ANL/XFD/VU--87288
CONF-9405102--4-Vugraphs

FIRST OPTICS MONOCHROMATOR PERFORMANCE AND OTHER HHL OPTICS R&D

Dennis M. Mills

Sixth Users Meeting for the APS
May 25-26, 1994

High Heat Load Monochromator

Program Goal

To procure a high heat load crystal monochromator system that can deliver the undulator beam to the sample with minimal loss of brilliance with:

- APS operating at 7 GeV and 100 mA
- a 2.5-m ID with k=2.17 (4.2 keV first harmonic)

Solution for Program Goal

The measured data and modeling indicate that a crystal in the inclined geometry (with appropriate inclination angle) cooled with liquid gallium will meet the needs of this near-term goal. The following should be noted:

- Liquid gallium has been selected as the coolant for its superior physical properties (as compared to water) such as thermal conductivity and high boiling point.
- The inclined crystal geometry has been chosen for its reduction in surface power loading and improved heat flow.

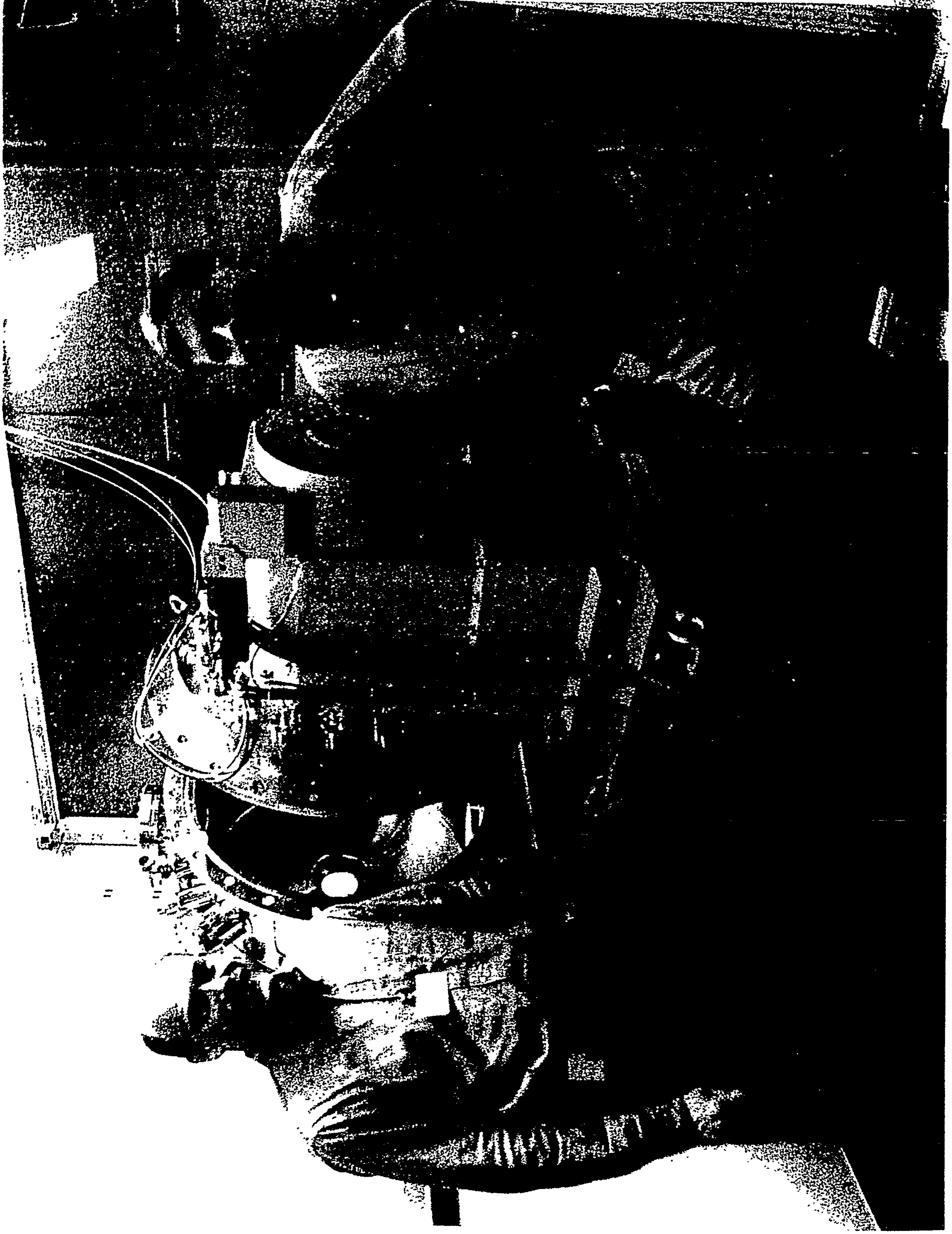
HHL Monochromator - Mechanical/Vacuum

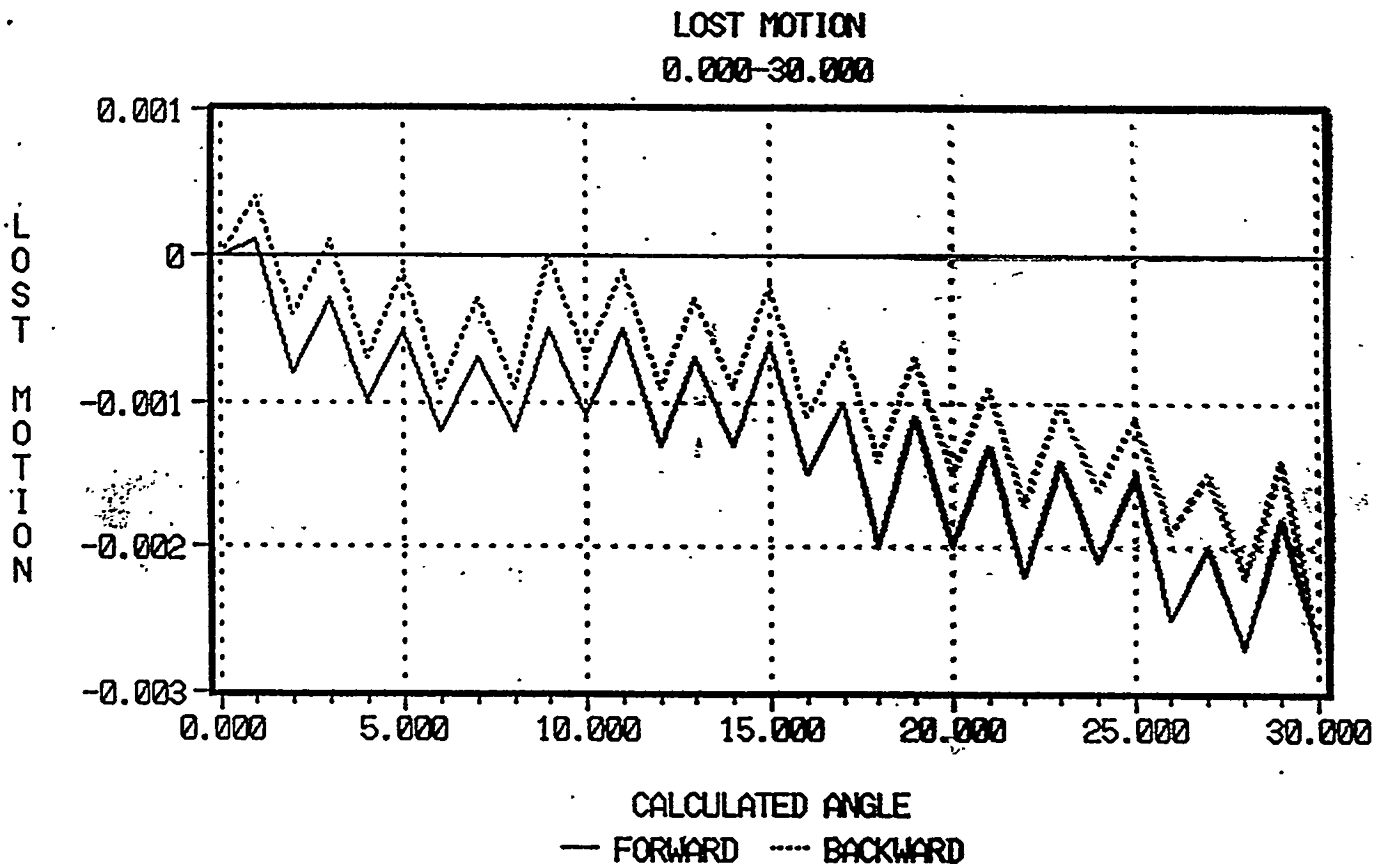
Design Goals:

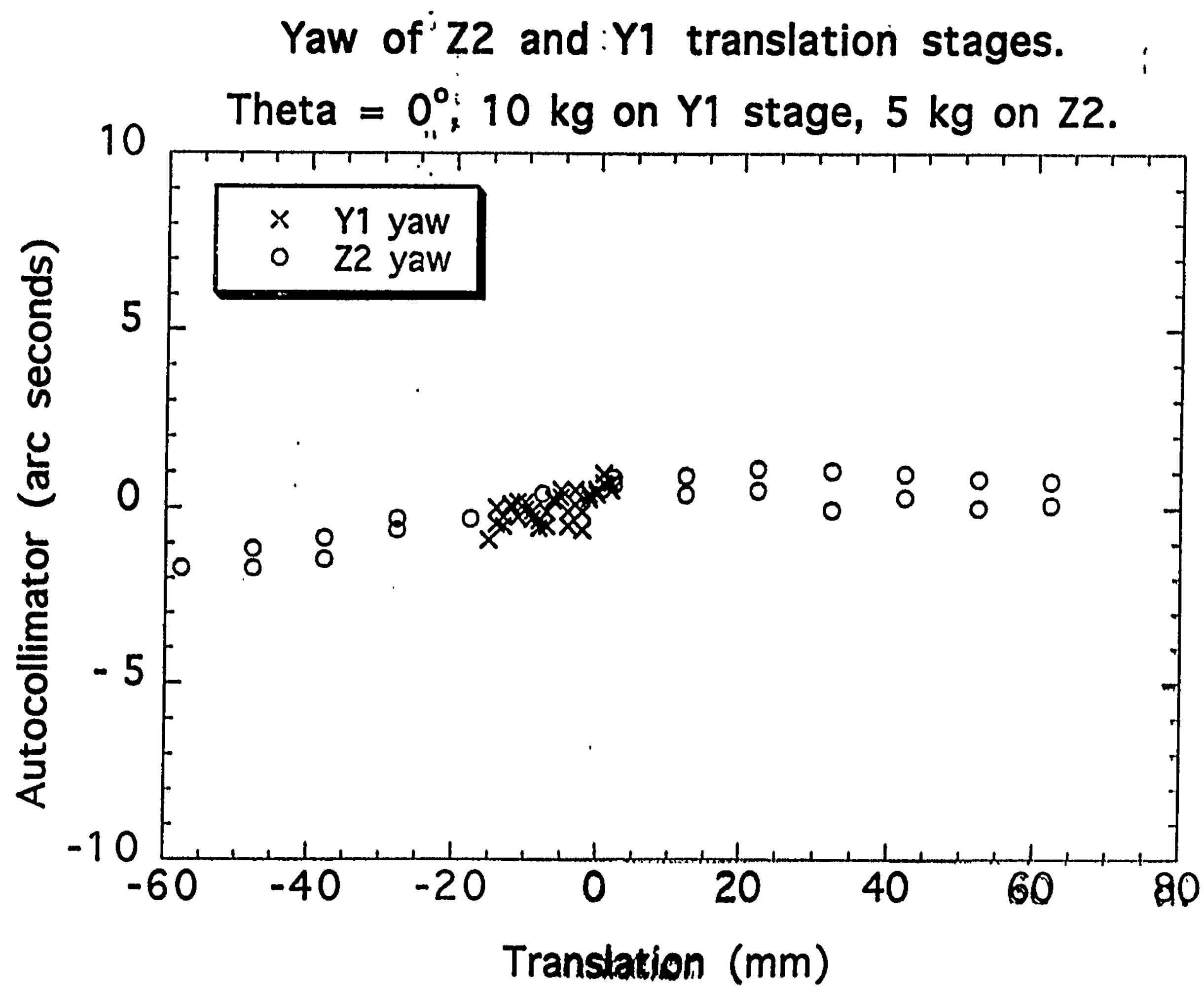
- fixed exit operation
- 35 mm offset
- tunable from 4-20 keV with Si (111)
- high vacuum (10^{-6} - 10^{-7} torr) compatible
- design independent of final crystal configuration
- operation with 2.5 m ID @ 7 GeV & 100 ma

Current Status:

The mechanical/vacuum portion of the APS monochromator was delivered by Kohzu Seiki in January 1994 and we have begun testing of the mechanics. We also have motions (step motors, servo-motors,) encoders, gallium pump read-out, and vacuum pumps and read-outs under EPICS control.




