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Dynamic Vacuum Analysis for APS High Heat Flux Beamline Front Ends Using Optical Ray-Tracing Simulation Methods

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ABSTRACT

The high-power and high-flux x-ray beams produced by third generation synchrotron radiation sources such as the Advanced Photon Source (APS) can cause significantly high gas desorption rates on beamline front-end components if beam missteering occurs. The effect of this gas desorption needs to be understood for dynamic vacuum analysis.

To simulate beam missteering conditions, optical ray-tracing methods have been employed. The results of the ray-tracing analysis have been entered into a system-oriented vacuum program to provide dynamic vacuum calculations for determination of pumping requirements for the beamline front-ends.

The APS will provide several types of synchrotron radiation sources, for example, undulators, wigglers, and bending magnets. For the purpose of this study, the wiggler source was chosen as a "worst case" scenario due to its high photon flux, high beam power, and relatively large beam cross section.

2. RAY-TRACING ANALYSIS

Figure 1 is an insertion device beamline front-end schematic[1]. The smallest aperture elements are of primary interest as these devices will be subjected to synchrotron radiation if beam missteering occurs. These elements are the first and second fixed masks as well as the second photon shutter. Photons that continue downstream of the second photon shutter will also interact with the filters in the filter box and the beryllium window at the end of the front-end.

The position and angular direction of the photon beam in the front end is controlled by the position and angular direction of the positron beam in the storage ring as it enters the insertion device vacuum chamber. Because the front-end components are at least 16 meters downstream of the source (insertion device), the positron angular direction through the insertion device will have a greater effect on the photon beam position than a positron beam position shift at the source.

For this paper, a Monte-Carlo program (Shadow) was used to simulate the photon beam flux spatial distribution produced by the APS Wiggler A source.[2] Figure 2a is an example of the (Shadow) output (5 keV - 32.57 keV) with a missteering parameter of 0.2 mrad at the first and second fixed masks and the second photon shutter. To simulate the source vertical angular missteering conditions from 0 to 0.30 mrad, a virtual scanning plane mirror was included in the system.

Figure 2b consists of a diagram of the beamline front-end ray-tracing data (5 keV - 32.57 keV) indicating beam size and position at fixed mask 1, fixed mask 2, and the second photon shutter with beam missteering conditions from 0 to 0.3 mrad. The rectangles represent aperture sizes, and the dotted areas are the beam size and position with respect to the aperture under different missteering conditions. Figure 2c indicates the ray- tracing data (5 keV - 32.57 keV) for rays that pass through the beryllium windows at the exit of the front-end.

Table 1 indicates the photon flux energy distribution. Table 2 depicts the number of rays striking each of mask 1, mask 2, shutter 2, and the number of rays passing through the beryllium windows at the exit of the front-end.

3. DYNAMIC VACUUM ANALYSIS

The purpose of the ray-tracing studies is to determine the number of photons/sec interacting with beamline front-end components under missteering conditions. When this is known for each component, the photon-induced desorption for each component can be calculated by:

des (Torr liter/sec) = $2 N \eta\gamma K$, [3]

where N = total photons/sec

$\eta\gamma$ = desorption coefficient (mol/photon)

$K = 3.11 \times 10^{-20}$ Torr liter/mol.

The desorption coefficient used in the front-end vacuum calculations (1×10^{-6} mol/photon) is a reasonable achievable value as measured and reported at the vacuum workshop at Cornell University in Jan. 1992.[4]

To determine the effects of the desorption gas loads created by beam missteering on the front-end vacuum profile, the front- end is divided into 17 elements and the volume, conductance, pumping speed, thermal desorption, and photon-induced desorption of each element is calculated. These are entered into a finite element analysis vacuum program developed at Argonne to plot pressure profiles of the front-end vacuum characteristics. The program provides "what if analysis" for changes in pumping speed or any of the input variables to determine the effect on the pressure profiles. The effect of "beam cleaning" with respect to time can also be examined providing estimates for commissioning times and beam currents acceptable for early start-up conditions.

Figure 3 is a pressure profile generated by the vacuum program with 100 ma stored positron current in the storage ring and approximately 3.3 x 1018 photons/sec produced by the wiggler. Normal operating conditions are shown with no missteering.

Figure 4 is a pressure profile produced under the same conditions as Figure 3 with the exception that the beam is missteered vertically by 0.3 mrad. The pressure increase due to missteering is quite evident.

