignment of the chambers. This last factor is critical. The chambers carry the beam position monitors. When the chamber is baked out, the BPMs move with the expansion and contraction of the chamber material, and then must return to their original locations within very demanding tolerances. Prototyping is essential to the construction of such a complex vacuum system, and our staff has learned a great deal from this test facility.

2. Magnets

Electromagnets being designed for the storage ring are crucial, and the most critical of these are the more than 400 quadrupole magnets, which have very demanding magnetic-field tolerances. We have now completed a second prototype storage-ring quadrupole and are developing facilities to test all the magnets in order to assure ourselves that magnetic-field requirements are met.

Having two prototype magnets on hand provides an opportunity to evaluate the girders that will support the magnets. The girder is central to the performance of the storage ring, which will have a very low emittance and very heavy tolerances. A resonant dynamical response by the girder to ground vibrations could lead to an amplified deflection of the stored beam. A girder has been loaded with a prototype storage ring magnet and concrete blocks to simulate the weight of the other magnets on the girder, and three-dimensional dynamical testing of the girder assembly has been done. Lessons learned from this exercise will be applied to the girder design, leading to greater stability.

3. Linac

The linac components are beginning to arrive, led by the electron-gun assembly. Procurement of these components has been gratifyingly successful in that to date the linac has been brought in under budget and on schedule. The electron gun is expected to be operational shortly; we hope to have electrons accelerated to 60 MeV by fall of this year.

4. Radio-frequency systems

Radio-frequency systems have historically been a major challenge for storage rings and synchrotron facilities. The APS staff began very early in the project to develop an rf acceleration cavity prototype that could be run at high power. Due to this lead time, the prototype storage ring copper cavity arrived at Argonne on schedule despite earlier subcontractor delays. The cavity has met all performance requirements and is now undergoing "hot" tests on the rf test stand, which consists of a 250 kW klystron and an rf waveguide to provide power to the cavity. Synchrotron rf acceleration cavities are being fabricated by Interatom G.m.b.H., of Germany; delivery of the first cavity is expected in the fall of 1991.

5. Diagnostics

Beam stability is an important element of the project. The members of the Diagnostics Group are working to develop the many beam position monitors required for the storage ring. These monitors must be capable of detecting the particle beam position to better than ± 0.1 mm in order to achieve the expected storage ring performance.

6. Insertion devices

The staff of the Experimental Facilities Division (XFD) have focused their activities on insertion devices (ID), high heat-load optics, front-end engineering, and novel techniques of various sorts. Two prototype insertion devices have been fabricated by industry. The first of these, which was designed in collaboration with staff from the Cornell High Energy Synchrotron Source, was installed on the Cornell storage ring, CESR, three years ago, where it had a very successful run. We are on the verge of a several-weeks-long run of that device beginning in June. Tests of the second prototype APS ID, which was designed for the U-5 port of the vacuum ultraviolet ring at the National Synchrotron Light Source (NSLS), have confirmed our choice of materials and constructability of the design and strengthened our faith in industry's ability to successfully construct insertion devices. We feel very comfortable with the state of the art in standard insertion devices and have begun to consider tapered undulators, devices to produce circular polarization, and other novel ID techniques.

7. Cooling

Thermal distortion of optical elements caused by high heat loading looms as one of the most challenging problems to the APS, as well as to the builders of the European Synchrotron Radiation Facility and the SPring-8 in Japan. There are also substantial thermal problems at existing synchrotron facilities. At Cornell, for instance, the insertion device beams are very hot, as are those at Brookhaven and at the Stanford Synchrotron Radiation Laboratory. The APS has been interested in the development of liquid metals as coolants, liquid gallium in particular. Our first liquid-Ga pump has been modified, increasing flow rates by a factor of five. New concepts have been devised for the channels that carry coolant through monochromating crystals. Using these new technologies, we have progressed further into the power densities that are appropriate for these new-generation machines. Power densities in the few tens of watts per square millimeter, approaching 100 W/mm^2, will be manageable. That would permit the APS to achieve brilliance levels of 10^{18} (photons • s^{-1} • mm^{-2} • mr^{-2} [0.1% bandwidth]$^{-1}$), corresponding to 5 or 10 mA stored in the storage ring. The full 100-mA current would afford brilliance of 10^{19} with power densities of a few hundred watts per square millimeter. Attaining that final level of brilliance will require further R&D, but we can all be very pleased with the progress that has been made in this area over the last few years.

8. Optics

In collaboration with R. Bionta at Lawrence Berkeley Laboratory, we have been making circular Fresnel jelly-roll structures measuring a few tenths of a millimeter in diameter to be used as hard x-ray zone plates. These zone plates have been used successfully at the NSLS to focus hard x-rays into spots of a micron or so. As work on these novel techniques progresses, we expect to see a number of new instruments and new optical devices become available for the user community.

Project staffing

At the time of the previous users meeting, the APS staff numbered approximately 150. That number currently stands at 265, ahead of the scheduled recruiting pace. Emphasis has been on adding technical staff in the Accelerator Systems Division (ASD) and the Experimental Facilities Division. It is particularly gratifying to have John Galayda as Division Director of the ASD. His appointment places that Division in the hands of someone who has had the experience of designing, constructing, commissioning, and operating the NSLS, experience that is critical to the APS. A staff of 265 requires room, and we are gratified that Argonne has been so responsive to our needs. We have been given access to a wide variety of space at the Laboratory.

User Issues

Collaborative Access Team proposals

Nineteen proposals to form Collaborative Access Teams (CAT), requesting use of 44 beamlines, were received for screening by the APS Proposal Evaluation Board. These proposals represent more than 400 principal investigators from 18 industries, 77 universities, 7 medical schools, and 19 research institutions (national labs and others). There have been 12 requests for APS standard undulators, 4 each for two types of wigglers, and 4 other devices have been requested.

Each sector on the ring will be managed by a CAT, which will make 25% or more of their beam time available to independent researchers. A number of proposed CATs are structuring themselves so as to afford considerably more than 25% of their beam time to outside users. That is particularly the case with the proposals put forth by the ANL's programmatic divisions. The Basic Energy Sciences Synchrotron Radiation Center (supported by the ANL Materials Sciences, Chemistry, and Physics divisions) is planning to provide 50% of their beam time to investigators from outside ANL. Plans for the proposed Structural Biology Center call for allotting a major share of beam time to the external research community.

The PEB is now commissioning four panels for scientific review of the proposals. This review process will include an effort to think through the standardization of beamline components. The objective is to assemble the most reliable beamlines for the lowest possible cost, and to put as much engineering as possible into the fewest devices. This review process is scheduled for completion by October 15, 1991.

Collaborative Research Program

The newly created Collaborative Research Program (CRP) will further the cause of working with the user community on instrumentation R&D by creating bridges between the XFD and outside users who have an interest in a particular instrumentation development idea. Users will present formal written proposals to be reviewed by members of the XFD staff and the APSUO Steering Committee. Those proposals deemed to have the greatest merit will receive expertise and support, such as engineering, from the XFD to complement resources brought by users. In this way, we hope to forge cooperative relationships between the APS and the user organization in the interest of meeting some of these very difficult instrumentation challenges.

User housing facility

Just as the quality of the APS technical facilities is of utmost concern, so is the quality of life for users of the APS. New, on-site housing to accommodate users without a residence in the Chicago area has been a goal for some time. This lodging will be within easy walking distance of the facility. We have selected a vacant parcel of land and are carrying out the environmental studies required for construction approval. Discussions with the State of Illinois on this idea began in 1986. Those discussions led to a commitment by then Governor James R. Thompson to provide state financing for a 240-bed facility. The newly elected Governor of Illinois, James Edgar, is faced with a considerably different financial situation than was his predecessor, but we believe the State will honor its commitment. The housing facility is projected to cost approximately $5 to $10 M. Discussions with user administrators at other synchrotron facilities have highlighted those amenities that are supportive of a successful research environment, and we welcome your input as well. We are in the process of developing an early conceptual design for the housing facility.

Funding

The current forecast for construction expenditures is consistent with the original $456 M total estimated cost. APS has spent $52 M to date, with $343 M estimated for completion. The difference of $61 M resides in the contingency account, which has essentially not yet been touched. An account of some $40 M is available for experimental facilities in the form of front ends and insertion devices. Gramm-Rudman-Hollings-mandated reductions cost the Project $600,000 in FY1990. For FY1991, the Congressional budget excised more than $5 M from APS funding, again as the result of Gramm-Rudman-Hollings action. The President's budget for FY1992, which has not yet been passed by Congress, contains $1.6 M less than called for in the original DOE funding profile. These reductions of $7.6 M to date are cause for concern on the part of the DOE, as well as the APS. The concern is not for meeting construction schedules in the next year or so, but for the impact that reduced funding may have on the number of front ends or insertion devices that can be built. The Department has worked with us to increase our planned funding for FY1993 from $105 M to $112.6 M. Given the budget climate of the last few years, to come this close to the original mark is a good indicator of the DOE's support for this project.

A similar shortfall has begun to appear in R&D funding. By FY1992, the total reduction will be $6.1 M. Many of the affected R&D items are essential to the project. Some of these are capital equipment purchases that can be made with construction money, so this shortfall has placed additional pressures on our construction budget to do certain things with that money that we had not originally planned. The DOE is concerned about that trend, and they are planning to restore the missing R&D funds in FY1993. These reductions are modest enough at this point that there are viable alternative plans to keep the project on the original schedule.

Help in dealing with these small shortfalls has come from the current buyer's market for both technical procurements and conventional-facilities subcontracts. Additionally, APS engineers have made the facility and technical component designs more cost effective. Sixteen million dollars worth of procurements (based on estimates) have been made to date for just over $10 M. Overall, procurement of technical components and construction subcontracts is running at or under budget.

CRITICAL ISSUES FOR ADVANCED PHOTON SOURCE OPERATION

STORAGE RING BEAM STABILITY

John Galayda
Advanced Photon Source

Fourth Users Meeting for the APS
May 7-8, 1991

ACCELERATOR SYSTEMS

Storage Ring Parameters

Figures of Merit in Operation

- Beam Current
- Lifetime
- Emittance

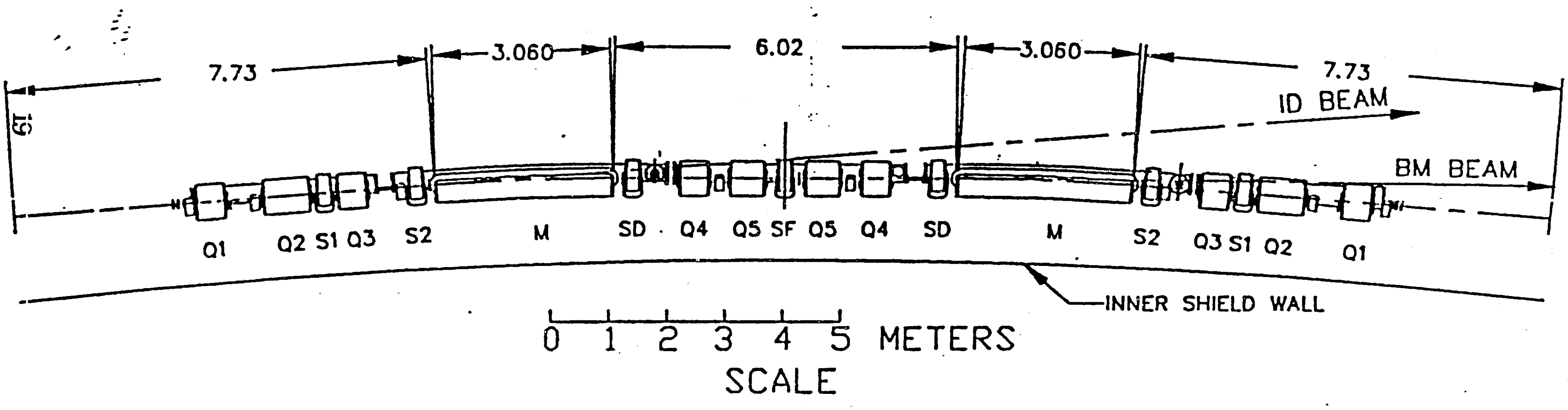
STORAGE RING LATTICE

- The Lattice for the APS Storage Ring is a Chasman-Green type containing 80 dipole magnets for bending and 400 quadrupoles for focusing the circulating positrons.
- The ring contains 40 dispersion free straight sections.
- 34 of these straight sections are available for insertion devices, each of which can be as long as 5.2 m.
- The ring is designed to contain more than 100 mA of positrons with a lifetime of greater than 10 hr.
- The structure and parameters of the storage ring are described in the following figures and tables.

Table II

Lattice Parameters

Circumference	1104
Revolution Time, T_o	3.6826 μs
Energy, E	7 GeV
No. of Insertion Regions	40
Length of Insertion Region	6.72 m
Dipole Length	3.06 m
Dipole Field	0.599 T
Bend Radius, ρ	38.9611 m
Maximum Quadrupole Strength	18.9 T/m
No. of Dipoles	80
No. of Quadrupoles	400
Tunes, ν_x and ν_y	35.22, 14.30
Transition Gamma, γ_T	66.24
Momentum Compaction Factor, α_p	2.279×10^{-4}
Chromaticities, ξ_x, ξ_y	-64.7, -26.4
Chrom. Corr. Sextupoles	$-3.33, -4.18/\text{m}^2$
Number of Chromatic Sextupoles	120
Number of Harmonic Sextupoles	160
Maximum Dispersion	0.3995 m
Maximum β_x and β_y	24.1, 21.4 m
Natural Emittance, ε_n	8.2×10^{-9} m
Transverse Damping Time, $\tau_x = \tau_y$	9.44 ms
Synchrotron Damping Time, τ_E	4.72 ms
Bending Magnet Critical Energy, ε_c	19.5 keV
Energy Loss per Turn, U_o	5.45 MeV
Radio Frequency, f_{rf}	351.929 MHz
Harmonic Number, h	1296
Natural Energy Spread, σ_E/E	0.096%
RF Voltage	9.5 MV
Synchrotron Frequency	1.96 kHz
Bunch Length (0 current)	5.3 mm
Bucket DE/E (BM only)	2.8%



Layout of magnets for one cell of the APS storage ring

BEAM CURRENT

Specification

Average Current	100 mA	Nominal
	300 mA	Maximum
One Bunch Current	5 mA	

Limited by self-induced E.M. disruption of the beam

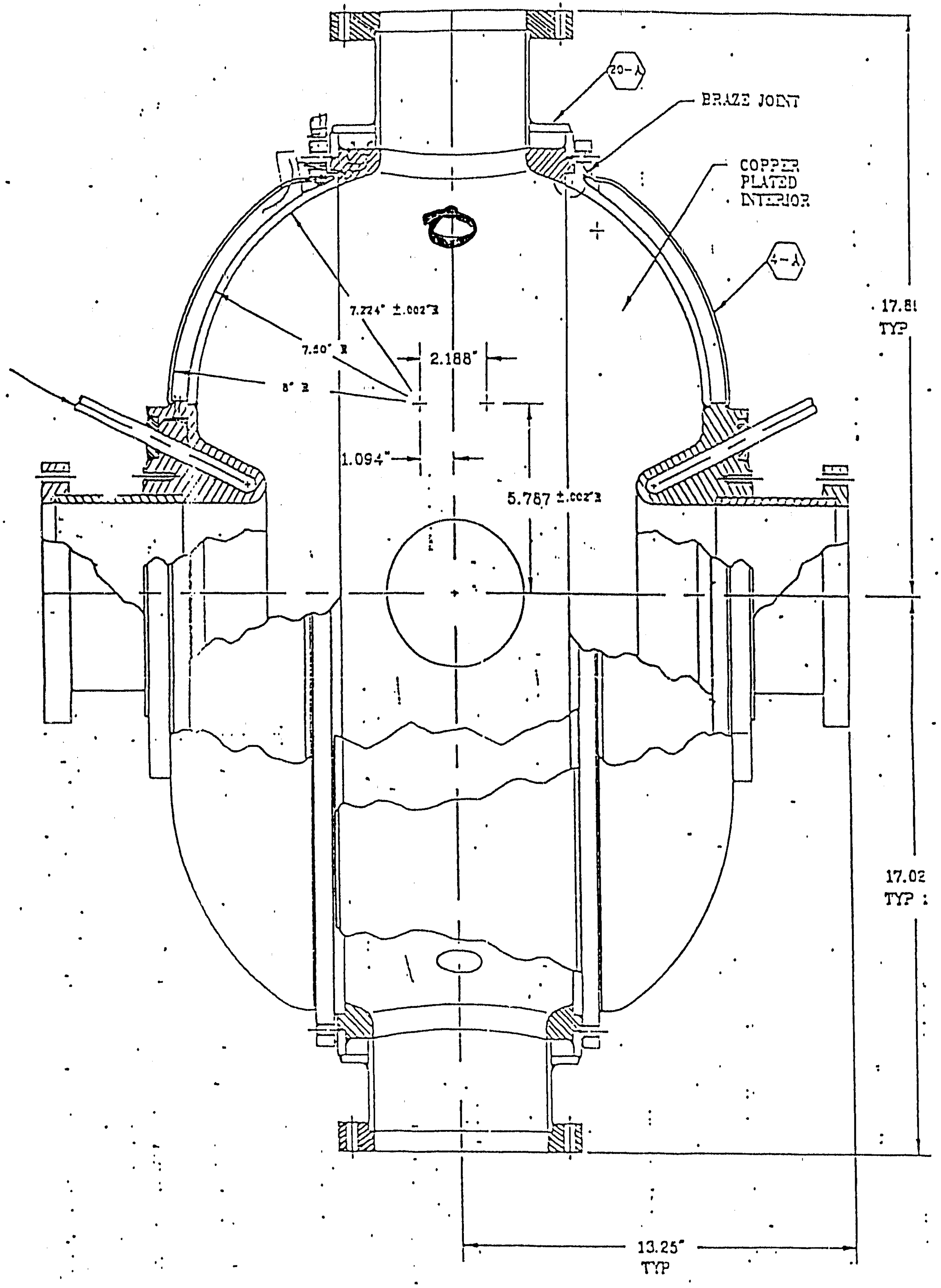
Average current limited by available RF power, or else coherent instabilities driven by high Q resonances (parasitic modes) in beampipe structures (longitudinal and transverse).

One-bunch current limited by E.M. forces created by discontinuitites in the beam chamber walls.

Reduce Q of high Q modes with damping antennae

Feedback for rigid bunch instabilities

Careful design of beampipe enclosure to minimize disruption of wall currents



RF Stainless Steel Cavity
(Dual Shell for Cooling)

LIFETIME

Quantum Lifetime: Years!

Touschek Lifetime α(positron density) $\frac{1}{E^2}\left(\frac{E}{\Delta E_{max}}\right)^2$

Gas Scattering

Bremsstrahlung α $PZ^2 \ln\left(\frac{E}{\Delta E_{max}}\right)$

Elastic α $P\frac{Z^2}{E^2}\left(\frac{\beta}{aperture^2}\right)_{max} <\beta>$

No enhanced scattering due to ion trapping because APS will have positrons

DETERMINANTS OF ΔE_{max}, MAXIMUM APERTURE:

Nonlinear Electron Optics

Orbit Errors in Sextupoles -

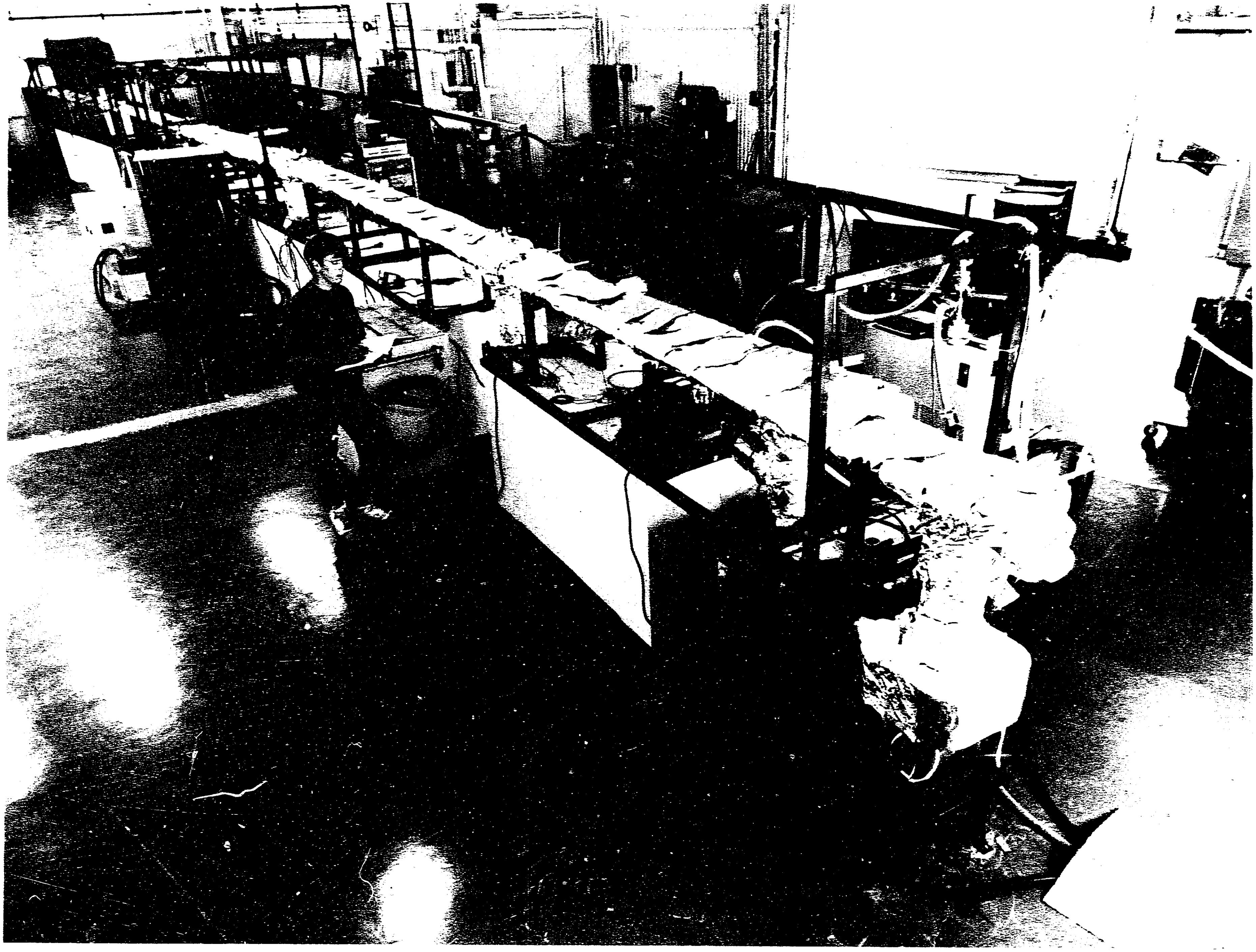
Goal to reduce errors to 0.2 mm by careful survey and orbit control in commissioning and operation

SUMMED CONTRIBUTIONS TO LIFETIME

$$\begin{array}{ccccccccc}
\frac{1}{\tau} & + & \frac{1}{\tau_q} & + & \frac{1}{\tau_b} & + & \frac{1}{\tau_c} & + & \frac{1}{\tau_c} \\
 & & \text{quantum} & & \text{Bremsst.} & & \text{elastic} & & \text{toschek} \\
 & & & & \frac{P_{(nTorr)}}{187\ \text{hr}} & & \frac{P_{(nTorr)}}{128} & & \frac{I_{(bunch,mA)}}{950\ \text{hr}}
\end{array}$$

$I_{avg} = 100$ mA, $P = 1$ nTorr, $I_{bunch} = 5$ mA

→ $\tau = 54$ hr



Operation of Synchrotron Light Sources with Multiple Insertion Devices

J. N. Galayda
Advanced Photon Source
Argonne National Laboratory

A. M. Fauchet
National Synchrotron Light Source
Brookhaven National Laboratory

Orbit Control

- Stability requirements
- Stability of a system of many loops

Effects of One Insertion Device on Users of the Others

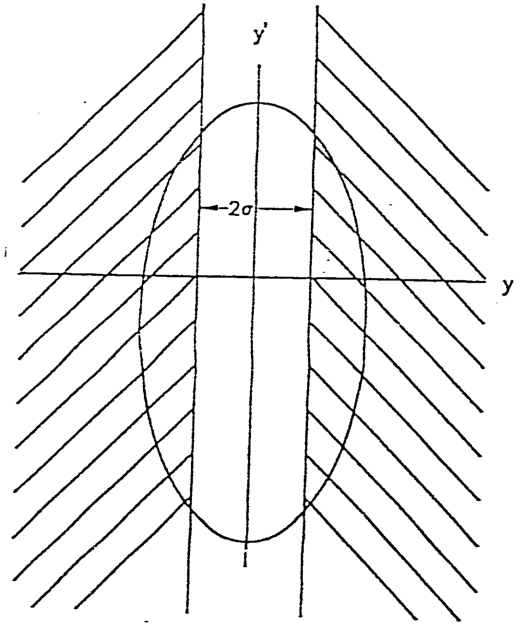
- Effects of an Ideal Undulator
    - Linear
    - Nonlinear
- Effects of Undulator Errors
- Requirements Placed on Accelerator Controls Systems

Orbit Control: Feedback

Consistency with utilization of the small emittance requires orbit stability of the order of 1/10 σ

	ϵ_X	δX	$\delta X'$	ϵ_y	δY	$\delta Y'$
APS	8 nm	30 μm	2 μ rad	0.8 nm	9 μm	0.9 μ radian
NSLS	100 nm	37 μm	27 μ rad	10 nm	6 μm	17 μ radian

For a SINGLE set of slits, set at width 2σ, this implies < 0.5% variation in incident flux



ADVANCED PHOTON SOURCE

Such motion could be caused by small deflecting fields or motions of focussing elements

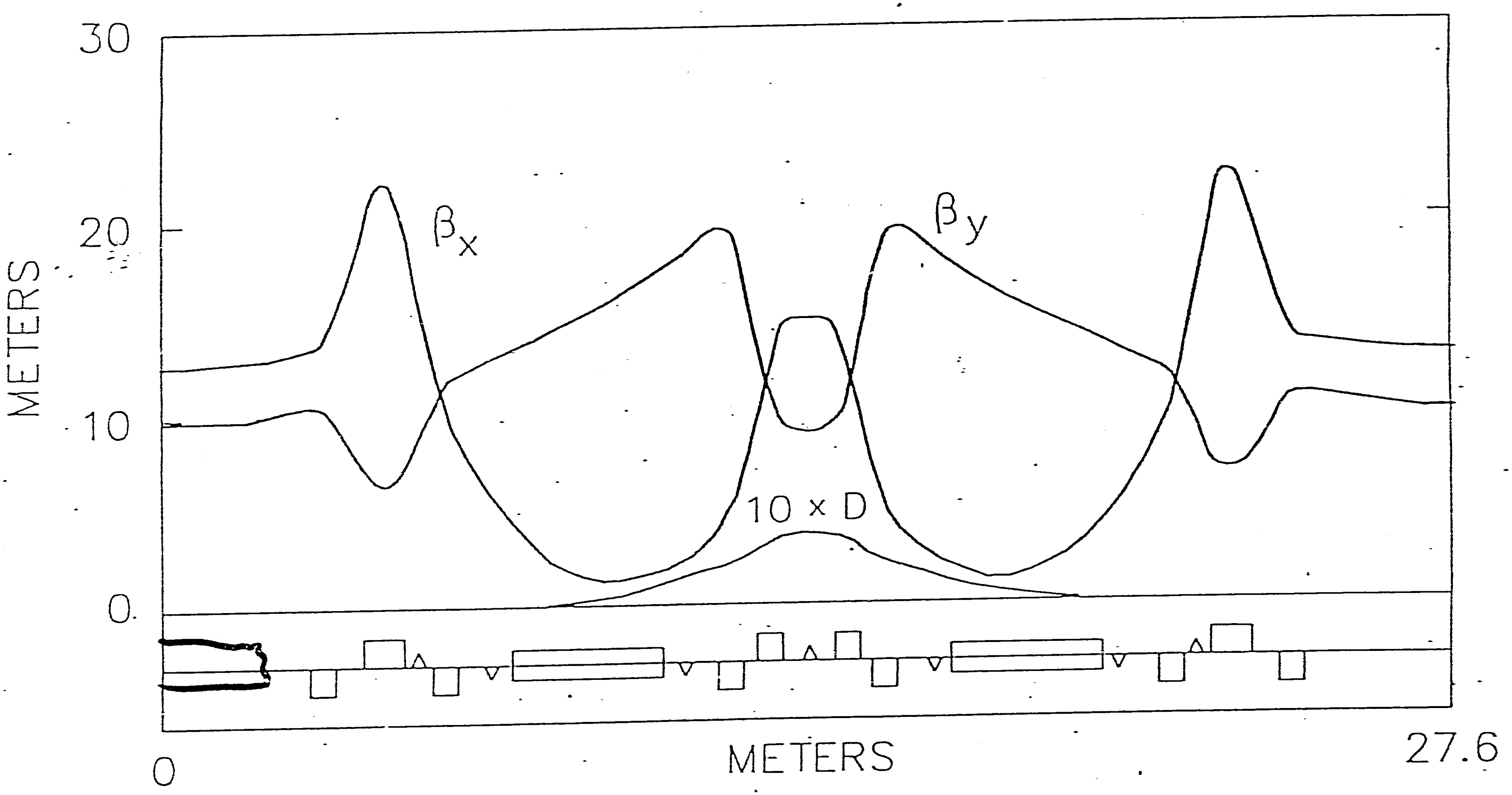
APS

0.2 Gauss • meter
1-2 micron displacement of 1 quadrupole

NSLS

0.3 Gauss • meter
2-4 micron displacement of 1 quadrupole

Feedback orbit control is necessary to meet these specs



Storage ring lattice and dispersion functions.

GROUND MOTION MONITORING

- Focus on 18.4 and 60.0 Hz Components
- Field Accelerometer Location 3 (Signal Integration → 60 Hz Bandpass Filter → Strip Chart Recorder)
- Continuous – July 1988 to Date

CONCLUSIONS

- Occurrence of 18.4 and 60.0-Hz Response – Isolated Incidence
- Site is Generally "Quiet"
  - Ground Motion at Site is of Small Amplitude (RMS Displacement < 0.05 μm) and Low Frequency (< 10 Hz)

SLOW VARIATIONS

Settling Less than 0.1 mm/10 m/year in 1994 and even less in future years

320 steering magnets for orbit correction

1.4 mradians maximum each

Possibly "tapped" down to 0.2 mrad

Each equivalent to ~0.3 mm displacement of a quadrupole

0.2 μradian set-ability for 1.4 millirad range

ADVANCED PHOTON SOURCE

Performance of Single Local Feedback Systems

NSLS   1/(G+1) ~ .01 at 0 Hz
1 at 60 Hz

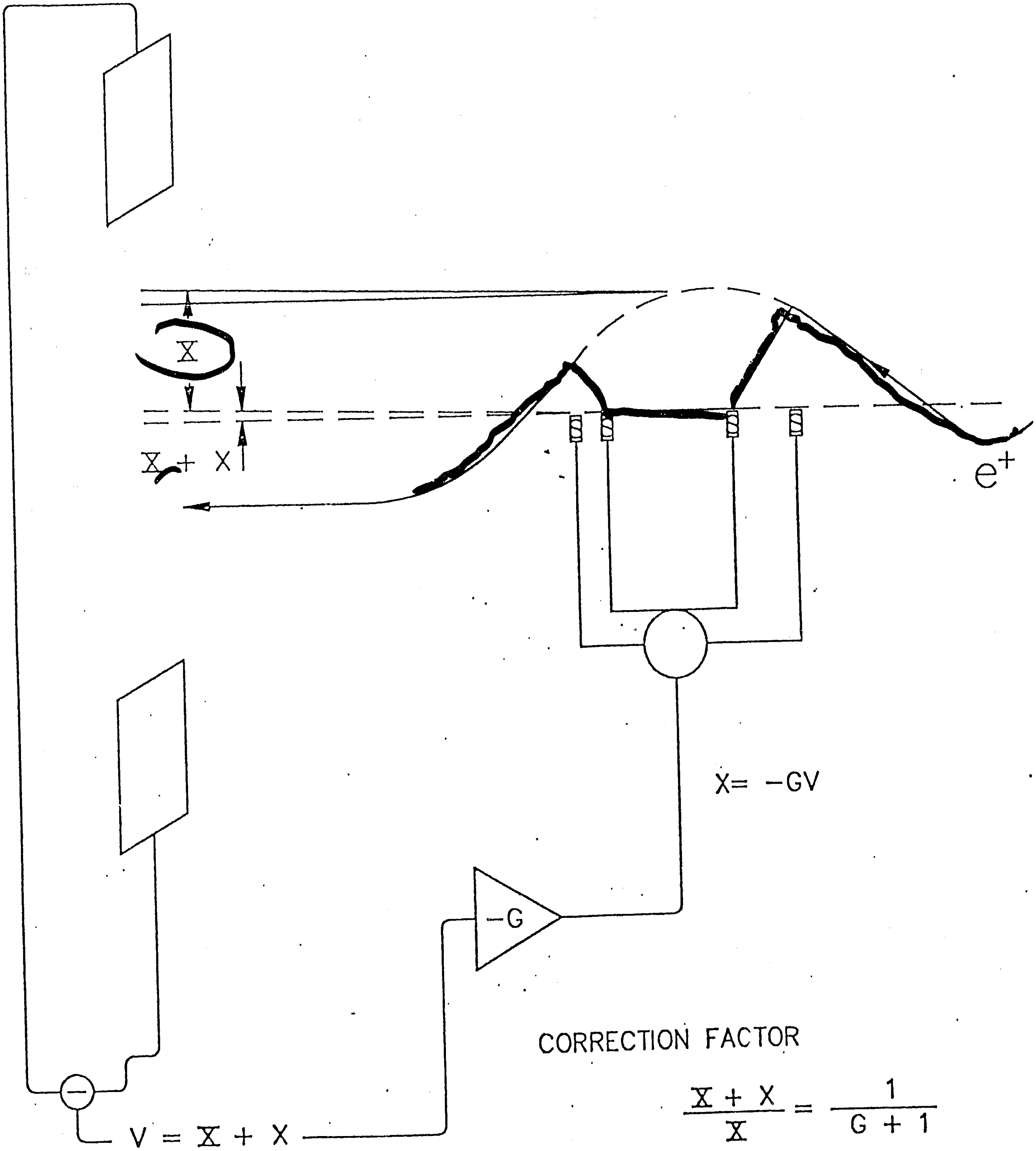
APS Performance Goal   1/(G+1) ~ 0.1 or better, 0-20 Hz

Many feedback loops

Idealization: one detector ⇔ one perfectly local bump
no interaction among loops

Reality: bumps are not perfectly local

Single Feedback Loop



CORRECTION FACTOR

$$\frac{\mathbb{X} + X}{\mathbb{X}} = \frac{1}{G + 1}$$

ADVANCED PHOTON SOURCE

N Loops $1 \leq i, j \leq N$

i^{th} detector output $\quad v_i = X_i + x_i$

X_i = Noise at i^{th} loop

x_i = Net correction at i^{th} loop,

$$x_i = -\sum_j G_{ij} V_j$$

G_{ij} gain matrix, including imperfect locality

$$X + x = (G+1)^{-1} X$$

$$G = \begin{bmatrix} A_{11} & b_{12} & b_{13} & \cdots & b_{1N} \\ b_{21} & A_{22} & b_{23} & \cdots & \\ \vdots & & & & \\ b_{N1} & b_{N2} & \cdots & \cdots & A_{NN} \end{bmatrix}$$

Sufficient for Stability: $\quad O(A\text{'s}) \gtrsim O(N \cdot b)$

$$\left(1 > \frac{Nb}{A}\left[\sum_{n=\cancel{1}\,2}^{\overset{N}{\cancel{N-1}}} \left(\frac{Nb}{A}\right)^n \frac{1}{n}\right]\right)$$

COUPLING OF IDEALLY LOCAL LOOPS

$$\epsilon_1 = x_1 + gV_1 + gk_{12} V_2$$

$$\epsilon_2 = x_2 + gV_2 + gk_{21} V_1$$

$$V_1 = \epsilon_1$$

$$V_2 = \epsilon_2$$

$$\begin{bmatrix} \epsilon_1 \\ \epsilon_2 \end{bmatrix} = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + g \begin{bmatrix} 1 & k_{12} \\ k_{21} & 1 \end{bmatrix} \begin{bmatrix} \epsilon_1 \\ \epsilon_2 \end{bmatrix}$$

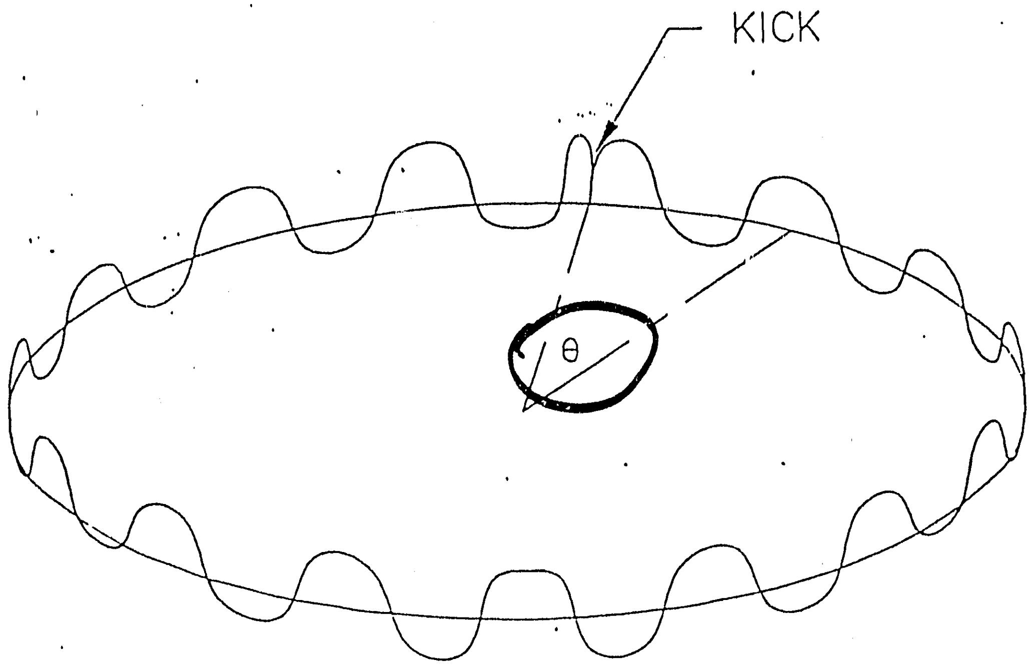
$$\begin{bmatrix} 1-g & gk_{12} \\ gk_{21} & 1-g \end{bmatrix} \begin{bmatrix} \epsilon_1 \\ \epsilon_2 \end{bmatrix} = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

$$\begin{bmatrix} \epsilon_1 \\ \epsilon_2 \end{bmatrix} = \frac{1}{(1-g)^2 \boxed{- g^2 k_{12} k_{21}}} \begin{bmatrix} 1-g & -gk_{12} \\ -gk_{21} & 1-g \end{bmatrix} = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