LOST MOTION
0.000-30.000
0.001
0
-0.001
-0.002
-0.003
LOST MOTION
0.000
5.000
10.000
15.000
20.000
25.000
30.000
CALCULATED ANGLE
FORWARD
BACKWARD


Yaw of Z2 and Y1 translation stages.
Theta = 0°, 10 kg on Y1 stage, 5 kg on Z2.
Y1 yaw
Z2 yaw
Autocollimator (arc seconds)
Translation (mm)
10
5
0
- 5
-10
-60
-40
-20
0
20
40
60
80

Power Density on the Crystal Surface

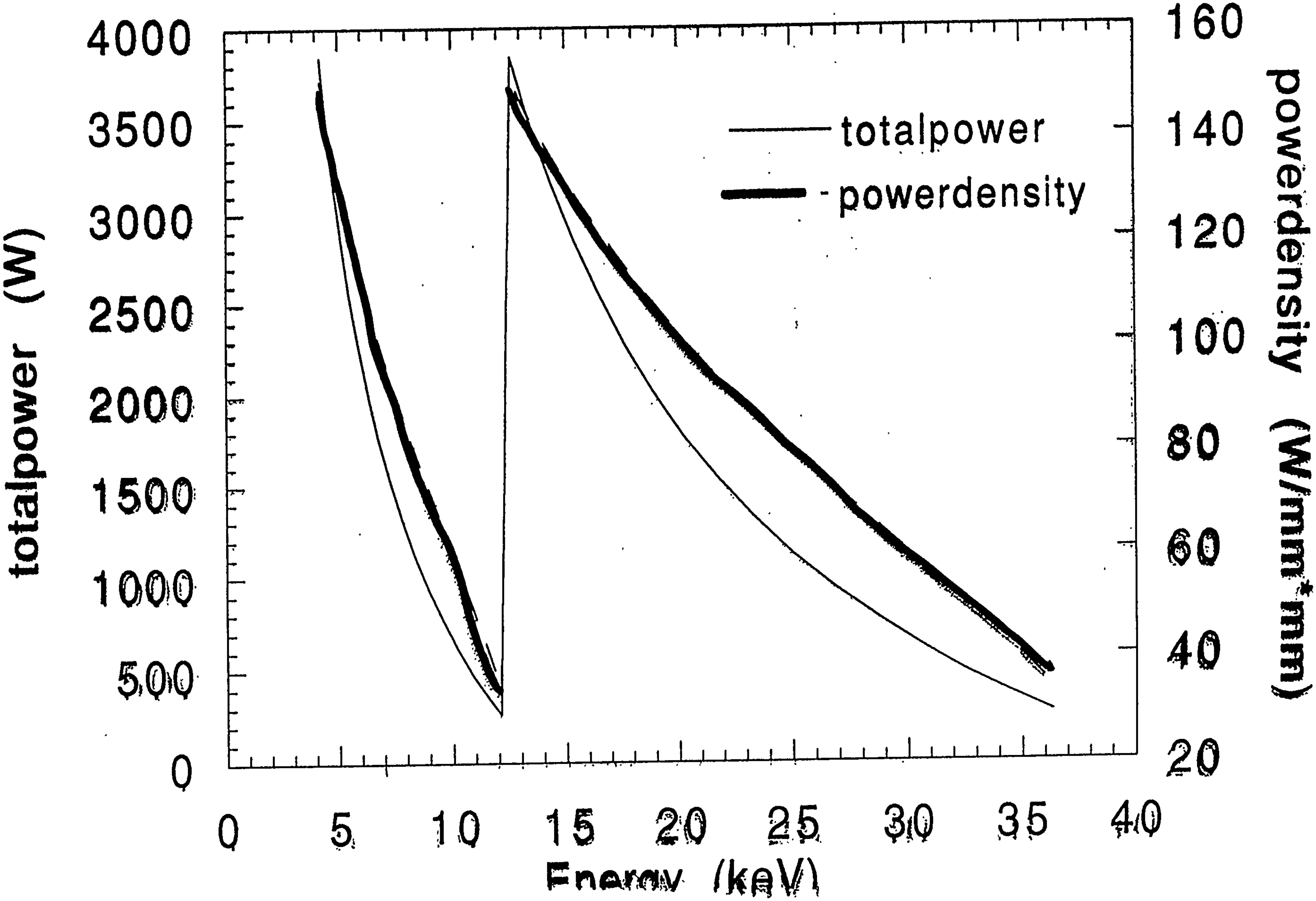
From the simulations and experimental results, we have ascertained that the maximum surface power density that our current cooling schemes (i.e., slotted crystals with liquid gallium coolant at 1 - 2 gpm) can handle without substantial thermal distortion on the crystal is about

4 or 5 watts/mm^2.

Initial finite element analysis of the APS Undulator A thermal loading on back-cooled inclined silicon monochromators has shown that, at closed gap and 4.2 keV (worst case power loading) and with an inclination angle of 85°, the thermally induced slope error is 40 microradians. This is with a heat flux of

6.1 watts/mm^2.

Undulator A, 3.3 cm period, 30 m from source



ANL/APS/TB-4

High Heat Load Monochromator Specifications

by Wah Keat Lee and Dennis Mills

February 1993

Advanced Photon Source

146

Argonne National Laboratory, Argonne, Illinois 60439
operated by The University of Chicago
for the United States Department of Energy under Contract W-31-109-Eng-38