Figure 5 is a pressure profile with 1 ma stored positron current in the storage ring with a corresponding decrease in the wiggler-produced photon flux and no beam missteering.

Figure 6 is a pressure profile with conditions the same as those in Figure 5 but with the beam missteered vertically by 0.3 mrad. Again the pressure increase due to missteering is evident.

The storage ring and the upstream area of the front-ends require a "beam on" pressure of 1×10^{-9} Torr or better in order to achieve the desired 10 hour beam lifetime. Examination of the pressure profiles (Figs. 3-6) indicates a pressure of 1×10^{-9} Torr would be achievable after 10 hours of running time with 100 ma stored beam in the storage ring with no beam missteering. If the beam was missteered by 0.30 mrad, the time to reach 1×10^{-9} Torr would increase to greater than 100 hours. Reducing the stored beam current to 1 ma would produce an upstream front-end pressure of 1×10^{-9} Torr within minutes even with 0.30 mrad beam missteering.

4. CONCLUSION

The pressure profiles indicate a stored beam current of between 1 ma and 100 ma (e.g. 10 ma) would be acceptable during initial start-up and commissioning. This current should provide pressures in the low 10^{-9} Torr range in the upstream front-end areas. Past experience has proven that commissioning currents are generally low due to accelerator tuning conditions and the learning time needed to optimize accelerator parameters. It appears unlikely that the beamline front-end vacuum would be a limiting factor for beam intensity during commissioning. It may in fact be advantageous to modulate the beam vertical steering parameters during commissioning to help "clean up" front-end components in order to reduce gas loads caused by any beam missteering during actual running periods. It must also be realized that accelerator diagnostics would not permit long periods of beam missteering. During accelerator operations, feedback systems would correct missteering conditions or "dump" the stored beam if missteering was severe and could not be corrected.

5. ACKNOWLEDGEMENTS

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6. REFERNECES

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2. S. Xu, B. Lai, and PJ Viccaro, "APS Undulator and Wiggler Sources: Monte-Carlo Simulation," Argonne National Laboratory ANL/APS/TB-1 (Feb. 1992)

3. S. Tazarri, "Synchrotron Radiation Distribution along the Vacuum Chamber," European Synchrotron Radiation Project Report ESRP-IRM-32/84 (1984)

4. International Workshop on Vacuum Systems for B-Factories and High Energy Synchrotron Light Sources, Cornell University, (Jan., 16-18, 1992)