GLOBAL FEEDBACK

Up to 10x reduction in orbit errors at all points in ring,with only six feedback loops involved

Yu, et al. (Galayda, S. R. News, Vol. 3, 3)



Error distribution approximately random in θ

$$\Delta B(\theta) = \sum_n a_n \sin(n\theta) + b_n \cos(n\theta)$$

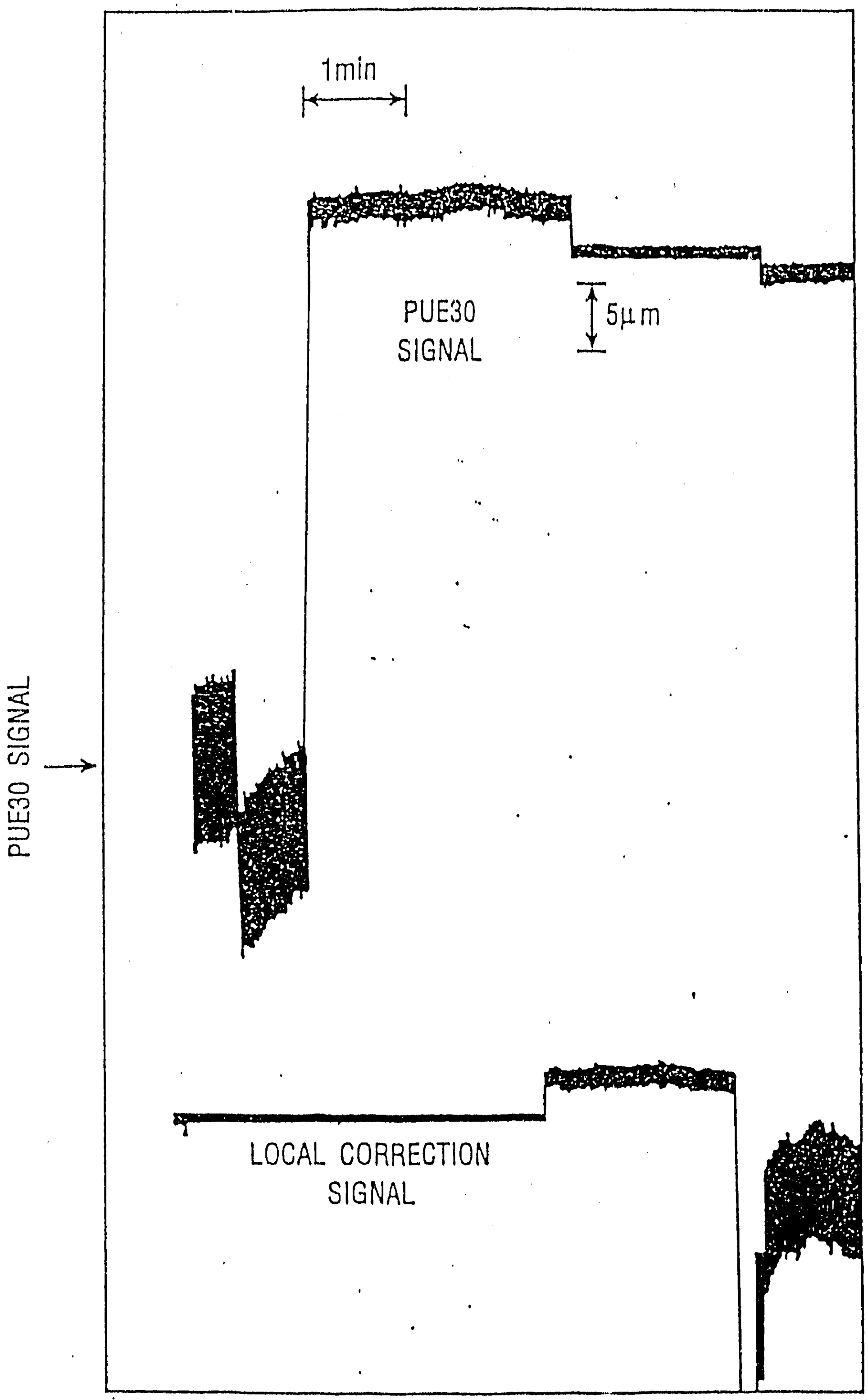
$$\Delta x(\theta) \ \alpha \ \sum_n \frac{a_n \sin(n\theta) + b_n \cos(n\theta)}{(n^2 - (35.22)^2)}$$

∴ correct n's close to 35.22

Global Feedback

Yu, et al. RGC-8

Reduced number of loops for a given improvement factor

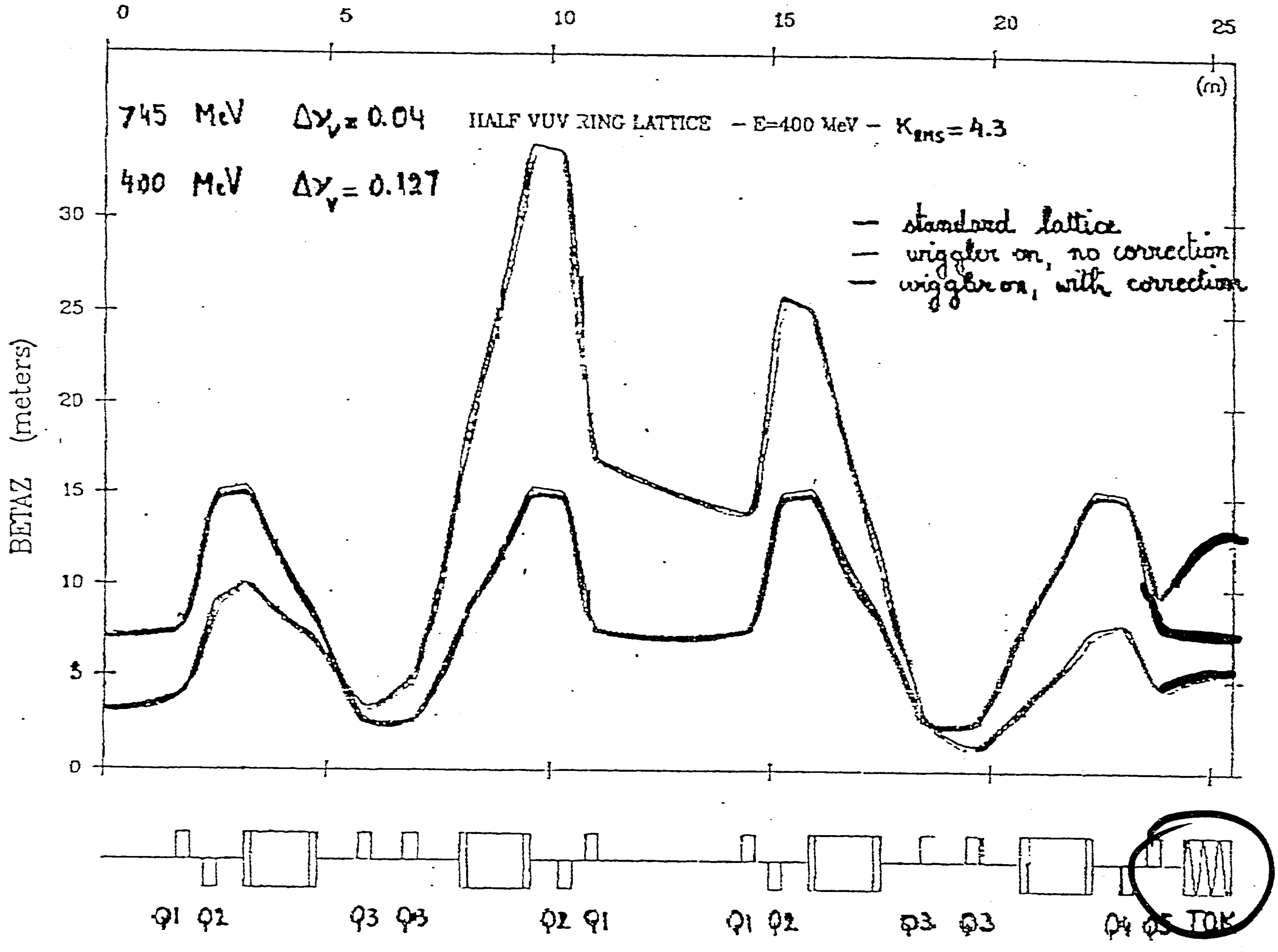


GLOBAL FEEDBACK	OFF	ON	ON	OFF
LOCAL	OFF	OFF	ON	ON

ADVANCED PHOTON SOURCE

Matching of VUV Lattice to U13 TOK

Used local and global quad correction to match alpha's and restore tunes



Beam Optical Effects of Undulators

Linear focussing effect:

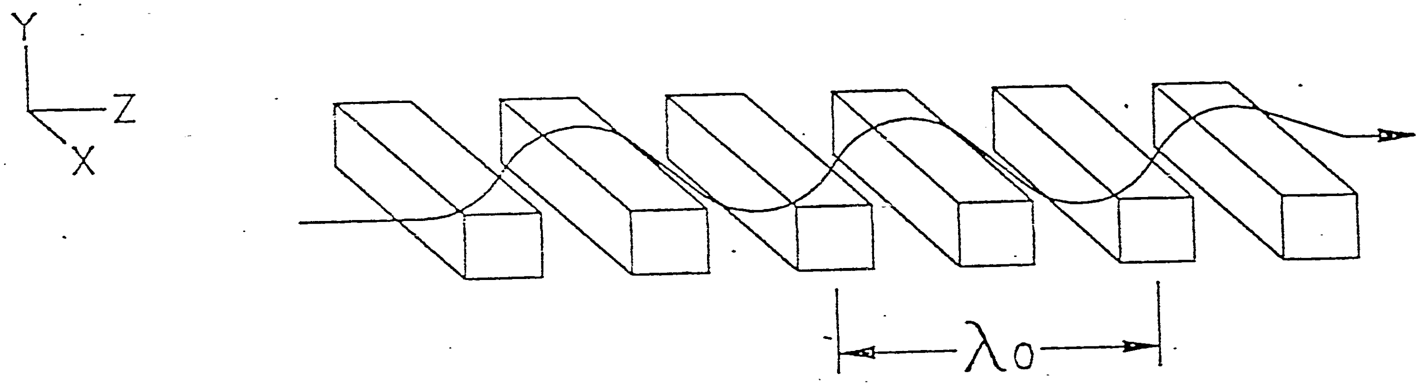
- Disrupts phase advance between sextupoles
- Tunes restored by adjustment of quadrupoles
    - Global tune correction
    - Local tune correction
    - Local tune correction, alpha match
    - Local QD, global QF tune correction

Nonlinear focussing effect:

- Responsible for $4 \cdot \nu_y$ stopbands

ADVANCED PHOTON SOURCE

Linear and Nonlinear Focussing in an "Ideal" Insertion Device



$$B_y\ (X,Y,Z) = B_0 \cosh(Ky)\cos(Kz)$$

$$B_z(Y,Z) = B_0 \sinh(Ky)\sin(Kz)$$

Force coefficients averaged over λ_0:

$$Y'' + \frac{1}{2}\left(\frac{B_0}{B\rho}\right)^2 Y + \frac{K^2}{(3\rho^2)} Y^3 = 0$$

$$K = \frac{2\pi}{\lambda_0}$$

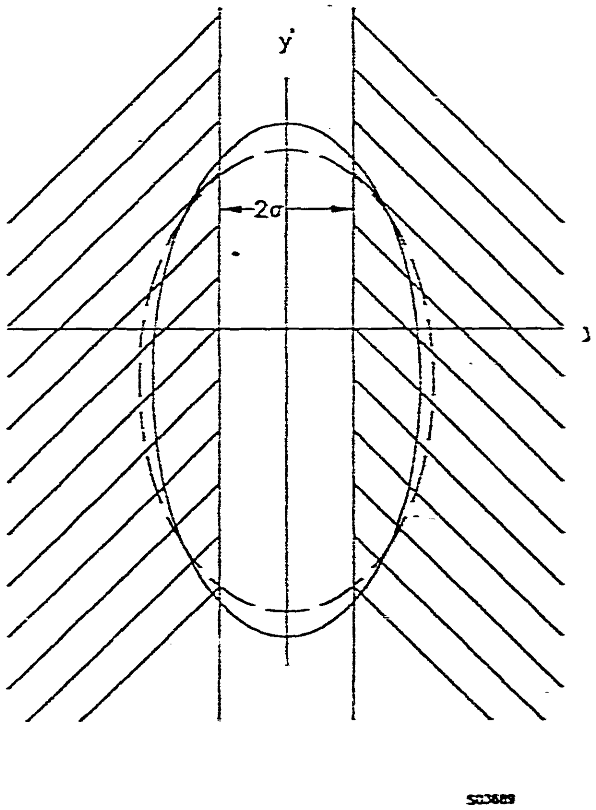
NSLS VUV Ring 0.75 GeV

	U5 APS	U13 TOK
Bo (Tesla)	.65	.46
λ (cm)	10.	7.5
$k=2\pi/\lambda (m^{-1})$	62.8	83.8
L (m)	2.2	2.1
$L/(2\rho^2)$ (m^{-1})	.075	.037
A $(m^{-3})=k^2 L/(3\pi^2)$	195	166.
β_y (m)	5.5	5.5
$\Delta \nu_y$	.034	.016
$A \cdot \beta_y^2$ (m^{-1})	6065	5163

ADVANCED PHOTON SOURCE

	ESRF	ALS		NSLS X-Ray Ring			APS	
	Undulator	U3.65	U20.0	X1	X17	X25	Undulator A	Wiggler A
Bo (Tesla)	0.45	0.61	1.1	0.35	5.0	1.1	0.86	1.0
λ (cm)	4.4	3.65	20.0	8	17.4	12	3.1	15
$k=2\pi/\lambda$ (m)	143	172	31.4	79	36.1	52.4	203	42
L (m)	1.6	4.9	4.6	3	0.6	1.7	2.5	1.5
$L/(2\rho^2)(m^{-1})$	.0004	.02	.063	.0026	.11	.015	.0017	.0014
A $(m^{-3}) = k^2L/(3\rho^2)$	3	404	41	11	94	27.	46.5	1.6
β_y^* (m)	14	4.	4.	0.35	0.35	0.35	10.	10.
$\Delta \nu_y$	.0005	.007	.02	.0005	.004	.001	.0013	.0011
$A \cdot \langle \beta^2_y \rangle$	675	8484	820	154	18	35	4650	160

Errors in Undulators



Dipole steering errors: tolerances same as for stray fields mentioned earlier

Skew quadrupole errors: what is an acceptable change in vertical beamsize?

0.5% flux variation through a 2σ slit is caused by a 2% change in emittance.

This corresponds to a change in coupling from 10% to 10.2%

This would be caused by a change in integrated skew quadrupole of 60 gauss in one 5-meter straight, or 0.13 gauss/cm average

Betatron function tracking:

Changes in betatron functions caused by undulators and their compensation should also be held below 2%

Emittance Coupling

$$\frac{\epsilon_y}{\epsilon_x+\epsilon_y} = \frac{2|K|^2}{\Delta^2+|2K|^2}$$

K = .02

Δ = .08

Δ = fractional part of $\Delta = \nu_x - \nu_y$

$$K = \frac{1}{4\pi}\int ds\ \sqrt{\beta_x\beta_y}\ \frac{1}{\beta\rho}\ \frac{\partial B_x}{\partial x}\ \cdot\ \exp^{i(\Phi)}$$

$$\Phi = \int_0^s ds' \left[\left(\frac{1}{\beta_x} - \frac{\nu_x}{R}\right) - \left(\frac{1}{\beta_z} - \frac{\nu_y}{R}\right) + \frac{n}{R}\right]$$

n = integer part of $(\nu_x - \nu_y)$

$2\pi R$ = circumference

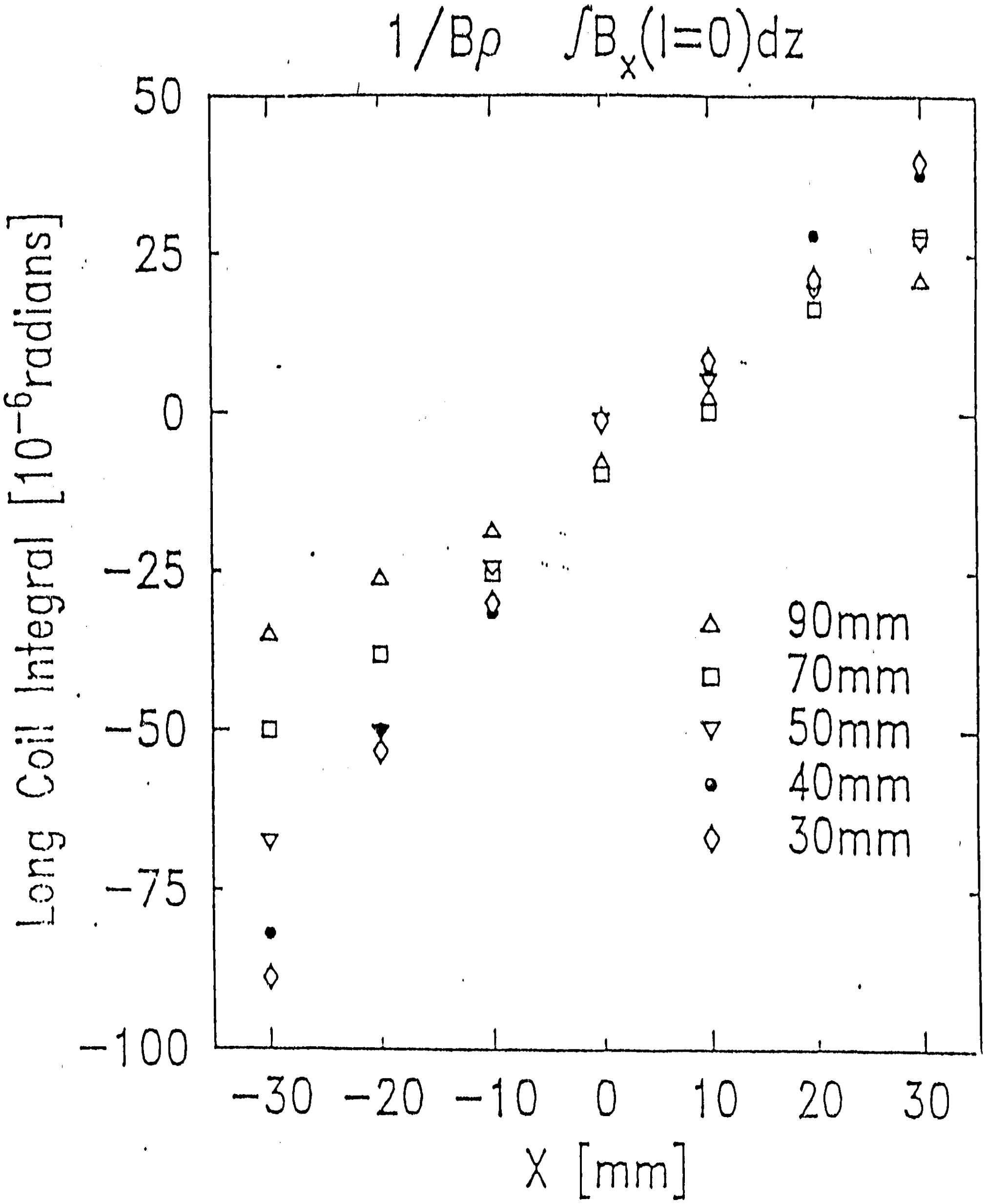


Figure 14 The long coil skew field integral at 90, 70, 50, 40, and 31mm gaps as a function of X.

NSLS X1 measurements- Solomon, et al.
Delivered Measurement Techniques yielding
0.1-0.2 gauss · meter sensitivity, normal and <u>skew</u> components

Skew multipoles in the SXU Magnet			
Gap	Dipole	Quadrupole	Sextupole
(mm)	Tesla Meter	Tesla	Tesla/Meter
90	-0.000052	0.008	0.018
70	-0.000095	0.011	0.007
50	-0.000055	0.013	-0.28
40	-0.000074	0.016	-0.22
31	-0.000054	0.017	-0.35

Table 4 Multipole analysis of the integrated skew dipole measurements.

STI U5 measurements - Gotteschalk, et al.

0.1 gauss meter sensitivity

	Requirement	Measured
Period (cm)	7.5	7.5
Number of Periods	27.5	27.5
Minimum Gap (mm)	34	34
Peak Magnetic Field	>4.25 kG	4.60 kG
$(\Delta b/B)_{RMS}$ [Peak]	<1%	0.22%
[Kick]	<1%	0.28%
Transverse Rolloff (l/cm)	<0.5%	<0.1%
Total Steering Error (G-cm)	<100	13*
Steering. Corrector Range (G-cm)	±100	±1000
Integrated Quadrupole (G)	<10	0 ± 3
Integrated Sextupole (G/cm)	<100	60 ± 1

*Magnetic Structure without Steering Correctors/Field Clamps

ADVANCED PHOTON SOURCE

	SPEAR	NSLS XR	Daresbury	Super ACO	KEK
# ID's	5	5	2	4	6
Local Feedbacks	9	10 now 16 soon			2
Global Feedbacks		6 harm.			1
Orbit corr. with Application Prog.	after fills	after fills	after fills	after fills	continuous
Gap Changes:					
anytime?	coming soon BL5		not required		YES
announced?	sometimes	usually			
between fills?	usually		(ALLOWED BUT NOT ROUTINE)	yes	
JNG thanks:	R. Hettel	A.M. Fauchet	M. Dykes	M. P. Level	T. Katsura

Operations and Controls

Changing an undulator gap and compensating for all undesired effects is much like ramping the storage ring, except we must superpose ramps

Several devices must track the changing gap of each undulator:

- vertical and horizontal steering
- skew quadrupole
- beta functions
- feedback system gain & offset, depending on detector sensitivity
- feedback system local bump ratios, if transfer matrix for the ID is a significant function of gap.

Can't be done?	Sure!
What if it can't be done?	Set your slits to 3 or 4 σ

Cooling of X-Ray Monochromator Crystals Under High Heat Loads: Present and Future Trends

Dennis M. Mills
Advanced Photon Source

Fourth Users Meeting for the APS
May 7-8, 1991

Outline of Presentation

I. The Problem

II. Liquid Gallium Cooling

III. Cryogenic Cooling

IV. New Concepts

Staff Involved with High Heat Load X-ray Optics

2.4.3.1 High Heat-Load X-ray Optics

2.4.3.1.1 Liquid gallium cooling

Dr. Robert Smither
Ron Hoph
Al Paugys

2.4.3.1.2 Cryogenic cooling

Dr. Tunch Kuzay
Dr. Dennis Mills
Dr. Robert Smither
Shawn Rogers
Jeff Collins
Al Paugys

2.4.3.1.3 New cooling concepts

Dr. Ali Khounsary
Dr. Wah Keat Lee
Dr. Al Macrander
Dr. Dennis Mills

2.4.3.1.4 Modeling studies

Dr. Ali Khounsary
Dr. Al Macrander
Dr. Dennis Mills
Shawn Rogers

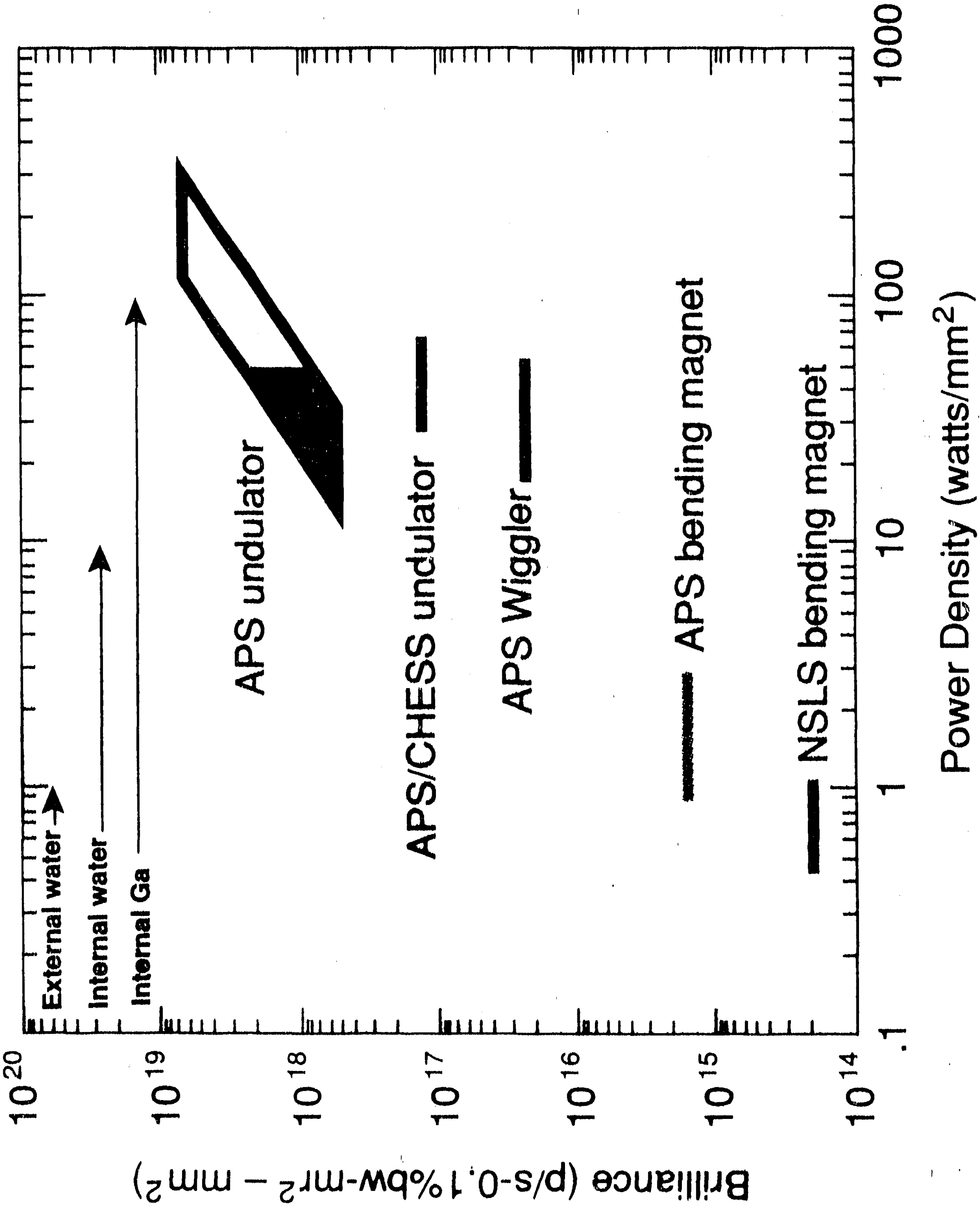

Brilliance (p/s-0.1%bw-mr² – mm²)
10^20
10^19
10^18
10^17
10^16
10^15
10^14
Power Density (watts/mm²)
.1
1
10
100
1000
External water
Internal water
Internal Ga
APS undulator
APS/CHESS undulator
APS Wiggler
APS bending magnet
NSLS bending magnet

TABLE II: Comparison of Approximate Heat Flux Levels in Various Physical Processes

Process of Component	Approx. Heat Flux (w/mm^2)
Meteor re-entry	100 to 500
Fusion reactor components	0.05 to 80
Sun's surface	60
Commercial plasma jet	20
Interior of rocket nozzle	10
Fission reactor cores	1 to 2

High Heat Load X-ray Optics

We have several concurrent ongoing programs in the area of high heat load x-rays optics which will be described in detail below. In addition, we have been participating and/or organizing workshops on the cooling of high heat load optics.

- Workshop on Cooling of X-ray Monochromators on High Power Beamlines, August 31, 1988 at KEK, Tsukuba, Japan - T. Matsushita and T. Ishikawa (Photon Factory). Organizers
- Workshop on High Heat Load Optics, August 3-5, 1989 at ANL - Robert Smither (APS) and Andreas Freund (ESRF), Organizer
- Workshop on High Heat Load Optics , Feb. 4, 1991 at NSLS - Lonny Berman (NSLS), Organizer
- Satellite Meeting to the International Synchrotron Radiation Instrumentation Meeting, July 20, 1991 at Chester, UK - Andreas Freund (ESRF) and Dennis Mills (APS), Co-Organizers

FIRST ANNOUNCEMENT

The 4th International Conference
on
Synchrotron Radiation Instrumentation
Chester, 15-19 July, 1991

THERMAL PROBLEMS OF SYNCHROTRON RADIATION OPTICS

Satellite Workshop: Saturday 20 July, 1991, Chester College, UK

This satellite workshop is planned as an international forum for discussion, similar to the workshop held at Argonne National Laboratory in 1989 but on a smaller scale. The aim is to provide an additional opportunity for discussion of the very latest progress and advances in high heat load x-ray optics and thus to be complementary to the main conference. There will be contributed papers only for oral presentation (about ten minutes each) with ten minutes for discussion. The Programme will be subdivided into three main sessions:

- Techniques avoiding or reducing thermal load and/or thermal deformation.
- Techniques correcting for thermal deformation.
- Problems related to cooling efficiency and technology.

All papers for the satellite (dealing with theoretical and/or experimental aspects of the principal topics) will be assembled to form a programme following receipt of a one page abstract. The deadline for submission is 31 May. Papers can also be submitted for inclusion in the full Proceedings for SRI-91 to be published in Rev.Sci.Instr. In this case the initial abstract must be in the hands of the Conference Secretariat at Daresbury by mid April at the latest. Such papers to be presented within the main Conference Proceedings must ultimately be delivered in camera ready form before or during the Conference itself (full details from the Conference Office.) The day's programme will start at around 9.00 am and finish at 6.00 pm and will be followed by a social evening. It is intended to write a report summarizing this meeting which will be included in the main conference proceedings for SRI-91.

The Satellite IV registration deadline is 31 May, 1991, but please fill in the slip below and return it as soon as possible (BY FAX) to: Dr Howard Padmore, SERC, Daresbury Laboratory, Warrington, WA4 4AD, UK FAX: 09925 603174 if you wish to participate in this Workshop.

There will be a registration fee of £40 for Satellite IV.

Andreas K Freund
European Synchrotron Radiation Facility
BP 220, 38043 Grenoble Cedex, France
e-mail: FREUND@FRILL
Tel: xx33 76 88 20 40 FAX: xx33 76 88 21 60

Dennis Mills
APS, Argonne National Laboratory
9700 South Cass Avenue Argonne, IL 60439, USA
e-mail: DMM@ANLAPS
Tel: xx1 708 972 5680 FAX: xx 1 708 972 4732

(PLEASE USE BLOCK CAPITALS)

NAME .... TITLE ....

ADDRESS ....

....

TELEPHONE NO .... FAX NO ....

	YES	NO
I expect to attend the Satellite Workshop on Thermal Problems of SR Optics	☐	☐
I also expect to register for the main SRI-91 Conference	☐	☐

Liquid Gallium Cooling of X-ray Optics

Physical Properties	Ga (@ 30°C)	H_2O (@27°C)
Boiling Point (°C)	2403	100
Vapor Pressure (mm Hg)	10^{-10}	31.8
Thermal Condundtivity (W/m-°C)	28.1	0.613
Specific Heat (Kg/l-°C)	2.24	4.179

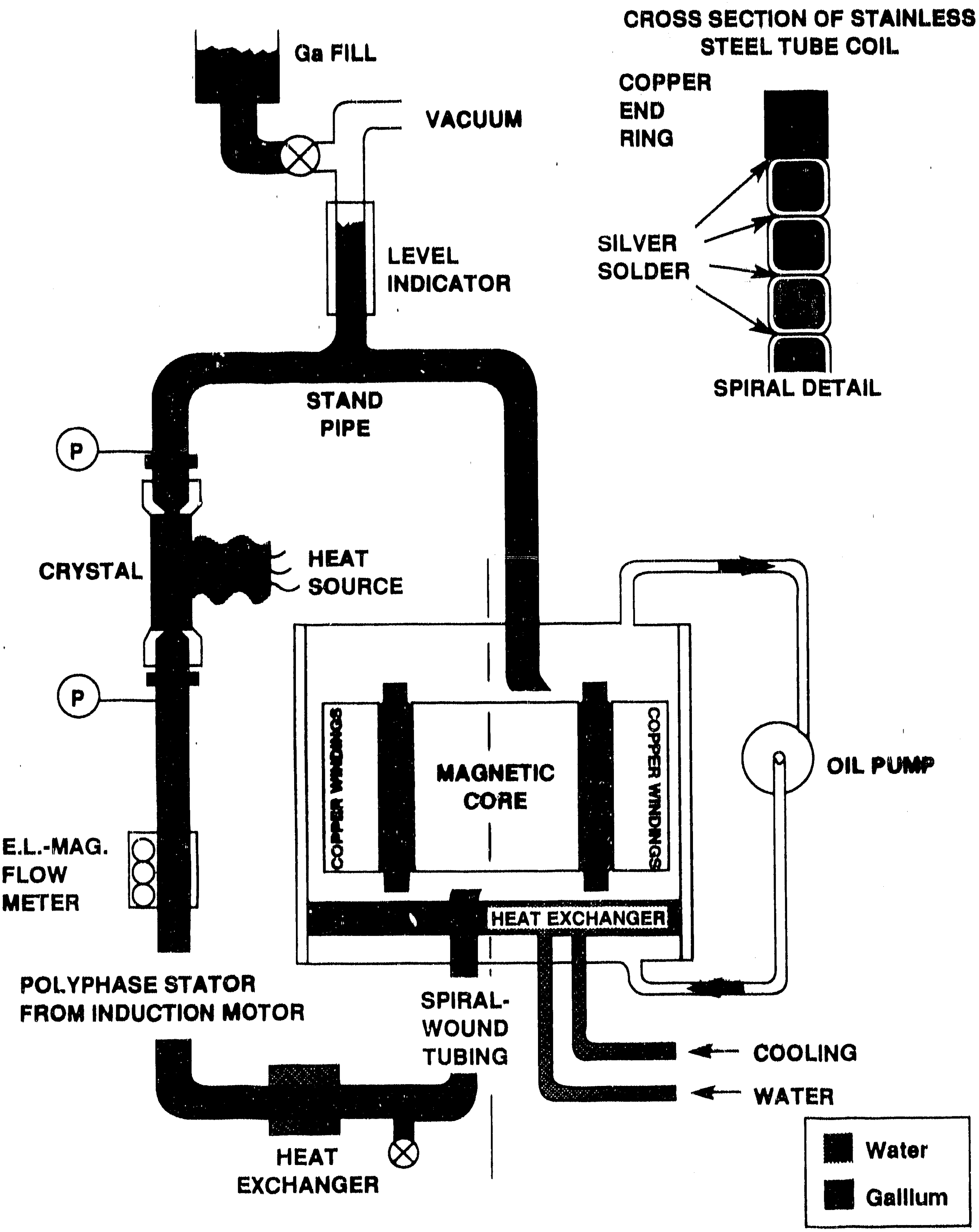
Alterations to the design of the AC induction pump for liquid gallium have been made to improve its performance.