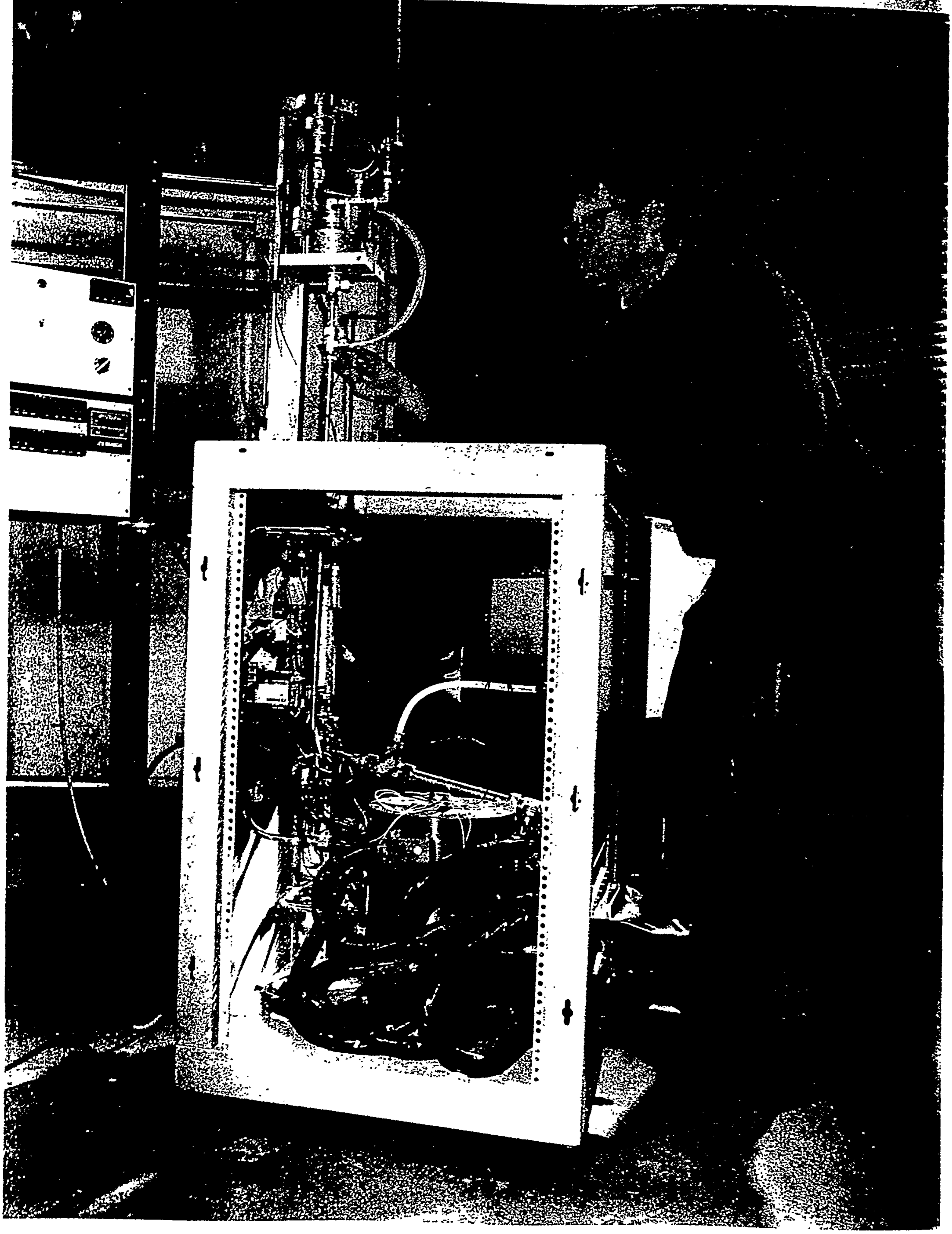
Liquid Gallium Pump

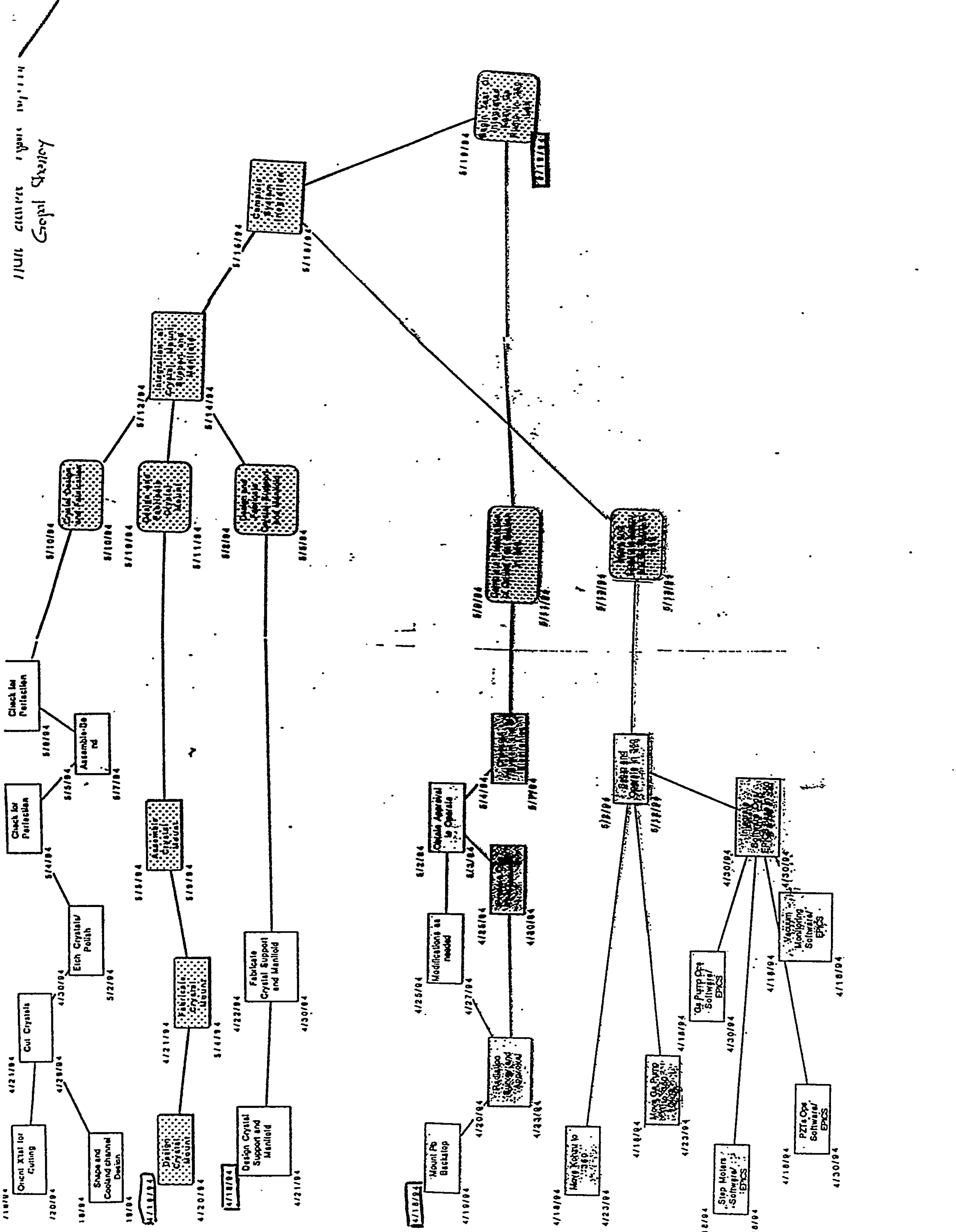
Performance Specifications

- Volume flow rate of 4 gallons per minute (gpm) while operating with a head pressure of 75 pounds per square inch (psi)
- Gallium temperature controllable between 40°C and 70°C and regulated to ±3°C with any heat load from 0 to 5 kwatts
- System should be able to withstand internal pressures of 200 psi and be able to be operated under vacuum (<1 torr)
- A gallium-to-water heat exchanger capable of removing 5 kW of power (with a 10 KW option) with water cooling of <5 gpm and 80 psi

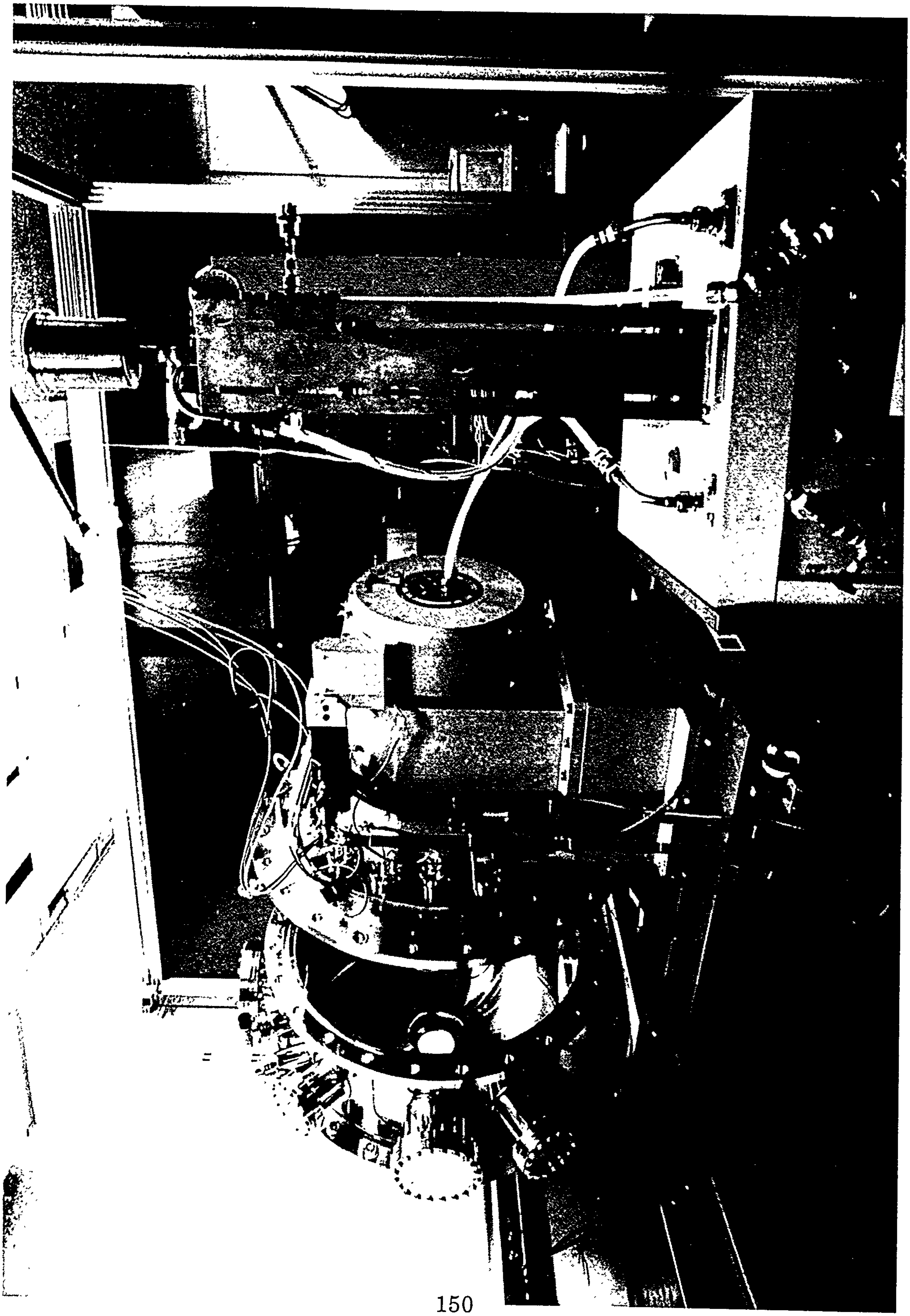
Current Status:

A commercially fabricated DC current pump was delivered by Qmax and passed acceptance tests here at ANL March 1994. We found the "settling time" with a ΔPower of 1kW was several minutes with a temperature excursion of <3°C. Displays can be readout through EPICS and we plan to have the pump under EPICS control in the next several months.