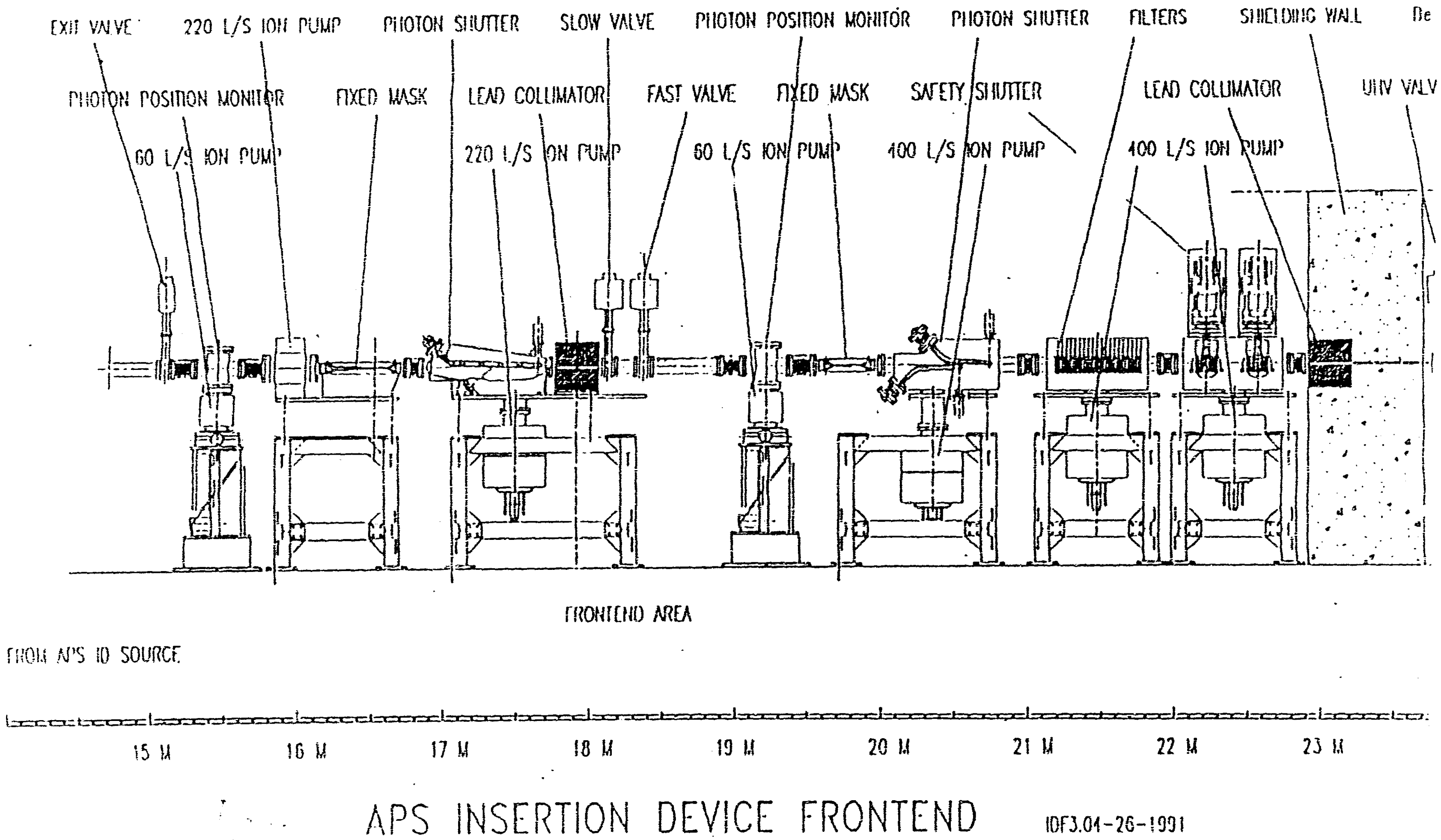
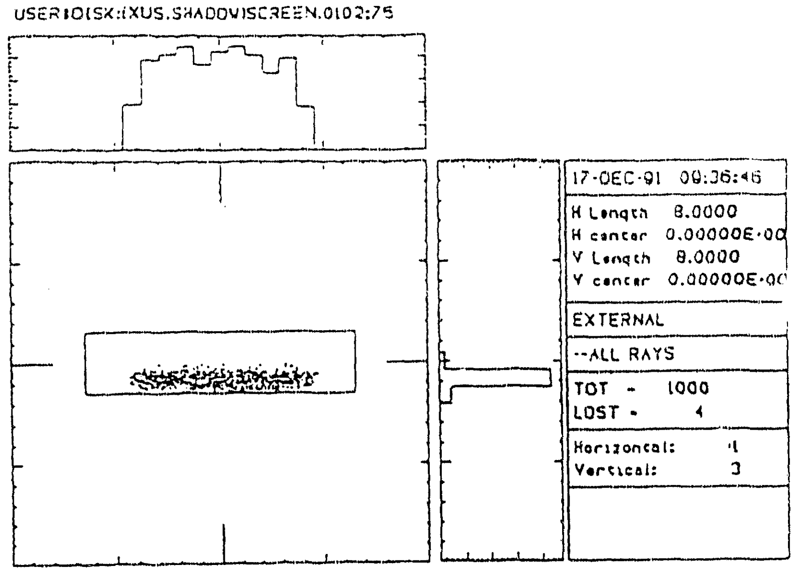