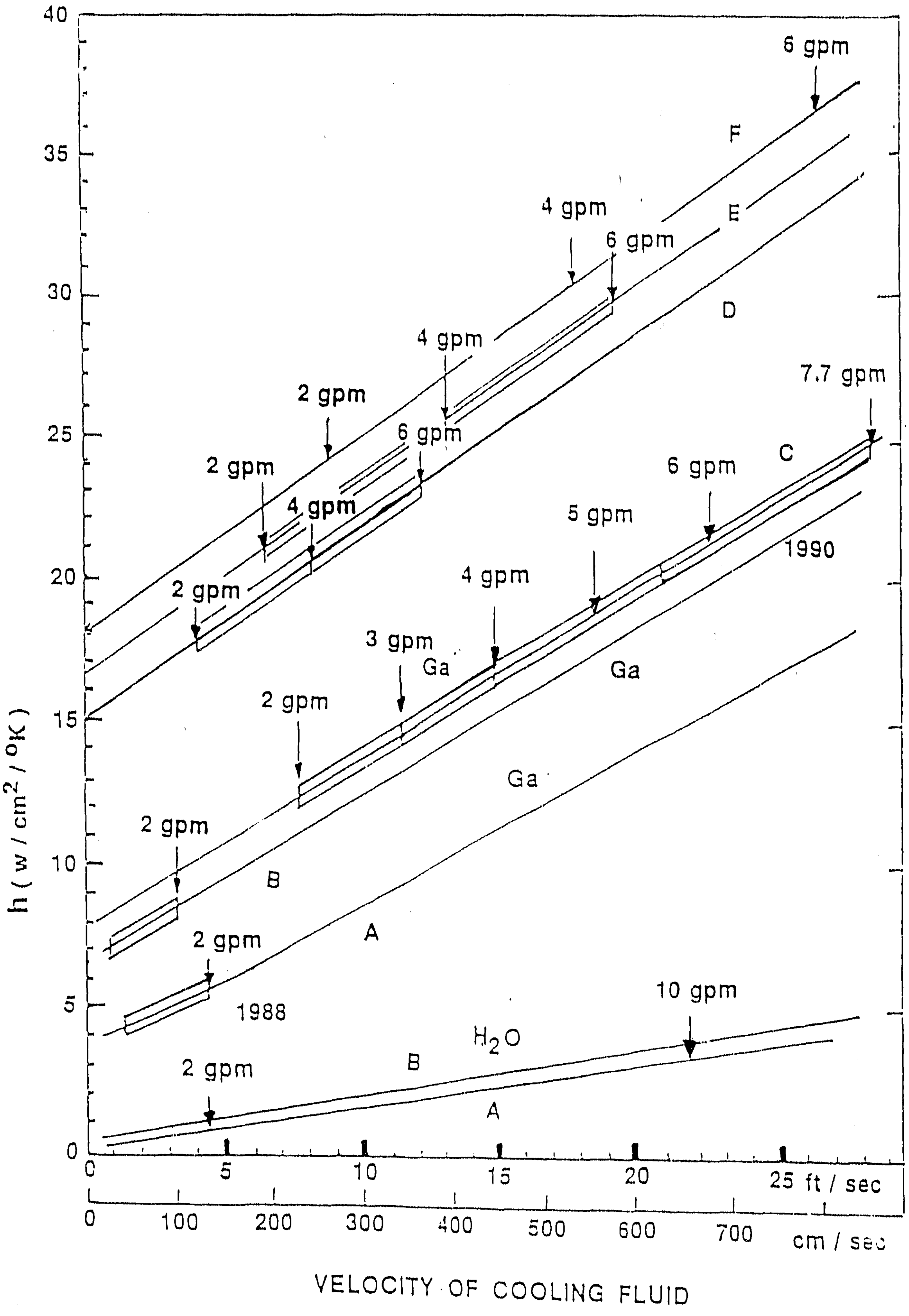
- Head pressure increased from 60 to 100 psi
- Flow increased from 1.6 to 5 gpm
- Improved vacuum compatibility

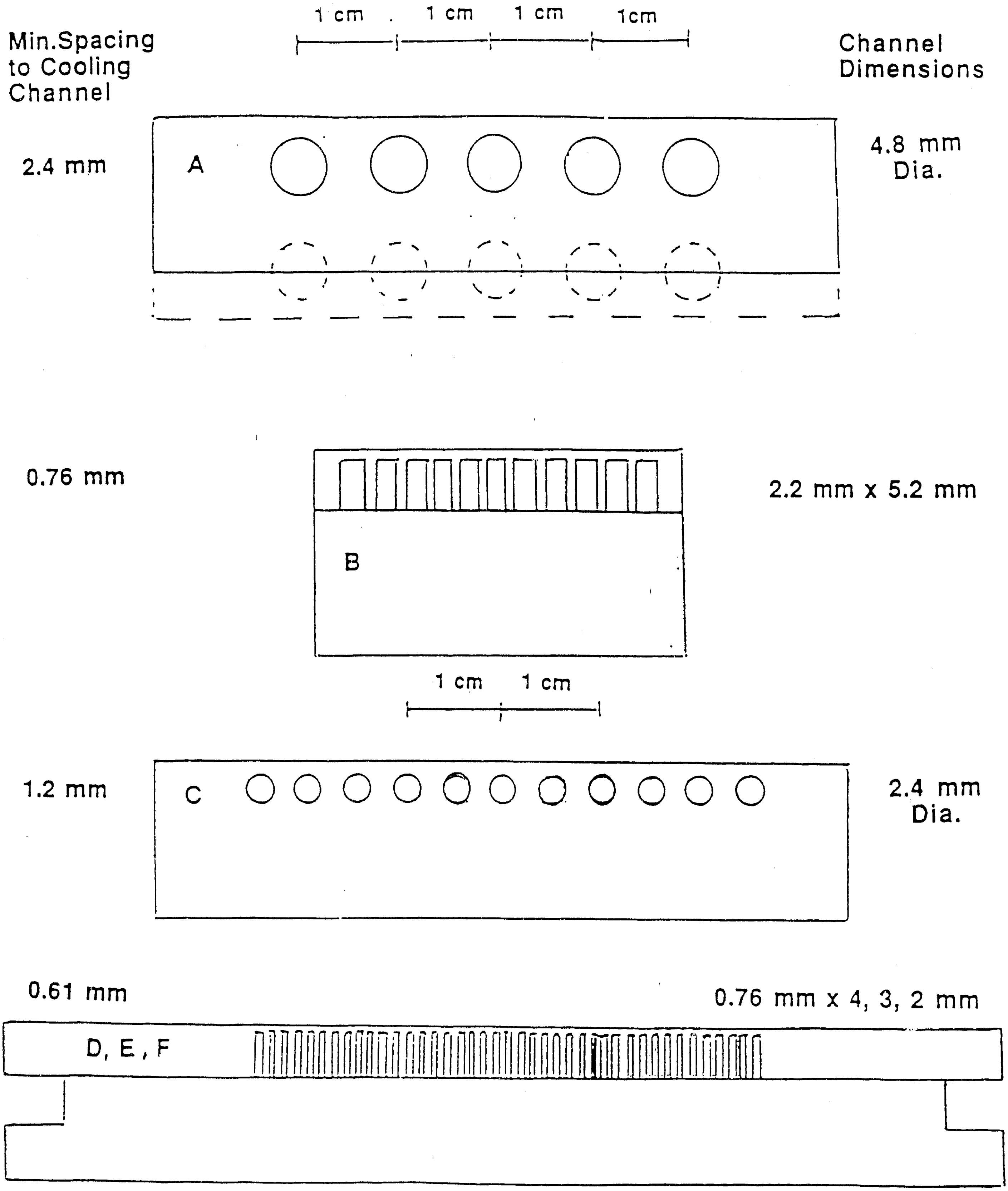
The increased flow rates and head will permit more effective heat removal from the first optical component.

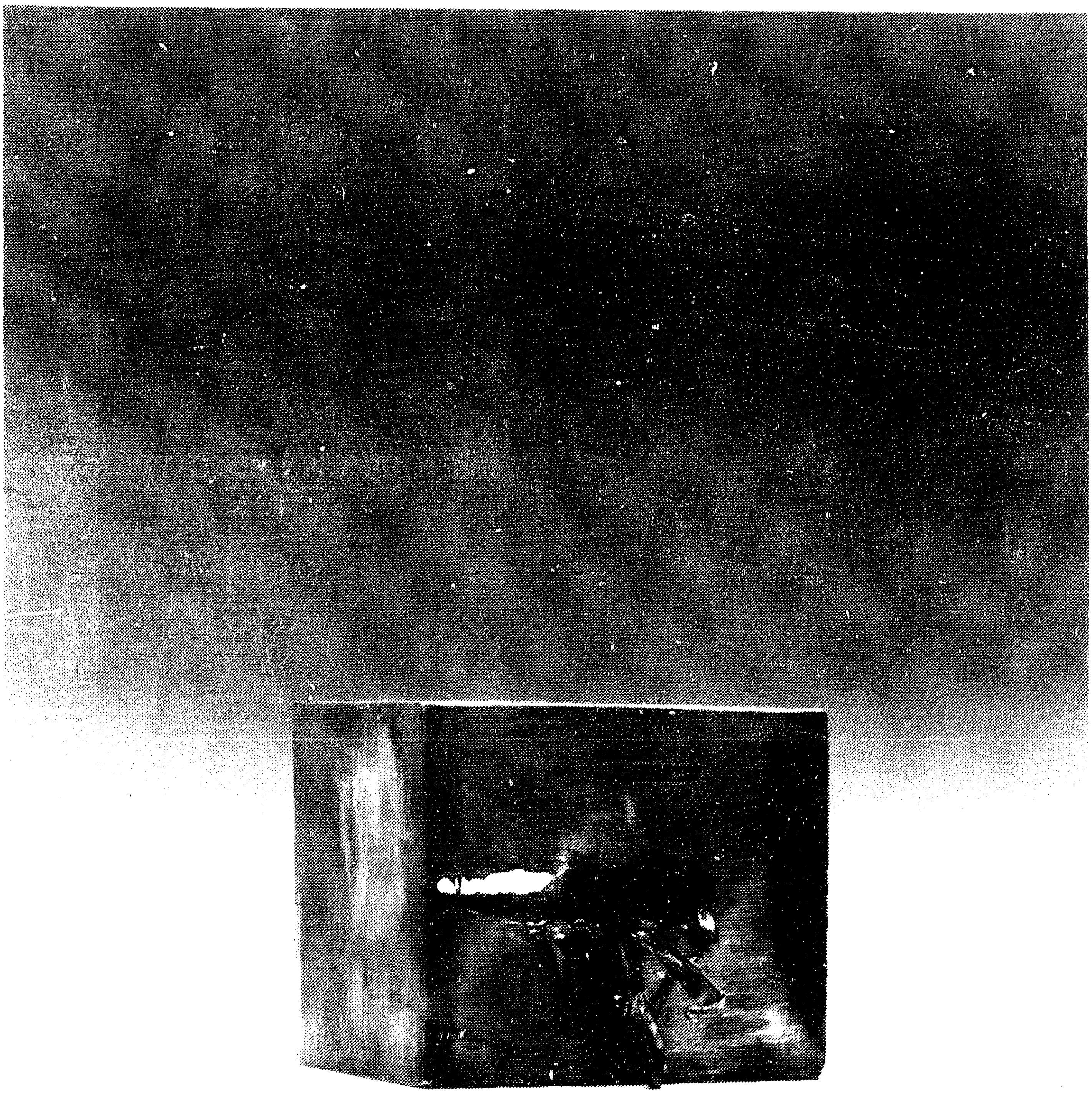
In addition, we have also fabricated several new single crystal monochromators with various coolant channel geometries for testing at existing synchrotron radiation facilities.

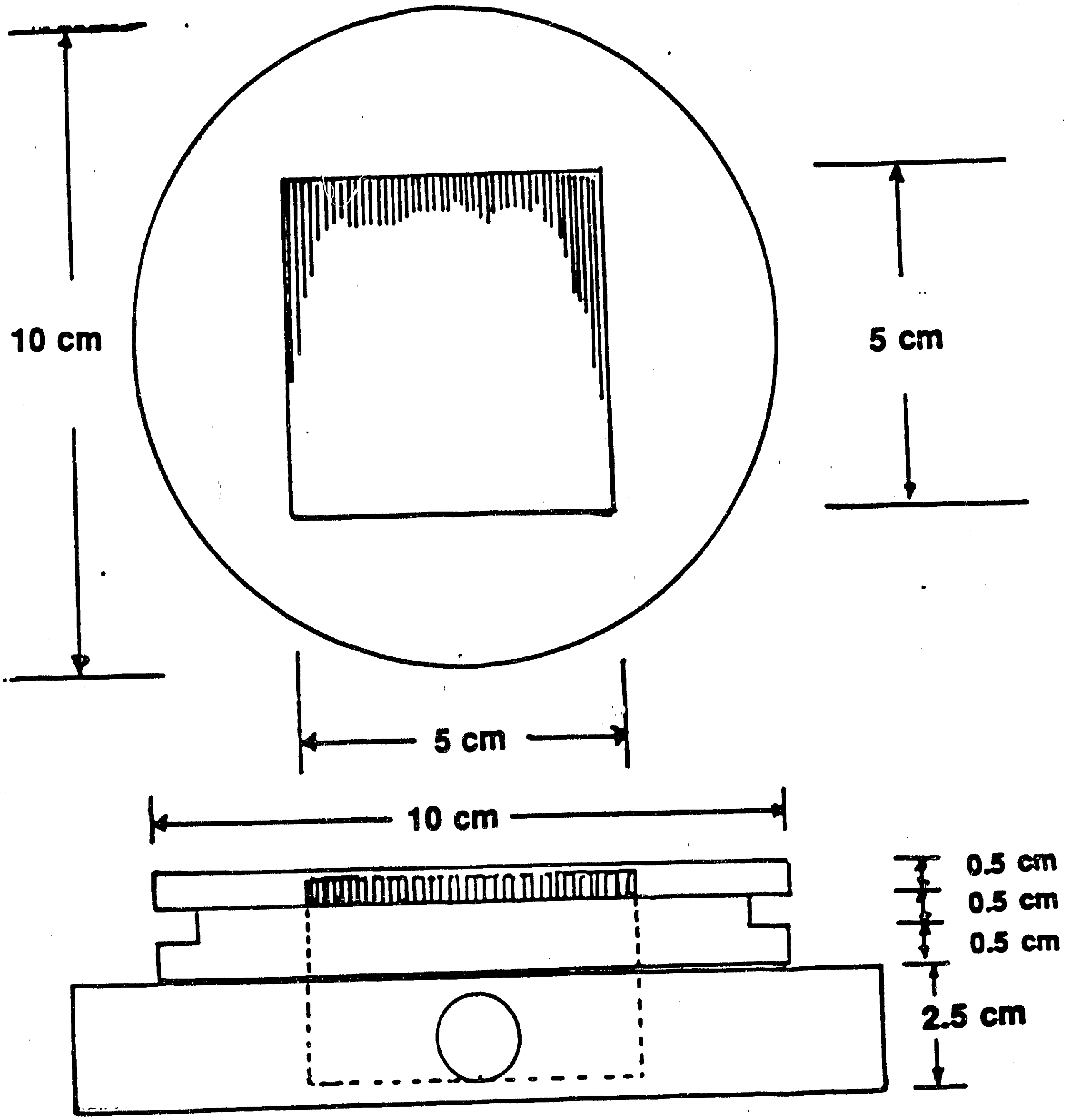
ADVANCED PHOTON SOURCE LIQUID-GALLIUM PUMP

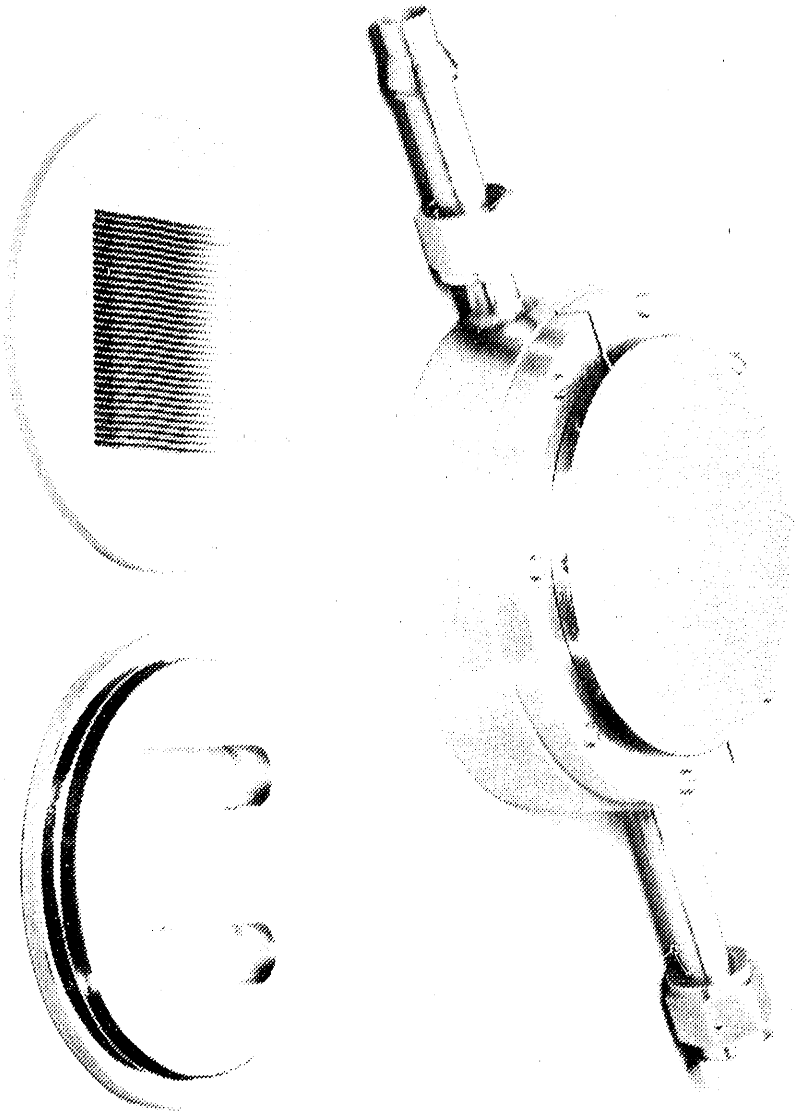



h (w / cm^2 / ^{o}K)
40
35
30
25
20
15
10
5
0
6 gpm
F
4 gpm
6 gpm
E
D
4 gpm
2 gpm
6 gpm
2 gpm
4 gpm
2 gpm
7.7 gpm
C
6 gpm
5 gpm
1990
4 gpm
3 gpm
Ga
Ga
2 gpm
Ga
2 gpm
B
2 gpm
A
1988
10 gpm
H_2O
B
2 gpm
A
0
5
10
15
20
25 ft / sec
0
100
200
300
400
500
600
700
cm / sec
VELOCITY OF COOLING FLUID


Min.Spacing to Cooling Channel
1 cm
1 cm
1 cm
1cm
Channel Dimensions
2.4 mm
A
4.8 mm Dia.
0.76 mm
2.2 mm x 5.2 mm
B
1 cm
1 cm
1.2 mm
C
2.4 mm Dia.
0.61 mm
0.76 mm x 4, 3, 2 mm
D, E, F

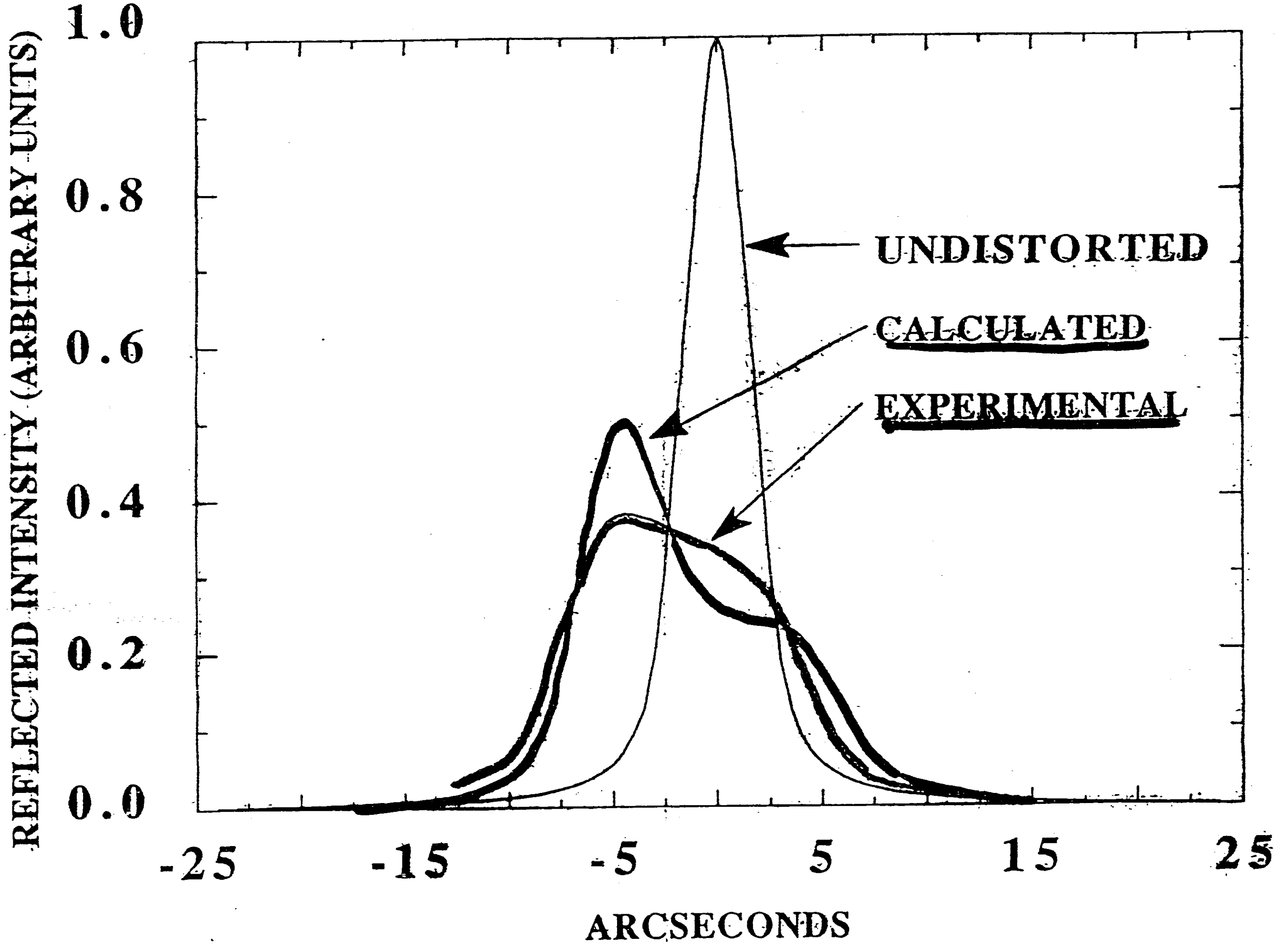


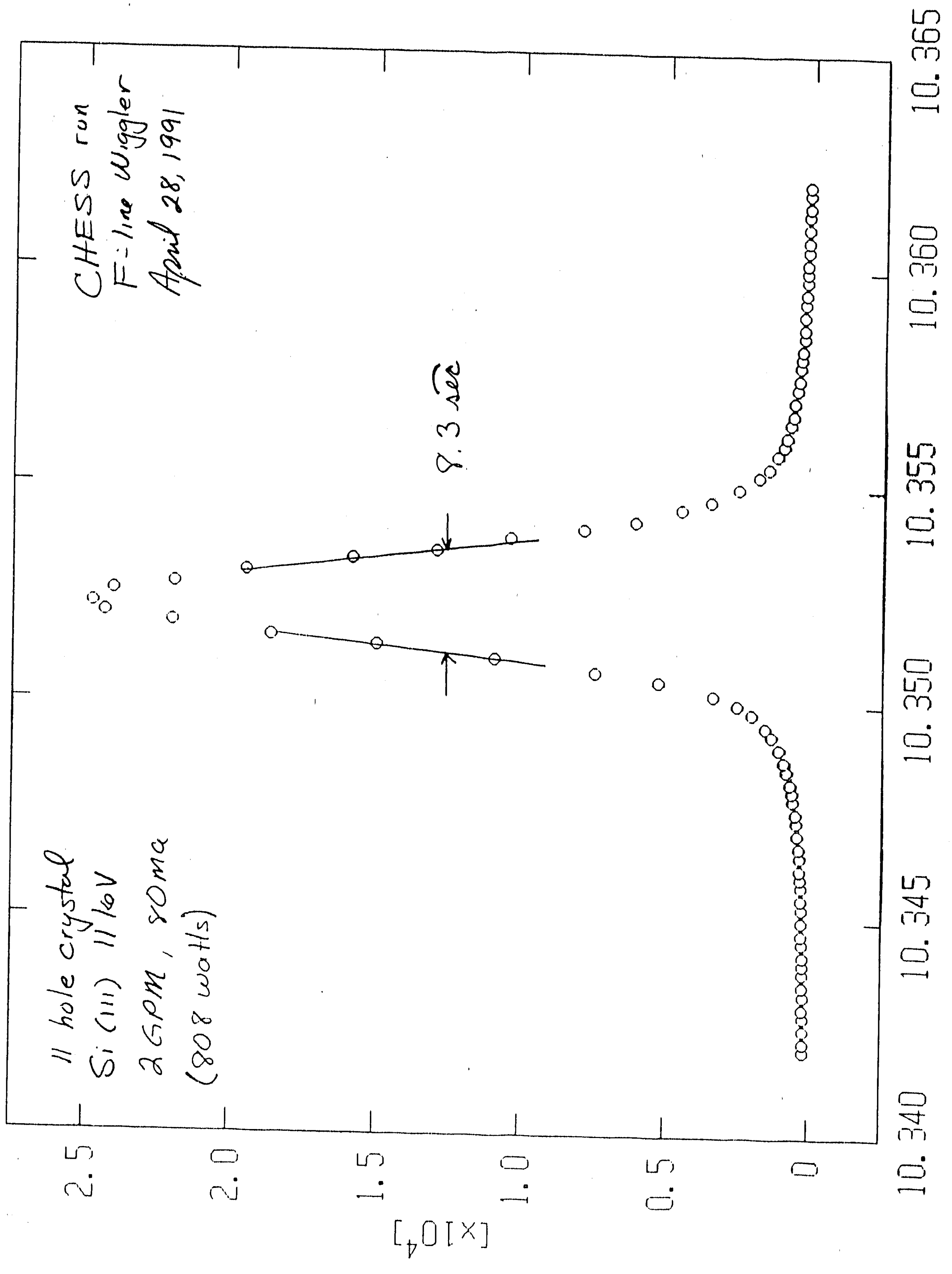

10 cm
5 cm
5 cm
10 cm
0.5 cm
0.5 cm
0.5 cm
2.5 cm

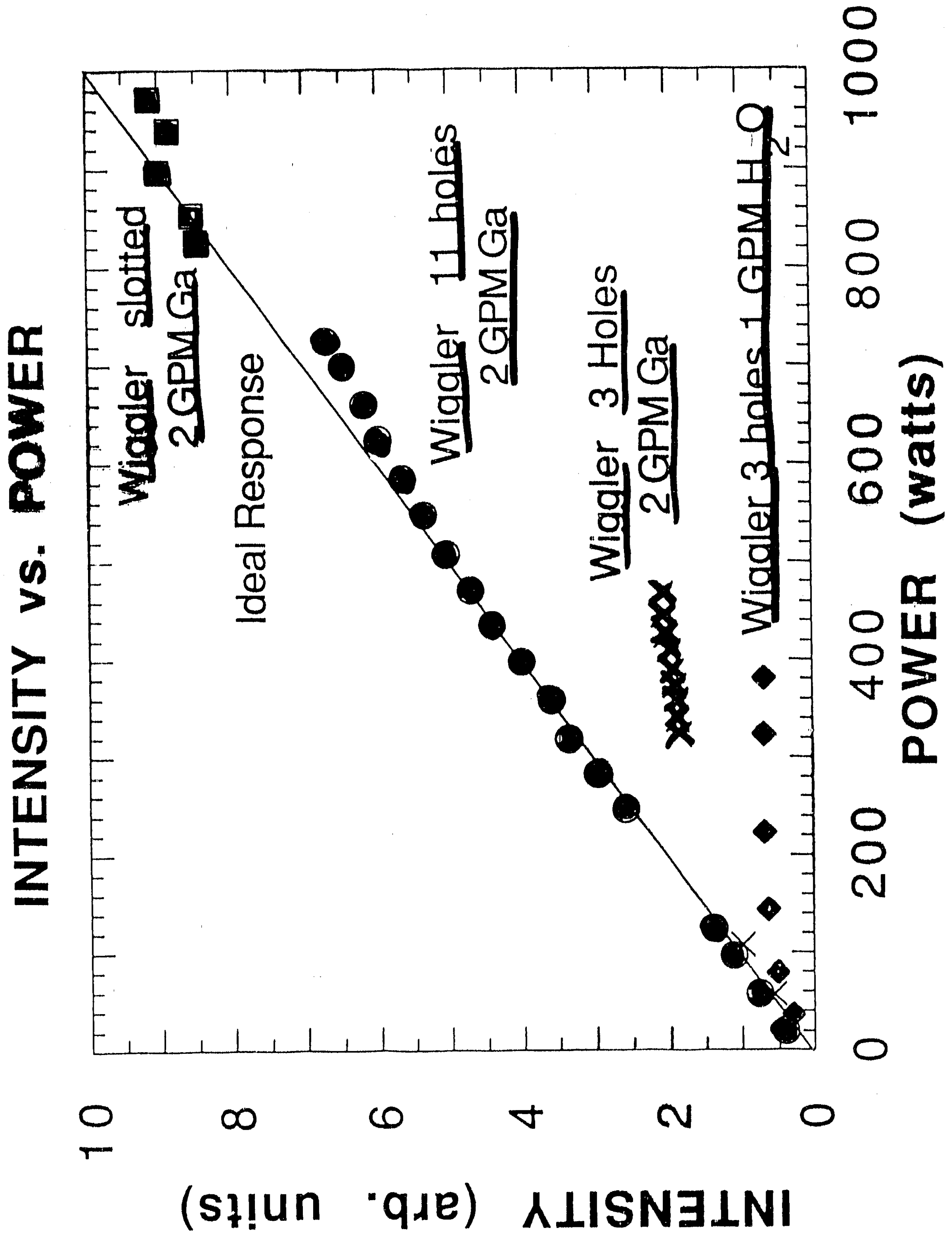


Ga cooled
CHESS wiggler

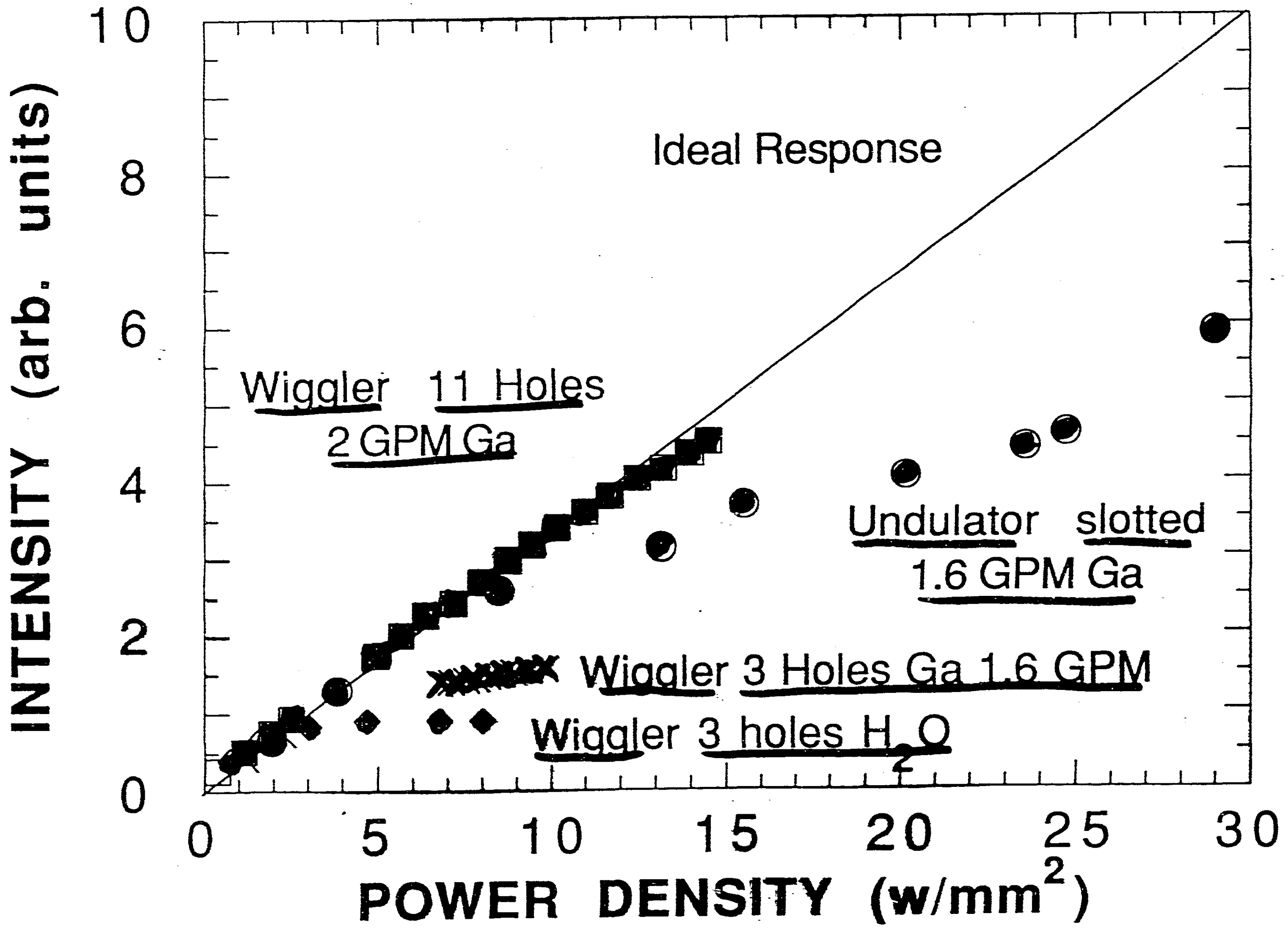
445 Watts
20 keV

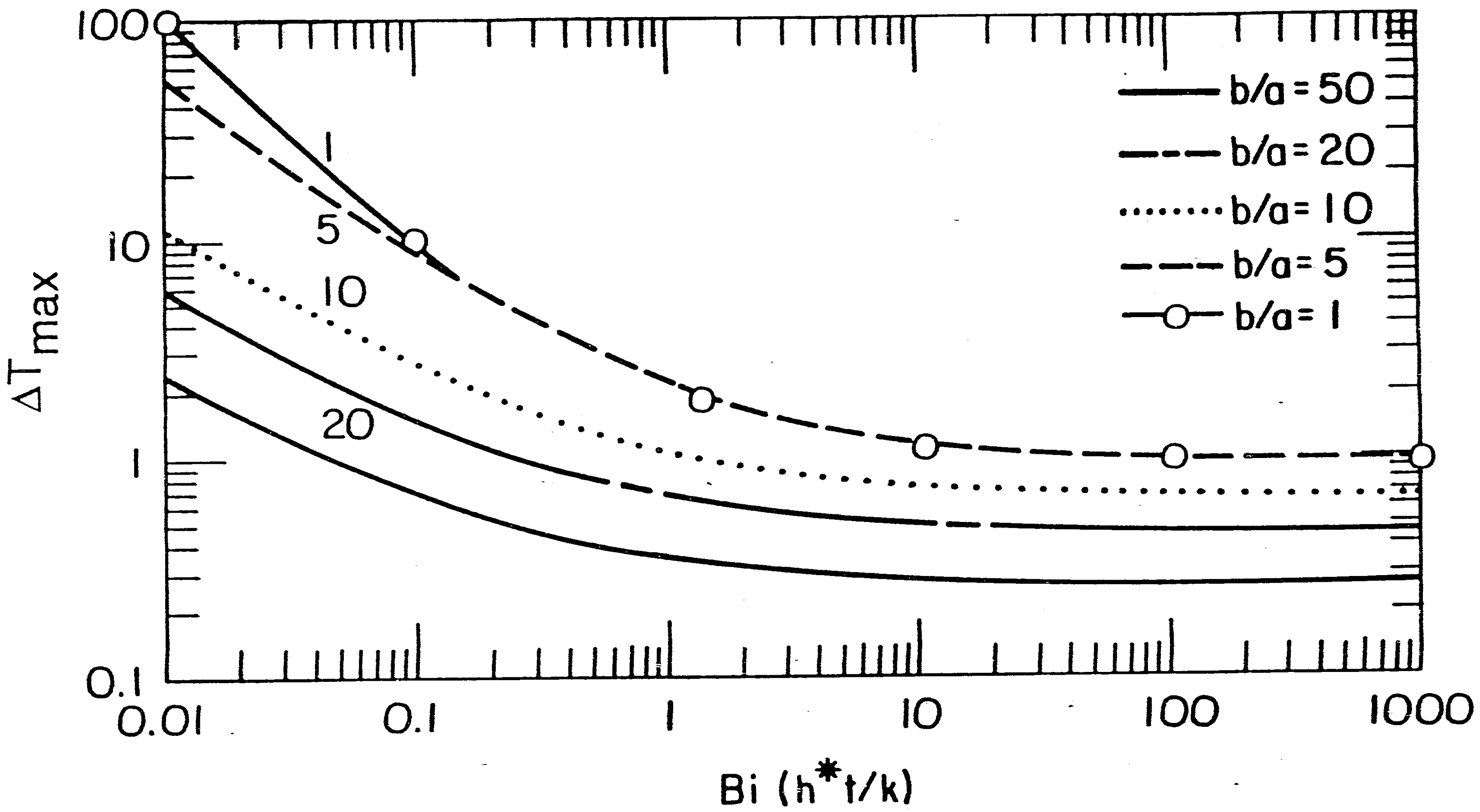



11 hole crystal
Si (111) 11 keV
2 GPM, 80 ma
(808 watts)
CHESS run
F-line Wiggler
April 28, 1991
8.3 sec
10.340
10.345
10.350
10.355
10.360
10.365
0
0.5
1.0
1.5
2.0
2.5
[X10⁴]


INTENSITY vs. POWER
INTENSITY (arb. units)
0
2
4
6
8
10
POWER (watts)
0
200
400
600
800
1000
Ideal Response
Wiggler slotted
2 GPM Ga
Wiggler 11 holes
2 GPM Ga
Wiggler 3 Holes
2 GPM Ga
Wiggler 3 holes 1 GPM H_2O

INTENSITY vs. POWER DENSITY





SCALED TEMPERATURE VS. BIOT NUMBER FOR
VARIOUS ASPECT RATIOS

2.4.3.1.2 Cryogenic Cooling of X-ray Optics

The use of cryogens has been suggested for cooling high heat load x-ray silicon monochromators or mirrors. There are several advantages to operating silicon optics at cryogenic temperatures.