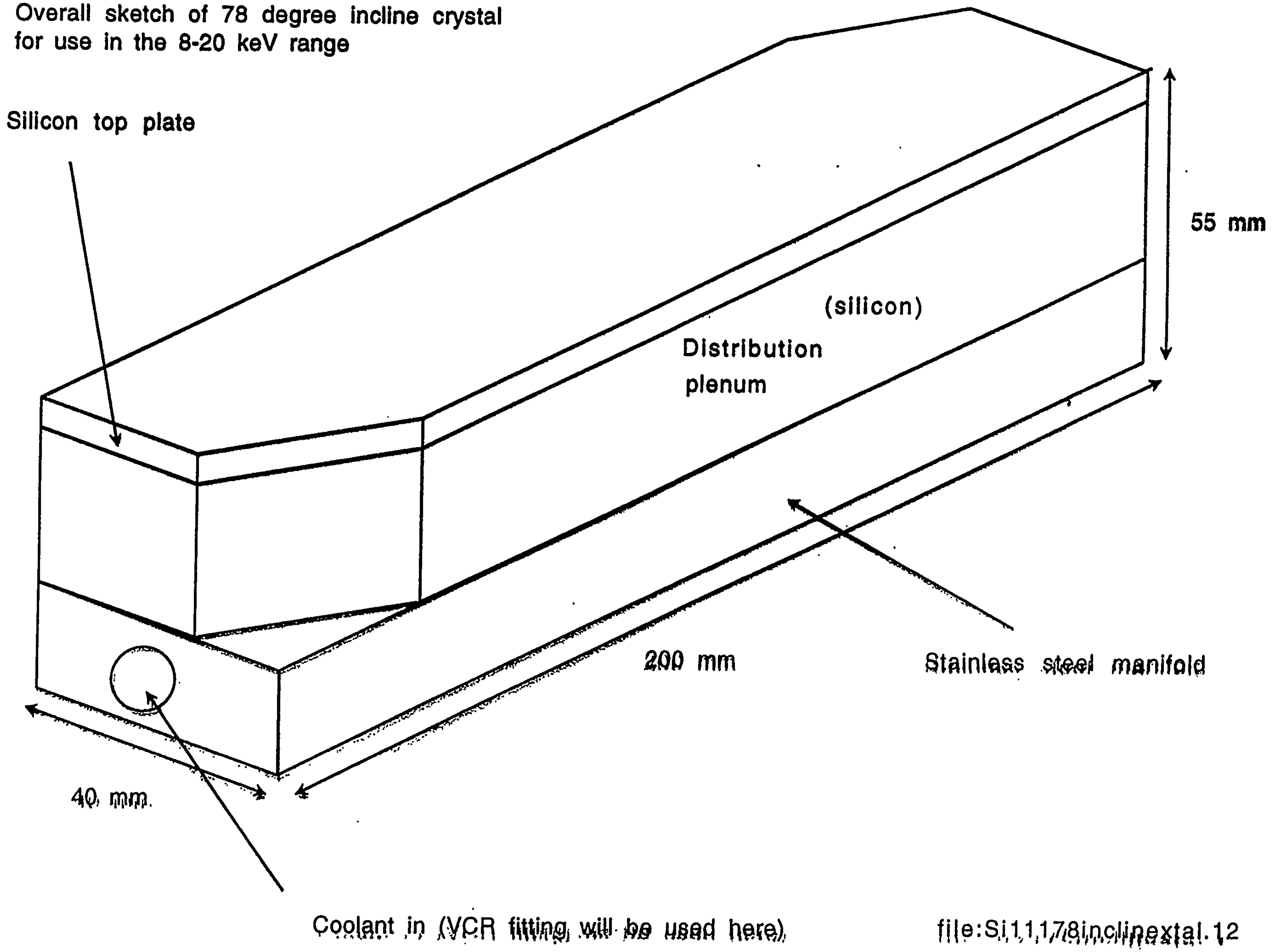


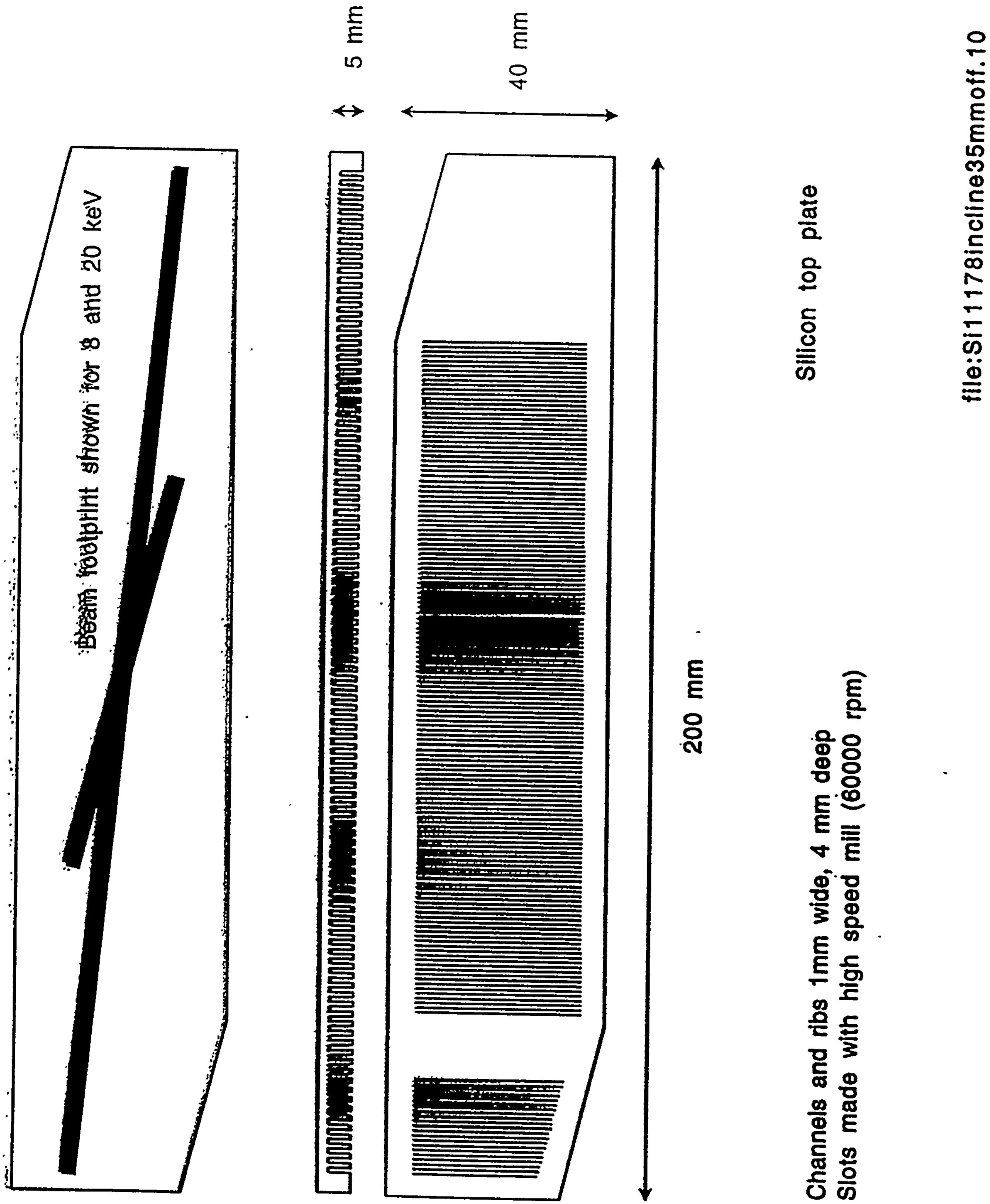


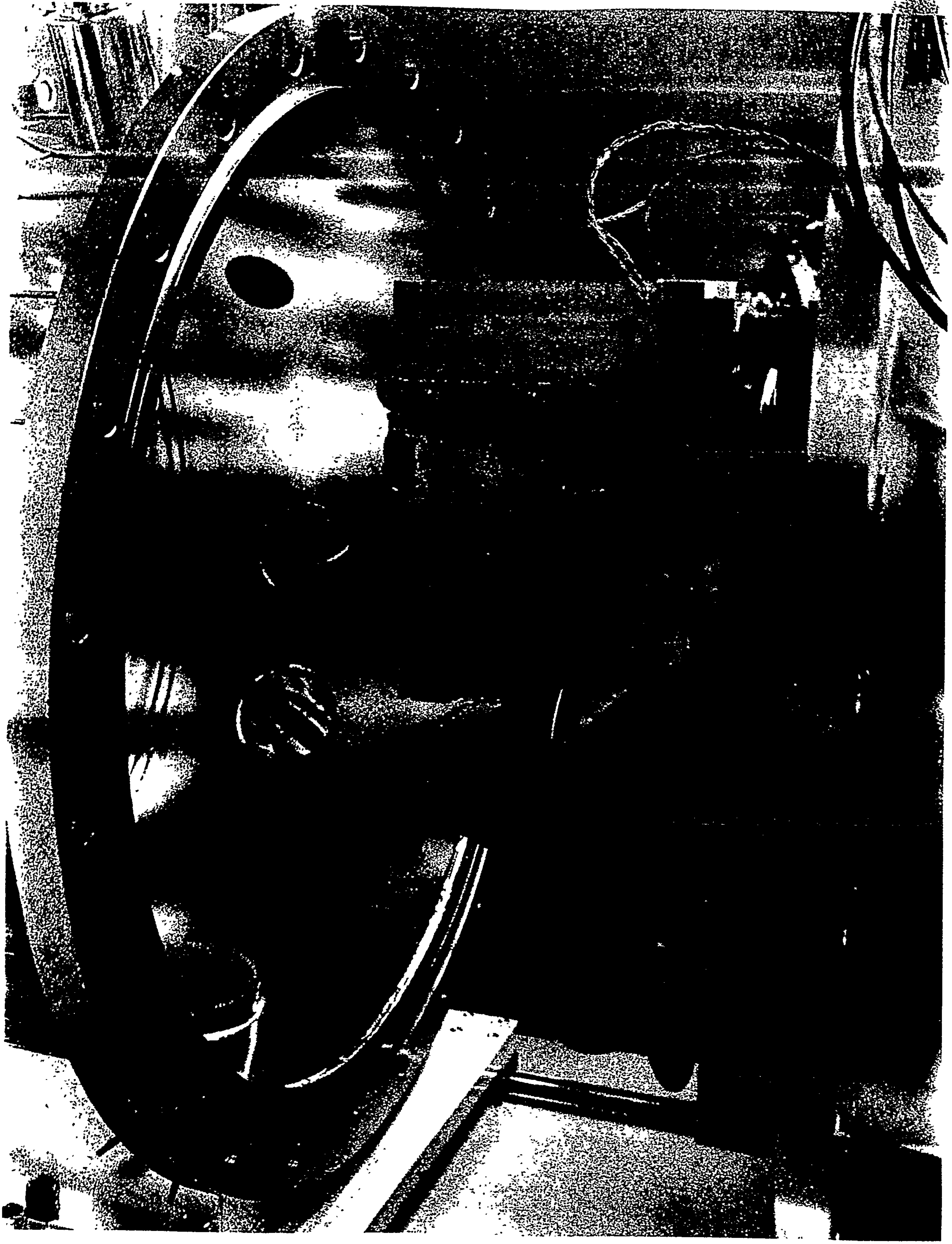
Orient Xtal for Cutting
Shape and Cooland channel Design
Cut Crystals
Etch Crystals/ Polish
Check for Perfection
Check for Perfection
Design Crystal Support and Manifold
Fabricate Crystal Support and Manifold
Mount Pb Backstop
Modifications as needed
Obtain Approval to Operate
Step Motors Software/ EPICS
PZTs Ops Software/ EPICS
Vacuum Monitoring Software/ EPICS



Overall sketch of 78 degree incline crystal
for use in the 8-20 keV range




Beam footprint shown for 8 and 20 keV
5 mm
40 mm
200 mm
Silicon top plate
Channels and ribs 1mm wide, 4 mm deep
Slots made with high speed mill (60000 rpm)
file:Si1178incline35mmoff.10



Additional Activities and Tests Planned for High Heat Load Monochromator/Crystals/Ga Pumping System

1. Further tests of mechanics of monochromator and of mono/crystal/pump system (examine flow induced vibrations and possible approaches for mitigation of any problems)

2. Fabricate and in-house test of 85° inclined xtal

3. Replace prototype 78° inclined crystal with frit-bonded crystal assembly

4. Test inclined crystals with high heat flux source (at CHESS with APS mirror, hopefully Summer 94)

5. Complete monochromator control system under EPICS (scanning capability/synchronous motor moves, PZT) and incorporate control of liquid gallium pump under EPICS

6. Improve prototype crystal mounts for ease of use and rapid changes of crystals.

7. Begin development of feedback electronics for maintaining stability of diffracted beam

Summary of High Heat Load Monochromator/Crystal/Gallium System

• We currently have in hand a HHL monochromator system that will work for many Undulator beamline designs at the APS and could be installed today if the APS were running.

• Final and complete testing can best occur when the APS is operational with undulator radiation. Until that time, we have been working with other facilities to simulate the thermal loadings expected at the APS.

• While we have tried to carry one approach to completion there are other approaches that we are investigating.

• We encourage Users to come to us with ideas, particularly when APS can provide support in terms of expertise, unique capabilities, and/or equipment.

APS Staff Working on High Heat Load Optics

Crystals:

Lahsen Assoufid	- FEA, HHL exp. program
Bob Blasdell	- ray-tracing inclined crystal, diamond monochromator pgm., crystal bonding program
Patricia Fernandez	- laser simulation, HHL exp. program (on leave)
Wah-Keat Lee	- exp. program, inclined crystal monochromator design, crystal bonding program
Dennis Mills	- group leader
Shawn Rogers	- FEA modeling, cryogenic cooling
Robert Smither	- liquid gallium pump, asymmetric crystals

Mirrors:

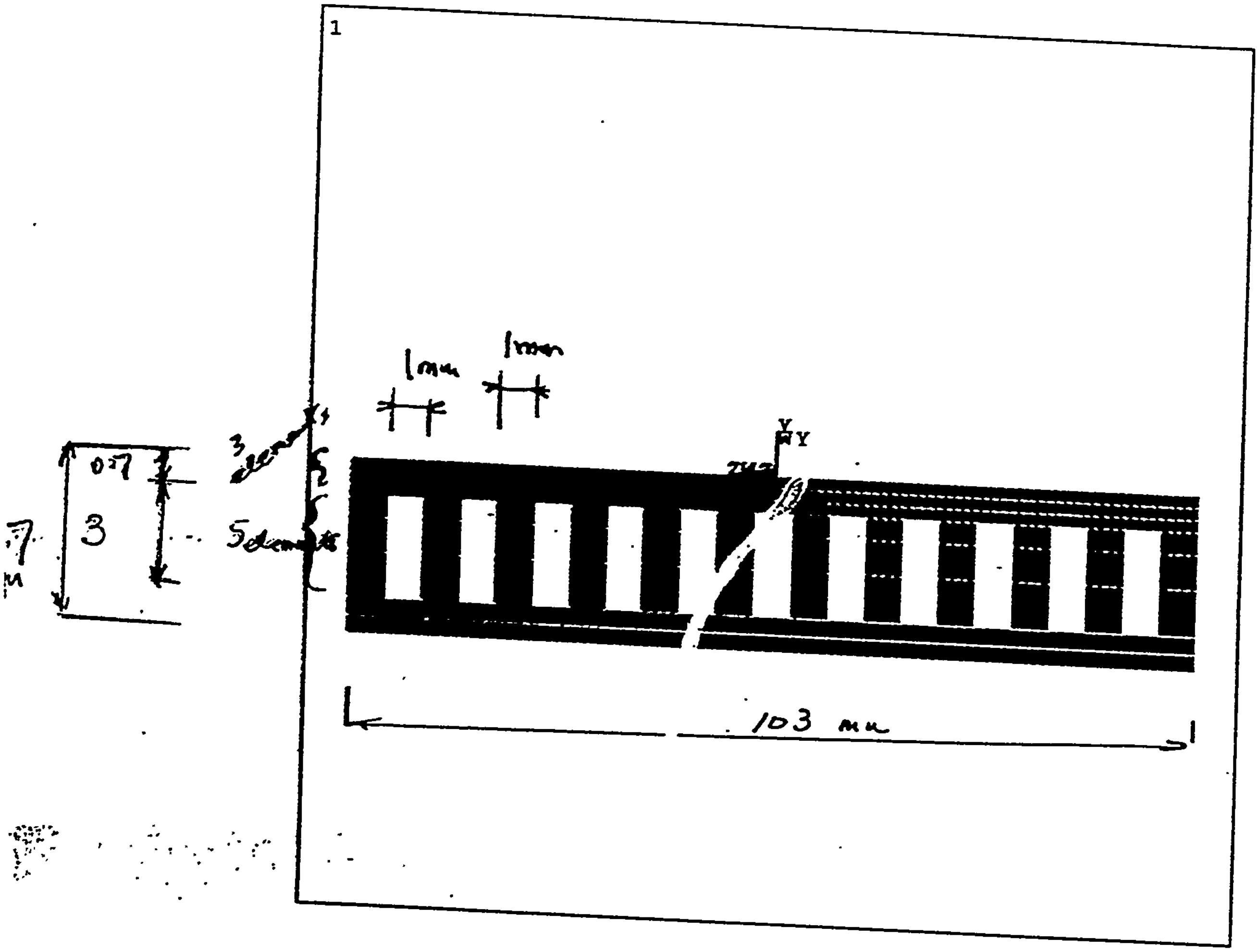
Lahsen Assoufid	- analysis and design for focusing mirror for high power density
Ali Khounsary*	- analysis & design of HHL mirror
Kevin Randall*	- design of HHL mirror
George Srajer*	- specs. and procure. for focusing mirror for high power density
Wenbing Yun*	- design for HHL mirror

Technicians:

Al Paugys
Dale Ferguson

We will add a Post Doc. in June. In addition I have requested an additional Mech. Eng. be assigned to this activity starting ASAP.

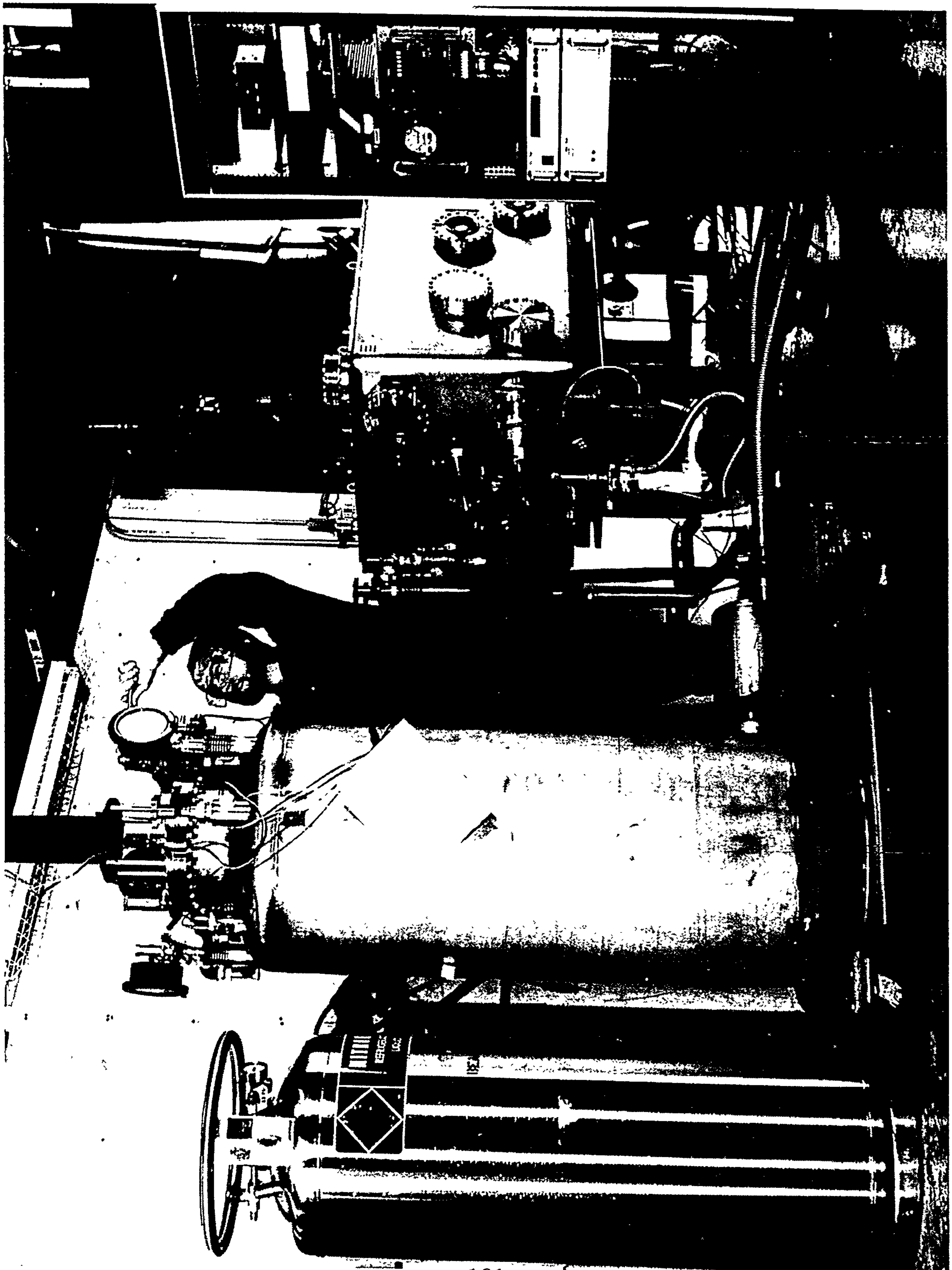
* not full time HHL staff

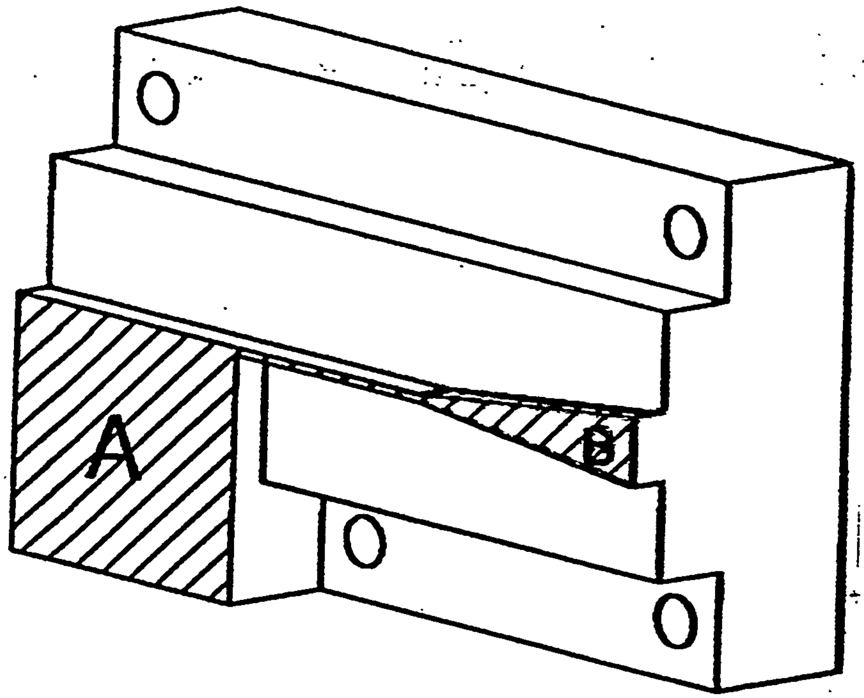

1
1mm
1mm
3 elements
2
5 elements
0.7
3
7
103 mm

Ongoing R&D Activities

Experimental: Monochromators and Crystals

- Tests of Kohzu monochromator **(Lee, Mills)**
- Test prototype inclined crystal on focused wiggler beam at CHESS **(Lee)**
- Test of coolant distribution manifolds (for the reduction of flow induced vibrations) **(Lee)**
- Test (commercial) DC liquid gallium pump at synchrotron source **(Smither)**
- Re-design and re-test Rocketdyne crystals with optimized pin/post pattern heat exchanger **(Smither)**
- Test of thick cryogenically cooled crystals in-house and at CHESS in the Summer 94 time frame **(Rogers)**
- Tests and improvements of closed loop cryogenic system **(Rogers)**
- A thin cryogenically compatible crystal has been designed and is being fabricated. In-house and HHL tests are planned for summer. **(Rogers and Knapp, MSD)**



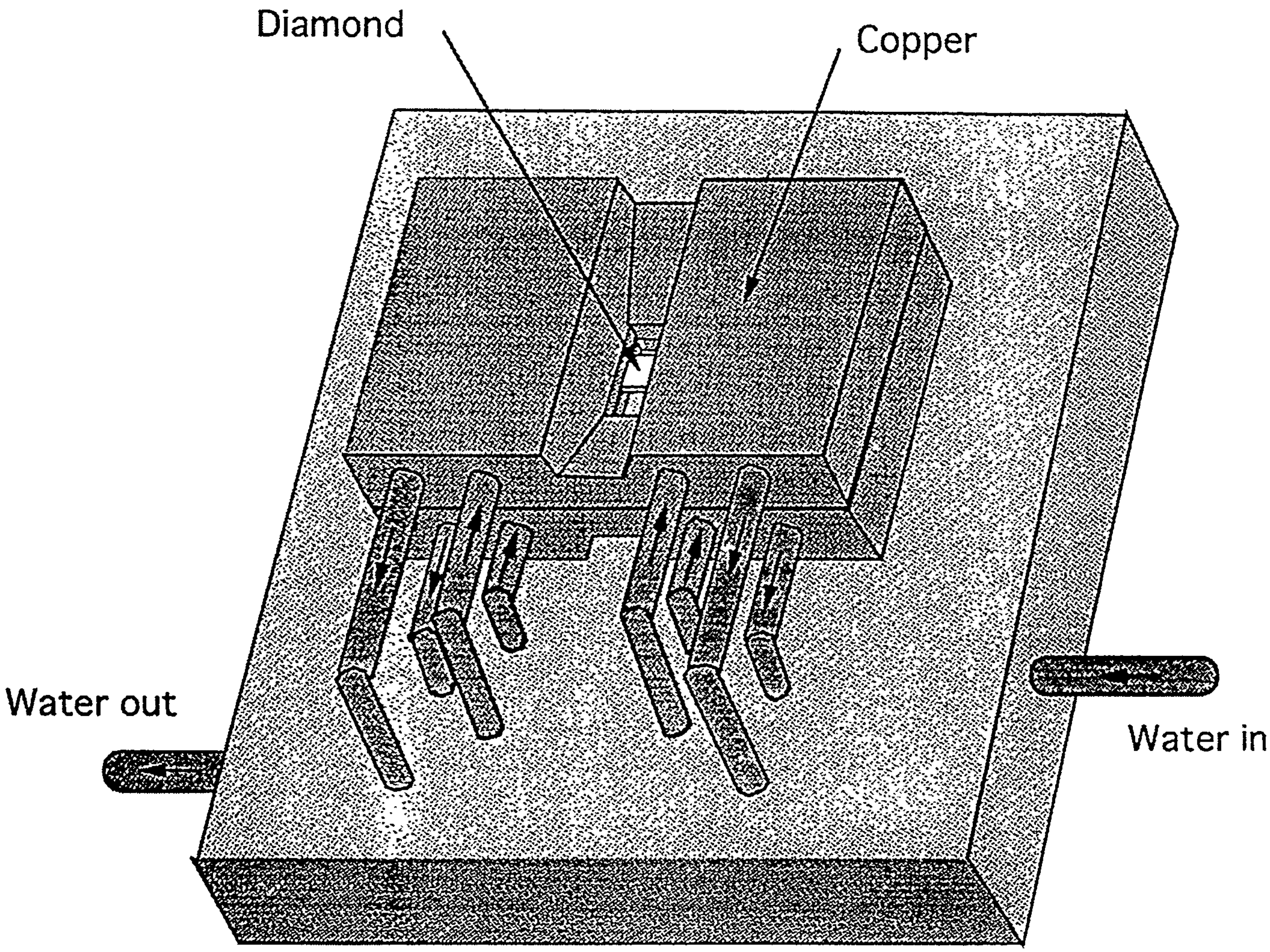


Perspective view of one half of the proposed crystal.