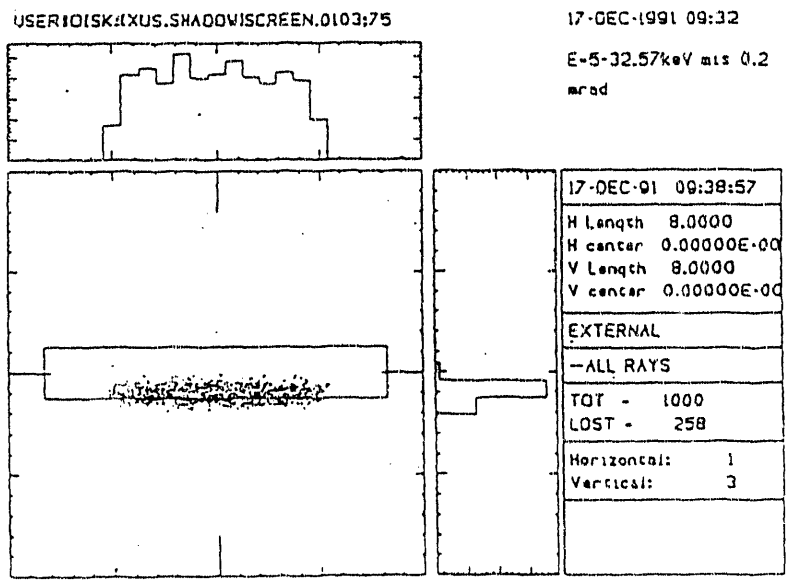