Advantages:

- thermal conductivity (k) increases as the temperature decreases
- coefficient of thermal expansion (α) decreases and goes through zero at 125°K

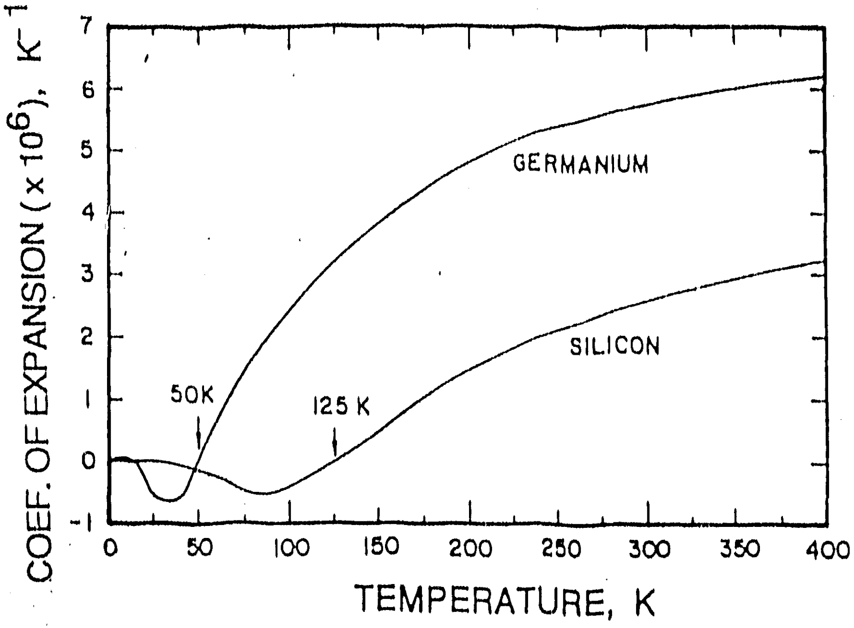
Disadvantages:

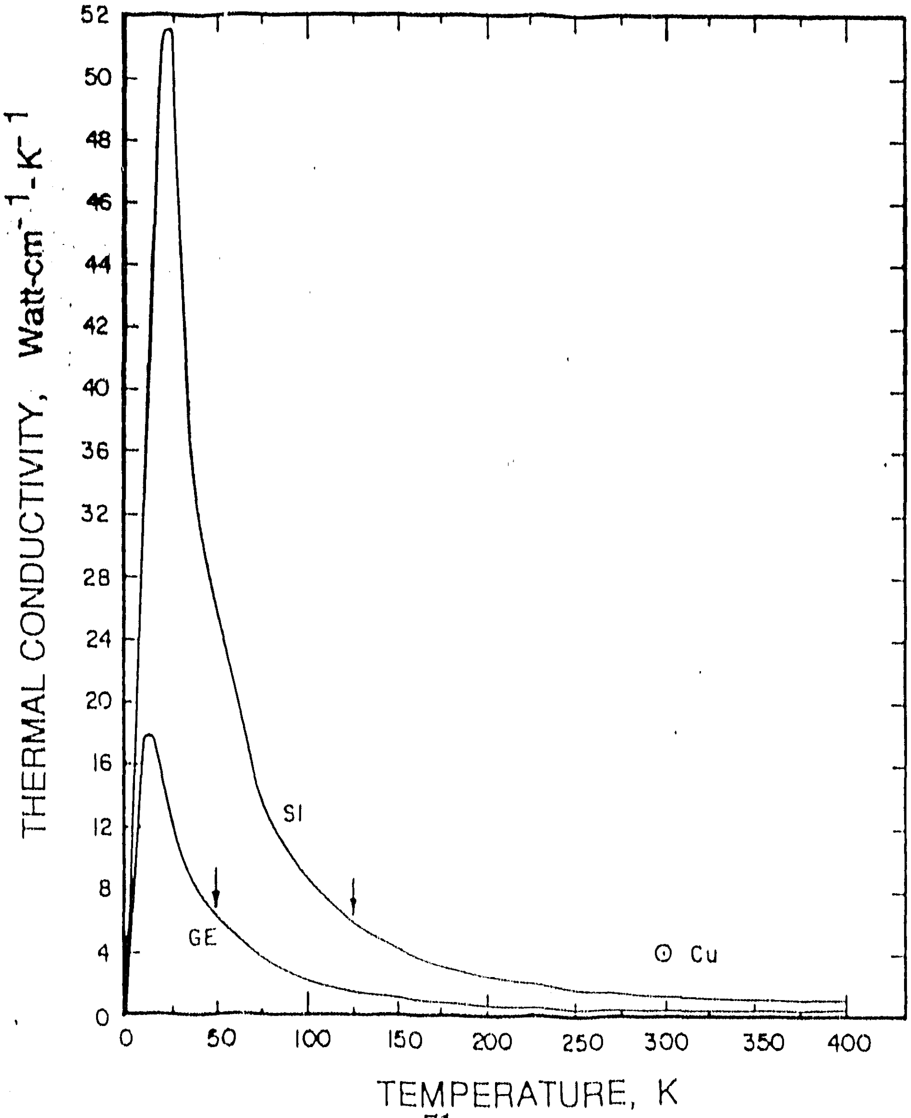
- large surface areas are required to remove the type of heat loads expected at the APS (kwatts) and so fabrication of coolant channels is difficult

Recent successes with liquid nitrogen cooling by the ESRF Group on the X25 focused wiggler beam line at NSLS (75 watts total power, 150 watts/mm^2) have encouraged us to pursue this approach more aggressively.

Things to be reckoned with (A. Freund and G. Marot (ESRF), 2/91).

- glue/brazing problems
- 3 kwatts total power
- closed loop system
- integration into monochromator


COEF. OF EXPANSION (x 10^6), K^-1
7
6
5
4
3
2
1
0
-1
0
50
100
150
200
250
300
350
400
TEMPERATURE, K
GERMANIUM
SILICON
50K
125 K


THERMAL CONDUCTIVITY, Watt-cm^-1-K^-1
52
50
48
46
44
42
40
36
32
28
24
20
16
12
8
4
0
0
50
100
150
200
250
300
350
400
TEMPERATURE, K
SI
GE
⊙ Cu

2.4.3.1.2 Cryogenic Cooling (cont.)

Si/SiC Bonding Program:

We are currently working with United Technologies Optical Systems (UTOS) to develop a method of bonding perfect single crystals of silicon to a silicon carbide substrate without introducing defects into the silicon. If successful, this will permit us to fabricate a new type of cryogenic heat exchanger.

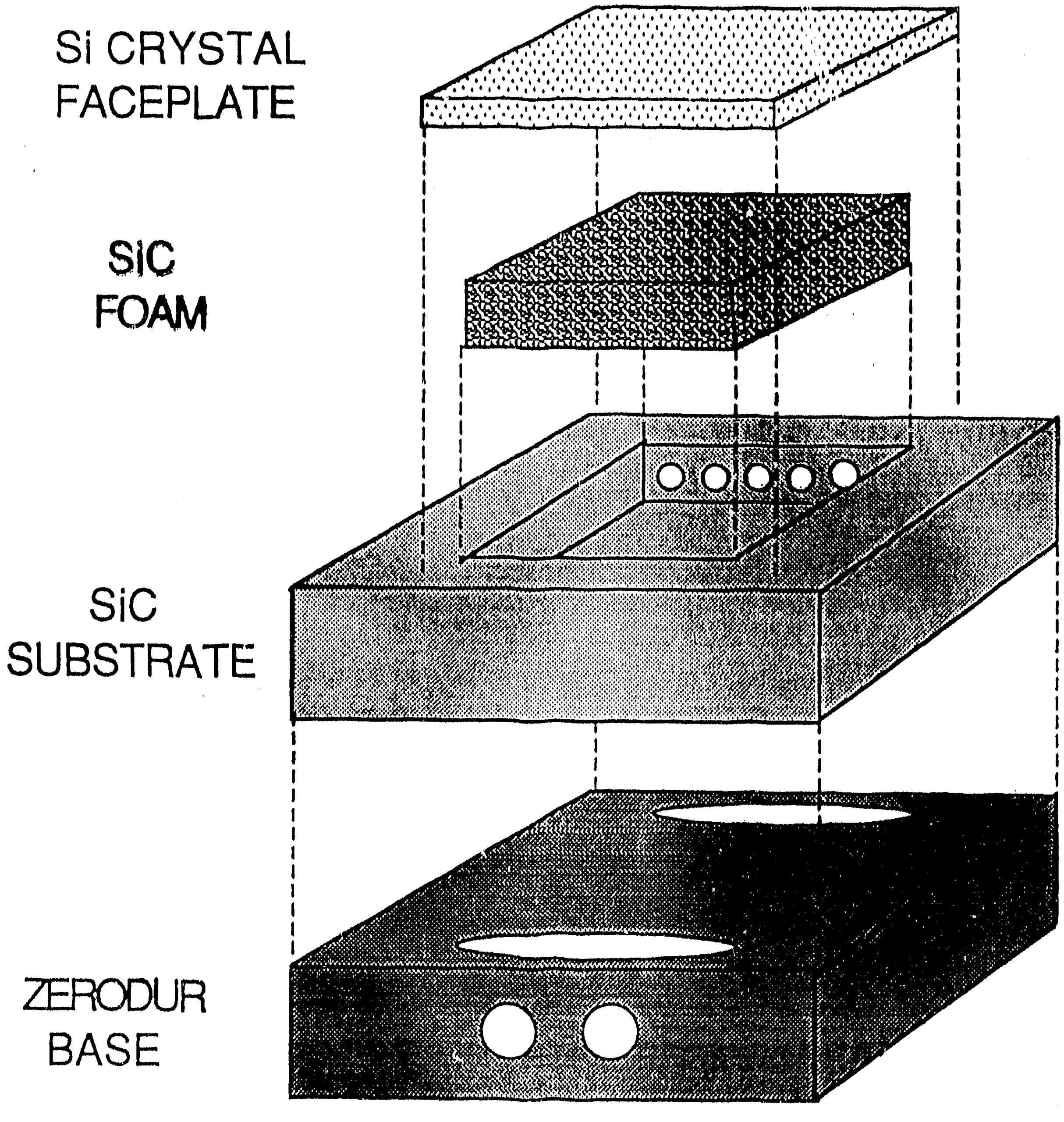
SiC Foam as a Heat Transfer Medium:

The amount of heat that can be removed using liquid nitrogen is limited by the surface area of the heat exchanger. We are investigating the use of porous foams for use as heat exchangers with cryogenic coolants. The foams have several advantages.

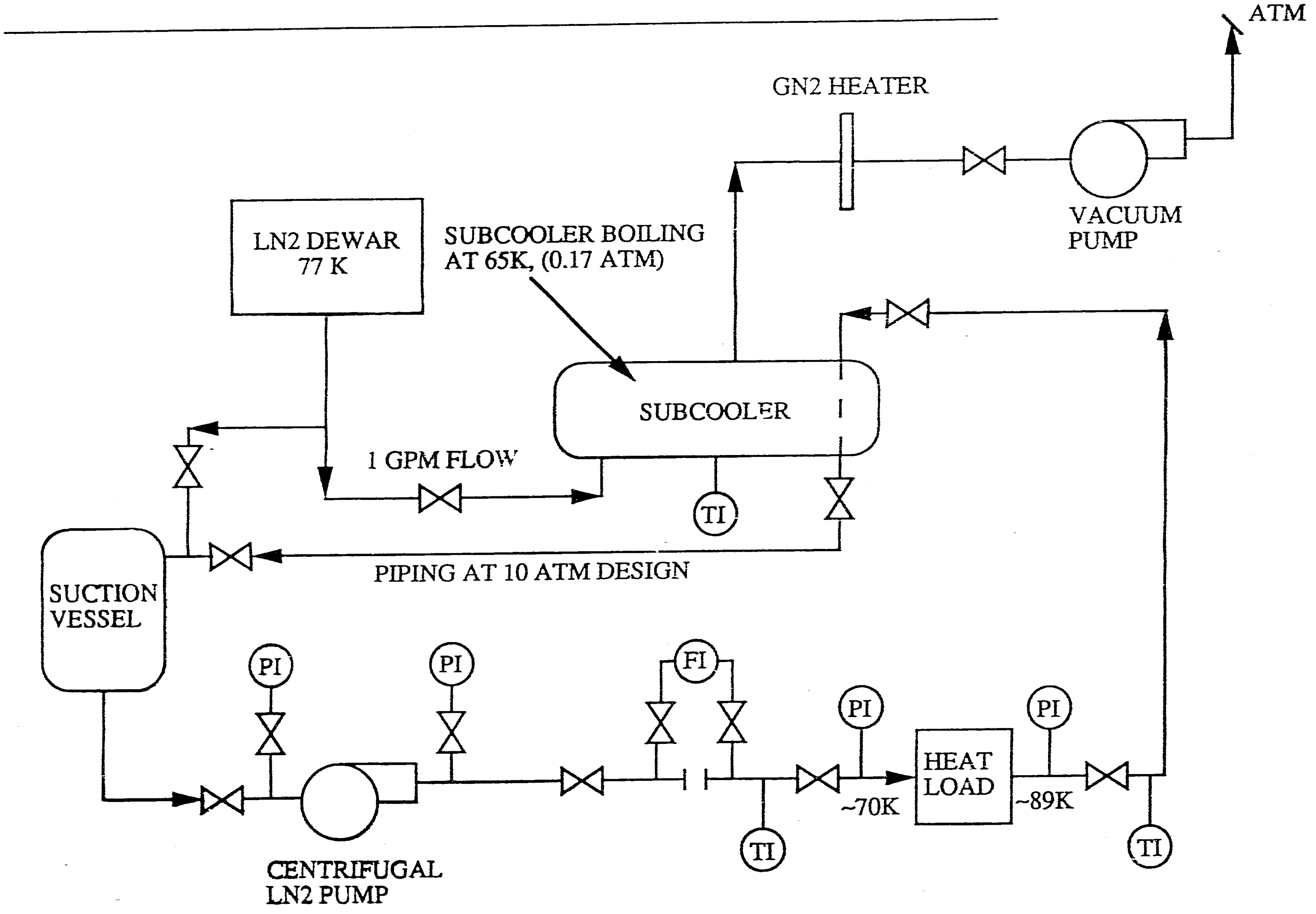
- Large surface areas
- Promote smooth, jitter free fluid flow
- Minimal pressure drop
- Structurally strong and mechanically stiff

Closed Loop Cryogenic System:

We are currently preparing a package for the procurement of a prototype closed loop liquid nitrogen cooling system.

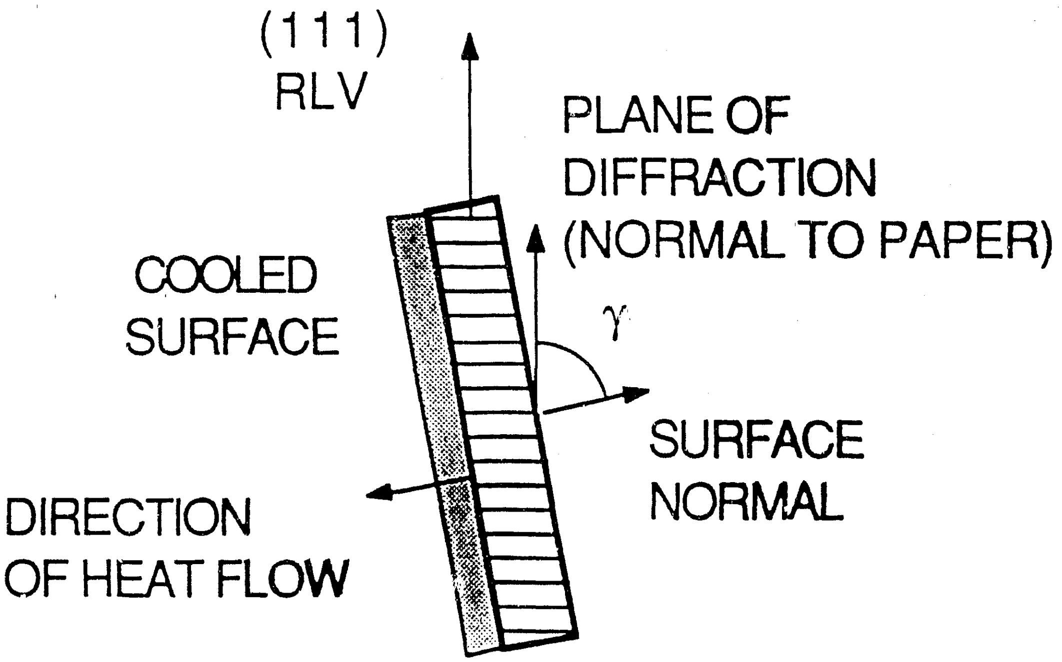

Si CRYSTAL
FACEPLATE
SiC
FOAM
SiC
SUBSTRATE
ZERODUR
BASE

ADVANCED PHOTON SOURCE



2.4.3.1.3 New Cooling Concepts

We have been investigating a variety of geometries to aid in the reduction of thermal distortion in optical components. One approach that looks very promising is the "inclined crystal". The geometry for the inclined crystal is shown below.



END VIEW OF INCLINED CRYSTAL GEOMETRY

Although the surface normal of the crystal does not lie in the scattering plane, it still makes equal angles with the incident and diffracted wavevectors and therefore the crystal diffracts as if it the surface was parallel to the planes (i.e. b=-1, the so-called symmetric reflection geometry).

2.4.3.1.3 New Cooling Concepts (cont.)

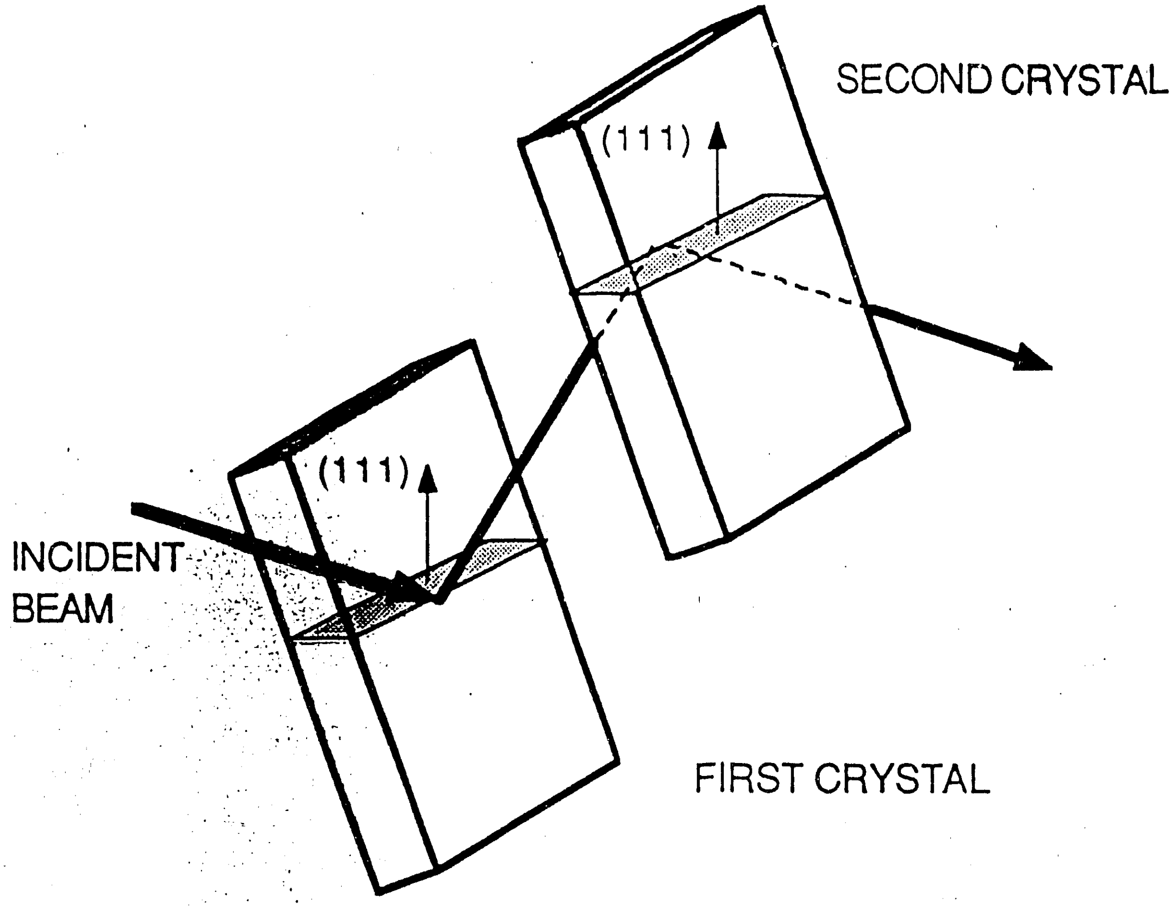
Advantages of the inclined crystal geometry compared with a symmetrically cut crystal are:

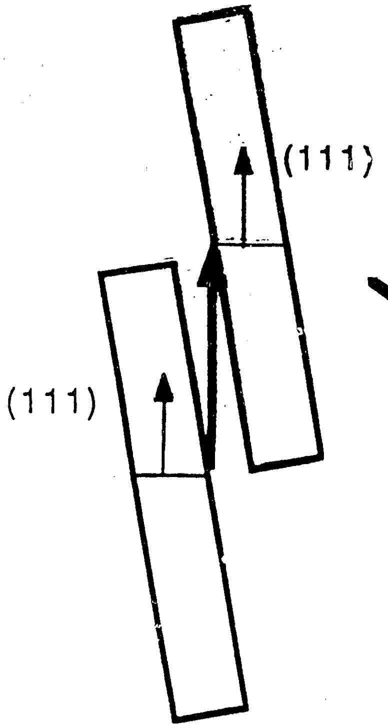
- The beam foot print is spread out by a factor of $1/\cos\gamma$ where γ is the angle between the surface normal and the diffraction plane. (This may be particularly important when used in conjunction with cryogenic cooling.)
- The temperature gradient is no longer perpendicular to the planes, but is approximately at an angle γ to the planes.

These two properties should reduce both the total thermal distortion of the crystal and the effect on the diffraction properties from that thermal distortion.

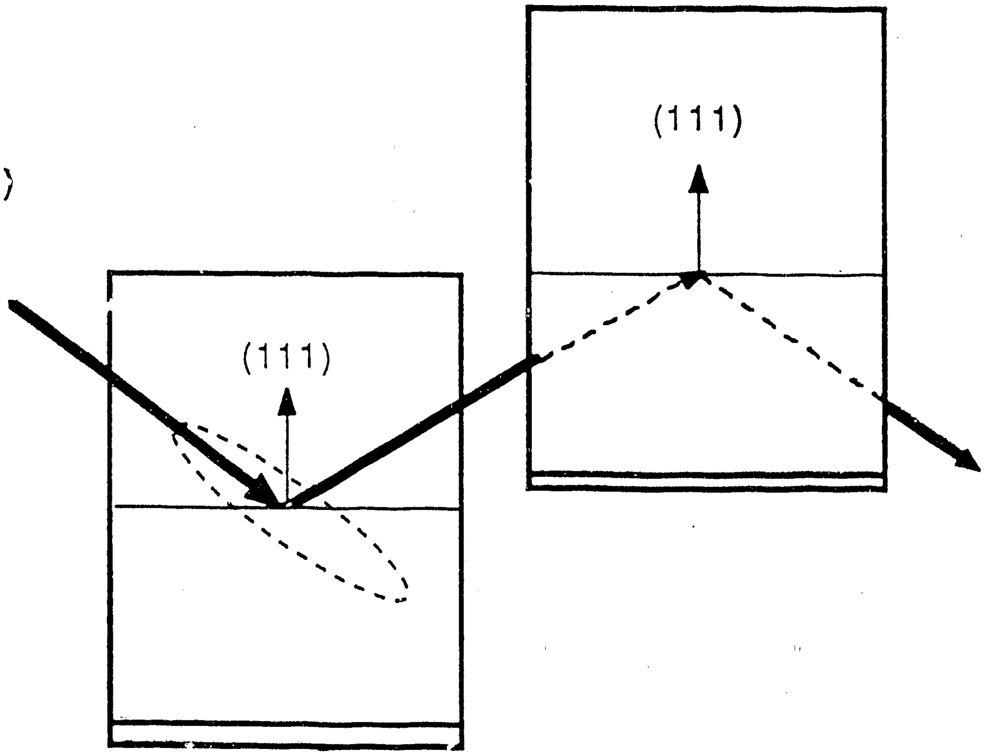
Disadvantages of the inclined crystal geometry compared with a symmetrically cut crystal are:

- A long crystal is required when γ approaches 90° and so this geometry may only be appropriate for beams of small horizontal dimensions, i.e. undulator radiation.
- Requires a second crystal with same geometry to return the beam to its original cross-section area.





END VIEW



SIDE VIEW

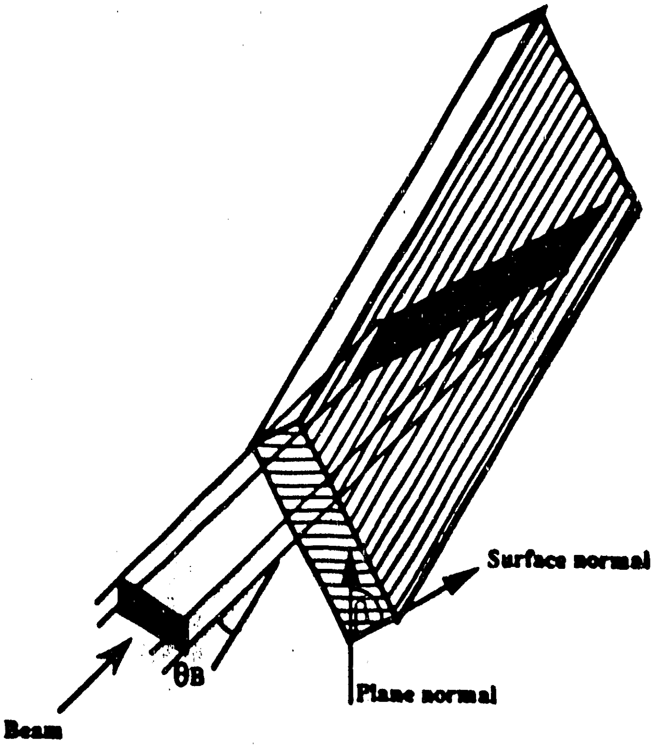


Figure 1: The inclined monochromator and the normal and inclined beam footprints. Also shown are the crystal diffraction planes and crystal diffraction surface. The Bragg angle is θB.

Experiments Planned at Existing Facilities:

1. CHESS Wiggler Run - April 24 to May 7
   - Test of new coolant channel geometries
   - Test of improved liquid gallium pump
2. APS/CHESS Undulator Run - June 16 to 22?
   - Test of new coolant channel geometries
   - Test of improved liquid gallium pump
   - Test of $\gamma=70.5°$ inclined crystal (footprint expansion $1/\cos\gamma = 3$)
3. NSLS X25 Wiggler Run - to be determined
   - Test of $\gamma=85°$ inclined crystal (footprint expansion $1/\cos\gamma = 11$)

Future runs will include tests of the DC liquid gallium pump and cryogenic cooling of high heat load optics.

ADVANCES IN SYNCHROTRON RADIATION APPLICATIONS

DEVELOPMENT OF NANOVOLT-RESOLUTION X-RAY DIFFRACTION USING RESONANT NUCLEAR SCATTERING*

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and
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1. Introduction

Mössbauer <u>absorption</u> spectroscopy using radioactive sources is a much used technique for the study of the local environment of Mössbauer resonant atomic species in solids. Mössbauer <u>scattering</u> spectroscopy is a powerful technique for investigating the dynamic aspects of materials and for separating dynamic and time-average phenomena, but the very low scattering intensities associated with diffraction studies have limited such investigations to special cases. Absorption spectroscopy benefits from the fact that absorption is an inherently global quantity and measurements are performed only in the forward direction. On the other hand, scattering measurements typically entail angular resolution elements corresponding to a very small portion of the 4π steradian domain of scattering spectroscopy. Even in cases such as Bragg scattering, where cross-sections are high and all the scattering falls in a restricted angular range, the inherently narrow width of lattice reflections is completely mismatched with the relatively broad divergences of beams from Mössbauer sources. It has been recognized for some time that the high brightness and the pulsed time-structure of synchrotrons would provide a tool complementary to radioactive sources for scattering spectroscopy investigations that require highly collimated incident beams. In this paper we discuss our work on the development of high collimation, nanovolt-resolution scattering spectroscopy using nuclear Bragg scattering, and we consider areas of application for this spectroscopy.

2. Resonant Beams from a Mosaic $^{57}Fe_2O_3$ Monochromator

Figure 1 shows a schematic diagram of the nuclear Bragg monochromator scheme in which the electronically forbidden (777) reflection from an enriched $^{57}Fe_2O_3$ crystal is used to obtain a Mössbauer resonant 14.4 KeV x-ray beam. The fundamentals of resonant diffraction have been investigated(1) theoretically and experimentally, and we direct our attention here to the intensity and time-structure of resonant

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*Research sponsored by the Exploratory Studies Program of Oak Ridge National Laboratory and the Division of Materials Sciences, U.S. Department of Energy, under contract DE-AC05-84OR21400 with Martin Marietta Energy Systems, Inc.

beams for use in scattering spectroscopy investigations. We report results obtained using a ~ 15 arcsecond mosaic $^{57}Fe_2O_3$ monochromator grown epitaxially on a natural Fe_2O_3 substrate. Nanosecond resolution time-resolved measurements of the (Mössbauer) resonant beams from this monochromator have been performed on the sagitally focussed X-14 beam line at the National Synchrotron Light Source (NSLS), and on the sagitally focussed A2 (6-pole wiggler) and F2 (25-pole wiggler) beam lines at the Cornell High Energy Synchrotron Source (CHESS). Results of measurements performed on the F2 line at CHESS are shown in Fig. 2. This figure demonstrates that the delayed time-structure separates the resonant scattering from the (prompt) nonresonant scattering, and it shows the low background noise level in the delayed time region. The dashed line indicates that the emission rate tends toward a 98 ns time constant for long times, and that only the initial rate is significantly enhanced by collective "speed-up" phenomena.(1)

Typical resonant beam powers attained on X-14 at NSLS were 15 photons/s in the 1-bunch mode (90 ma) and 25 photons/s in the 5-bunch mode (175 ma). At CHESS, 60 photons/s were obtained on A2 (45 ma) and 165 photons/s were obtained on the F2 (45 ma) line as indicated in Fig. 2. The A2 and F2 beam line monochromators were heat load limited at 45 ma so the CHESS results do not represent the maximum potential from these sources. Since 90 ma is presently the normal operating current for CHESS, resonant beams of ~ 500 photons/s should be possible when monochromators with higher heat loading tolerances are installed. Beams several times these powers have been achieved by groups working at synchrotron facilities with access to undulators (J. Arthur et al, reference 1).

Resonant beams of up to a few thousand photons are still very weak for most diffraction experiments, and the long term viability of nanovolt-resolution scattering spectroscopy depends sensitively on next generation synchrotrons and the use of undulator insertion devices. Using projections of ~ 10^{15} photons/s/0.1% bandwidth for the Advanced Photon Source (APS), resonant beams of ~ 10^5 photons/s will be possible with ~2×10^{-8} eV bandwidth if ~ 10 % of the resonant photons are collected. Highly collimated (~10 μrad.) beams of this nature would represent more than a thousand fold increase over beams that could be extracted from conventional Mössbauer sources with only ~ mrad. collimation.(2)

3. Elastic and Inelastic Scattering of a Resonant Photon Beam

In order to perform scattering spectroscopy in the nanovolt range, it is necessary to be able to identify and separate elastic and inelastic scattering at that level. Figure 3 shows the time-spectrum of resonant photons elastically (i.e. Bragg) scattering from the (111) reflection of a Ge crystal. These measurements were made on the X-14 beam line at NSLS during single bunch operation; a calculated time-spectrum for resonant scattering from the (777) reflection of $^{57}Fe_2O_3$ is shown for comparison. The features of the calculated interference structure (from the beating of the Zeeman split resonant energy levels) are in good agreement with the measured spectrum.

The ~15–20 arcsecond mosaic width of the monochromator was taken into consideration by an incoherent average of individual time-spectra calculated (using dynamical diffraction theory) for angles ranging over ±10 arcseconds relative to the Bragg angle. This average assumes the enriched epitaxial layer to be composed of thick grains with varying orientation; better detailed agreement with the measurements is be expected when scattering from underlying grains with orientations different from that of the surface are considered. Although Bragg scattering from a perfect crystal with a highly collimated incident beam is overwhelmingly elastic, inelastic scattering from the Ge crystal would not make a detectable change in the time-structure shown in fig. 3 unless it were present in the form of quasi-elastic scattering (i.e. from excitations of ~ 10^{-8} eV or ~ 10^{7} Hz).

For separating elastic and inelastic scattering, the time-structure of scattering can be made sensitive to the (elastic or inelastic) nature of the scattering through the use of a resonant filter as an analyzer. The insertion of a resonant filter between the sample and the detector as shown in Fig. 1 modifies the energy spectrum of resonant photons through enhanced absorption of photons with energies near the resonance energies. As investigated in detail using radioactive sources,(3) this changes the time-spectrum of resonant photons while not affecting inelastically scattered photons. Inelastically scattered photons are no longer near resonance energies and, hence, do not feel the presence of the resonant filter.

Figure 4 demonstrates the effect of a resonant filter on the time-structure of the elastically scattered (i.e. resonant) photons. The solid black profile is a plot of the time-spectrum of the resonant beam from Fig. 3; the gray profile shows modification by the insertion of a powdered $^{57}Fe_2O_3$ filter (65% enriched) with an effective thickness of ~25 μm and 55% nonresonant transmission. The solid white line shows the time-spectrum of the black profile adjusted for the 55% (nonresonant) transmission of the filter. In addition to an overall reduction in the scattering as a result of the resonant filter (gray profile), we notice that the peaks in the 20–35 ns range and the peak centered at 42 ns of the gray profile are preferentially attenuated by the resonant filter. As indicated above,(3) this time signature is understood through the Fourier transform relationship between the energy and time spectra, and it can be used to distinguish between resonant and nonresonant photons.

Doppler shifting of the Ge crystal provides a well defined energy change in the scattered beam to demonstrate the reduced attenuation and time-spectrum changes as the photon beam is moved off the exact resonance. The open circles in Fig. 4 were measured using a 1 mm/s (5×10^{-8} eV) Doppler shift in energy of the Bragg reflected beam. Although the statistical precision is not high, the amplitudes of the strongly attenuated peaks for the longer times show nearly complete recovery to the solid white line, which corresponds to the 55% transmission level for photoelectric absorption of nonresonant photons. This demonstrates that resonant absorption is significantly reduced, and that energy resolution on the scale of nanovolts is obtained. Full recovery would not be expected at the shorter times because of the wider energy bandwidth. The data in Fig. 4 were collected in the single bunch mode at NSLS for which the Ge Bragg reflection yielded only ~5 photons/s before the insertion of the resonant filter.

Since integration of time-spectra measurements provide a direct measure of attenuation, phase-locked time-domain measurements (with and without a resonant filter) would provide a means for separating elastic and inelastic scattering without use of the form of the time spectra. In principle, though, the time-spectra can be used to simultaneously measure the elastic and inelastic scattering fractions without removing or Doppler shifting the filter. This can be accomplished by fitting measured time-spectra to a linear combination of (experimentally determined) resonant and nonresonant absorption spectra.

4. Potential Applications of Nanovolt Resolution Scattering Spectroscopy

The unique aspects of Mössbauer resonant beams from synchrotrons relative to radioactive sources are the high collimation (or brightness), the polarization, and the pulsed time-structure. High collimation lends itself to applications requiring high resolution, such as investigations of sharply peaked Bragg scattering rather than broad diffuse scattering distributions. It is expected in general that the ability to carry out high brightness measurements with five orders of magnitude better energy resolution than possible by usual x-ray methods will generate investigations in a number of areas not previously considered.

Phase transformations represent an area in which high resolution scattering spectroscopy should be particulary useful, especially in investigations of weakly first order transitions. The separation of dynamic and time-average scattering in structural and order-disorder phase-transformations studies is an area in which the ability to differentiate between elastic and inelastic scattering is important. Systems containing soft modes such as those associated with ferroelectric phase transitions in perovskites are of interest with respect to quasi-elastic scattering in the narrow central peak. In work on the ω-phase in Nb-Zr alloys small angular shifts of elastic peaks relative to inelastic peaks were found to be of interest even though the elastic-inelastic nature of broad diffuse scattering distributions were of the primary topic of interest.(4) Organic materials such as CH_4 in many cases possess a rich structure of low level tunneling and free rotator excitations and phase transitions(5) that may be candidates for x-ray investigation. They are presently under investigation with ultrahigh energy resolution neutron scattering techniques such as spin-echo spectroscopy, which provides energy resolution down to the nanovolt level, but does not have high momentum resolution.

Investigations of defect clusters in materials by diffuse scattering near Bragg reflections would benefit significantly from a separation of the (inelastic) thermal diffuse scattering from the elastic scattering from defect distortions. For instance, measurements of solute precipitation kinetics could be performed in situ at high temperatures without contamination by the strongly peaking thermal scattering.

Changing of thermal scattering due to elastic constant changes during solute precipitation represents another aspect avoided by measuring only elastic scattering. The possibility of doing crystallographic lattice phasing utilizing substitutional Mössbauer nuclei would be enhanced by the high collimation relative to work with broad radioactive source beams, although recent techniques involving multiple diffraction may supersede anomalous scattering techniques in any case. In special cases it may be possible to stimulate physical phenomenon in phase with the synchrotron pulses and utilize the pulsed nature of synchrotron radiation to carry out high resolution, time-resolved measurements. However, the resonant photons are really no longer short pulses and care would have to be given to selecting such a measurement.

It may even be possible to apply these techniques to the case of broad (weak) diffuse scattering measurements through the use of 2-dimensional position sensitive detectors with nanosecond time-resolution. Incident beams will, of course, remain relatively low compared to beam powers normally required for x-ray studies of broad diffuse scattering, but the advantages afforded by the separation of the elastic and inelastic scattering in combination with a 2-dimensional detector may facilitate selected diffuse scattering measurements as well as high resolution scattering investigations suggested above.

4. Conclusions

The experimental aspects needed for performing nanovolt-resolution scattering spectroscopy using resonant nuclear monochromators are available, and resonant beams with sufficient fluxes for selected experiments can be obtained using present wiggler beam lines. Also, recent testing of advanced beam line monochromators (as reported by D. Mills at this meeting) indicate that the increased resonant beam powers from wigglers anticipated in Section 2 are now possible. However, the availability of undulator insertion devices on next generation, high energy synchrotrons such as the Advanced Photon Source remains critical for full development of this technique. Scattering spectroscopy applications requiring high momentum-resolution will be enhanced by incident beams several orders of magnitude higher than presently achievable with radioactive sources.

5. References

1. The following recent papers and references therein provide an overview of the field: D. P. Siddons, J. B. Hastings, G. Faigel, L. E. Berman, P. E. Haustein, and J. R. Grover, *Phys. Rev. Lett.* **62**, 1384 (1989); J. Arthur, G. S. Brown, D. E. Brown, and S. L. Ruby, *Phys. Rev. Lett.* **63**, 1629 (1989); and J. B. Hastings, D. P. Siddons, U. van Bürck, R. Hollatz, and U. Bergmann, *Phys. Rev. Lett.* **66**, 770 (1991).

2. R. L. Cohen, in *Topics in Current Physics: Mössbauer Spectroscopy II*, ed. by U. Gonser (Springer-Verlag, Berlin 1981), p. 81.
3. F. J. Lynch, R. E. Holland, and M. Hamermesh, *Phys. Rev.* **120**, 513 (1960).
4. W. Lin, H. Spalt, and B. W. Batterman, *Phys. Rev.* **B13**, 5158 (1976).
5. M. Rasolt and A. D. N. Haymet, *Phys. Rev.* **B30**, 1619 (1984).