- Expand and accelerate R&D program in use of diamonds as first optical components. In collaboration with the ESRF and SPring-8, encourage and work with single crystal diamonds growers to increase size and perfection **(Blasdell)**

- Test of variable asymmetric crystal in the Summer 94 time frame. **(Smither)**

- In collaboration with HASYLAB, test various HHL x-ray optical components on DORIS III wiggler beamline (early 1995) **(Lee, Smither)**



Edge Cooled Diamond Monochromator Design

Experimental: Mirrors and Multilayers

- Fabrication of a cooled prototype mirror **(Khounsary, Randall, and Yun)**

  Specifications:

Type	horizontally deflecting
Angle of incidence	1.25°
Size	300 x 100 x 61 mm
Shape	cylinder (ρ = 1400m)
Surface roughness	3 Å rms
Slope error	<2 μradians rms (no power) <3 μradians rms (power)
Max. heat flux	3.2 watts/mm^2
Incident power.	2 kW
Coatings	Ni, Pt, Rh
Substrate	silicon
Cooling	water

  Expected delivery date is now June 1994.

- Install, test and evaluation of CHESS high heat load mirror. The HHL mirror for the CHESS wiggler is about to be delivered. (Expected delivery date is now mid June). Plans are being made for installation in June. **(Srajer, Assoufid)**

Comparison of power and power densities from various synchrotron sources

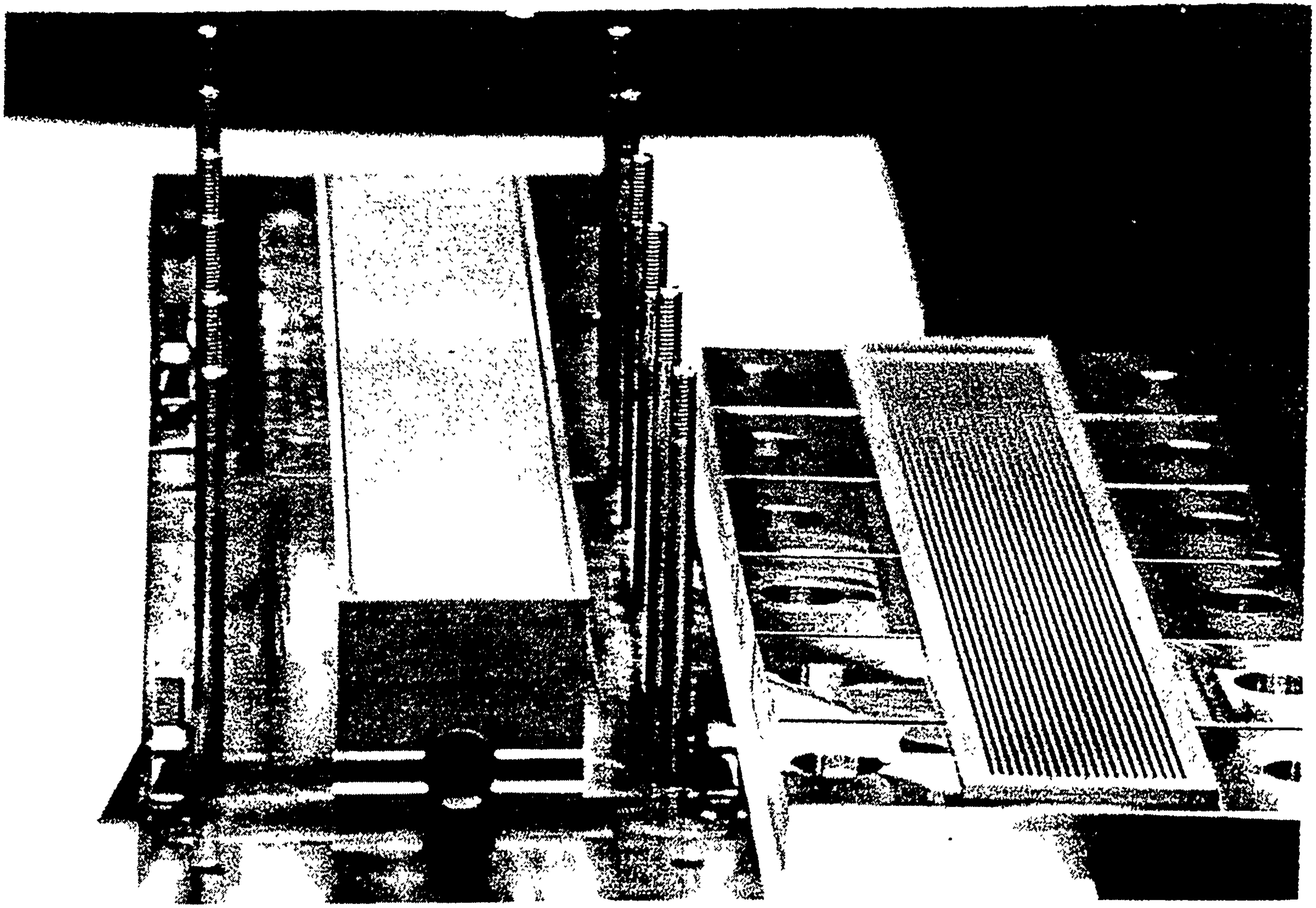
Source	Power (kW)	Power Density (w/mm2)
CHESS F-2 wiggler (unfocused)	1.0	15
APS/CHESS prototype undulator	0.4	50
NSLS X-25 wiggler (focused)	0.04	120
CHESS A-2 wiggler (focused)	**0.7**	**150-200**
APS Undulator A (slit)	0.8	150
APS Undulator A (no slit)	3.8	150

In addition to using this mirror for producing a test beam, we plan to examine mirror figure distortions under thermal loads. Heat loadings similar to that expected at the APS can be achieved by increasing the angle of incidence over that typically used in actual operation. Our plan is to attempt to optically monitor thermal distortions *in situ.*

Specifications for CHESS Wiggler Mirror:

Size	1200 x 80 mm
Shape	bent cylinder (torus)
Surface roughness	3 Å rms
Slope error	1 μradians rms (no power)
	2 μradians rms (power)
Max. heat flux	0.5 watts/mm^2
Max. power abs.	2 kW
Meridional radius	∞ to 2.2 km (variable)
Sagittal radius	3.88 ±0.02 cm
Coatings	Ni with 300 Å Pt
Substrate	Glidcop
Cooling	water

MIRROR SUBSTRATE CONFIGURATION

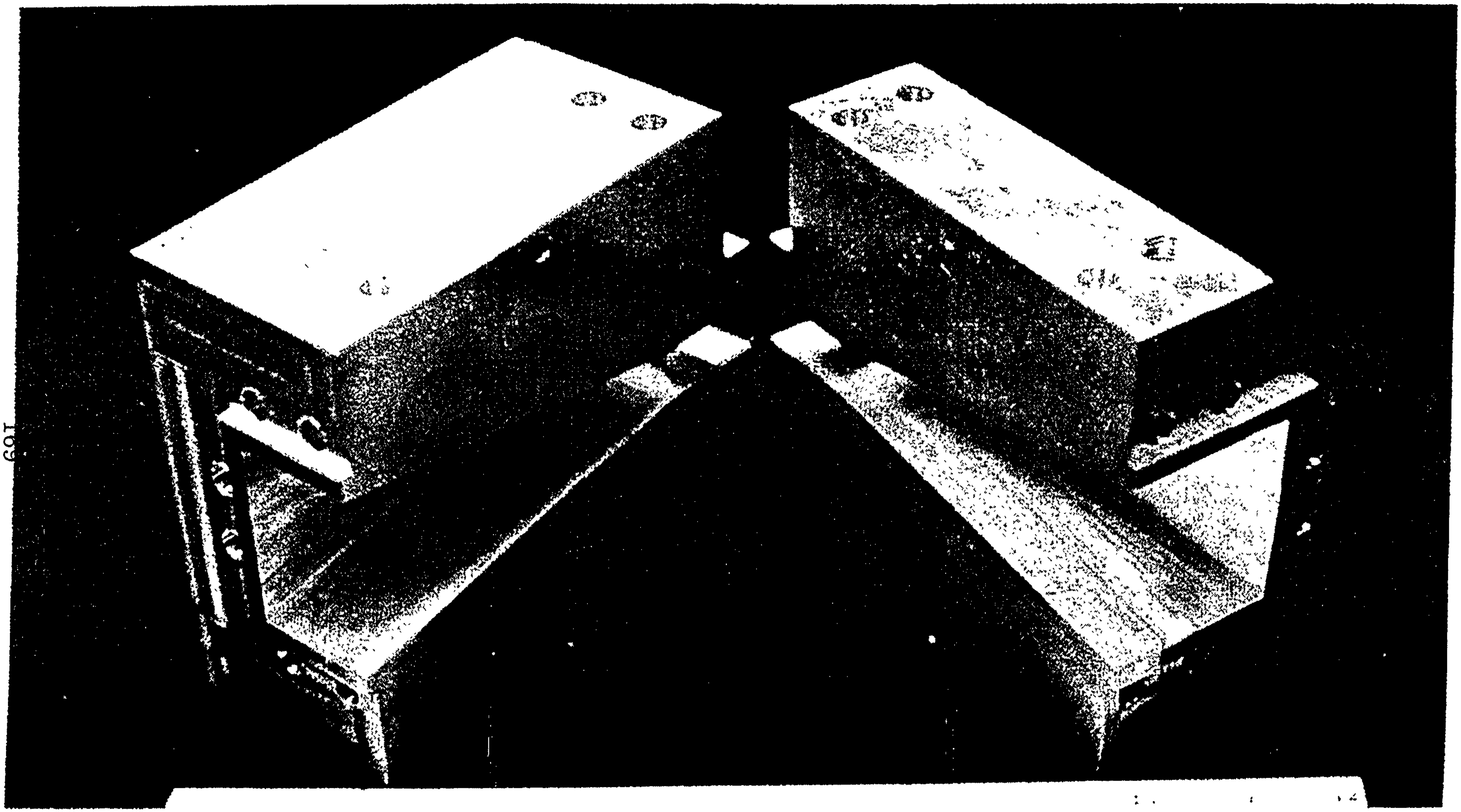


- **Mirror face plate with water channels and body mounted in braze fixture.**

ADVANCED PHOTON SOURCE HIGH HEAT LOAD PROGRAM.