EXIT VALVE
220 L/S ION PUMP
PHOTON SHUTTER
SLOW VALVE
PHOTON POSITION MONITOR
PHOTON SHUTTER
FILTERS
SHIELDING WALL
PHOTON POSITION MONITOR
FIXED MASK
LEAD COLLIMATOR
FAST VALVE
FIXED MASK
SAFETY SHUTTER
LEAD COLLIMATOR
UHV VALV
60 L/S ION PUMP
220 L/S ION PUMP
60 L/S ION PUMP
400 L/S ION PUMP
400 L/S ION PUMP
FRONTEND AREA
FROM APS ID SOURCE
15 M
16 M
17 M
18 M
19 M
20 M
21 M
22 M
23 M
APS INSERTION DEVICE FRONTEND
IDF3.04-26-1991

Figure 1

Shadow
Results



On the
Fixed Mask 1



On the
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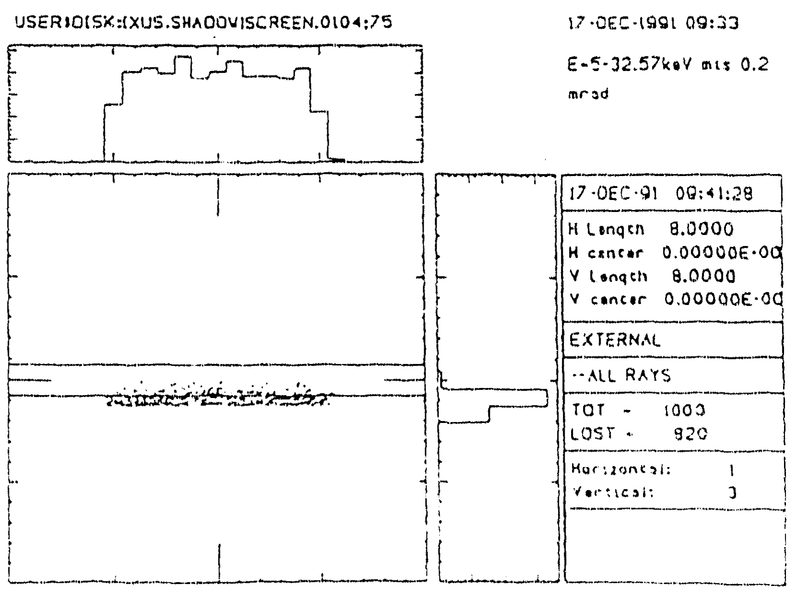
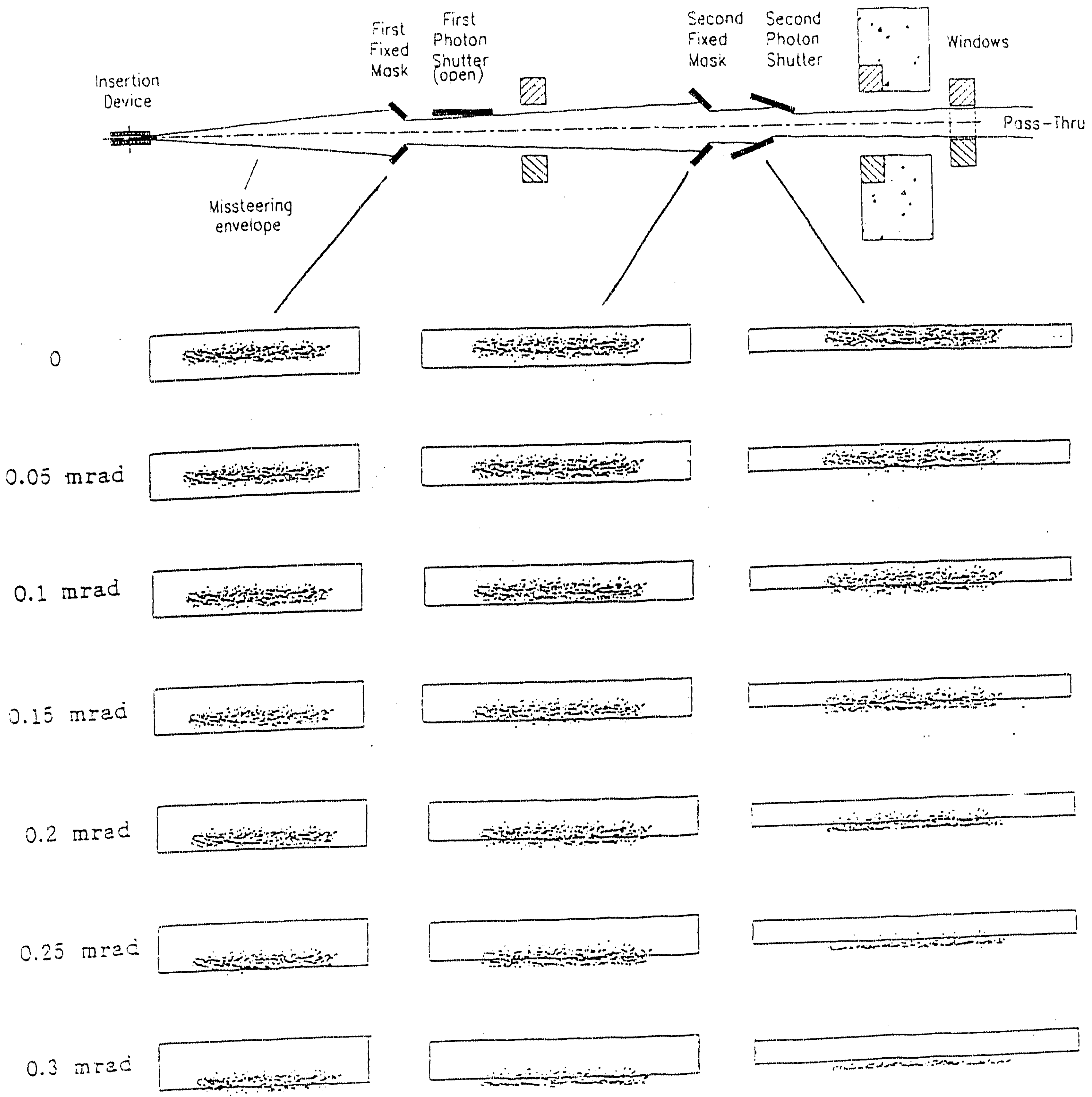


On the
Second Photon
Shutter

Figure 2a



Wiggler beam (E = 5 - 32.5keV) ray-tracing data under 0 to 0.3 mrad missteering conditions