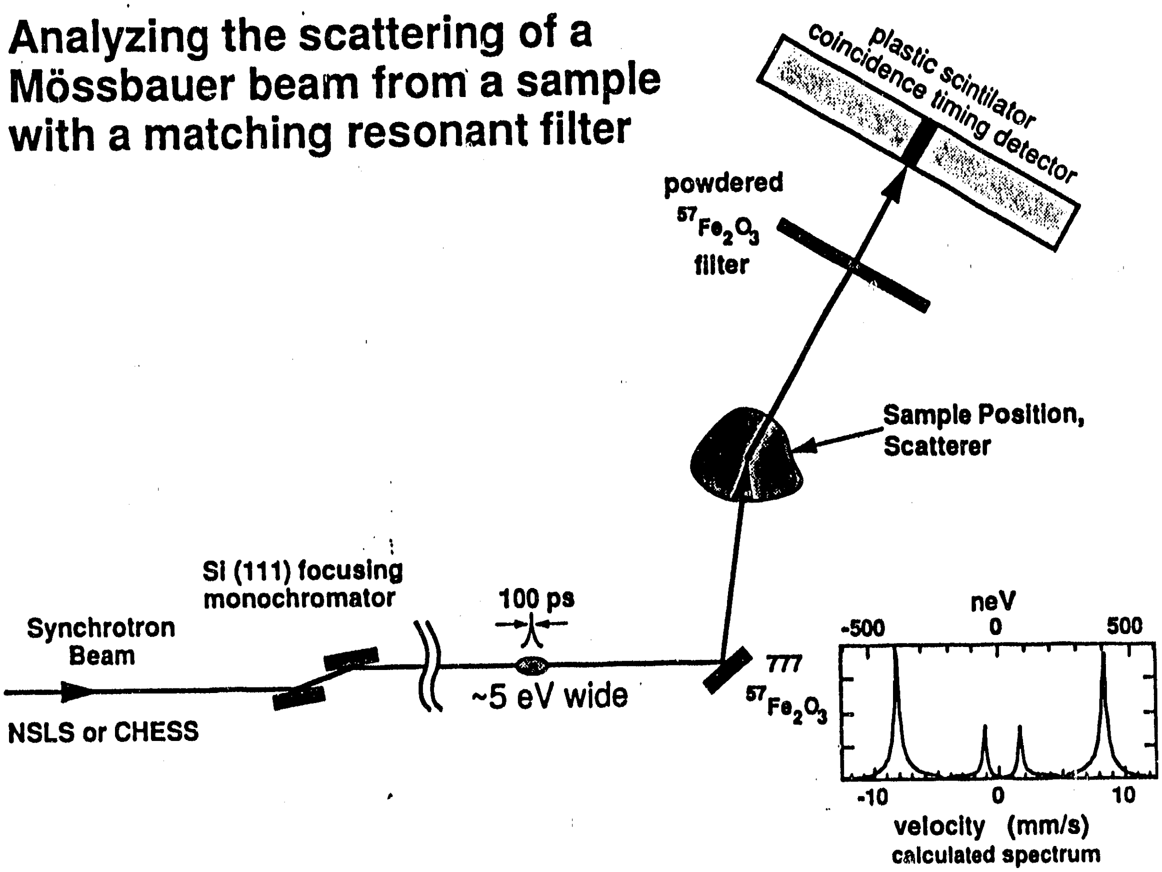

Fig. 1. Schematic view of a time-domain scattering spectroscopy experiment depicting the energy spectrum from a $^{57}Fe_2O_3$ resonant monochromator and analysis of the scattered beam with a resonant filter analyzer.

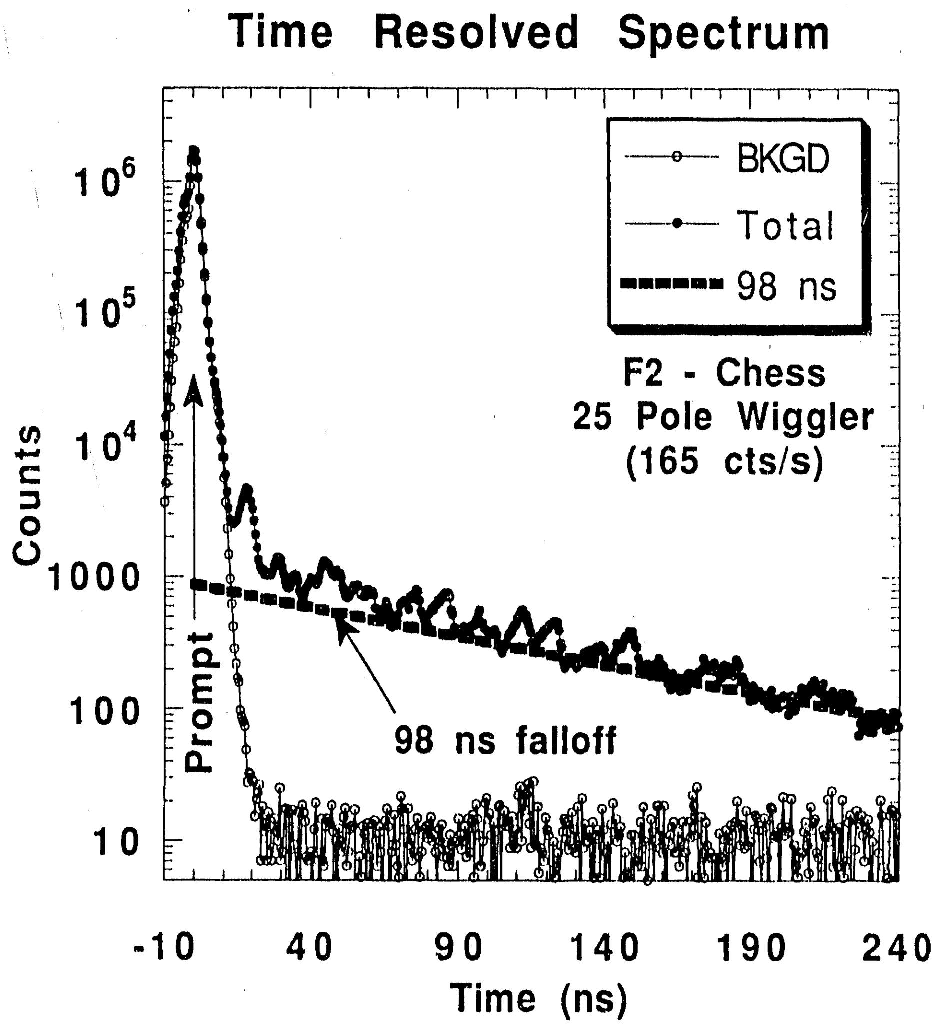

Fig. 2. Delayed time-spectrum of resonant photons from a mosaic $57Fe_2O_3$ resonant monochromator measured on the F2 beam line at CHESS. The background spectrum shows the separation of the nonresonant (prompt) photons from the resonant photons.

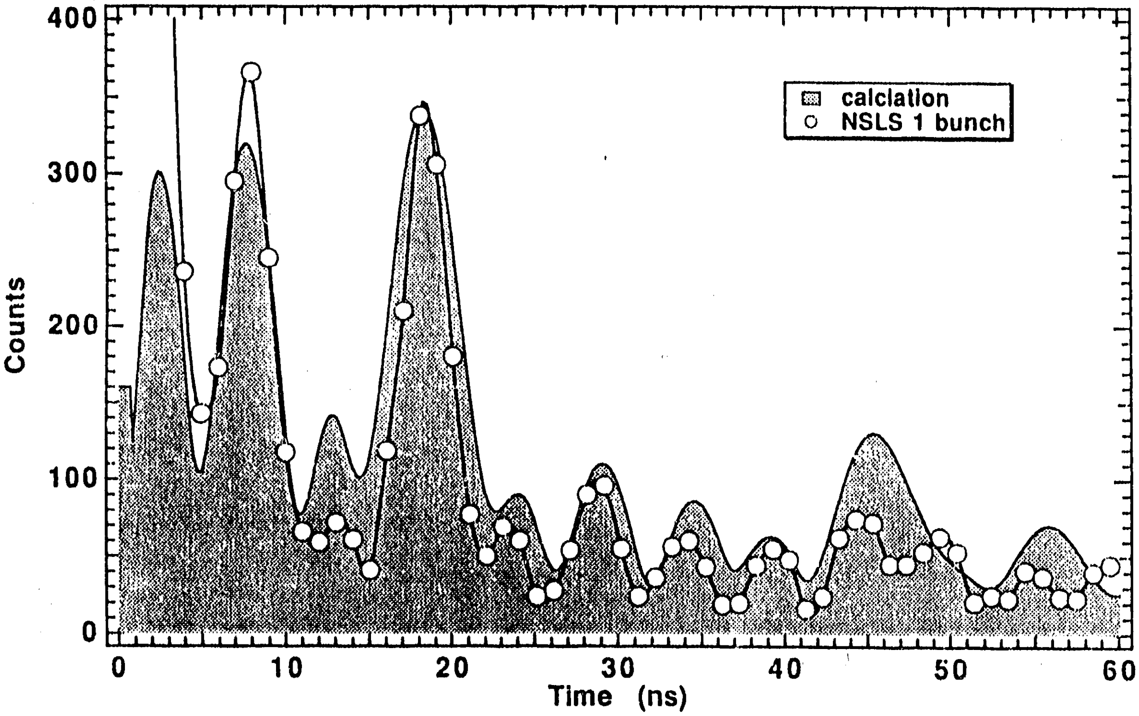

Fig. 3. Delayed time-spectrum of resonant photons after Bragg scattering from the (111) reflection of Ge. The points were measured on the X-14 beam line at NSLS during single bunch operation; the solid line represents dynamical diffraction calculations for $^{57}Fe_2O_3$ scaled to the data.

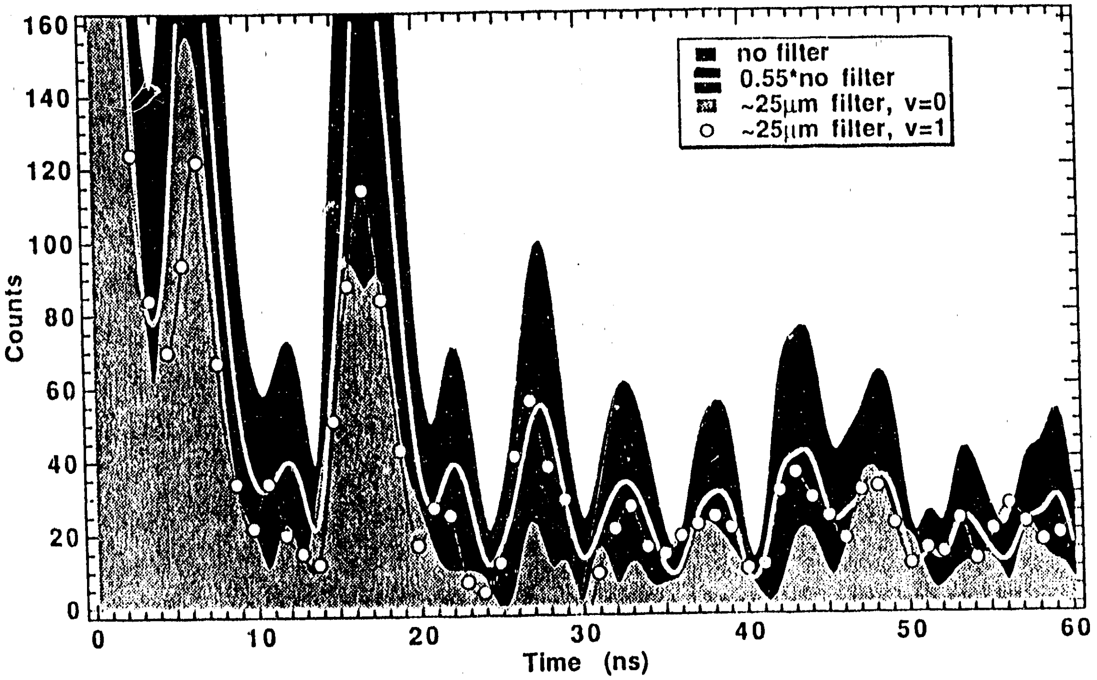

Fig. 4. Delayed time-spectrum of resonant photons after Bragg scattering from the (111) reflection of Ge. (Solid black profile) no filter in scattered beam; (Gray profile) 25 μm resonant filter in the scattered beam; (Open circles) 25 μm resonant filter in the scattered beam and 1mm/s Doppler shift of scattered beam; (Solid white line) no filter profile adjusted for the 55% (nonresonant) transmission of the resonant filter.

TIME-RESOLVED STUDIES OF INTERFACE KINETICS

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1. Introduction

The evolution of short time structural changes that have long range correlations are difficult to study. One such place where these types of studies are important is the interface kinetics of semiconductors. The term kinetics itself implies that the crystal lattice must be measured rapidly with a probe capable of resolving minute changes in the atomic order or correlated perturbations within the lattice. In semiconductor processing the associated time scale of dynamic changes in interface structure is known to be strongly temperature dependent. Structural changes are expected to occur in less than 1 sec. As will be shown in this report certain kinetic interface effects only occur during rapid temperature changes. Thus these effects are truly kinetic - - depending on the time rate of change of temperature rather than the temperature itself.

A set of criteria is established to qualify structural probes that can time-resolve interface kinetics. Probe candidates must have high spatial resolution with the ability to sample large specimen areas. In high quality interfaces kinetic effects will be long range. Furthermore it is not always possible to "cycle" the specimen to make multiple

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[1] Supported in part by NSF grant DMR 8805156.

measurements. In some cases the excitation probe, such as temperature for instance, cannot be cycled and stabilized at high enough rates to time-resolve the kinetics. In reality these requirements make x-ray diffraction the only likely candidate. However pragmatically until now x-ray diffraction experiments have not been done under these extreme requirements of temporal resolution, $\vec{q}$-space resolution and parallel rather than sequential intensity acquisition.

The experiments discussed in this report were done at the NSLS on beam line X16B.[2] Bend magnet lines are modest with respect to their brilliance, however X16B does provide an opportunity to demonstrate the usefulness of dispersive scattering geometry and area detectors.

2. Scattering Geometry

To time-resolve the kinetics of semiconductor interfaces, we use a scattering geometry that measures a range of $\vec{q}$s but does not require translations or rotations of the x-ray beam or sample. The scattering geometry is shown in figure 1.

Using an asymmetrically cut and bent Ge(111) monochromator the incoming x-ray beam is monochromatized and focussed vertically onto the sample.[Lemonnier], [Schildkamp] Using an experimental pixel detector of the CCD[3] variety, a wedge of diffraction can be recorded from the sample. Each pixel of the CCD subtends a small solid angle in the scattering plane (horizontal) making possible the simultaneous recording of diverging scattered x-ray photons. Details of the CCD pixel detector are published elsewhere.[Rodricks] This unique geometry is ideal for time-resolved studies

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[2] NSLS is supported by the DoE, Basic Energy Sciences, Materials and Chemical Sciences under contract No. DE-AC02-76CA0016.

[3] Development partially funded by DoE under Contract W-31-109-Eng-38.

and is facilitated by the high intensity of the synchrotron radiation and parallel data acquisition of the CCD detector.

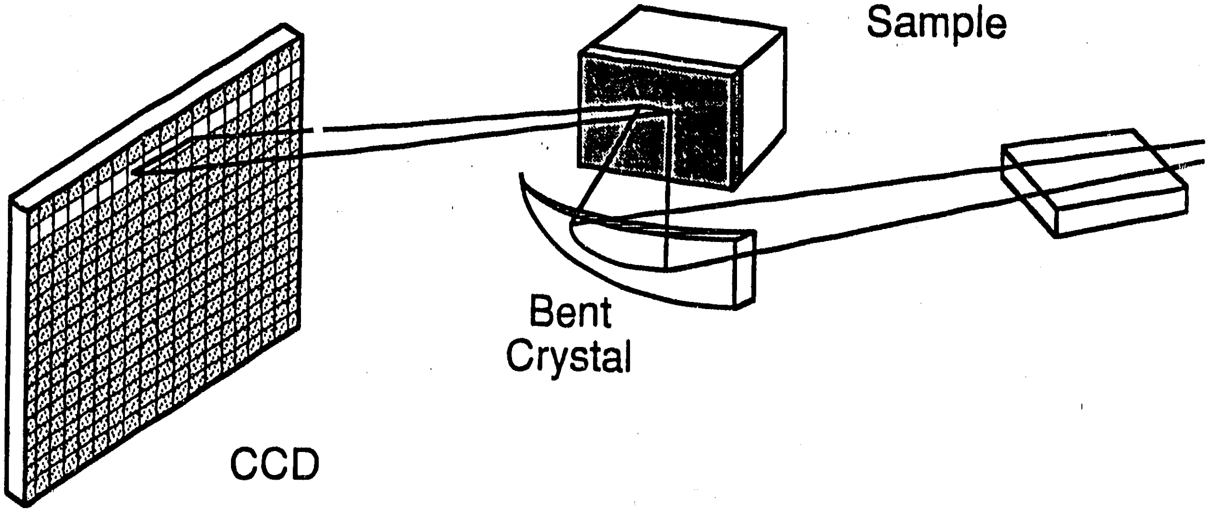

Figure 1. Schematic of beam line X16B at NSLS showing the bent crystal monochromator and the Charge Couple Device detector.

All but one row of the CCD is masked permitting the diffraction pattern to be recorded at this row. The other rows are used as storage in a scheme where the detected intensity in the exposed row is electronically shifted down to the row beneath the mask. Each row is simultaneously shifted down until all rows of the device contains one diffraction pattern.

At this point the first diffraction pattern (in the last row of pixels) is then readout and stored in computer memory. When the rows are retrieved and stacked, an image of the data is formed showing a streak of the diffraction peak moving laterally across the image. The integration time for each row is limited by the speed at which successive rows can be shifted downward and is usually on the order of 3 μsec. However these speeds exceed the integration time needed to acquire data of statistical precision using current synchrotron sources of limited brilliance. New synchrotron radiation facilities utilizing insertion devices such as undulators will improve x-ray photon intensity significantly.[Shenoy] These third generation facilities are the Advanced Photon Source

(APS) at Argonne, the European Synchrotron Radiation Facility (ESRF) at Grenoble and SPring-8 at Tsukaba, Japan.

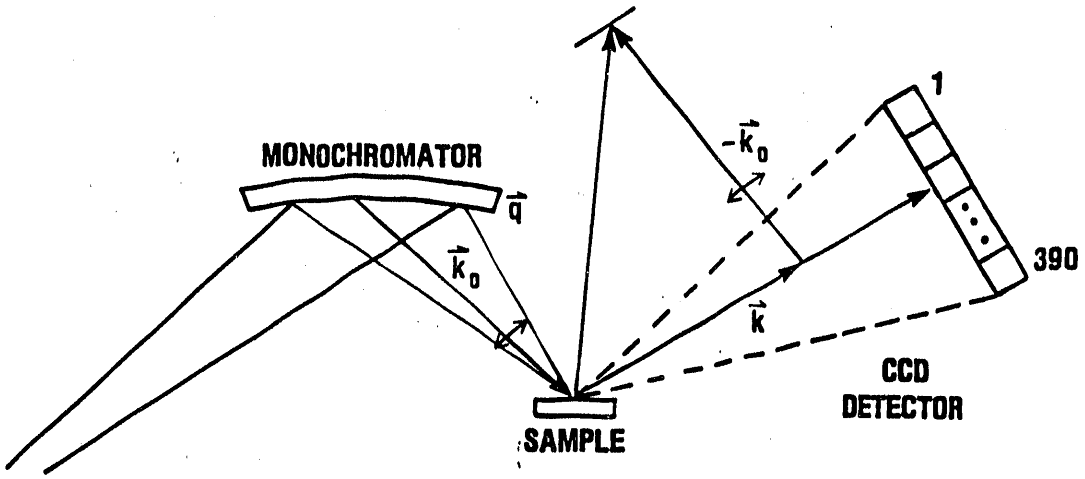

Figure 2. Reciprocal space representation of the scattering geometry.

Figure 2 is a diagram of the scattering geometry in reciprocal space. Incident wave-vectors $\vec{k}_0$ with an angular spread over .1 degrees are incident on the sample. Each $\vec{k}_0$ has an energy bandwidth of 10^{-4}. All of the scattered photons $\vec{k}$ within a range subtended by the CCD detector are collected into individual pixels (390 total) depending on their scattering angle. The momentum transfer $\vec{q}$ is then an arc (approximated by a line) in reciprocal space. The arc length is determined by the angular range of - $\vec{k}_0$ and the thickness of the arc is determined by the energy bandwidth. The intensity collected into a single pixel is then the form factor of the sample integrated over this arc. With 390 pixels per row a "window in reciprocal space" is formed containing 390 separate and independent arcs. Using this large but high spatial resolution view of reciprocal space, the position of diffraction peaks can be followed in real-time.As mentioned above the kinetics of interfaces in semiconductors is of considerable technological interest. Strained-layer epitaxy of thin films on substrates is a large constituent of semiconductor device structures. An interface which is both technologically important and lends itself readily to these types of x-ray measurements is GeSi on Si.[Kasper] A sample of $Ge_{0.2}Si_{0.8}$ was prepared using Si MBE to study the interface structure as a function of rapid temperature changes or rapid thermal anneals (RTA). Many interesting and important time-resolved experiments are in a category where all the data must be collected in "one pass".[Clarke] Rapid thermal processing of materials is prominently within this group of "one shot" measurements. Therefore it is emphasized that using the method above *all the diffraction data is collected in one temperature cycle.*

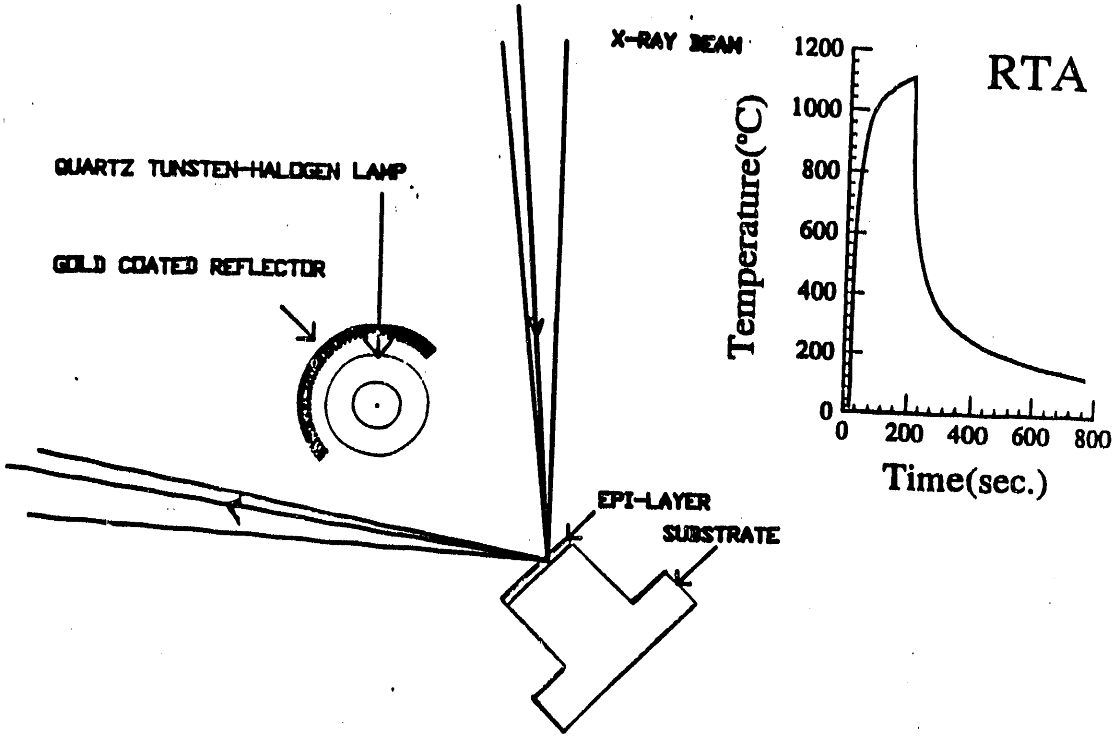

Figure 3. Apparatus for performing x-ray diffraction during Rapid Thermal Annealing (RTA). The temperature profile is shown in the inset.

In figure 3 the experimental set-up is shown in which a 2000 Å $Ge_{0.2}Si_{0.8}$ film on a Si(001) substrate is heated by a quartz-halogen lamp. The temperature-time profile is shown at upper left of figure 3. The Si(001) substrate is "T" shaped to allow for strain free clamping to the sample holder.

3. The Ge $_x$Si$_{(1-x)}$ /Si Interface

In a simplistic view a strained layer can be viewed as a thin film + a single crystal substrate (fig. 4).

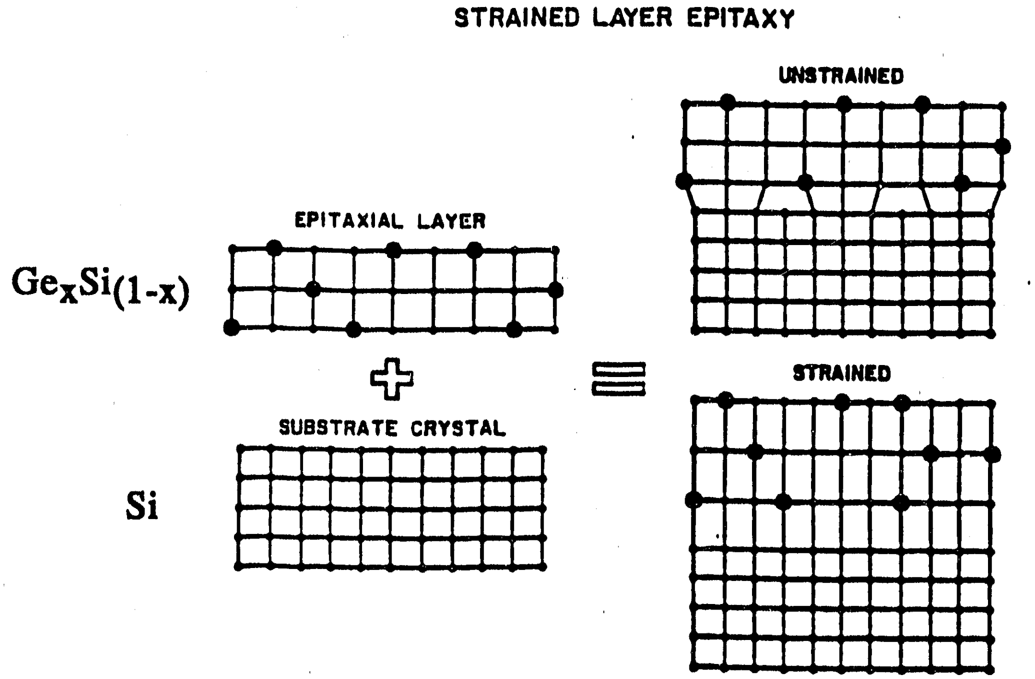

Figure 4. Schematic of strained layer epitaxy in $Ge_xSi_{(1-x)}$.

Since there is a lattice mismatch between the film and the substrate, the issue is how to account for this mismatch. This mismatch can be totally taken up in misfit dislocations (shown top right of fig. 4) or totally in strain (shown lower right of fig. 4). Generally the lattice mismatch is accommodated by a combination of strain and misfit dislocations thus residing at some intermediate state between the top right and bottom right figure. When some part of the mismatch is accommodated by strain a tetragonal distortion is introduced in the $Ge_{0.2}Si_{0.8}$ layer. Since the $Ge_{0.2}Si_{0.8}$ lattice constant is larger than the Si lattice constant resulting in a compressive basal plane strain, the perpendicular lattice constant $b_\perp$ exceeds the in-plane lattice constant $b_{\parallel}$.[Zhdanova]

As the $Ge_{0.2}Si_{0.8}$ film thickness is increased (or the Ge content increased) the lattice strain increases to some critical value causing the film to relax by converting more of the strain into misfit dislocations. The critical thickness for $Ge_xSi_{(1-x)}$ is shown in figure 5.

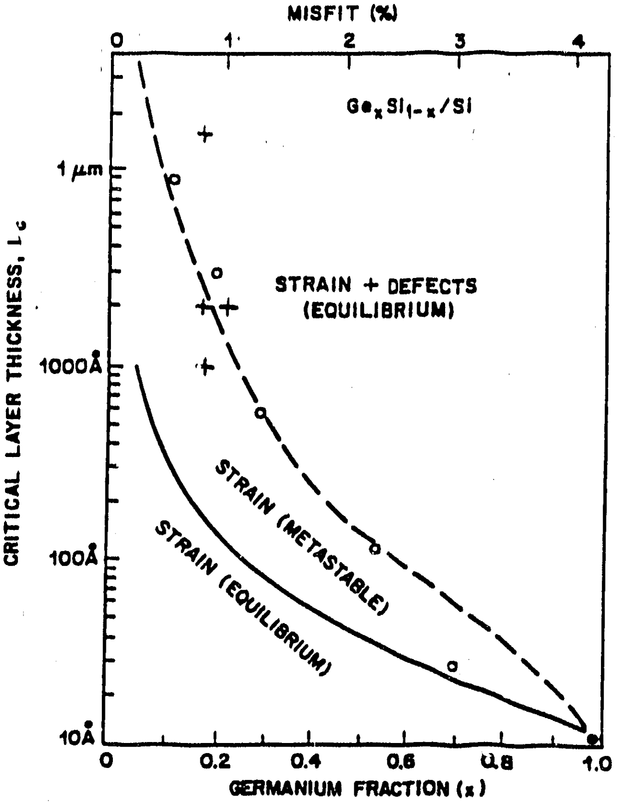

Figure 5. The critical thickness phase space for $Ge_xSi_{(1-x)}$.

The critical thickness is defined as the thickness at which the film is totally relaxed by the introduction of misfit dislocations. Of course whether dislocations can be seen is strongly dependent on the resolution of the probe, making the critical thickness curve placement somewhat arbitrary. Note there are several regions of coexistence between strain and dislocations. The interface kinetics have been studied in samples marked by the + symbols.[Lowe] Here we will report on the 2000 Å samples (marked in fig. 5).

Both samples showed very similar behavior and contain the most interesting kinetic effects observed to date. This could be attributed to being on or near the critical thickness curve.

Under RTA conditions the perpendicular lattice constants of the Si substrate and the $Ge_{0.2}Si_{0.8}$ strained layer (curve a and open circles respectively) is shown in figure 6.

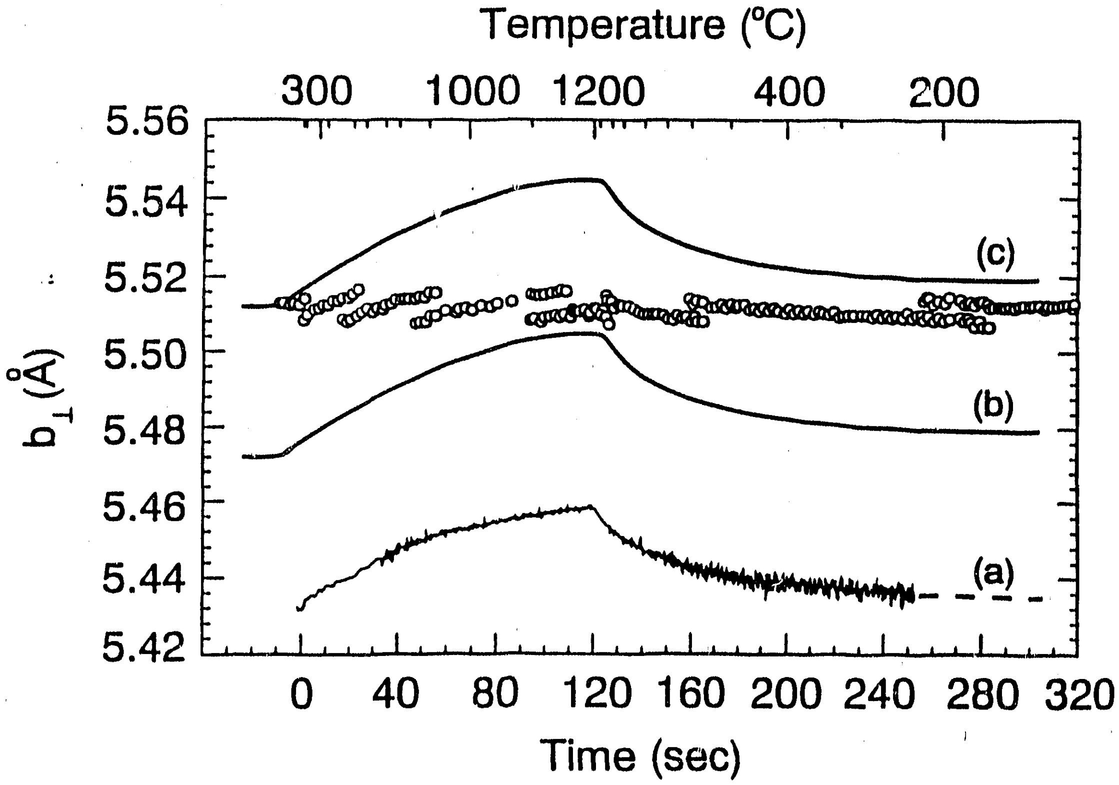

Figure 6. Time-resolved x-ray diffraction data from a $Ge_xSi_{(1-x)}/Si$ strained layer as a function of time-temperature. The time-resolved data for Si is curve 6a and the lattice constant for the $Ge_{0.2}Si_{0.8}$ overlayer is represented by the open circles. The smooth curve 6b is the calculated lattice constant for diamond cubic $Ge_{0.2}Si_{0.8}$ and curve 6c is the calculated lattice constant for pseudomorphic (containing a tetragonal distortion) $Ge_{0.2}Si_{0.8}$.

The smooth curves 6b and 6c are the calculated $b_{\perp}$ for a totally relaxed film and a pseudomorphic film (totally strained film) respectively. In the pseudomorphic case cell volume is conserved at all temperatures leading to the tetragonal distortion driven by thermal expansion. Concentrating attention on the circles there are several prominant features:

i) The thermal expansion is discontinuous and even overlaps in some regions. The discontinuities in $b_\perp$ do not occur for slow or static heating and cooling. Within each there is an overlap of $b_\perp$ which unambiguously results from two types of scattering domains. Therefore the $Ge_{0.2}Si_{0.8}$ film contains two domains distinguished by $b'_\perp$ and $b''_\perp$ for which $b'_\perp > b''_\perp$.

ii) The slope of the discontinuities is reversed in the cooling cycle. In both heating and cooling phases the slope of $b_\perp$ matches the slope of Si. The number of discontinuities are 7 with 5 on heating and 2 on cooling. The average slope of the circles is small indicating that the thermal expansion in the vertical direction does not develop fully as compared with the pseudomorphic case curve 6c.

iii) $b_\perp$ closely approaches the relaxed value at the maximum temperature obtained. At approximately 1200C the lamp is switched off and the film - substrate begins to contract. Initially there is a downward trend in $b_\perp$, along the solid curve 6b towards relaxation. However at this point the $b'_\perp$ domains also exist and a sharp discontinuity in $b_\perp$ is present.

4. A Simple Model of a Kinetic Interface

A complete understanding of the kinetic interface cannot be gained from this data, however there are pieces of the picture that are clear. Using the data from the previous figure and a simple model based on that of Frenkel and Kontorova, a simple model including kinetics can be conjectured.[Frenkel] Figure 7 shows schematically a portion of an interface between a strained film which is commensurate with the underlying substrate.

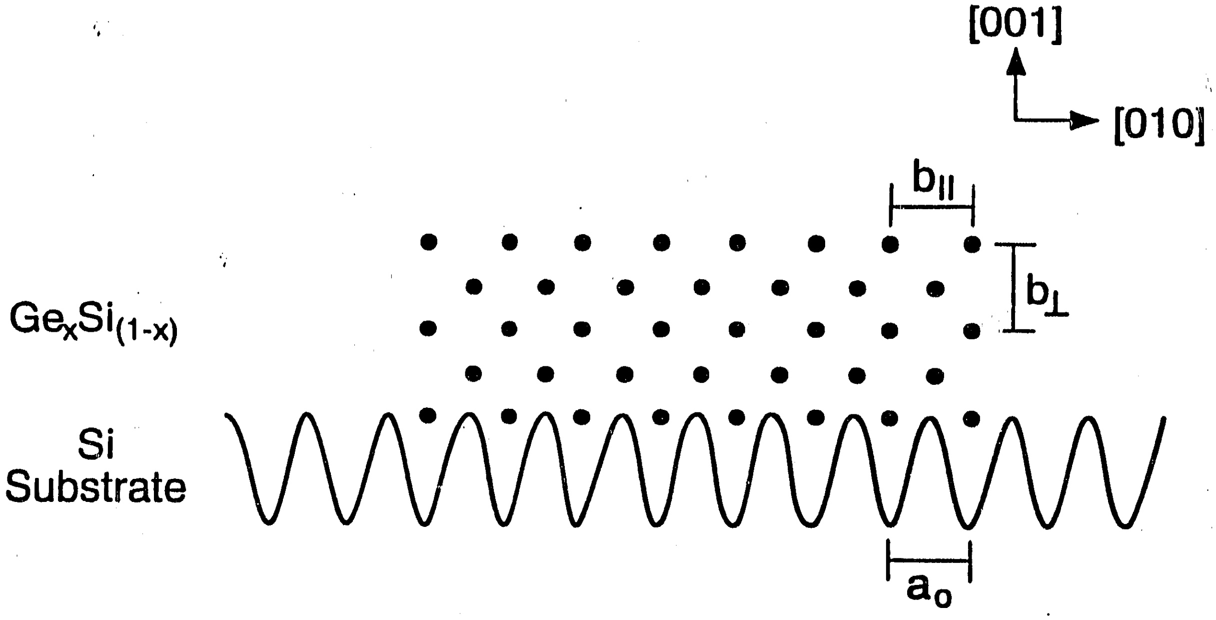

Figure 7. A simple model depicting the Si(001) substrate potential and the $Ge_{0.2}Si_{0.8}$ strained layer at the interface.

The film consist of these commensurate regions separated by discommensurations (misfit dislocations).