Photon Sciences
International Incorporated

WHITE BEAM MASK BODY



- **OFHC Copper Body Details**

ADVANCED PHOTON SOURCE HIGH HEAT LOAD PROGRAM.

Photon Sciences
International Incorporated

- Complete tests and evaluation of micro-channel cooled substrates for multilayers. **(Khounsary, Yun)**

Specifications:

Angle of incidence	0.5° - 6° (30 ev < E < 4 kev)
Size	90 x 45 x 43 mm
Shape	flat
Surface roughness	1 Å rms
Slope error	<2 μradians rms (no power)
Max. heat flux	1.5 watts/mm^2
Incident power.	360 watts
Substrate	silicon
Cooling	water thru μchannels

The unpolished unit has been delivered and tested in-house for vacuum compatibility and pressure induced distortions from the coolant. It has now been sent back for final polishing for acceptance of multilayer deposition. Expected delivery date is end of July.

Modeling:

- Modeling of warm Si inclined crystal for Undulator A and flat crystals for BM and Wiggler A source. This is currently being summarized and written up for distribution. **(Assoufid)**

- FEA of diamond crystal with Undulator A **(Assoufid)**

- Continue FEA of thin crystals (Si, diamond) at room temperature and cryogenic temperatures with APS undulator power and power densities **(Assoufid and Rogers)**

ANL/APS/TB-19

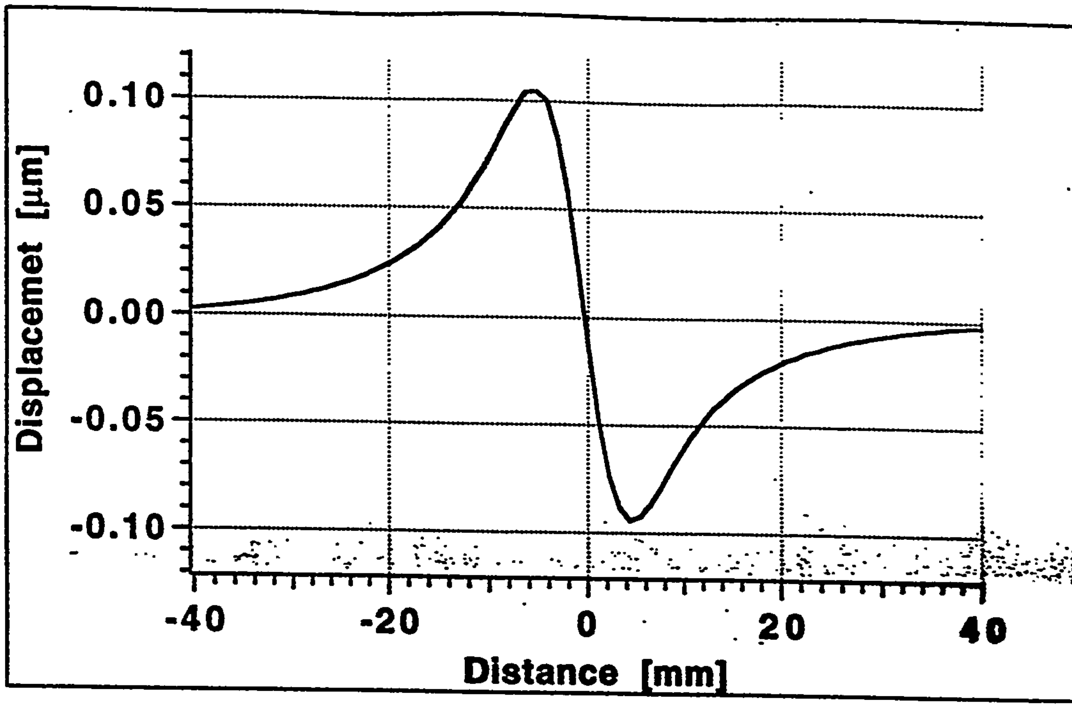
A Finite Element Analysis of Room Temperature Silicon Crystals for the Advanced Photon Source Bending-Magnet and Insertion-Device Beams

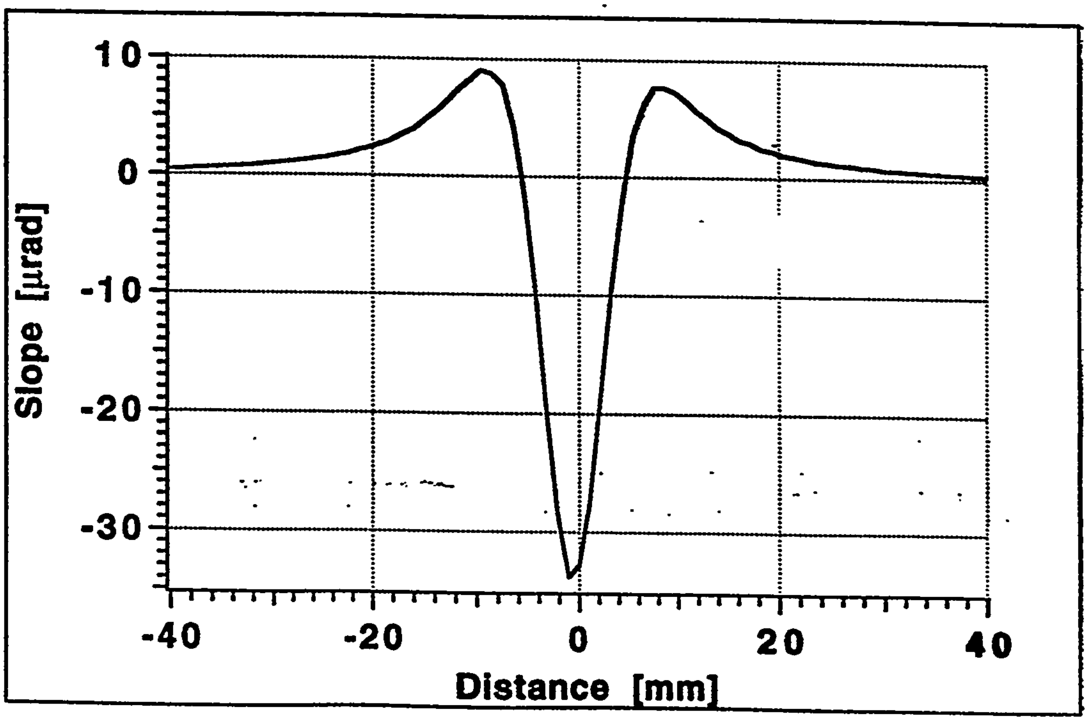
by L. Assoufid, W.-K. Lee, and D.M. Mills

August 1994

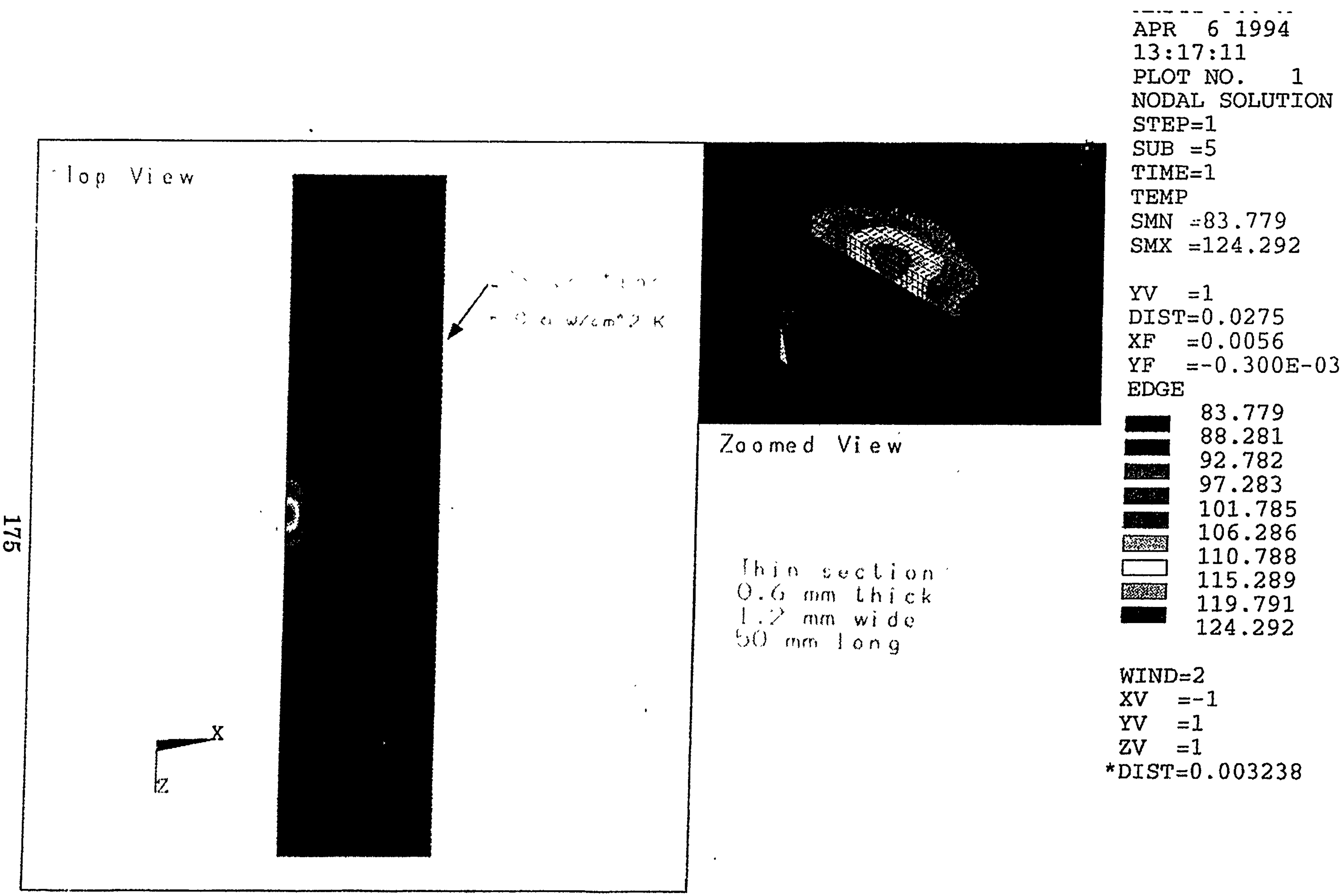
Advanced Photon Source

Argonne National Laboratory
operated by The University of Chicago for the U.S. Department of Energy under Contract W-31-109-Eng-38