During the rapid heating the $Ge_{0.2}Si_{0.8}$ layer expands along the [001] direction (and also in the basal plane) increasing the vertical strain $b_{\perp} - b_{\parallel}$ faster than the basal plane expansion. The $Ge_{0.2}Si_{0.8}$ basal plane is pinned to the Si lattice by the periodic surface potentials shown in figure 7. As $b_{\perp} - b_{\parallel}$ becomes critical, the $Ge_{0.2}Si_{0.8}$ strained layer can reduce its vertical strain as well as continue its expansion in the [001] direction by unpinning and slipping along the interface. Once this occurs the strain along [001] is decreased abruptly. A sharp discontinuity in $b_{\perp}$ accompanied by coexistence clearly indicates that two scattering domains exist concurrently - one with less strain ($b''_{\perp}$) and one with more strain ($b'_{\perp}$), and further that the domains exist for some time interval Δt.

Taking the difference between $b'_\perp$ and $b''_\perp$ and keeping the cell volume constant, the increase of each basal plane axis is 0.05% or 5Å/10,000Å. Therefore the transition of the entire scattering volume (0.5 mm x 0.5 mm x 2000Å) from $b'_\perp$ to $b''_\perp$ occurs at discrete temperatures (T) on a time scale $\Delta t(T)$. Since $b_\perp$ changes by a constant, discrete, amount at each discontinuity, one might surmise that coherent regions of typical size 1µm undergo a sudden expansion by one lattice constant. Evidence for coherent microstructures on this length scale has been seen in plan-view TEM.[Matthews], [Hull]

5. Summary

In summary the time-resolved x-ray diffraction data unambiguously shows the existence of two concurrent (in time) strain states with a time dependence based on the time rate of change of the temperature. We see that the faster the rate of heating (or cooling) the shorter is the coexistence of $b'_\perp$ and $b''_\perp$. The overall time behavior following a power law dependence. We do not yet fully understand the significance of this except to point out that it identifies the transitions as being kinetic in origin, depending on the time derivative of T rather than on T itself. In addition to the new scientific findings we have demonstrated a time-resolved x-ray diffraction method that permits the simultaneous acquisition of complete diffraction patterns. It is also demonstrated that in order to continue progress in time-resolved x-ray diffraction studies, detector research into novel pixel devices such as the CCD must continue.

6. References

Frenkel, Y. I. and Kontorova, T., Zh. Eksp. Teor. Fiz. **8**, 1340 (1938).

Hull, R. and Bean, J. C., J. Vac. Sci. Tech. **A. 4** , 2580 (1989).

Kasper, E. and Bean, J. C., eds. Silicon Molecular Beam Epitaxy, 1 (CRC Press, Boca Raton, FL, 1988).

Lemonnier, M., Fourme, R., Rousseaux, F. and Kahn, R., Nucl. Instrum. Methods, **152,** 173 (1978).

Lowe, W., MacHarrie, R. A., Bean, J. C., Peticolas, L., Clarke, R., Dos Passos, W., Brizard, C., and Rodricks, B., to be published in Phys. Rev. Lett.

Matthews, J. W. and Blakeslee, A. E., J. Cryst. Growth **27**, 118 (1974); **29**, 273 (1975); **32**, 265 (1976).

Rodricks B., Clarke, R., Smither, R. and Fontaine, A., Rev. Sci. Instrum. **60**(8), 2586 (1989).

Schildkamp W., Nucl. Instrum. Methods, **A266,** 479 (1988).

Shenoy, G. K. Viccaro, P. J. and Mills, D. M., Characteristics of the 7-GeV Advanced Photon Source: A Guide for Users, **ANL-88-9** (1988).

Zhdanova, V. V., Kakna, M. G., Samadashvili, T. Z., Izv. Akad. Nauk. Neorg. Mater. **3**, 1263 (1967).

IMAGING OF CORONARY ARTERIES USING SYNCHROTRON RADIATION

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1. Introduction

The monochromaticity, collimation and intensity of x-ray beams produced from a synchrotron source provide unique opportunities for medical imaging. The Argonne APS with its next generation x-ray beam lines may become a center for medical research if some of these applications are realized. One medical application that has already had extensive development first at SSRL and now at NSLS, is imaging of the coronary arteries using a venous injection of contrast agent instead of an arterial injection. This technique will allow research on coronary artery disease that is currently impossible because of the risk of the standard imaging technique.

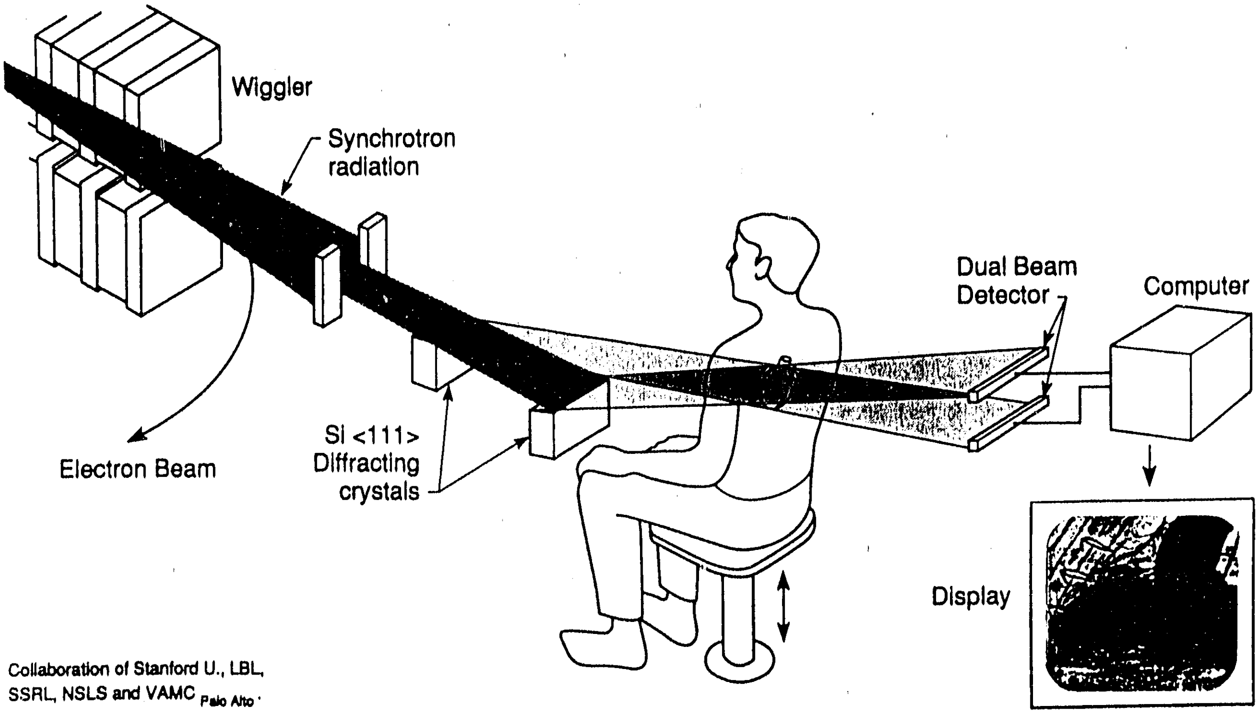

Figure 1. Schematic layout of the imaging system.

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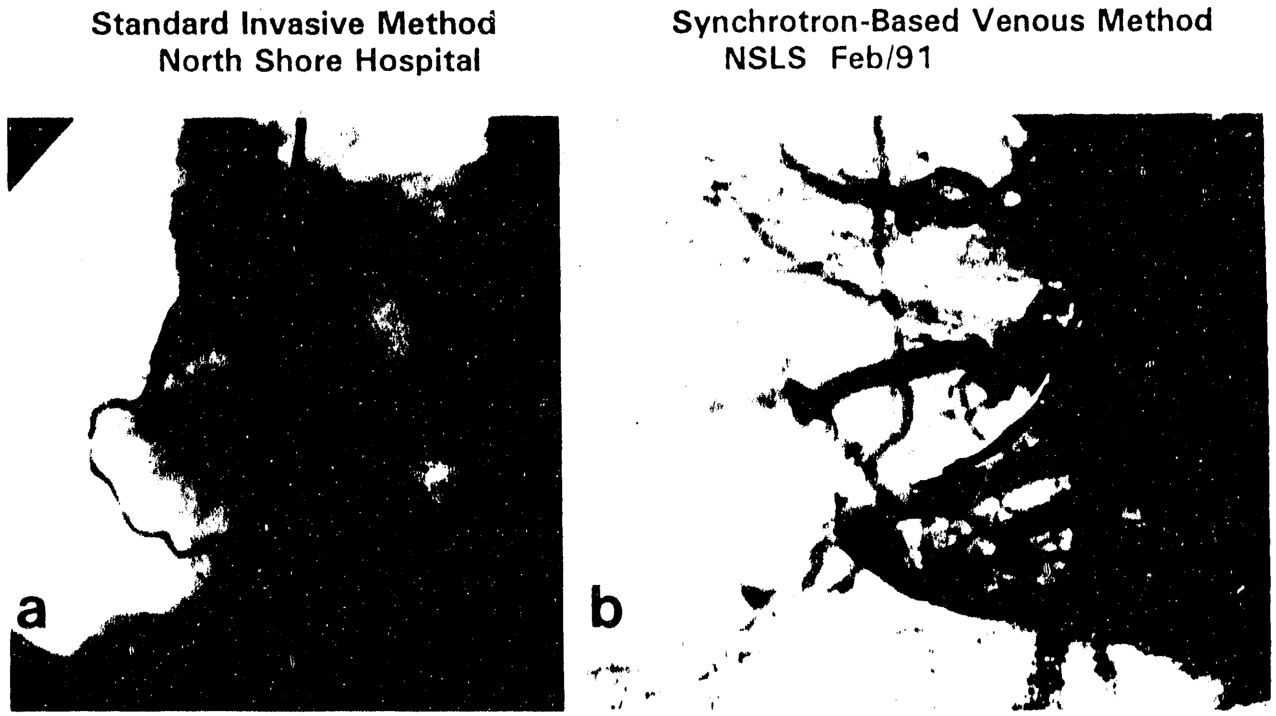
[*] This project was supported by the National Institutes of Health Grant 1 R01 HL 39253-01 and the Department of Energy grant DE-FG03887 ER. Parts of the work reported herein was done at the National Synchrotron Light Source which is supported by the Department of Energy, Office of Basic Energy Sciences under contract No. DE-AC02-76CH00016.

2. Description of System

The imaging procedure is based on using two x-ray beams of slightly different energies to acquire two simultaneous images at either side of the iodine K edge at 33.17 keV. The contrast agent that is used for imaging coronary arteries contains a high concentration of iodine. Since the absorption of x-rays increases by over a factor of 6 at this edge, the logarithmic difference of the two images produces an image which is very sensitive to contrast agent and minimally sensitive to intervening tissue and bone.

At SSRL the parameters for a useful imaging system were established and most of the components for a medical imaging facility were tested.[1,2,3] A schematic layout of the imaging system is shown in Figure 1. A pair of asymmetrically cut Si<111> crystals are used to produce a pair of fan x-ray beams that are 125 mm wide and 0.5 mm high. The beams cross at the patient and then diverge into a 600 element, dual-row Si(Li) detector which has a center-to-center spacing of 0.5 mm. Following an injection of contrast agent, an image is obtained by scanning the patient in a vertically moving chair. The contrast agent is injected using a power injector through a catheter which is inserted in the right arm and advanced to the superior vena cava. For a typical imaging procedure around 35 ml of contrast agent is injected at an injection rate of 12 ml/s. A series of frames is then taken by moving the patient up and down at a chair speed of 12 cm/s. The exposure time for each


Standard Invasive Method
North Shore Hospital

Synchrotron-Based Venous Method
NSLS Feb/91

Figure 2. Images of a 44 year old male patient with a totally occluded right coronary artery (RCA) distal to the acute marginal branch. Figure (a) was taken with the standard angiogram method at North Shore Hospital in Nov/90 and Figure (b) is a 30° left anterior oblique view that was taken with the synchrotron technique at NSLS in Feb/91. The blockage of the RCA artery is clearly seen in both images.

line of the image is 4 msec and therefore a complete 256 line image requires 1.02 sec to acquire. An additional 1 second is taken between frames to reverse the chair motion.

3. Results

In 1989 the experimental equipment was moved from SSRL and installed at NSLS as part of a new dedicated medical imaging suite. The suite is at the end of the X17 4.4 Tesla superconducting wiggler beam line. The first operation of this new facility occurred in October, 1990 when two patients were studied.[4] After improvements to the monochromator crystals, a second run was done in February, 1991 in which another patient was studied. The radiation exposure per frame in the February run was 0.71 rads/frame.

The patient in February was a 44 year old male who had a totally blocked right coronary artery just downstream of the acute marginal branch. He had undergone a standard angiogram in November in 1990 was now taking aspirin and beta blocking drugs. He had not been operated on because the distal RCA is filled by good collateral circulation from the left coronary artery system. Both a lateral view and a 30° left anterior oblique (LAO) view of his heart were taken. In figure 2 one of the images taken in February is shown with the comparison image that was taken with the standard procedure. Figure 2b one of the LAO images taken 11 seconds after injection of 36 ml of Angiovist contrast agent. Three lines of the image were noisy and have been removed from this image by substituting the average of adjacent channels. The patient attended a Broadway musical in the evening after the synchrotron angiogram.

The images obtained so far clearly show that large portions of both the left anterior and the right coronary arteries can be visualized with this method. However, some additional improvement in the image quality is needed before a large group of patients is studied. It is planned to have these improvements completed within a year.

4. Conclusions

Once this imaging facility comes into routine operation we plan to image a group of patients every year for several years to monitor changes in their coronary arteries. This procedure will be useful in evaluating the effectiveness of different drugs or intervention techniques. We also plan to image patients who have had an angioplasty operation. At present in about 30% of these patients the artery closes again within a year - this experiment will try to identify which patients have this problem by imaging them 6-9 months after the operation. These studies, and many others, are presently impossible because of the danger of the invasive arterial catheter procedure. It will be possible to study coronary artery disease more effectively with the availability of this synchrotron based technique. In addition to our program there are angiography programs in Germany, Japan and the U.S.S.R. It is easy to imagine a next-generation facility at the Argonne APS which could serve as a Mid West center for this kind of research.

5. Acknowledgments

This experiment is a collaboration of many scientists and physicians from many institutions. The present research team includes: Ed Rubenstein (Stanford University); Dean Chapman, Richard Garrett, Nick Gmur and Bill Thomlinson (National Synchrotron Light Source); Herbert Zeman (University of Tennessee); John Giacomini and Helen Gordon (Palo Alto Veterans Administration Hospital); and Steve Green, John Morrison, Lawrence Ong, Vellore Padmanabhan, Peter Reiser(North Shore University Hospital); George Brown (Stanford Synchrotron Radiation Laboratory); and Al Thompson (Lawrence Berkeley Laboratory). We have also had the excellent assistance of many members of the staff from SSRL, NSLS and LBL.

6. References

1. E. Rubenstein, R. Hofstadter, H.D. Zeman, A.C. Thompson, J.N. Otis, G.S. Brown, J.C. Giacomini, H.J. Gordon, R.S. Kernoff, D.C. Harrison and W. Thomlinson, Transvenous Coronary Angiography in Humans Using Synchrotron Radiation, *Proc. Nat. Acad. Sci. USA.* 83, 9724 (1986).

2. A.C. Thompson, E. Rubenstein, H.D. Zeman, R.Hofstadter, J.N. Otis, J.C. Giacomini, H.J. Gordon, G.S. Brown, W. Thomlinson and R.S. Kernoff, Coronary Angiography Using Synchrotron Radiation, *Rev. Sci. Instrum.* 60 (1989) 1674.

3. A.C. Thompson, E. Rubenstein, R.S. Kernoff, H. Zeman, N. Gmur, W. Thomlinson, R. Hofstadter, J.C. Giacomini, H.J. Gordon and G.S. Brown, Application of Synchrotron Radiation to the Imaging of Coronary Arteries, *SPIE Proceedings* 1140 (1989) 201.

4. W. Thomlinson, N. Gmur, D. Chapman, R. Garrett, N. Lazarz, J. Morrison, P. Reiser, V. Padmanabhan, L. Ong, S, Green, A. Thompson, H. Zeman, R. Hofstadter, G. Brown, J. Giacomini, H. Gordon and E. Rubenstein, Venous Synchrotron Coronary Angiography, *Lancet* 337, 360 (1991).

ADVANCED PHOTON SOURCE USER ISSUES

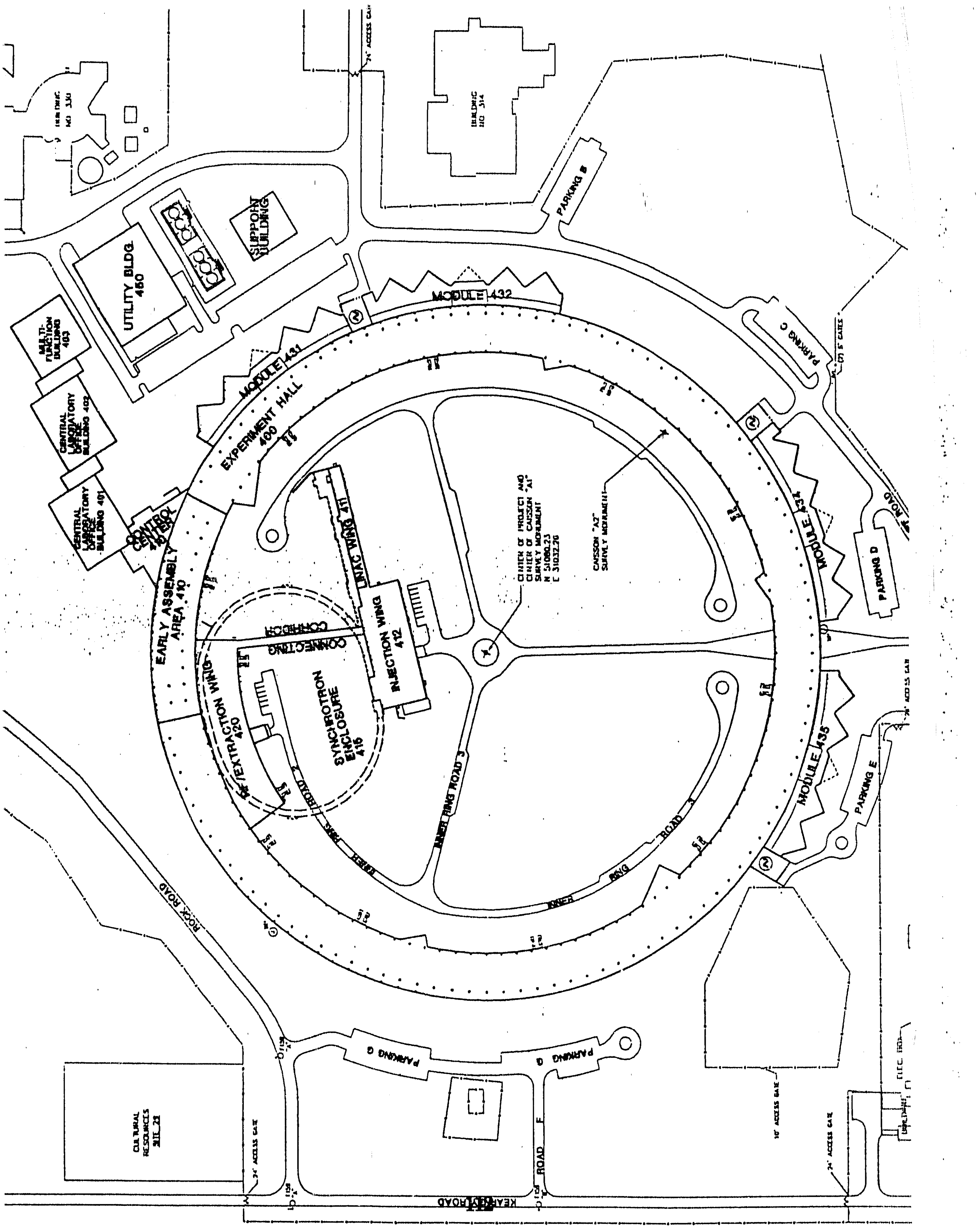
USER PERSPECTIVES

IN

FACILITY PLANNING

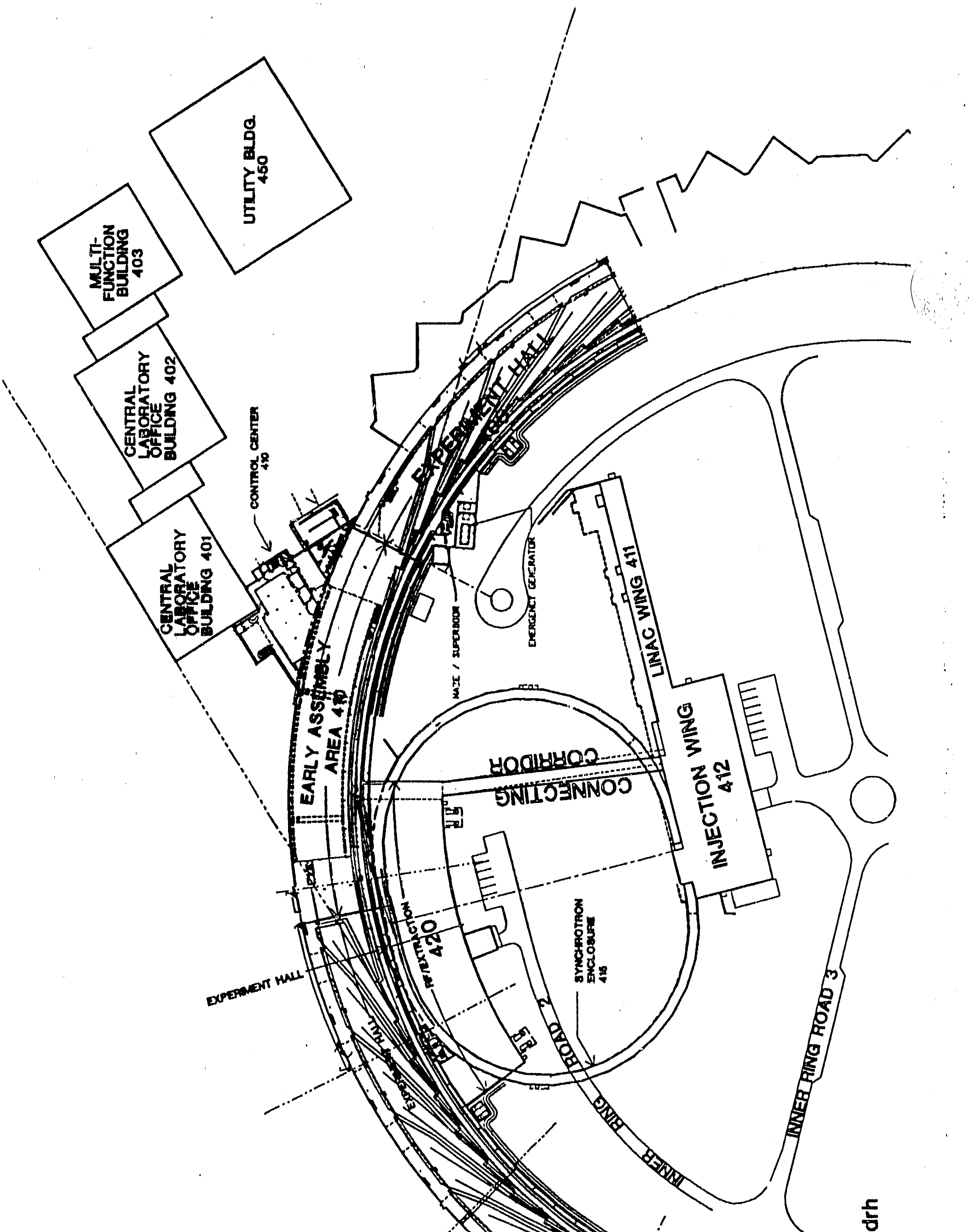
Martin Knott

Argonne National Laboratory


BUILDING NO. 330
BUILDING NO. 314
PARKING B
SUPPORT BUILDING
UTILITY BLDG. 450
MULTI-FUNCTION BUILDING 403
CENTRAL LABORATORY OFFICE BUILDING 402
CENTRAL LABORATORY OFFICE BUILDING 401
CONTROL CENTER 410
MODULE 431
MODULE 432
MODULE 434
MODULE 435
EXPERIMENT HALL 400
EARLY ASSEMBLY AREA 410
LINAC WING 411
INJECTION WING 412
CONNECTING CORRIDOR
SYNCHROTRON ENCLOSURE 415
RF/EXTRACTION WING 420
INNER RING ROAD 2
INNER RING ROAD 3
CENTER OF PROJECT AND CENTER OF CAISSON "A1" SURVEY MONUMENT N 31080.23 E 31032.20
CAISSON "A2" SURVEY MONUMENT
PARKING C
PARKING D
PARKING E
PARKING G
ROAD
ROCK ROAD
ROAD F
KEARNEY ROAD
CULTURAL RESOURCES SITE 23
24' ACCESS GATE
10' ACCESS GATE

EFFECTS OF THE RF RECONFIGURATION

- Consolidation of the 6 Ring Related Sector "Shadows" Leaving 34 Experimental Sectors
    - RF
    - Injection
    - Diagnostics and beam dump
- Relocation of Central Lab/Office Building (CLO)
    - Out of direct beamline trajectories
    - Will make it safe for all workers in spite of future regulations
    - Greater shielding used here
    - Option to add shielding later
- Creation of the "Early Assembly Area" (EAA)
    - 17,500 SF of air conditioned space
    - 15 ton crane coverage
    - 6,000 SF of magnet and girder staging space
    - Later conversion to the "Experiment Assembly Area" (EAA)
    - Later conversion of staging space to labs


UTILITY BLDG. 450
MULTI-FUNCTION BUILDING 403
CENTRAL LABORATORY OFFICE BUILDING 402
CENTRAL LABORATORY OFFICE BUILDING 401
CONTROL CENTER 410
EXPERIMENT HALL
EARLY ASSEMBLY AREA 410
MAZE / SUPERDOOR
EMERGENCY GENERATOR
LINAC WING 411
CONNECTING CORRIDOR
INJECTION WING 412
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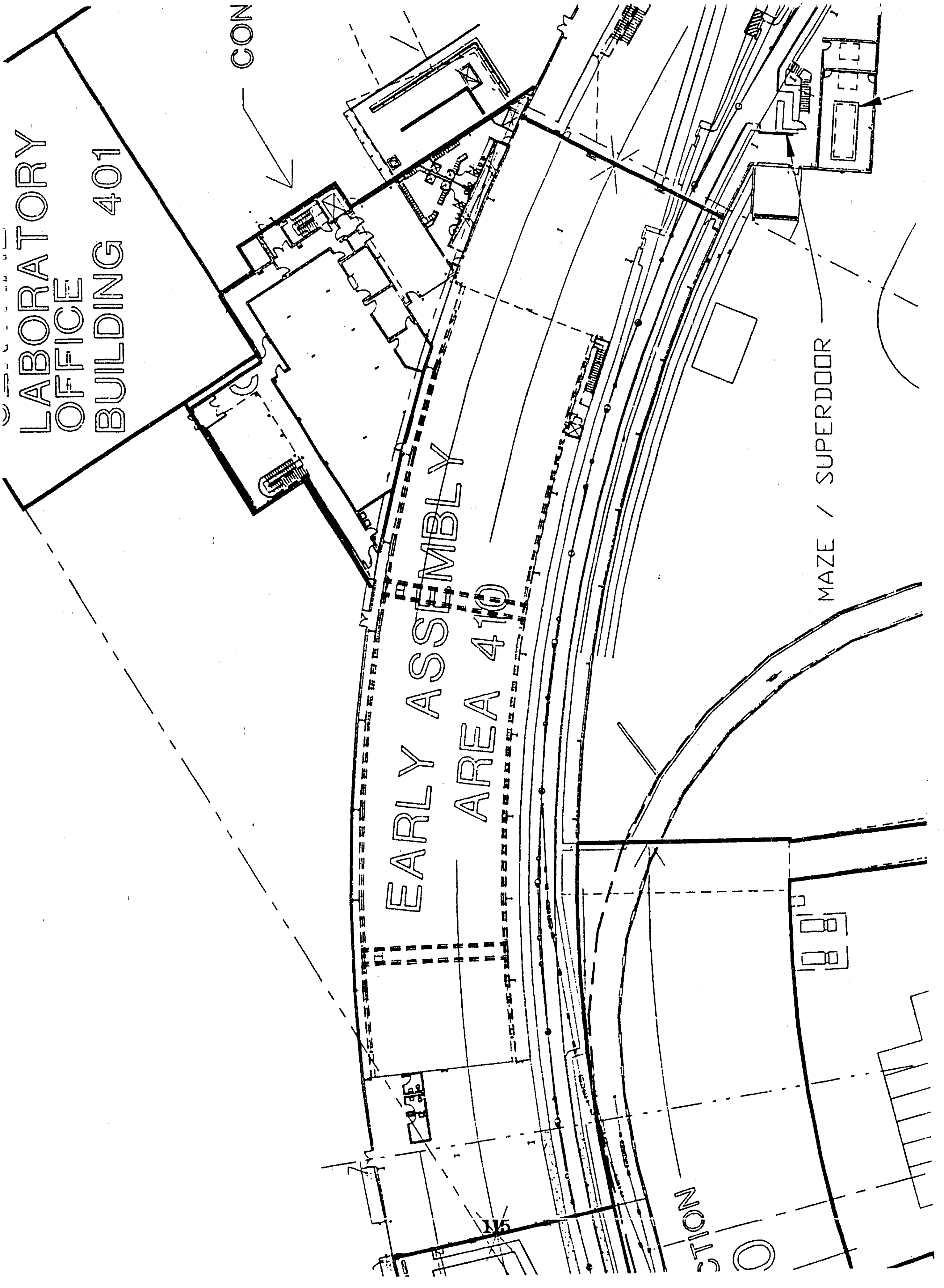
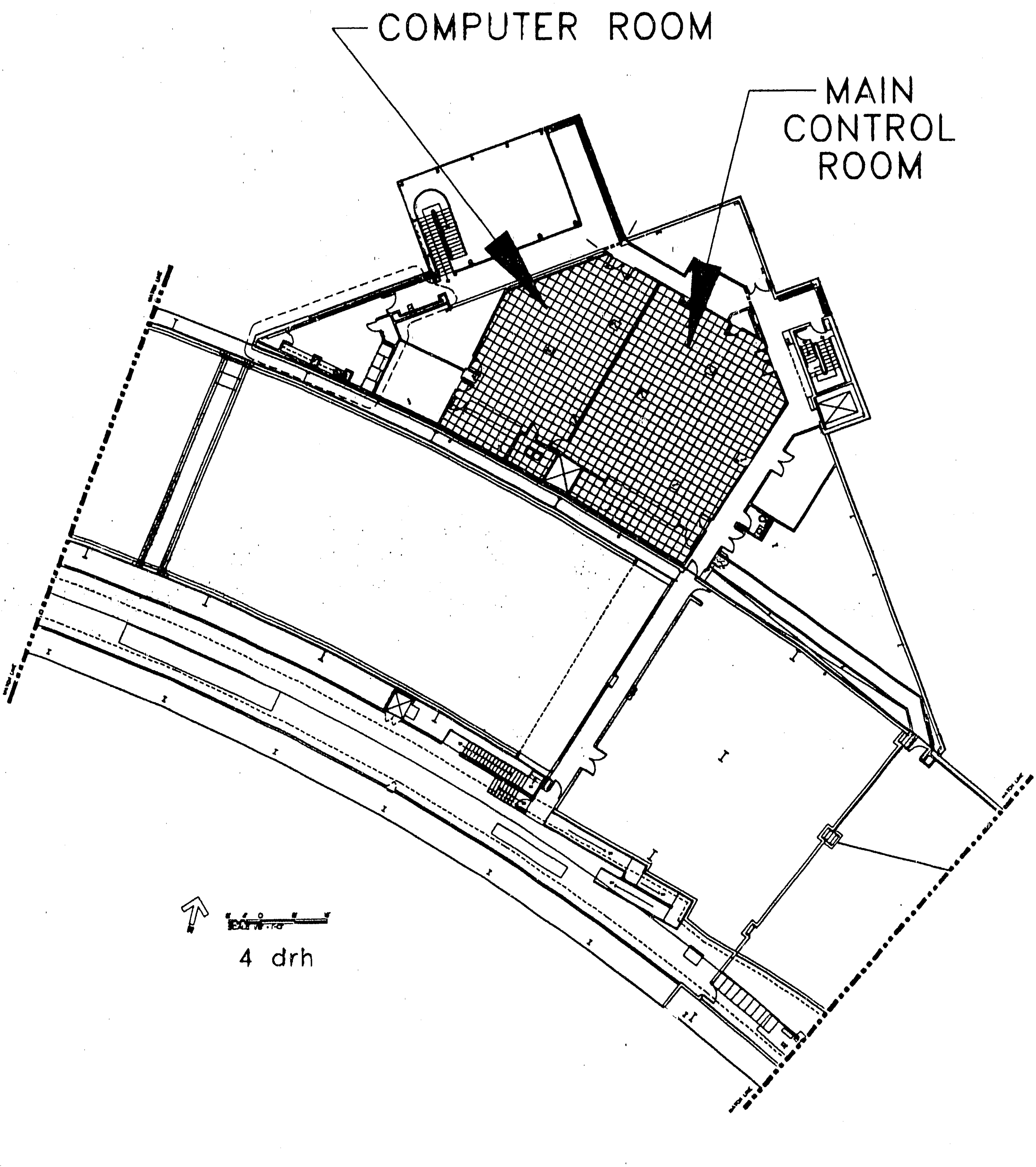
EXPERIMENT HALL
INNER RING ROAD 2
INNER RING ROAD 3
3 drh


LABORATORY OFFICE BUILDING 401
CON
EARLY ASSEMBLY AREA 410
MAZE / SUPERDOOR
TION

EFFECTS OF THE RF RECONFIGURATION (CONT'D)

Creation of the Control Center

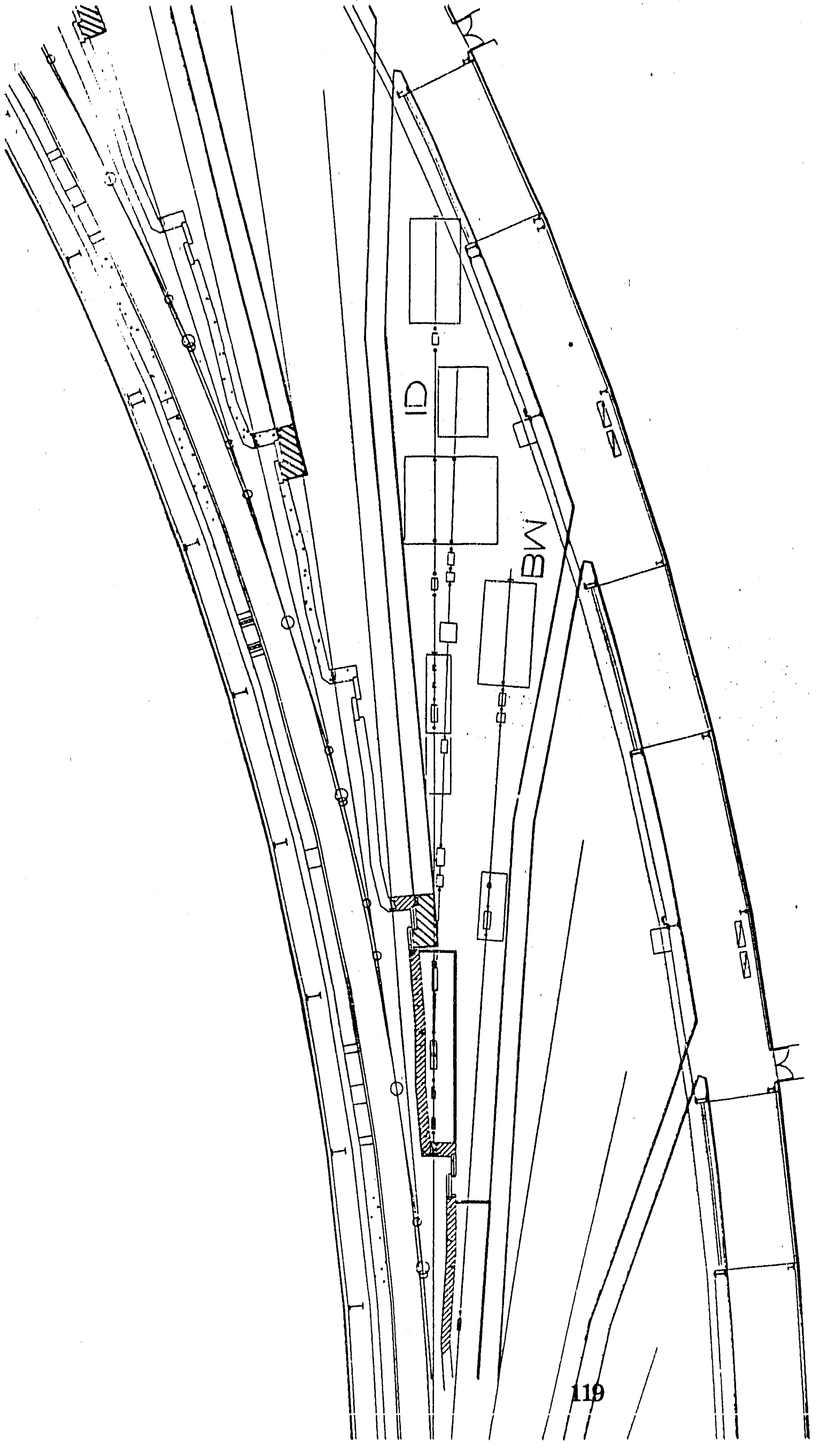
- APS main control room (MCR)
  - Adjacent to CLO "first floor"
  - Convenient to APS technical areas
- APS computer room
- Machine shop on ground floor
  - Adjacent to EAA and experiment floor
  - Adjacent to CLO service level for possible expansion
- CLO design essentially unchanged with final details to be determined later
  - Will house the APS technical staff
  - Library
  - User relations offices
  - Stock room
- Multi-function meeting building unchanged
  - Maximum seating is 600
  - Many smaller configurations


COMPUTER ROOM
MAIN CONTROL ROOM
4 drh

EXPERIMENT HALL

Sequence of Beamline Devices

- Insertion devices and control cabinets
- Frontends and control cabinets
- Frontend-access doors
- Frontend enclosure (FOE)
    - Tight spacing requires special design
    - Beamline-to-wall space starts at 20 cm and increases to 50 cm
- Electrical power available for beamlines
    - Clean power - 25 KVA
    - Utility power - 36 KVA
- Experimental stations


ID
BW

EXPERIMENT HALL (CONT'D)

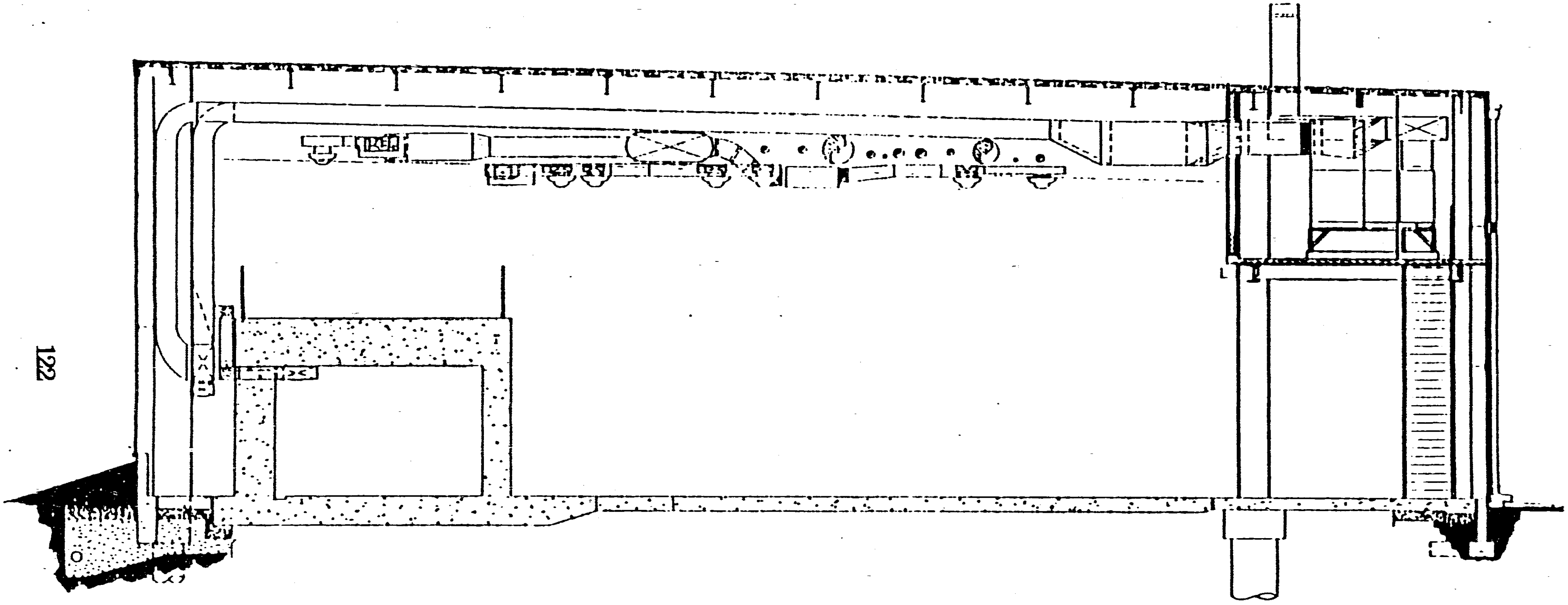
Sequence of Beamline Devices

- Aisle end supplies remaining utilities
    - Process water at 90 F
    - Chilled water at 40 F must use local exchangers and dionizers if needed
    - Electrical power
    - Telephone service (3 lines/sector)
    - Computer network
    - Cable tray route to labs, offices
- Aisle / mezzanine area (12 feet wide)

EXPERIMENT HALL

Cross Section

- Storage ring shield
    - 56 cm heavy concrete wall
      Expected steady state dose is 0.5 mr/hour at the wall surface
    - Same equivalent door shield
    - Storage ring, ID, and frontend equipment racks on top
    - Beam and survey holes in ratchet face (80 cm heavy concrete)
- All ducting, piping, lighting, etc. is above 20 feet



EXPERIMENT HALL FEATURES (CONT'D)

- Outer aisle space - 12 feet clear
- Mezzanine space above aisle (900 SF per sector)
  - 2/3 use for HVAC equipment
  - 1/3 available for user equipment which is noisy or vibration-prone
  - Stairway access at each sector
  - No handicapped access
- Lighting is metal halide for correct color
- Much of the above was developed with the help of the User Organization's Special Committee on APS Conventional Facilities under Walt Trela

EXPERIMENT HALL VIBRATION ABATEMENT

Acentech Study

- ANL site measurements and modeling used to estimate the effects of soil and normal ANL vibration sources
- Experiment floor is isolated from aisle floor by flexible expansion joints
- EAA area floor is isolated from the hall in the same way
- Utility building
    - Located at a maximum practical distance from the hall (twice the distance recommended)
    - Rotating equipment used
    - Vibration isolation mounts used
    - Similar to treatment in semiconductor industry

EXPERIMENT HALL VIBRATION ABATEMENT (CONT'D)

- HVAC equipment in mezzanine
    - Vibration characteristics used in equipment selection
    - Vibration inhibiting mounts used
- Independent support for experiment floor and building structure
    - Floor rests on clay and gravel base which dampens vibration transmission
    - Building supported on caissons resting 20-40 feet below surface depending on soil strength
    - Isolates the effects of wind and solar heating of structure
- Studies indicate that the largest expected sources will be the experimental equipment
    - Equipment will be tested and rated before acceptance on floor

EXPERIMENT HALL NOISE ABATEMENT

Acentech Inc. Study

- Three major sources of noise:
    - HVAC equipment in mezzanine
    - Air ducts and distribution system
    - Experimental equipment

- Treatments to these three:
    - Mezzanine equipment:
        Concrete floor
        Soundproof wall on hall side

    - Air ducts and distribution system:
        Sound attenuation duct sections
        Internally lined ducts

    - Experimental equipment:
        NSLS sound survey use for database
        Recommended equipment should be used
        Up to users to conform

EXPERIMENT HALL NOISE ABATEMENT (CONT'D)

- Treatment to hall:
  - Studies show that between 10 and 30% of all interior surfaces should be covered with sound treatment material
- Results indicate that a rating of NC-50 may be achieved, depending on the contribution from user equipment
  - NSLS level measured at NC-55, a level five orders of magnitude greater

EXPERIMENT HALL

TEMPERATURE CONTROL

- Temperature is to be maintained at 72 +/- 2 F year round

- Six temperature-control zones in each sector

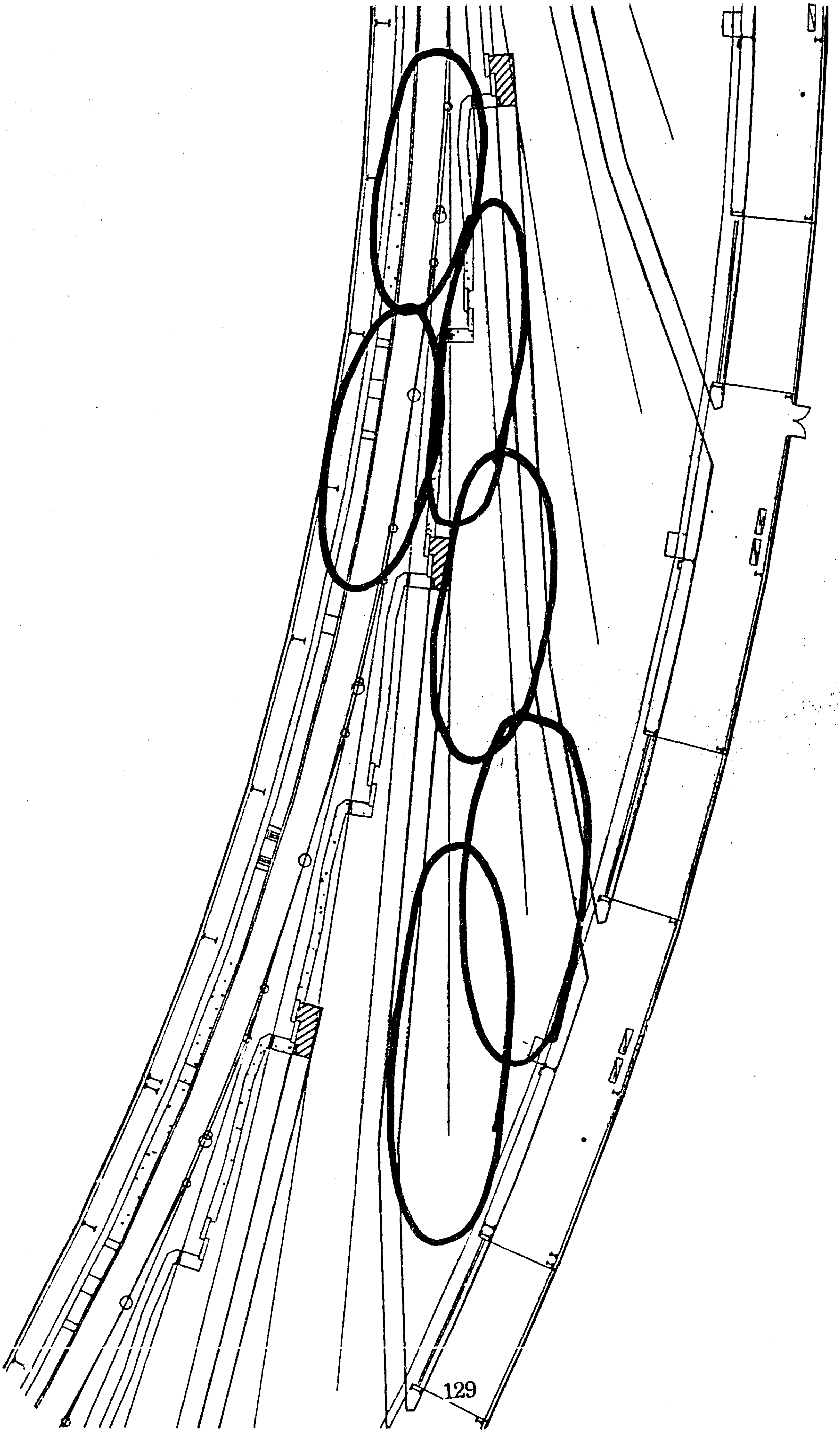
    - Two over the storage ring and FOE area
    - Four over the pair of beamlines

- Sensors are pendant-hung with final location chosen after beamline hutches and heat sources are located

- Several additional duct taps can be made

    - To serve specific needs with direct ducting
    - To provide more capacity to particular sector regions by adding diffusers

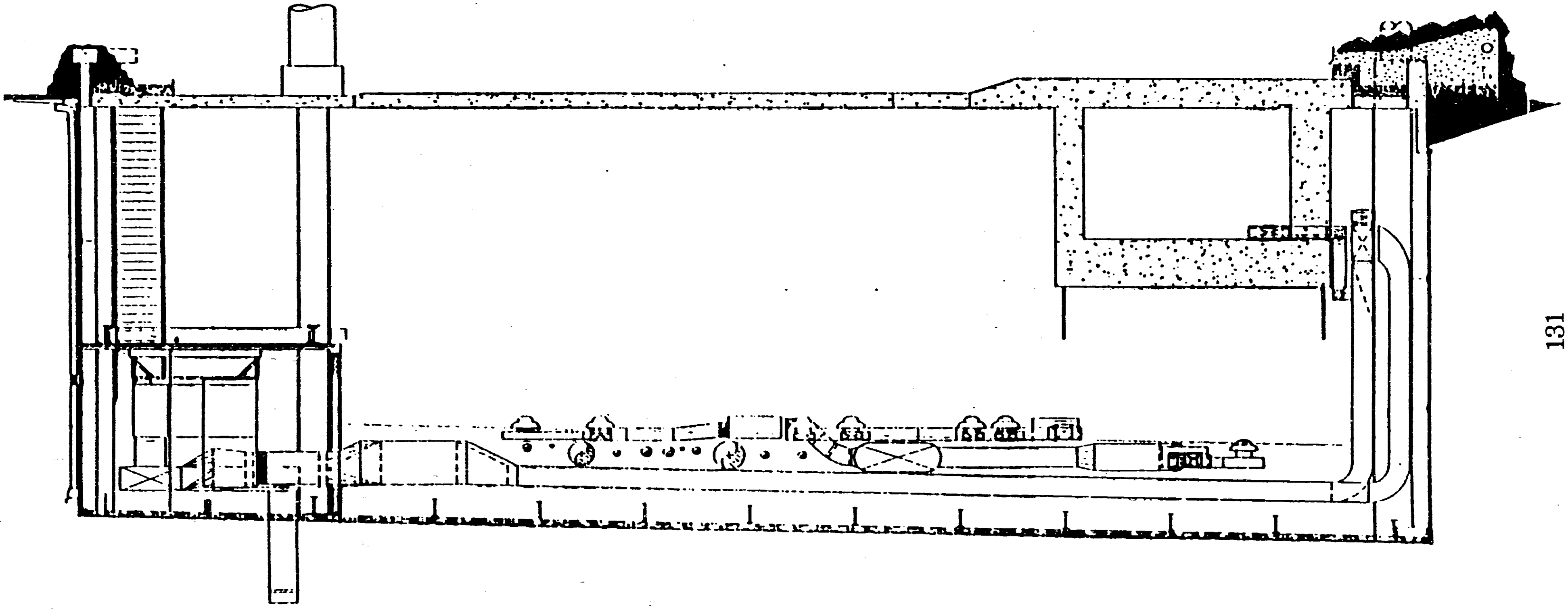
- Dedicated experimental station exhaust can be used to carry away heat



EXPERIMENT HALL

FLOOR MOTIONS

- Settlement-related:
  - 90% of all settlement will be complete after the first year
  - 30-40 mils of differential settlement estimated for 1995
- Concrete cure-related shrinkage:
  - Multiple pours and small final pour regions will be used
  - 90% occurs during first year
  - Pouring will begin in April of 1992 shrinkage should be undetectable by 1995
- Temperature-related changes:
  - Hall is temperature-controlled
  - Floor is protected from outside conditions at the edge
  - Floor is in contact with a substantial heat sink
  - Even a long-term loss of HVAC can be recovered with stress buildup and micro-cracks (such power loss is very unusual in this area)



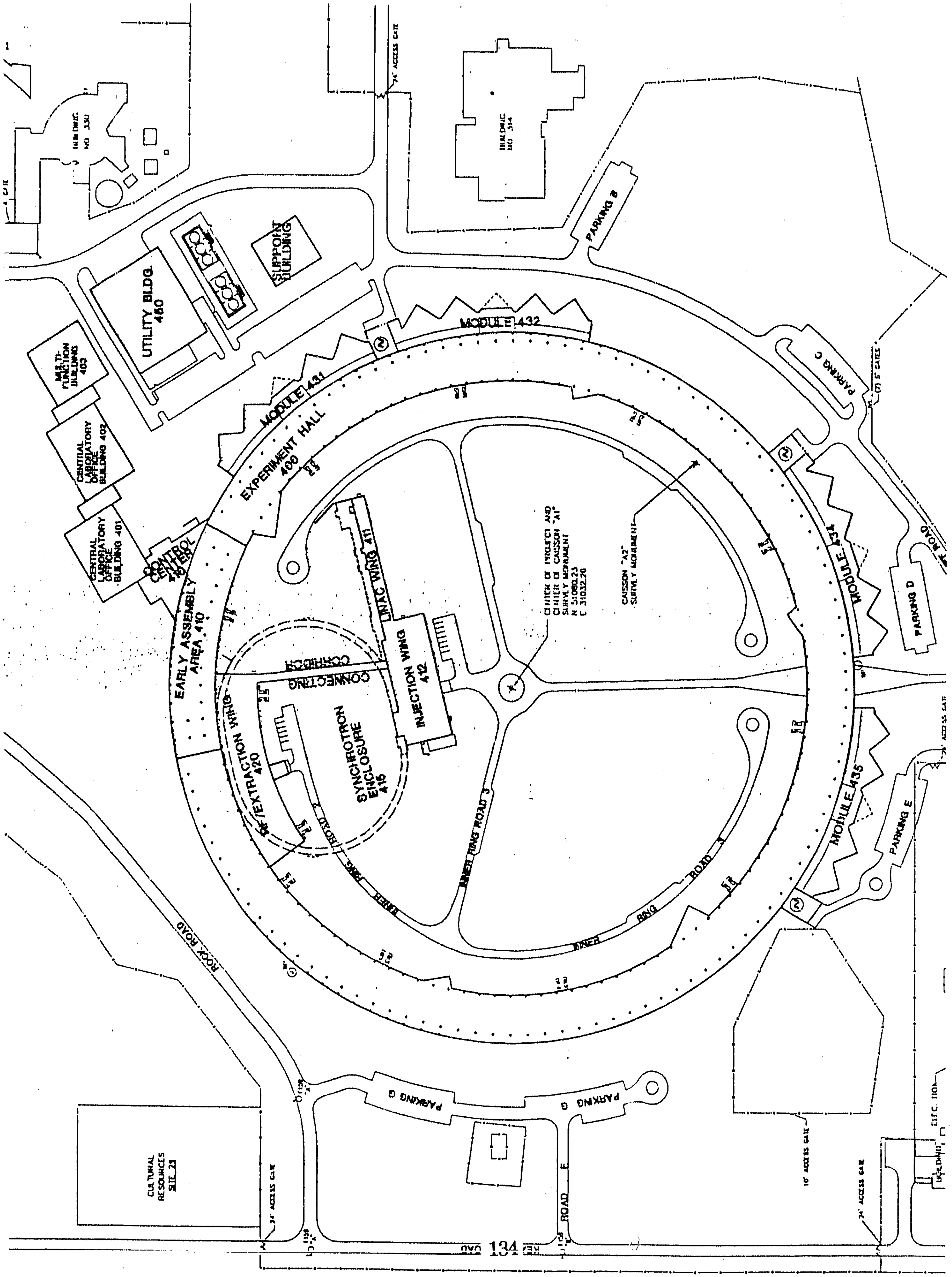
EXPERIMENT HALL (CONT'D)

Floor Motions

- Study underway now to verify the use of continuous reinforcement construction
    - No expansion joints to concentrate floor motions
    - Expansion joints only at long edges to help isolate vibrations

LAB / OFFICE MODULES (LOM)

- Four to be built and fitted out during initial construction phase
    - Chosen locations will allow gaps for staging
    - Future modules can be larger if needed
- Sixteen sectors can be accommodated
- Truck air-lock to maintain temperature and cleanliness
- Personnel entry to LOM and hall to be concentrated here under card-key control
- Both open and full partition offices possible
- Office environment hallway to entire LOM


BUILDING NO. 330
BUILDING NO. 314
24" ACCESS GATE
PARKING B
PARKING C
(2) 5' GATES
PARKING D
PARKING E
PARKING G
PARKING G
SUPPORT BUILDING
UTILITY BLDG. 450
MULTI-FUNCTION BUILDING 403
CENTRAL LABORATORY OFFICE BUILDING 402
CENTRAL LABORATORY OFFICE BUILDING 401
CONTROL CENTER
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MODULE 432
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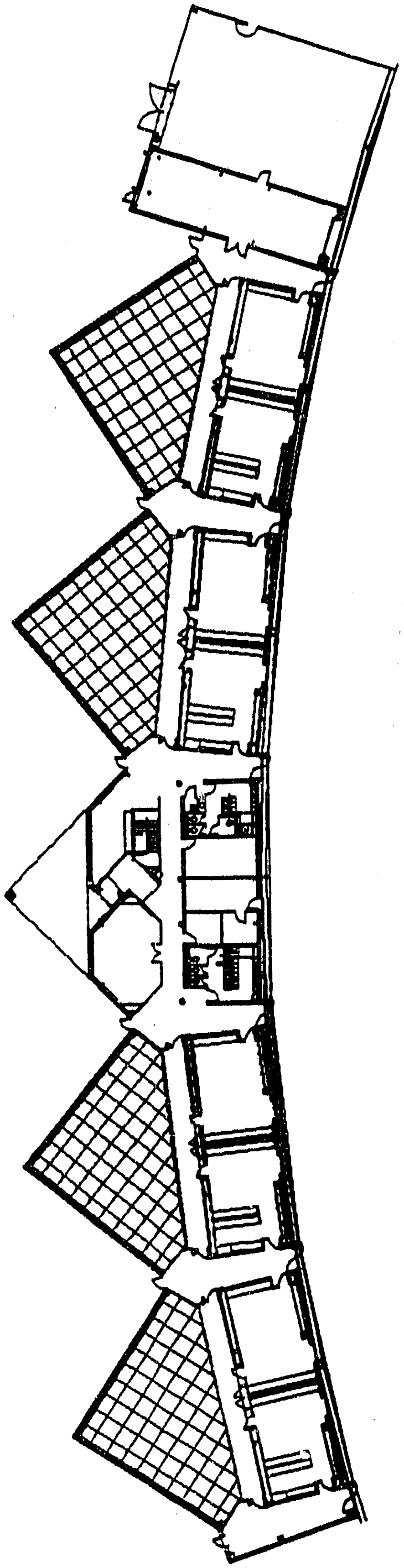
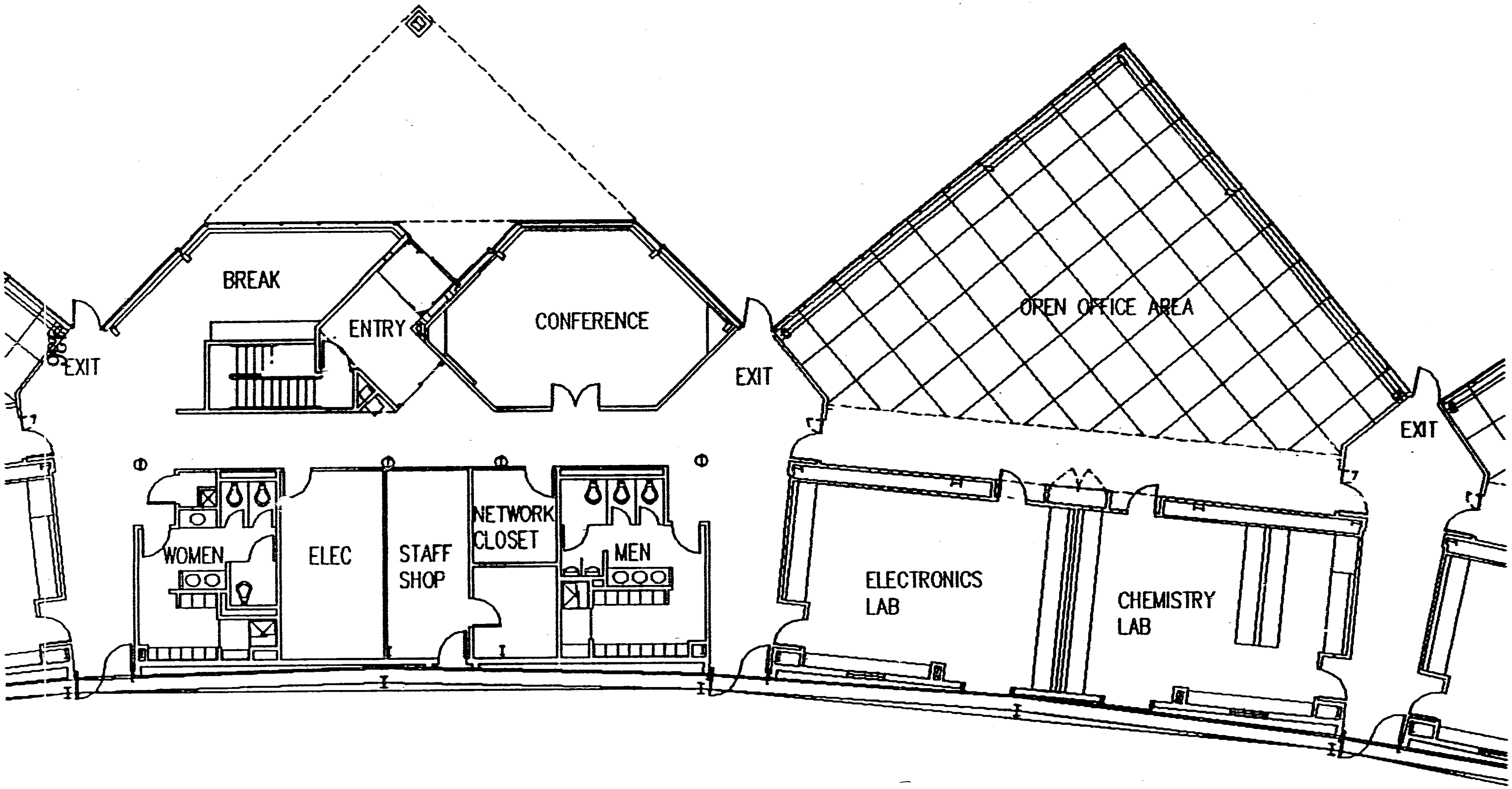
SYNCHROTRON ENCLOSURE 415
CONNECTING CORRIDOR
INJECTION WING 412
LINAC WING 411
INNER RING ROAD 2
INNER RING ROAD 3
INNER RING ROAD 3
CENTER OF PROJECT AND
CENTER OF CAISSON "A1"
SURVEY MONUMENT
N 31080.23
E 31032.70
CAISSON "A2"
SURVEY MONUMENT
ROCK ROAD
ROAD E
CULTURAL RESOURCES SITE 23
24" ACCESS GATE
10' ACCESS GATE
24" ACCESS GATE
24" ACCESS GATE
E.T.C. 110A




BREAK
ENTRY
CONFERENCE
EXIT
OPEN OFFICE AREA
EXIT
EXIT
WOMEN
ELEC
STAFF SHOP
NETWORK CLOSET
MEN
ELECTRONICS LAB
CHEMISTRY LAB

LAB / OFFICE MODULES (LOM)

(CONT'D)

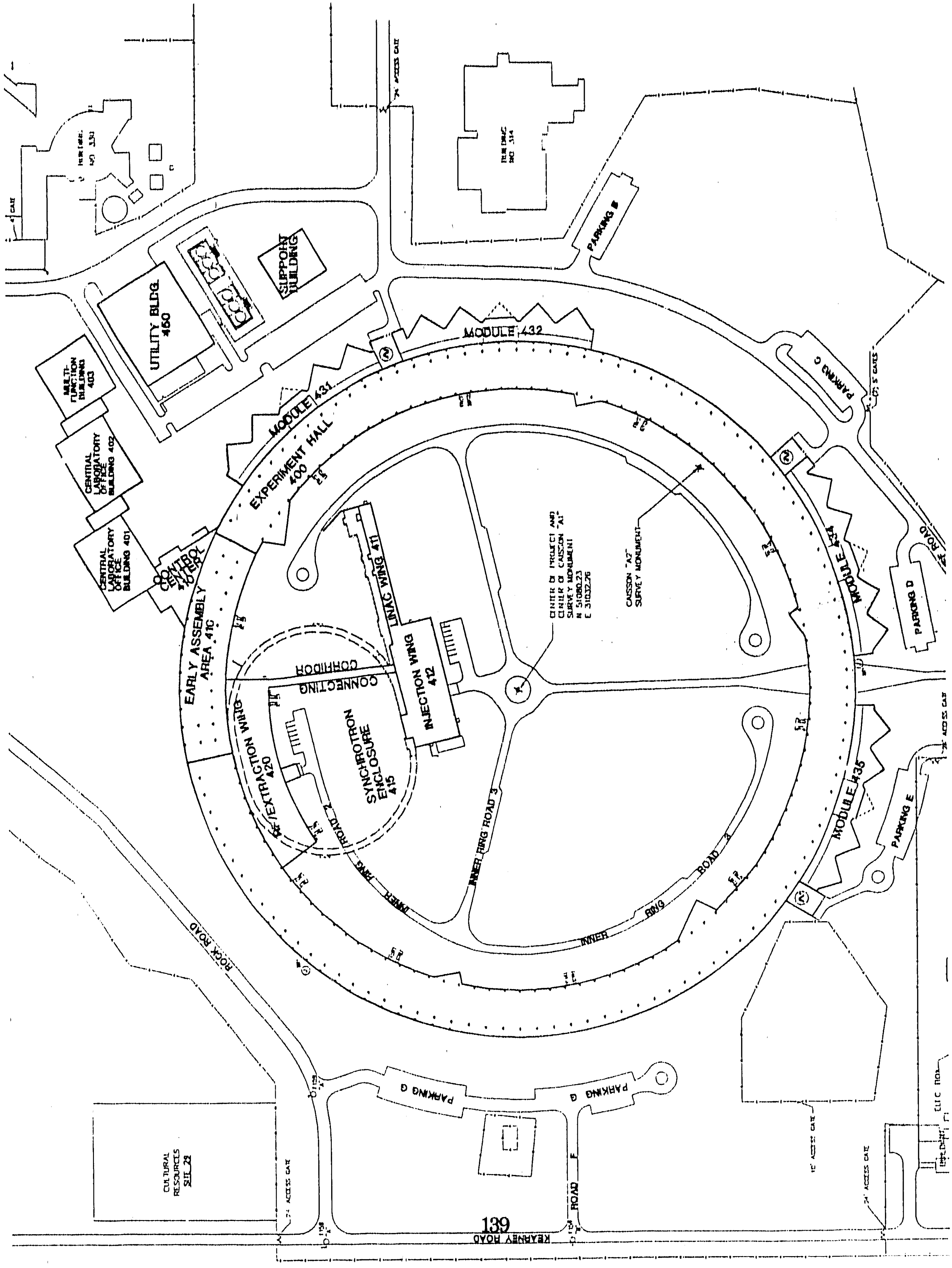
- Other common facilities
  - Work-break area
  - Conference room
  - Staff shop
  - Rest rooms with lockers
  - Secure computer network bridge closet

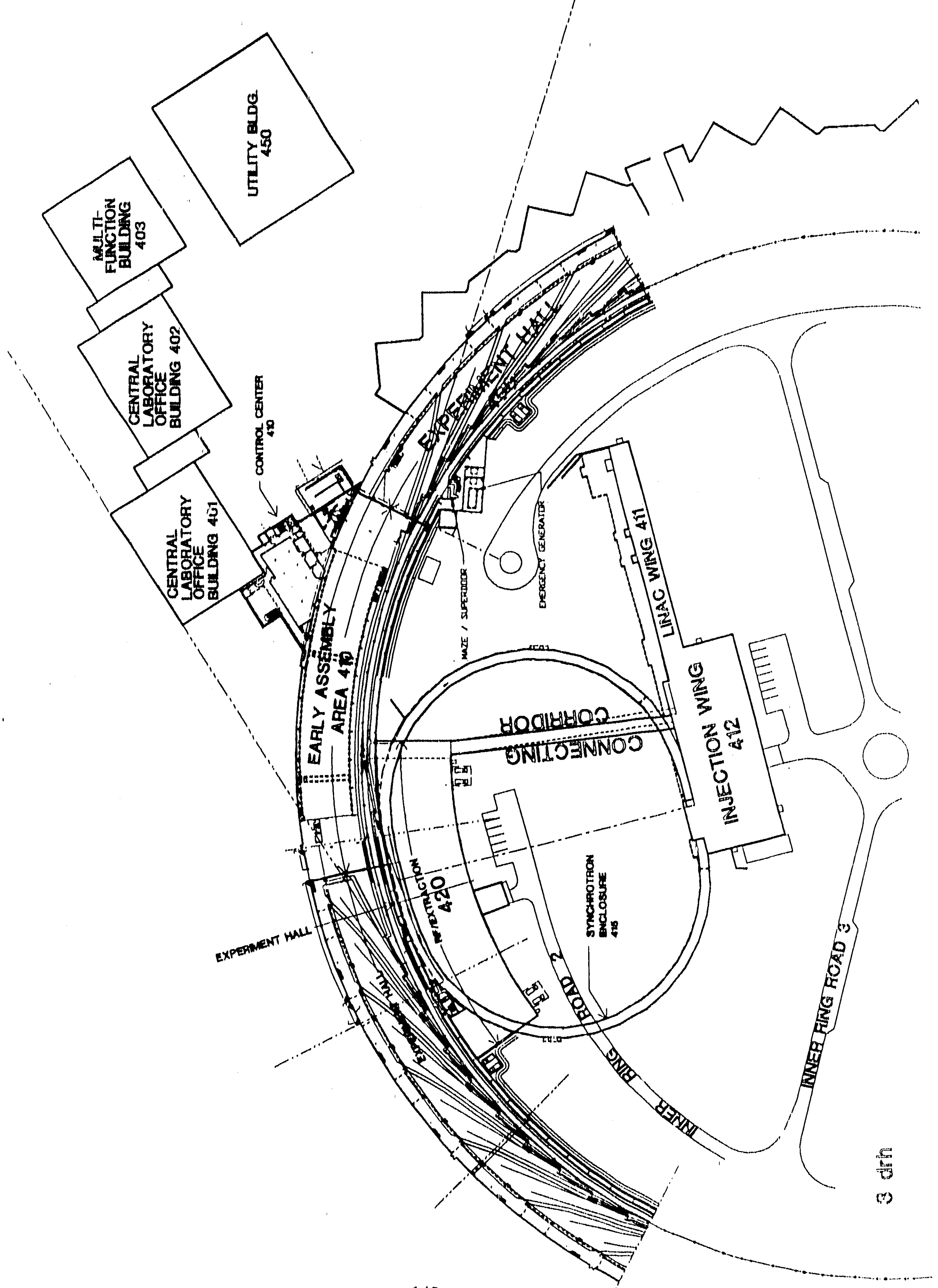
- Laboratories
  - Two per sector
  - One electronics, one chemical with hood
  - Two personnel doors per lab
  - One oversize equipment door per lab
  - Special fitups possible

WHEN CAN WE MOVE IN?

Current Beneficial Occupancy Dates:

- Early assembly area - April, 1992
- Experiment hall complete - January, 1994
- Lab/office modules
  - First: November, 1994
  - Fourth: June, 1995


BUILDING NO 330
BUILDING NO 314
PARKING B
SUPPORT BUILDING
UTILITY BLDG 450
MULTI-FUNCTION BUILDING 403
CENTRAL LABORATORY OFFICE BUILDING 402
CENTRAL LABORATORY OFFICE BUILDING 401
CONTROL CENTER
MODULE 431
MODULE 432
EXPERIMENT HALL 400
EARLY ASSEMBLY AREA 410
LINAC WING 411
INJECTION WING 412
CONNECTING CORRIDOR
SYNCHROTRON ENCLOSURE 415
/EXTRACTION WING 420
INNER RING ROAD 3
INNER RING ROAD 2
INNER RING ROAD 2
CENTER OF PROJECT AND CENTER OF CAISSON "A1" SURVEY MONUMENT N 51080.23 E 31032.26
CAISSON "A2" SURVEY MONUMENT
PARKING C
MODULE 434
PARKING D
MODULE 435
PARKING E
ROAD
PARKING G
PARKING G
ROCK ROAD
ROAD F
KEARNEY ROAD
CULTURAL RESOURCES SITE 29
24' ACCESS GATE
24' ACCESS GATE
24' ACCESS GATE
24' ACCESS GATE
12' ACCESS GATE
GATES


UTILITY BLDG. 450
MULTI-FUNCTION BUILDING 403
CENTRAL LABORATORY OFFICE BUILDING 402
CENTRAL LABORATORY OFFICE BUILDING 401
CONTROL CENTER 410
EXPERIMENT HALL 430
EARLY ASSEMBLY AREA 410
MAZE / SUPERDOOR
EMERGENCY GENERATOR
LINAC WING 411
INJECTION WING 412
CONNECTING CORRIDOR
INJ/EXTRACTION 420
SYNCHROTRON ENCLOSURE 415
EXPERIMENT HALL
EXPERIMENT HALL
INNER RING ROAD 2
INNER RING ROAD 3
3 drh

USER ACTIVITY PLANS

Gopal Shenoy
Advanced Photon Source

Fourth Users Meeting for the APS
May 7-8, 1991

Q. Could you **summarize the CAT interests** at this time?

A.

Information from CATs on their Requirements at the Proposal Stage

Total CAT Proposals Received	19
Total Sectors Requested	23
Approximate Number of Sectors To Be Instrumented Behind Shield Wall with Present Funds	16
Undulator Type A Requests	12
Wiggler Type A Requests	4
Wiggler Type B Requests	4
Other Types of Devices	3

Distribution of Proposed CAT Members:

• Total Principal Investigators	432
• Universities	77
• Industries	18
• Research Institutes (Excluding Government Labs.)	23
• Medical Schools	7
• Government Labs.	9
• Approximate Cost of Construction of Proposed Beam Lines	$220 M

ADVANCED PHOTON SOURCE

Q. How are the **CAT proposals evaluated**?

A. They are evaluated by first assigning them to one or more of the following **Scientific Review Panels (SRPs)**:

SRP I	**Agricultural Sciences/ Environmental Science/Geoscience**
SRP II	**Biology/Life Sciences/Medicine**
SRP III	**Chemistry/Physics/ Materials Science**
SRP IV	**Instrumentation/Methodology Feasibility**

ADVANCED PHOTON SOURCE

Q. How many proposals belong to each of the SRP categories?

A.

Agricultural Science/Environmental Science/ Geoscience	4
Biology/Life Sciences/Medicine	7
Chemistry/Physics/Material Science	14
Instrumentation/Methodology Feasibility	19
TOTAL PROPOSALS	**19**

Q. What are the steps in the review process?

A.

STEP I	SRP Invites Mail Reviews on All Proposals in That Panel
STEP II	SRP Assigns a Rating to Each Proposal
STEP III	PEB Prepares Recommendations Based on: - PEB Evaluation - SRP Ratings - CAT Presentation to PEB
STEP IV	APS Transmits Decisions to CATs
STEP V	Any Shortcomings in the Proposal on Instrumentation or Management Are Addressed

ADVANCED PHOTON SOURCE

Q. What is a Memorandum of Understanding?

A. It is an non-legal agreement between the CAT and the APS that will commit both the CAT and the APS to obtain the best utilization of the APS.