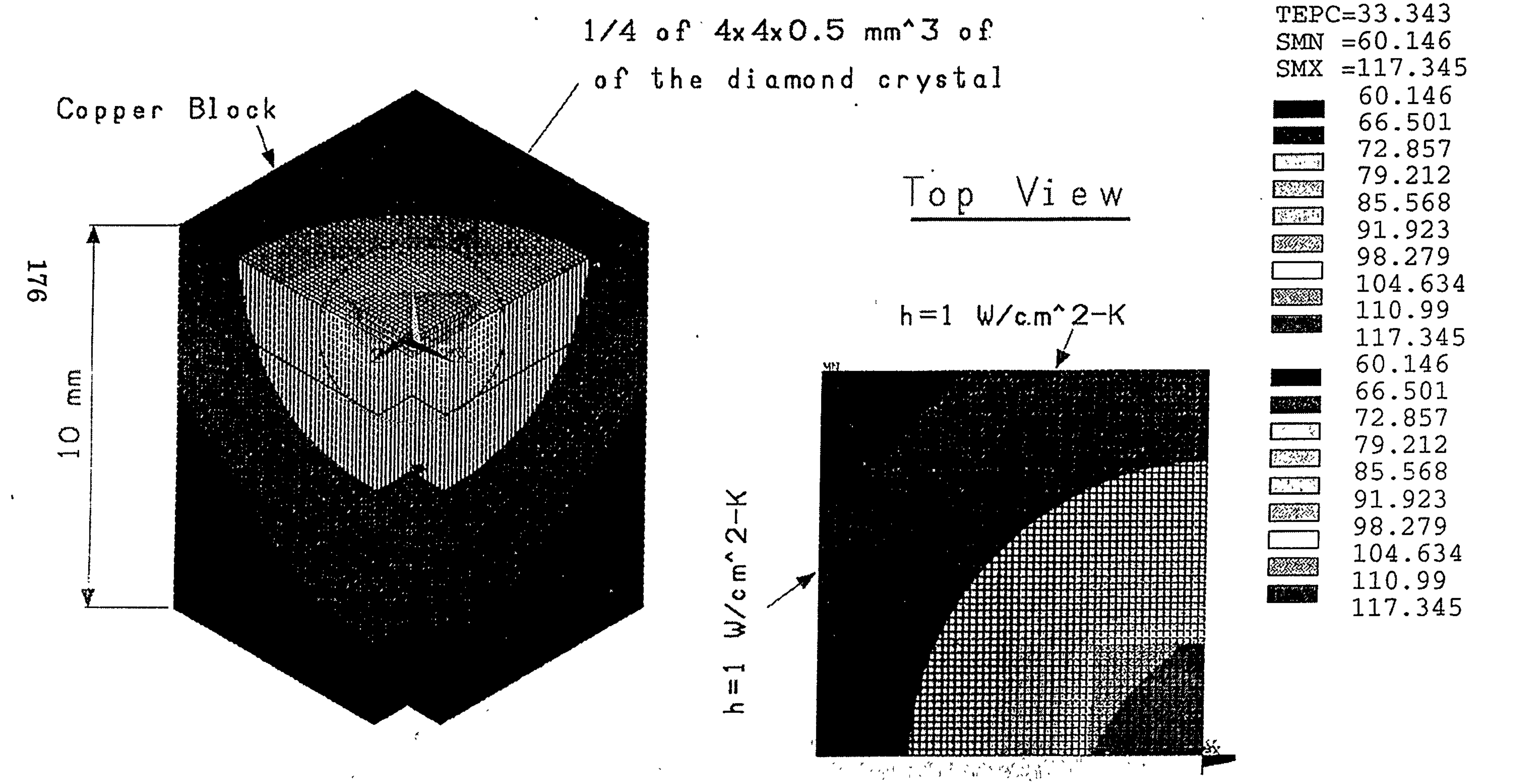


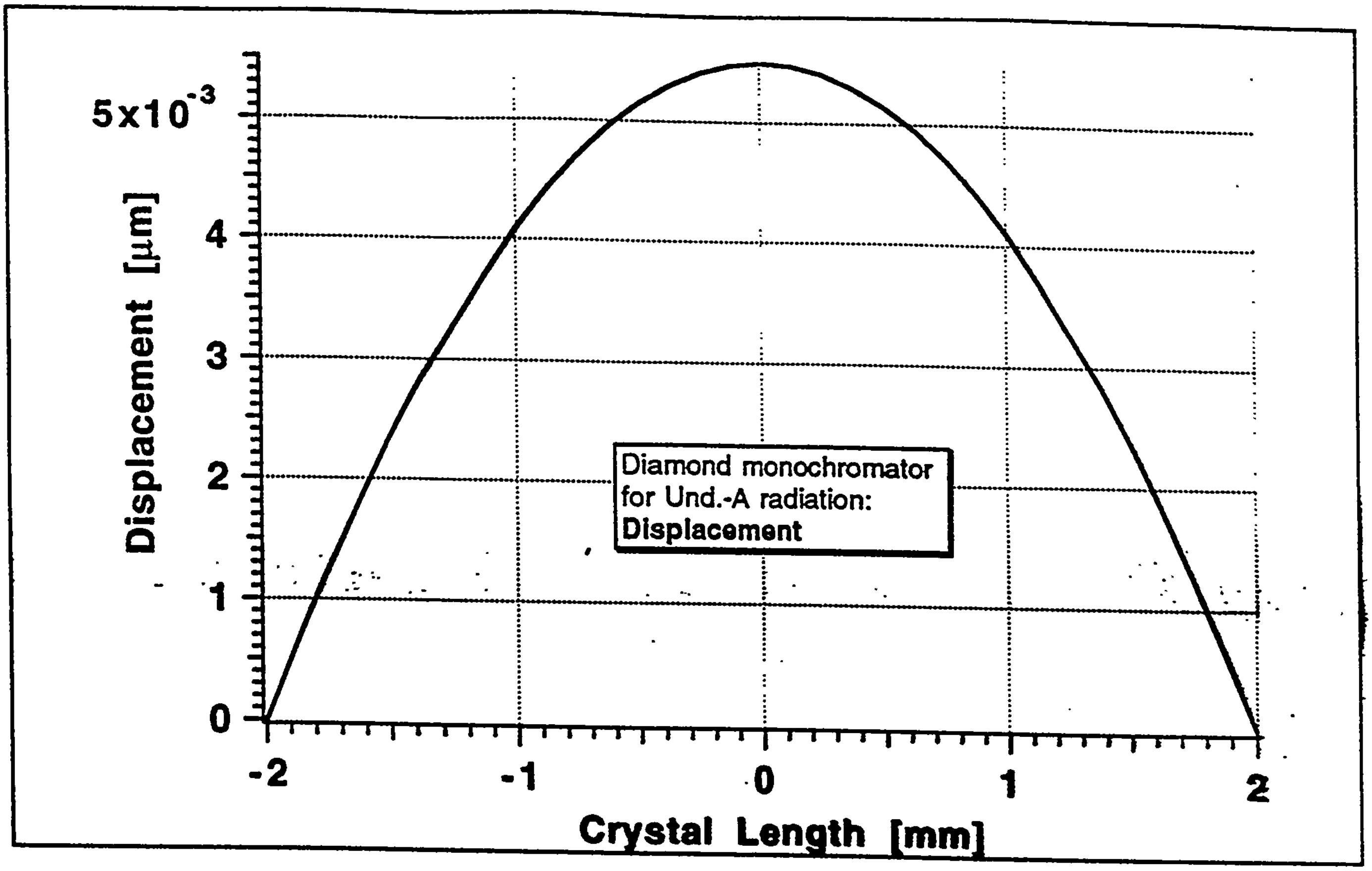
Inclined crystal with no slits: displacement and slope along the crystal main axis, normal to the planes of diffraction.
April 10, 1994



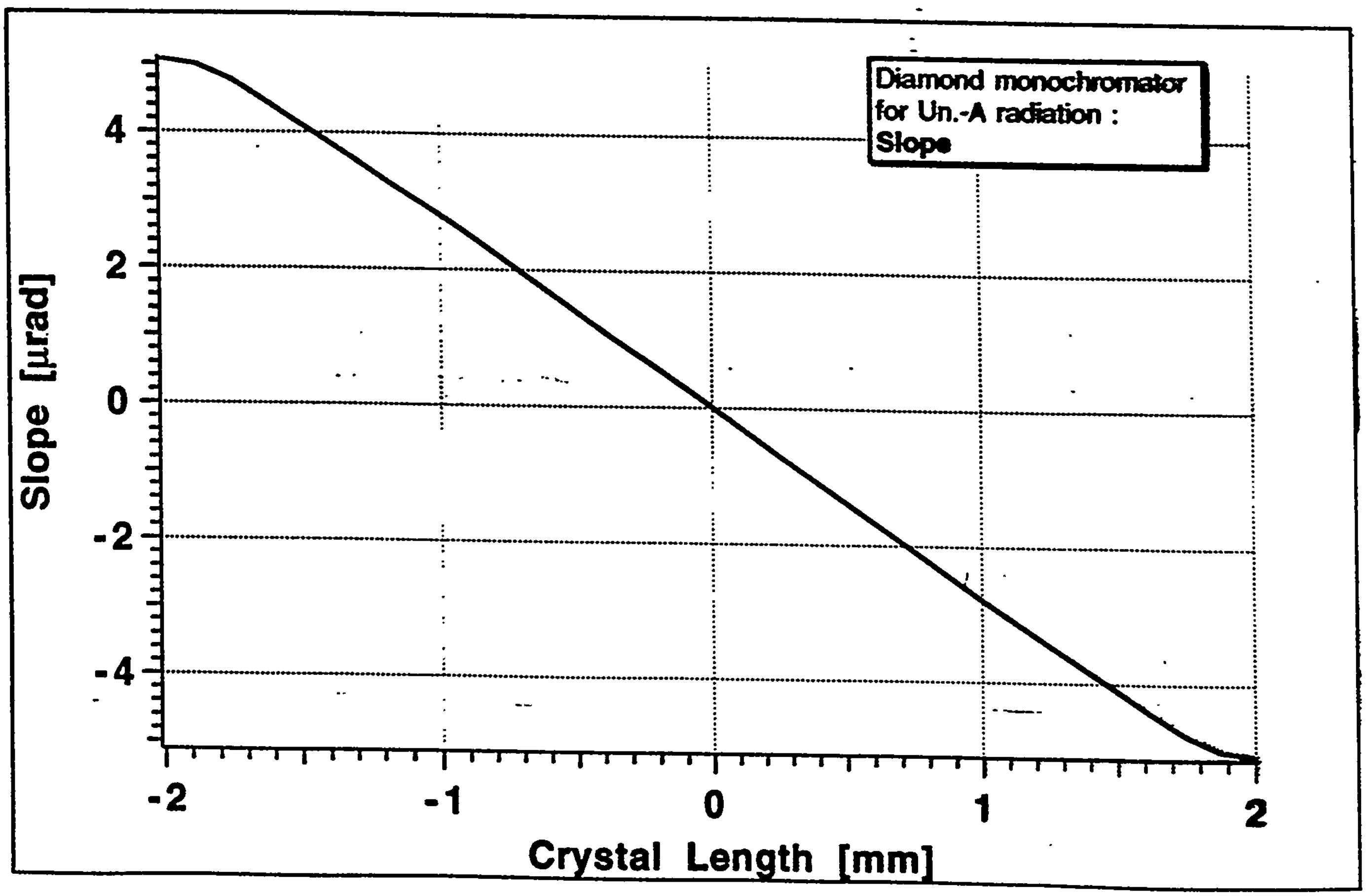
Thin cryogenic crystal,Si<111>,3.866 keV,K=2.33,I=100 mA Power=65 W

Diamond crystal subject to the APS UA beam





Diamond monochromator
for Und.-A radiation:
Displacement
Displacement [µm]
5x10^{-3}
4
3
2
1
0
-2
-1
0
1
2
Crystal Length [mm]



Diamond monochromator
for Un.-A radiation :
Slope
Slope [µrad]
4
2
0
-2
-4
-2
-1
0
1
2
Crystal Length [mm]