Typically, it will address the following:

- Proof of funding availability to a CAT from an Agency(ies)/Institution(s)
- Agreement to abide by the APS User Policy and Procedures
- Agreement by the APS to provide agreed facilities to the CAT and maintain them
- Agreement to abide by the plan developed to support Independent Investigators

ADVANCED PHOTON SOURCE

Q. I am aware that the APS is working on **standardizing beam line components**. When will the CATs hear about this? Should the CATs wait for the APS designs?

A. There is a **Standardization Committee** made up of very experienced beam line designers assisting the APS towards this goal. While the committee has identified certain generic components what could be considered standard, it would like to broaden the design database using all the beam lines in the CAT proposals. This work will proceed, and the results will be available in a **specification format in fall of 1991**. Detailed **engineering drawings** will follow.

ADVANCED PHOTON SOURCE

Q. What are the **objectives of standardization**?

A.
1. Identify **standard and modular components of a generic APS beam line.** Reevaluate when the scientific proposals are received.
2. Insure **safety and quality** in the beam line design concepts.
3. Develop **conceptual and engineering designs** for the components.
4. Review the designs and **develop prototypes**.
5. **Disseminate the information** to the CATs and vendors.

ADVANCED PHOTON SOURCE

Q. Who are the **members** of the Standardization Committee?

A.

Richard Boyce	SSRL
Rich Hewitt	Exxon
Tunch Kuzay	APS
Richard Levesque	LLNL
Ed Melczer	ALS
Dennis Mills	APS
Tom Oversluizen	NSLS
Wilfred Schildkamp	U of Chicago

ADVANCED PHOTON SOURCE

Q. What are considered '**standard components**' of a beam line?

A. Some of the **design issues** addressed by the Committee are:

- Vacuum requirements
- Shielding requirements
- Control of ozone and other noxious emissions
- Compton scattering reduction
- Experimental station
- Filter assemblies, slits, pin-holes, beam stops, etc.
- Actuators, kinematic mounts, supports, tables, etc.
- Beam transport
- Interlocks, feedback loops, networks, etc.

ADVANCED PHOTON SOURCE

Q. Should CATs perform calculations of **shielding requirements and ozone production** in their beam lines?

A. Many of these calculations will be done by the APS as a part of the standardization exercise. Details of such calculations, specifications, and **safety-based designs** will become available to each CAT. The CAT beam line designs will be reviewed by the APS to ascertain the adequacy of shielding and its safety.

Q. Will the APS provide modular **designs for experimental stations**? Who will install the Stations?

A. **Yes**. As a part of the standardization activity, modular experimental station designs will be generated. The **APS will install these stations** using union labor (carpenters, plumbers, electricians, etc.). Also, the **safety interlock system** will be designed and installed by the APS.

Q. What **other user groups** are working with the APS?

A. The most important user groups that have contributed to the design of the APS are:

- **National Committee on Energy Selection**
- **User Subcommittee on the Design of the Experimental Hall and User Lab-Office Modules (LOMs)**
- **User Subcommittee on APS User Policy**
- **Standardization and Modularization Committee**

In the **future**, we expect input from the users on the following:

- **Optimization of additional storage ring parameters,** such as ß functions, x-y coupling of positron beam, dispersion, etc.
- Matters related to **Environmental Safety and Health (ESH)**
- **User computational and networking needs**
- **Use housing**

Of course, the **Steering Committee of APSUO** meets regularly to appraise progress and provide guidance to the APS.

Q. When can CATs expect to **begin construction of the beam lines at the APS**?

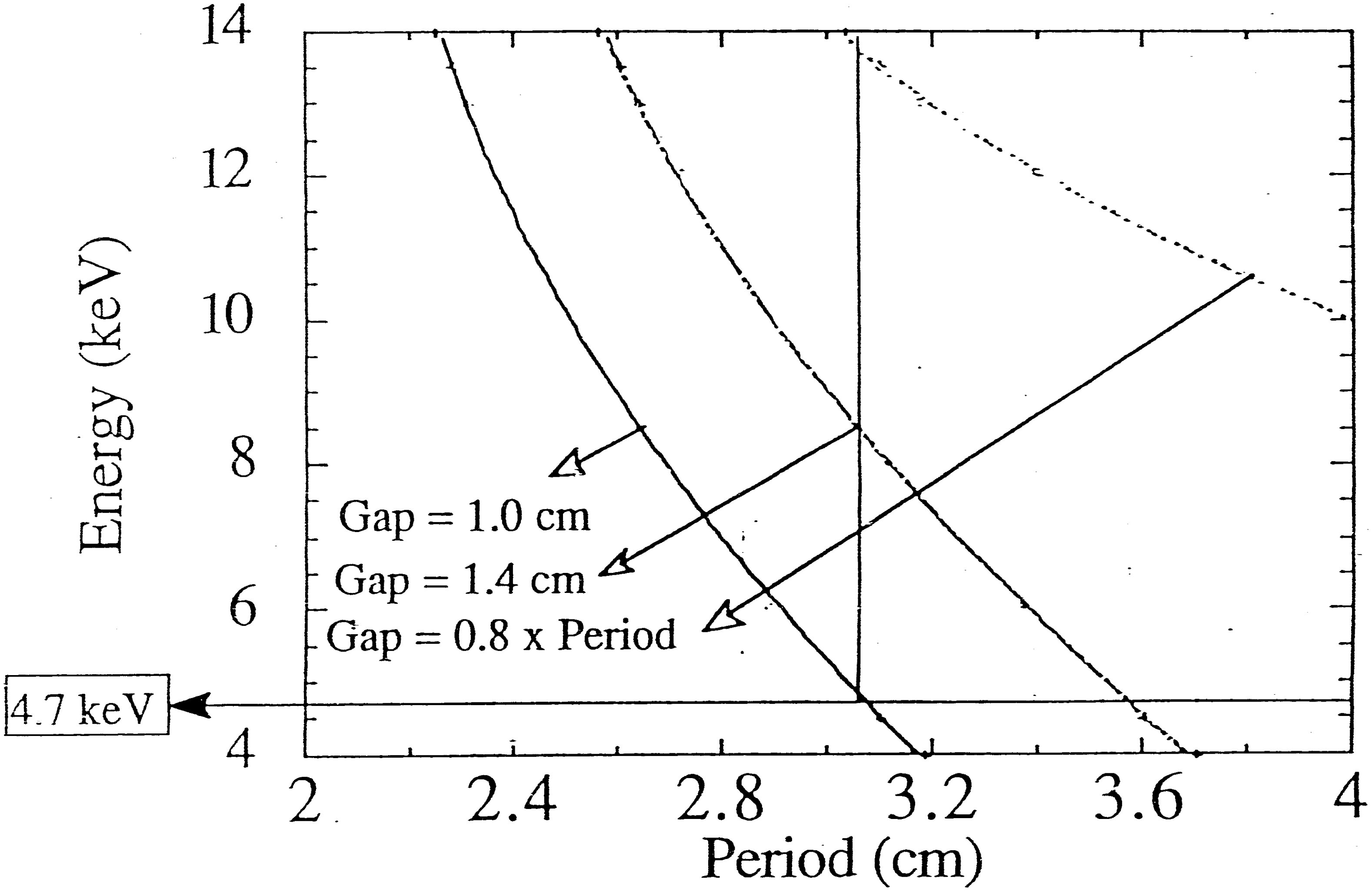
A. The beneficial occupancy schedule permits CATs to occupy the Experiment Hall in a limited fashion starting in **February 1994**. Of course, the LOMs will not be built at this time. However, plenty of space should be available on the Experiment Hall floor.

During 1994 and early 1995, the storage ring will be installed, tested, and commissioned. These activities will have a higher priority than beam line installation.

ADVANCED PHOTON SOURCE

Q. Will the undulators provide **full tunability** (from about 4 to 14 keV in the first harmonic of the Type A undulator) **on day-one** of operation?

A. The tunability is governed by the minimum gap achievable. **Early in operation,** this minimum gap will be a few millimeters larger than its ultimate value of 10 mm. This will indeed reduce the tunability at the lower energy end. However, we are presently working on newer undulator magnet geometries to enhance the field experienced by the positrons in order to alleviat the constraints in early operation.

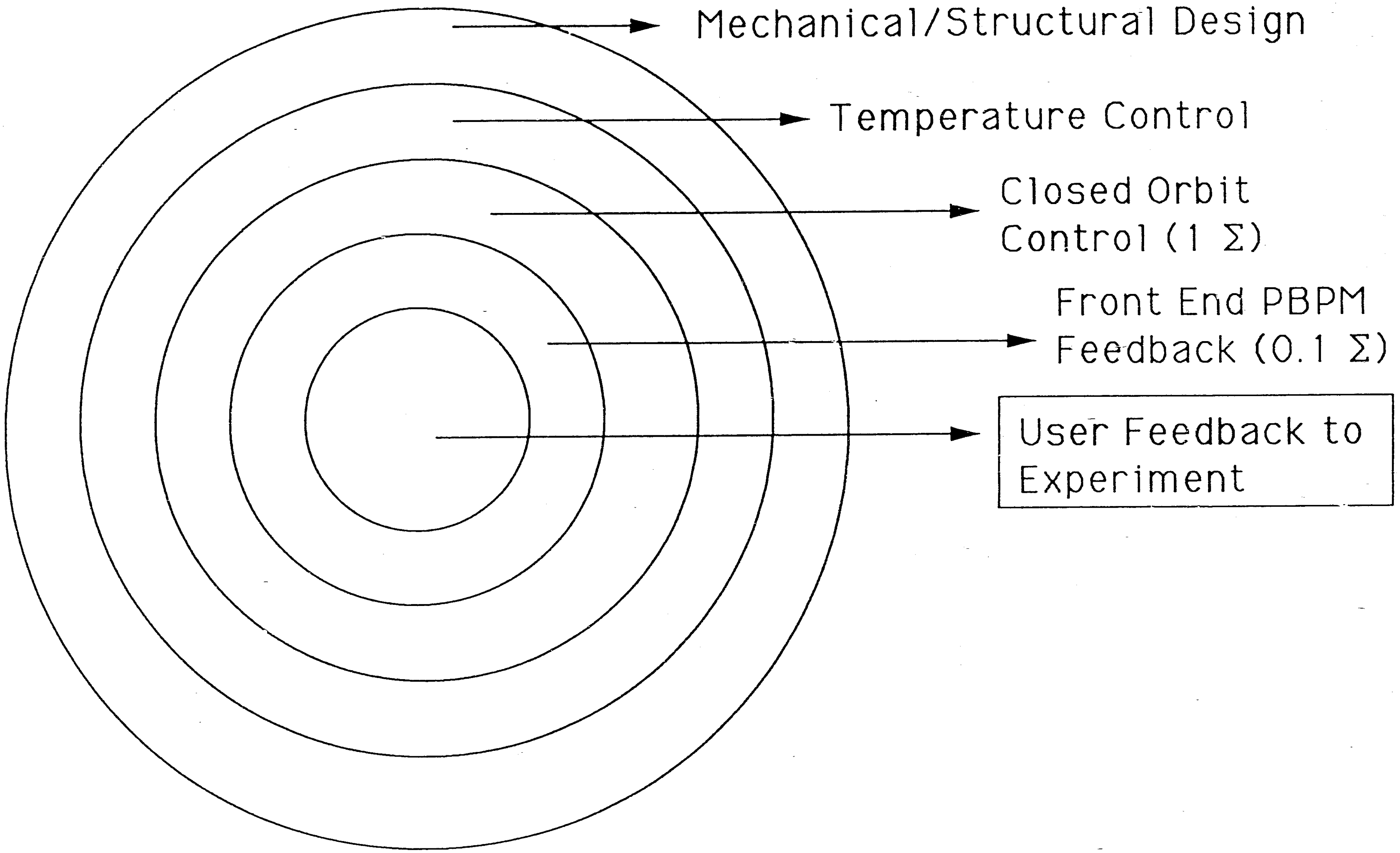

Energy (keV)
14
12
10
8
6
4
2
2.4
2.8
3.2
3.6
4
Period (cm)
Gap = 1.0 cm
Gap = 1.4 cm
Gap = 0.8 x Period
4.7 keV

ADVANCED PHOTON SOURCE

Q. Is it necessary to include **photon beam position monitors (PBPMs)** in the beam line design?

A. The purpose of any such PBPMs is to have the ability to stabilize the photon beam at the sample. Hence the need of PBPMs will depend on the nature of the experiment. To fully address this question, it is important to appreciate **beam stability goals of the APS**. Various aspects of beam stability are schematically presented in the drawing. The user PBPMs, most likely on a monochromatic beam, will provide a feedback loop to adjust the motion of an optical element (e.g. mirror) to keep the beam on to the sample.

APS Beam Stability Strategy



Mechanical/Structural Design

Temperature Control

Closed Orbit
Control (1 Σ)

Front End PBPM
Feedback (0.1 Σ)

User Feedback to
Experiment

ADVANCED PHOTON SOURCE

Q. At the last CAT Workshop, there was some mention of **collaborative R&D with the APS**. Are there any further thoughts?

A. **Yes**. A **Collaborative Research Program (CRP)** is now in place. This program has been endorsed by the Steering Committee of the APSUO. The announcement on the CRP will be sent to all users. Copies are also available from the APS User Administration office.

ADVANCED PHOTON SOURCE

Collaborative Research Program (CRP)

Description and Guidelines

To optimize the use of the Advanced Photon Source (APS) for its User Community, the Experimental Facilities staff of the APS will conduct collaborative instrumentation research and development (R&D) with prospective users. The projects to be pursued for these collaborative ventures will be selected by means of a competitive proposal process, with preference given to those activities that will exploit the unique nature of the APS facility and its scientific capabilities. The R&D will be conducted jointly, with personnel and resources provided by the proposing institution or Collaborative Access Team (CAT) and the Experimental Facilities Division of the APS. The resources made available by the proposer and the APS will be used to cover the cost of effort, materials, and services. The exact division of costs between the APS and the proposer will be determined on a case-by-case basis. Any prototype resulting from such R&D activities may be installed on the beam line being built by the proposing institution or CAT. The technical details will also be made available to the APS user community.

Groups or individuals wishing to participate in this program should complete the attached application and return it to Susan H. Barr at the address given below. Applications will be evaluated by a panel of reviewers consisting of several APS Users Organization Steering Committee members and APS staff. Intrinsic scientific merit, uniqueness, feasibility, and suitability for APS facilities will be the factors receiving greatest weight in the review process, with availability of institutional or agency support considered as well. For the current cycle, completed applications should be submitted before July 31, 1991. Principal investigators will be notified of proposal status during the fall of 1991.

Please return completed application by July 31, 1991, to

Susan H. Barr
User Program Administrator
Advanced Photon Source - Bldg. 362
Argonne National Laboratory
9700 South Cass Avenue
Argonne, IL 60439

ADVANCED PHOTON SOURCE

Q. What are the areas of R&D in which **currently** the Experimental Facilities/APS is involved ?

A.

- Insertion Devices Development
- High Heat-Load Optics Development
- Front End Development
- Beam Position Monitors
- CCD Detectors
- Photon Beam Choppers
- X-ray Optics Fabrication
- Adaptive Optics
- Coherent Optics
- UHR Optics (mV, μV)

Q. Is the APS in contact with the **funding agencies to inform them of CAT beam line needs**?

A. **Yes**. The APS has used every opportunity to inform most of the funding agencies about the project and the needs of the users in broad terms.

Towards this goal, the APS carried out a survey to generate information on **CAT funding needs through a questionnaire** sent to all the CATs. Based on this survey, a table of funding requirements has been generated.

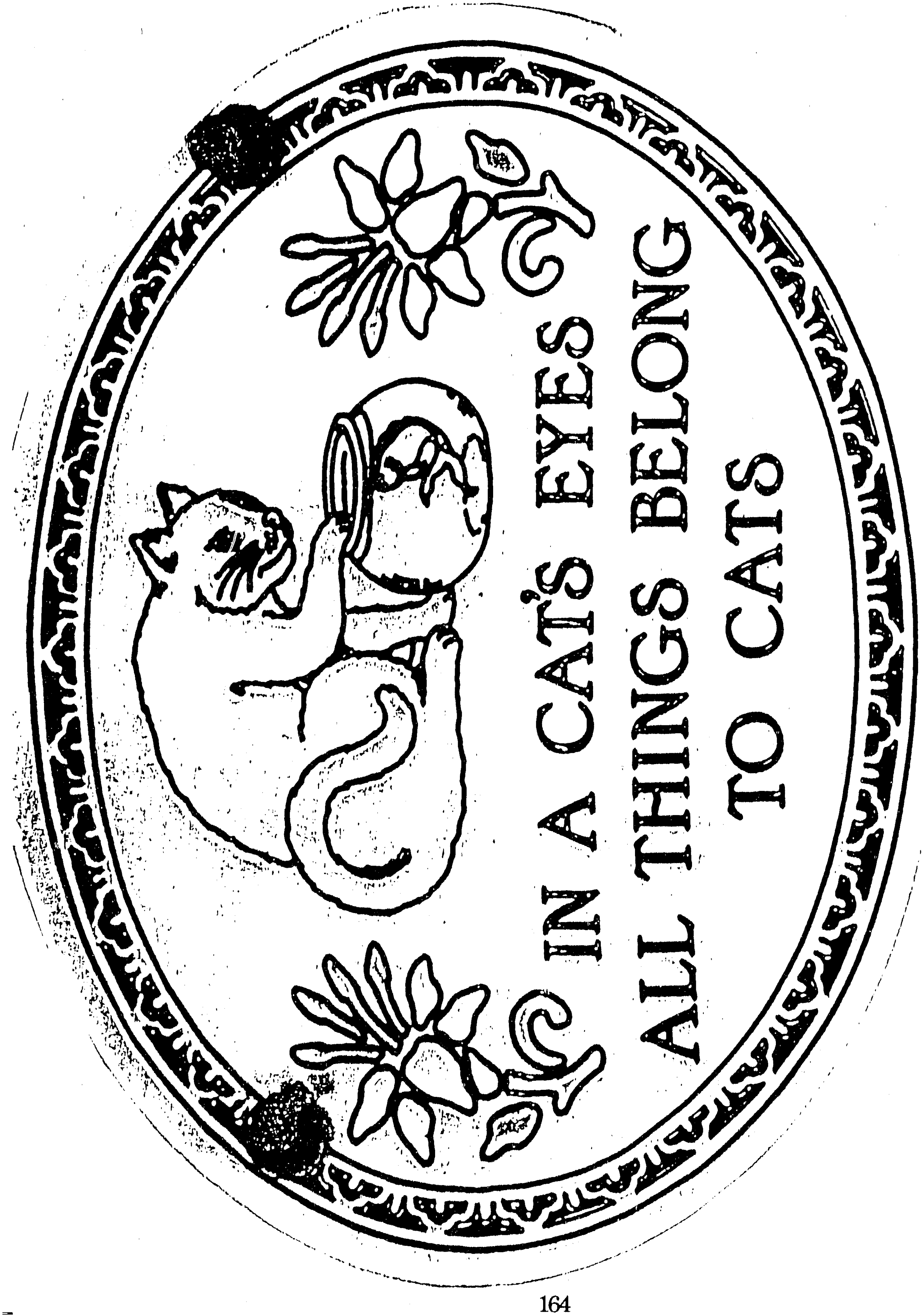
In addition, the Steering Committee of the APSUO has invited representatives from various funding agencies to this meeting.

ADVANCED PHOTON SOURCE

Construction Funding Needs Estimated by CATS in Response to APS Questionnaire

AGENCY/SOURCE	AMOUNT ($M)
DOE (Line Item Request)	72
DOE (Rest)	37
DOD	5
INDUSTRY	20
NIH	10
NSF	19
PRIVATE FOUNDATIONS	13
STATES	11
TOTAL	**187***

*** This estimate has increased to about $220M at the proposal stage.**


IN A CAT'S EYES
ALL THINGS BELONG
TO CATS

ADVANCED PHOTON SOURCE

Q. What is the **beam line construction plan at the ESRF?**

A. As of April 1991, ESRF plans to build the following **8 beam lines based on IDs**:

1. Microfocus	Tapered Undulator
2. Materials Science	Wiggler
3. Biology	Wiggler
4. High Flux	Tapered Undulator
5. High Energy Scattering	Superconducting Wavelength Shifter
6. Circular Polarization (below 2.5 keV)	Helical Undulator
7. Surface Diffraction	Undulator
8. Dispersive EXAFS	Wiggler or Tapered Undulator

Opportunities for Beamline Funding from the NSF

William T. Oosterhuis
Solid State Physics and Materials Chemistry
Division of Materials Sciences
U. S. Department of Energy

- We begin from the premise that any funding source (federal agency, industry, university, state, etc...) which supports research which will utilize the APS, should provide a proportionate share of the instrumentation necessary to carry out that research.

- NSF has studied this issue and has noted that there are a number of possible funding modes including:

  - Science and Technology Centers
    (there may be a new competition in FY1993)
  - Materials Research Groups
  - Instrumentation Programs in the Division of Materials Research, Chemistry, Earth Sciences, and Biological Instrumentation and Resources.
  - A Presidential Initiative on Academic Research Instrumentation

- Other Points

  - Cost sharing - will be required in most cases
  - When to submit - between summer 1991 and January 1, 1992
  - 5-year proposals seem appropriate in this case.

- Message: NSF will be "open for business" through a variety of programs. If there are no proposals for beamlines, there certainly will be no support for them.

WASHINGTON VIEW OF THE NATIONAL MATERIALS AGENDA

D. L. Huber

National Critical Materials Council and Office of Science and Technology Policy
Executive Office of the President
Washington DC, 20506

Advanced materials and materials processing are recognized by the Federal government as being vitally important for national defense, economic prosperity and quality of life. In the list of twenty two critical technologies identified by the National Critical Technologies Panel, five are in the materials category: synthesis and processing, ceramics, composites, electronic and photonic materials, and high performance metals and alloys. Steps are being taken to increase support for materials science and engineering in 1992 and beyond. In the President's FY 1992 budget, $84 is proposed for an NSF initiative in synthesis and processing, with particular emphasis on electronic/photonic and biomolecular materials. Advanced planning (crosscut) is underway for a possible Presidential initiative in advanced materials and processing in the FY 1993 budget. The details of the initiative, if approved, will be released with the President's budget next February.

WASHINGTON VIEW OF THE NATIONAL MATERIALS AGENDA

("SYNTHESIS AND PROCESSING" OF MATERIALS POLICY)

MAJOR POINTS

O ADVANCED MATERIALS AND MATERIALS PROCESSING ARE RECOGNIZED BY THE FEDERAL GOVERNMENT AS BEING VITALLY IMPORTANT FOR NATIONAL DEFENSE, ECONOMIC PROSPERITY, AND QUALITY OF LIFE

O STEPS ARE BEING TAKEN TO INCREASE SUPPORT FOR MATERIALS SCIENCE AND ENGINEERING IN 1992 AND BEYOND

TECHNOLOGY LISTS

- VARIOUS AGENCIES AND PRIVATE SECTOR GROUPS HAVE PREPARED KEY TECHNOLOGY LISTS. ALL OF THEM HAVE MATERIALS-RELATED ENTRIES.

- DEPARTMENT OF DEFENSE CRITICAL TECHNOLOGIES LIST INCLUDES SEMICONDUCTOR MATERIALS, SUPERCONDUCTORS, AND COMPOSITES AS ENTRIES.

- DEPARTMENT OF COMMERCE EMERGING TECHNOLOGIES LIST INCLUDES ADVANCED MATERIALS, SUPERCONDUCTORS, AND OPTOELECTRONIC MATERIALS AS ENTRIES.

NATIONAL CRITICAL TECHNOLOGIES PANEL

- CREATED BY THE 1990 DEFENSE AUTHORIZATION ACT TO IDENTIFY UP TO 30 TECHNOLOGIES CRITICAL TO NATIONAL DEFENSE AND ECONOMIC PROSPERITY. TECHNOLOGY LIST TO BE UPDATED EVERY TWO YEARS.
- PANEL, APPOINTED BY THE DIRECTOR OF THE OFFICE OF SCIENCE AND TECHNOLOGY POLICY, INCLUDES SENIOR FEDERAL AGENCY AND PRIVATE SECTOR OFFICIALS WHO ARE RESPONSIBLE FOR TECHNOLOGY DEVELOPMENT AND APPLICATION
- FIRST REPORT RELEASED IN APRIL.
- CRITICAL TECHNOLOGIES INSTITUTE

NATIONAL CRITICAL TECHNOLOGIES LIST

CATEGORIES

1. MATERIALS
2. MANUFACTURING
3. INFORMATION AND COMMUNICATIONS
4. BIOTECHNOLOGY AND LIFE SCIENCES
5. AERONAUTICS AND SURFACE TRANSPORTATION
6. ENERGY AND ENVIRONMENT

MATERIALS-RELATED CRITICAL TECHNOLOGIES

- SYNTHESIS AND PROCESSING
- CERAMICS
- COMPOSITES
- ELECTRONIC AND PHOTONIC MATERIALS
- HIGH-PERFORMANCE METALS AND ALLOYS

MS&E STUDIES

- NRC REPORT <u>MATERIALS SCIENCE AND ENGINEERING FOR THE 1990s</u> RELEASED IN 1989. REPORT EMPHASIZES THE NEED FOR INCREASED EFFORTS IN SYNTHESIS AND PROCESSING.
- REGIONAL FOLLOW-UP MEETINGS HELD TO DISCUSS IMPLEMENTING THE MS&E REPORT.
- RESULTS OF THE FOLLOW-UP MEETINGS SUMMARIZED IN REPORT <u>A NATIONAL AGENDA IN MATERIALS SCIENCE AND ENGINEERING</u> RELEASED IN FEBRUARY, 1991

NEW MATERIALS-RELATED PROGRAMS IN PRESIDENT'S FY 1992 BUDGET

- NSF INITIATIVE IN MATERIALS SYNTHESIS AND PROCESSING
- PRESIDENTIAL INITIATIVE IN HIGH PERFORMANCE COMPUTING AND COMMUNICATIONS
- PRESIDENTIAL INITIATIVE IN MATH AND SCIENCE EDUCATION

NSF INITIATIVE IN MATERIALS SYNTHESIS AND PROCESSING

- $84 MILLION PROPOSED FOR FY 1992
- EMPHASIS ON
  - STRENGTHENING INDIVIDUAL INVESTIGATOR AND GROUP INTERDISCIPLINARY RESEARCH
  - INVOLVING GRADUATE AND UNDERGRADUATE STUDENTS
  - PROMOTING STRONGER UNIVERSITY-INDUSTRY-GOVERNMENT LINKAGES
  - PROVIDING STATE-OF-THE-ART INSTRUMENTATION AND RESEARCH FACILITIES
- FIRST YEAR FOCUS ON ELECTRONIC AND PHOTONIC MATERIALS AND BIOMOLECULAR MATERIALS

PRESIDENTIAL INITIATIVES

- COORDINATED MULTI-AGENCY, MULTI-YEAR PROGRAMS

- HIGH PERFORMANCE COMPUTING

  A THIRTY PER CENT INCREASE IN FUNDING, WITH THE LARGEST FRACTION GOING TO THE DEPARTMENTS OF DEFENSE AND ENERGY, NSF, AND NASA. WILL INCREASE ABILITY OF RESEARCHERS TO ADDRESS PROBLEMS IN MATERIALS THEORY, SIMULATION, AND MODELLING.

- MATH AND SCIENCE EDUCATION

  A THIRTEEN PERCENT INCREASE IN FUNDING, WITH THE LARGEST FRACTION GOING TO PRE-COLLEGE EDUCATION

PRESIDENTIAL MATERIALS INITIATIVE IN FY 1993 ?

- ADVANCED PLANNING (CROSSCUT) FOR A POSSIBLE MULTI-AGENCY INITIATIVE IN MATERIALS SCIENCE AND ENGINEERING IN THE FY 1993 BUDGET IS UNDERWAY.

- PLANNING IS CARRIED OUT BY A WORKING GROUP OF COMAT. COMAT IS THE MATERIALS SUBCOMMITTEE OF THE FCCSET COMMITTEE ON INDUSTRY AND TECHNOLOGY (CIT). OVERSIGHT IS PROVIDED BY A MATERIALS STEERING GROUP OF CIT, ALONG WITH OSTP AND OMB.

- DETAILS OF THE INITIATIVE, IF APPROVED, WILL BE RELEASED WITH THE FY 1993 BUDGET NEXT YEAR.

MATERIALS INVENTORY

O FIRST STEP IN THE PLANNING IS TO CARRY OUT A MATERIALS INVENTORY DETAILING THE SPENDING ACCORDING TO AGENCY IN VARIOUS MATERIALS CATEGORIES

O AGENCIES: DOD, DOE, NSF, NASA, NIST, NIH, NRC, BOM

O ADVANCED MATERIALS CATEGORIES

- BIOMATERIALS
- OPTICAL/PHOTONIC
- MAGNETIC
- SUPERCONDUCTOR
- ELECTRONIC
- COMPOSITES
- POLYMERS
- CERAMICS
- METALS

WRAP-UP

- ADVANCED MATERIALS AND MATERIALS PROCESSING ARE RECOGNIZED AS BEING IMPORTANT TO THE U.S.
- 92 BUDGET INCLUDES NEW PROGRAMS THAT WILL BENEFIT MATERIALS RESEARCH
- ADVANCED PLANNING IS UNDERWAY FOR A POSSIBLE MATERIALS INITIATIVE IN THE 93 BUDGET

PROSPECTS FOR FUNDING IN STRUCTURAL BIOLOGY: A CASE STUDY

Keith Moffat
Department of Biochemistry and Molecular Biology
The University of Chicago
Chicago, Illinois 60637

Prior to 1989, the synchrotron structural biology community did not have a need for formal organization or a national voice. Groups of users dealt directly with the management of SSRL, CHESS, and NSLS, or via the local users' organizations. With the APS on the horizon, it became clear that a more coordinated approach by the community was essential, perhaps as advocated by J.V. Smith (University of Chicago) along the lines pioneered by the synchrotron earth sciences community through GeoSync. For the structural biologists, what began in August 1989 as a Midwest, APS-oriented crystallography group under the leadership of Ed Westbrook (Argonne), rapidly grew to a national group supporting all existing and proposed new synchrotron crystallography facilities. At the first national meeting of "BioSync" in February 1990, attended by about 70 structural biologists and representatives of funding sources, the scientific scope was widened to include scattering from non-crystalline samples, biological X-ray spectroscopy and soft X-ray imaging as well as crystallography. Thus BioSync, which now includes about 350 Principal Investigators as members, covers all of synchrotron biology except medical imaging.

The members established BioSync as an advocacy group that will promote access to all synchrotron sources by structural biologists and will seek ways to "increase the size of the pie" to support their synchrotron research, but will not itself operate or build beamlines. The members also instructed the Steering Committee of BioSync (Charles Bugg, University of Alabama - Birmingham; Hugh Huxley, Brandeis; Keith Moffat, The University of Chicago; Janet Smith, Purdue, Vice-Chair; Keith Watenpaugh, The Upjohn Company, Chair; Ed Westbrook, Argonne) to conduct a survey of existing synchrotron use and identify present and future scientific opportunities and funding needs. The Steering Committee distributed questionnaires to all synchrotron users in the U.S. and to all synchrotron facilities known to be used by U.S. scientists, including those in Japan and Europe. Responses were analyzed and interpreted by a study group which included representatives from NIH, NSF, DOE, and HHMI as well as structural biologists. The group prepared a report* under the sponsorship of NSF titled "Structural Biology and Synchrotron Radiation: Assessment of Resources and Needs". The report compiles quantitative (and anecdotal) data on synchrotron structural biology, present and projected, and puts forward several recommendations. Where assumptions are made about future demand, the report tries to make them explicit. The report may serve to assist decision-makers and funding agencies who will be called upon for a realistic evaluation of funding requests. It shows that synchrotron structural biology is an exciting, rapidly expanding research area populated by young, well-funded scientist who can point to notable recent successes; but its continued development requires major research support, both to enhance existing facilities and to construct effective new beamlines at ALS and APS.

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*Available from BioSync, c/o Helene Prongay, Department of Biological Sciences, Purdue University, West Lafayette, Indiana 47907

Business Meeting of the Advanced Photon Source Users Organization

Paul Horn, the outgoing Chairman of the APSUO Steering Committee, called the Business Meeting of the APSUO to order on May 8, 1991. He briefly reviewed the accomplishments of the Steering Committee in the last year:

- At the last meeting, the APS was asking for $500,000 earnest money up-front. The Steering Committee worked vigorously and successfully to have that requirement removed.
- The Steering Committee played an important role in the establishment of a Collaborative Research Program with the APS. This program, which is now being developed, will foster active collaborations for the benefit of the user community. The Steering Committee will also play a role in evaluating the proposals.
- The Steering Committee reviewed the PEB procedures for proposal evaluation and approved the procedures unanimously. The Steering Committee will also act as a court of last resort for CATs who have **substantive** concerns about the validity of the review process.
- The Steering Committee played a role in key designs of the Experiment Hall. The quality of life on the floor of APS will be fundamentally better than that available in the past, thanks especially to the efforts of Walt Trela and Rich Hewitt.

Paul Horn then thanked the Program Committee for their part in planning this meeting, Susan Barr and Bonnie Meyer for meeting organization, and Gopal Shenoy for his overall efforts on behalf of prospective APS users.

The gavel was then passed to Steve Durbin, new APSUO Steering Committee Chairman. Steve Durbin presided over the election of new Steering Committee members and the revision of the APSUO by-laws. Ten candidates were running for six positions on the Steering Committee. Nine candidates had been slated in advance by the Nominating Committee; an additional candidate was brought to the attention of various Steering Committee members on May 7, 1991, and was added to the list of nominees by consensus. No one was nominated from the floor during the Business Meeting. The Users were asked to vote for up to six members by ranking them in order of preference. The winning candidates — Phil Coppens, John Faber, Alan Goldman, Gene Ice, William Orme-Johnson, and Albert Thompson — assumed office immediately after the end of the Business Meeting.

Following the voting for the new Steering Committee members, Steve Durbin discussed the proposed revisions in the by-laws, which can only be adopted by a two thirds vote of the participants at the annual meeting. The following items, which have been the general practice of the APSUO, were considered for incorporation into the by-laws:

- A weighted voting system will be used for the election of Steering Committee members. In this system, candidates receive six points for a first-choice vote, five points for a second choice vote, etc.

- Six members will be elected to the Steering Committee at each meeting.

- A Nominating Committee will nominate a slate of candidates to be elected to the Steering Committee. Nominees from the floor will also be taken.

- The Vice Chair will organize the annual meeting.

- Directors of other synchrotron facilities are invited to be nonvoting, *ex officio* members of the Steering Committee.

A motion to accept the changes in the by-laws was seconded and passed by hand vote. No opposing votes were registered; thus, these items will be incorporated into the by-laws of the APSUO. Steve Durbin then closed the APSUO Business Meeting.

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PROGRAM

FOURTH USERS MEETING
for the
Advanced Photon Source

May 7-8, 1991
Argonne National Laboratory
Argonne, Illinois 60439
Bldg. 362 Auditorium

Monday, May 6, 1991

6:00-8:00 p.m. **Registration - Holiday Inn of Willowbrook**

Tuesday, May 7, 1991

7:30-8:30 a.m. **Registration - Bldg. 362 Lobby**

Morning Session: Advanced Photon Source: A Look Ahead

8:30 a.m. **Welcoming Remarks**

- Paul Horn, Chairman, Advanced Photon Source Users Organization
- Bill Oosterhuis, Office of Basic Energy Sciences, U. S. Department of Energy

9:00 a.m. **Advanced Photon Source Project Overview - David Moncton**

10:00 a.m. **Break**

10:30 a.m. **Critical Issues for Advanced Photon Source Operation**

- *Storage Ring Beam Stability* - John Galayda
- *Cooling of X-ray Monochromator Crystals under High Heat Loads: Present and Future Trends* - Dennis Mills

12:00 noon **No-Host Lunch - Argonne Cafeteria**

Afternoon Session: Advances in Synchrotron Radiation Applications

1:30 p.m. **Session I - Paul Sigler, Chair**

- *Issues in Muscle Diffraction* - Hugh Huxley, Brandeis University
- *Nuclear Bragg Scattering* - Bennett Larson, Oak Ridge National Laboratory
- *Time-Resolved Studies of Interface Kinetics* - Walter Lowe, AT&T Bell Laboratories

2:45 p.m. **Break**

3:15 p.m. **Session II - Doon Gibbs, Chair**

- *Cooling and Monochromators Revisited* - Bob Batterman, Cornell High Energy Synchrotron Source
- *Synchrotron Radiation Applications of Importance to Engineers* - Bill O'Grady, Naval Research Laboratory
- *Coronary Angiography Using Synchrotron Radiation* - Albert Thompson, Lawrence Berkeley Laboratory

4:45 p.m. **Tour of Site or Staging Areas**

5:45 p.m. **Buses Leave for the Art Institute of Chicago**

6:30 p.m. **Reception and Banquet**
The Art Institute of Chicago

Wednesday, May 8, 1991

Morning Session: Advanced Photon Source User Issues

8:30 a.m. **User Perspectives - Roy Clarke, Chair**

- *User Facility Plans* - Marty Knott
- *User Activity Plans* - Gopal Shenoy

10:00a.m. **Break**

10:30 a.m. **APSUO Business Meeting**

- Election of new Steering Committee members
- Proposed by-laws revisions

11:00 a.m. **Funding Perspectives - Steve Durbin, Chair**

- *Opportunities for Beam-Line Funding from the National Science Foundation* - Bill Oosterhuis, Office of Basic Energy Sciences, U. S. Department of Energy
- *Washington's View of the National Materials Agenda* - David Huber, National Critical Materials Council, Executive Office of the President
- *Prospects for Funding in Structural Biology - A Case Study* - Keith Moffat, Professor, The University of Chicago, and member of BioSync

12:00 noon **Election Results and Concluding Remarks - Steve Durbin**

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Haydn Chen (Univ. of Illinois)
Roy Clarke (Univ. of Michigan)
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Doon Gibbs (NSLS)
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Keith Moffat (The Univ. of Chicago)
Paul Sigler (Yale Univ.)
William Thomlinson (NSLS)
Keith Watenpaugh (Upjohn)
Bob Batterman, *ex-officio* (CHESS)
Arthur Bienenstock, *ex-officio* (SSRL)
Denis McWhan, *ex-officio* (NSLS)
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