Figure 2b

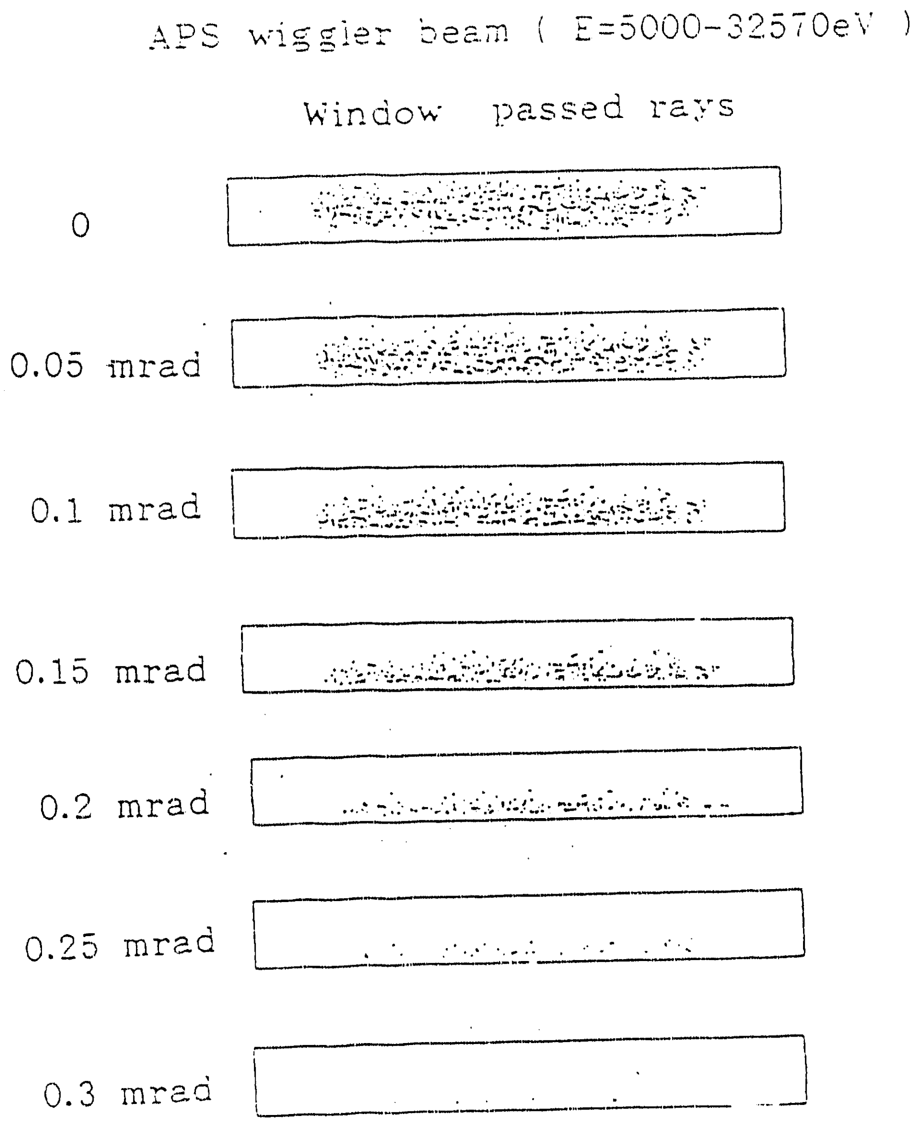
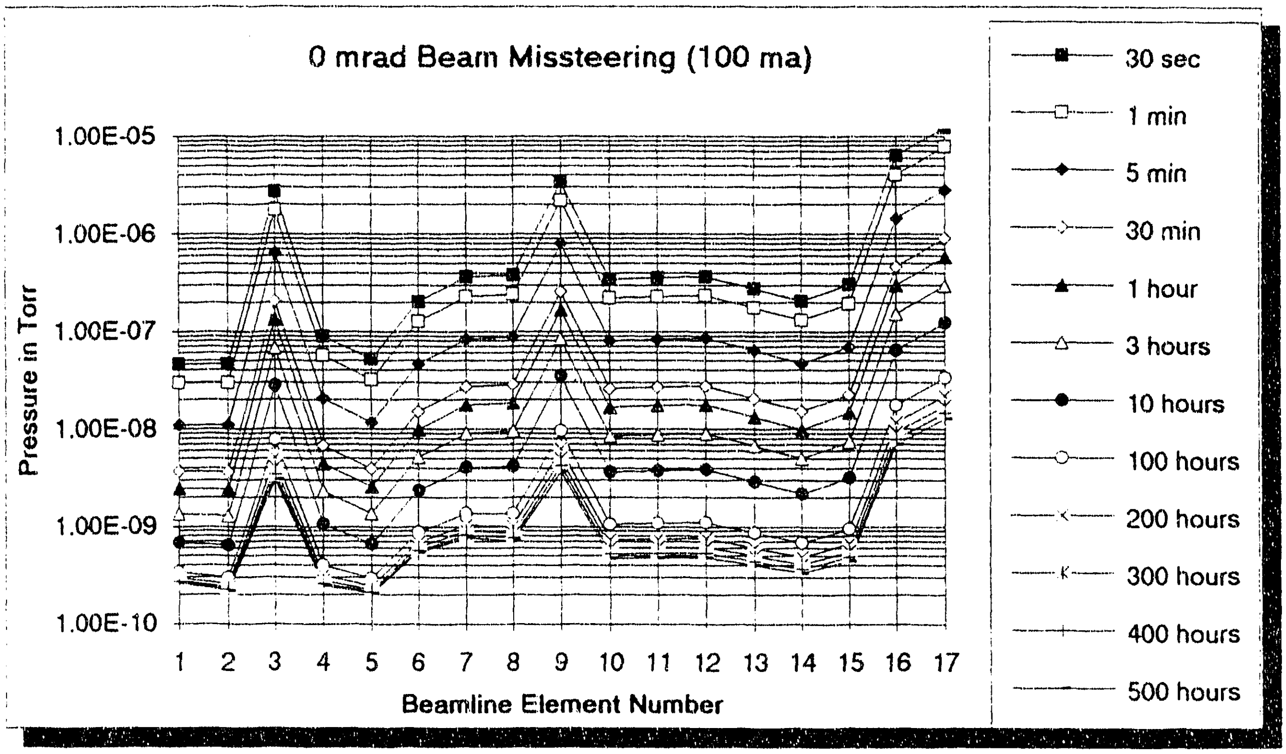
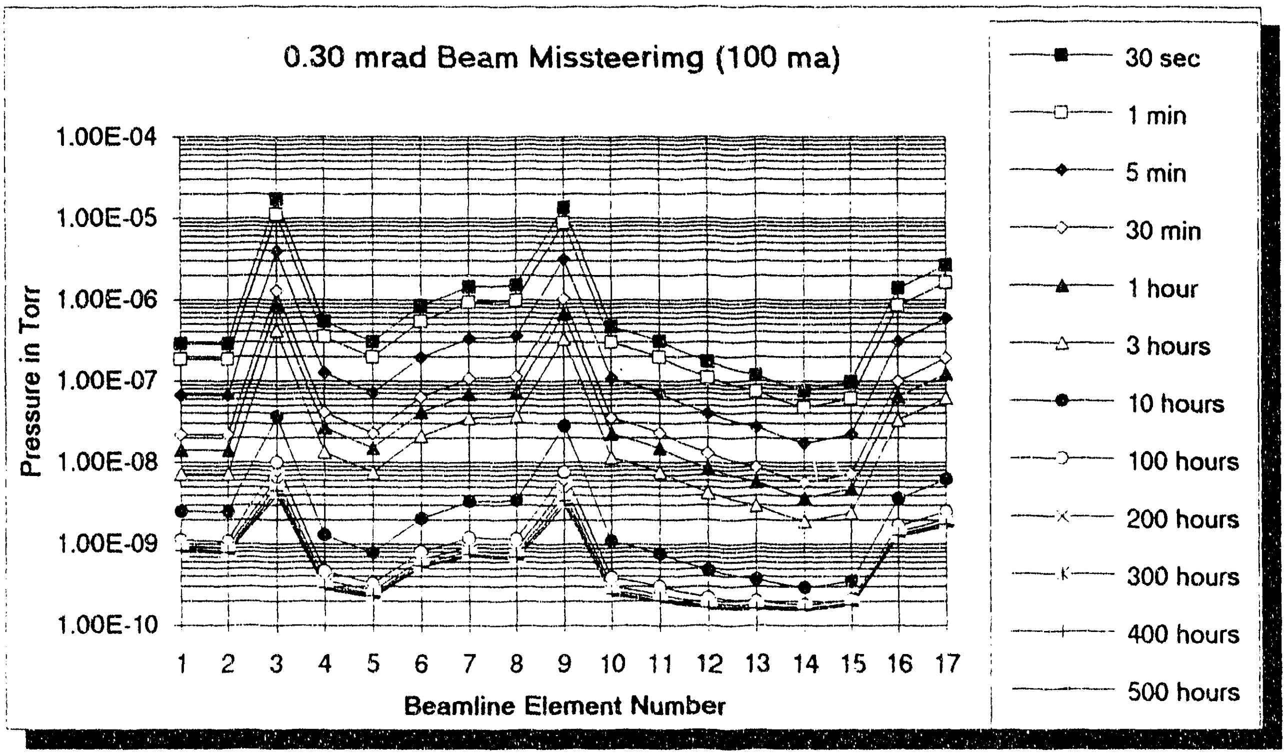

APS wiggler beam (E=5000-32570eV)
Window passed rays
0
0.05 mrad
0.1 mrad
0.15 mrad
0.2 mrad
0.25 mrad
0.3 mrad

Figure 2c



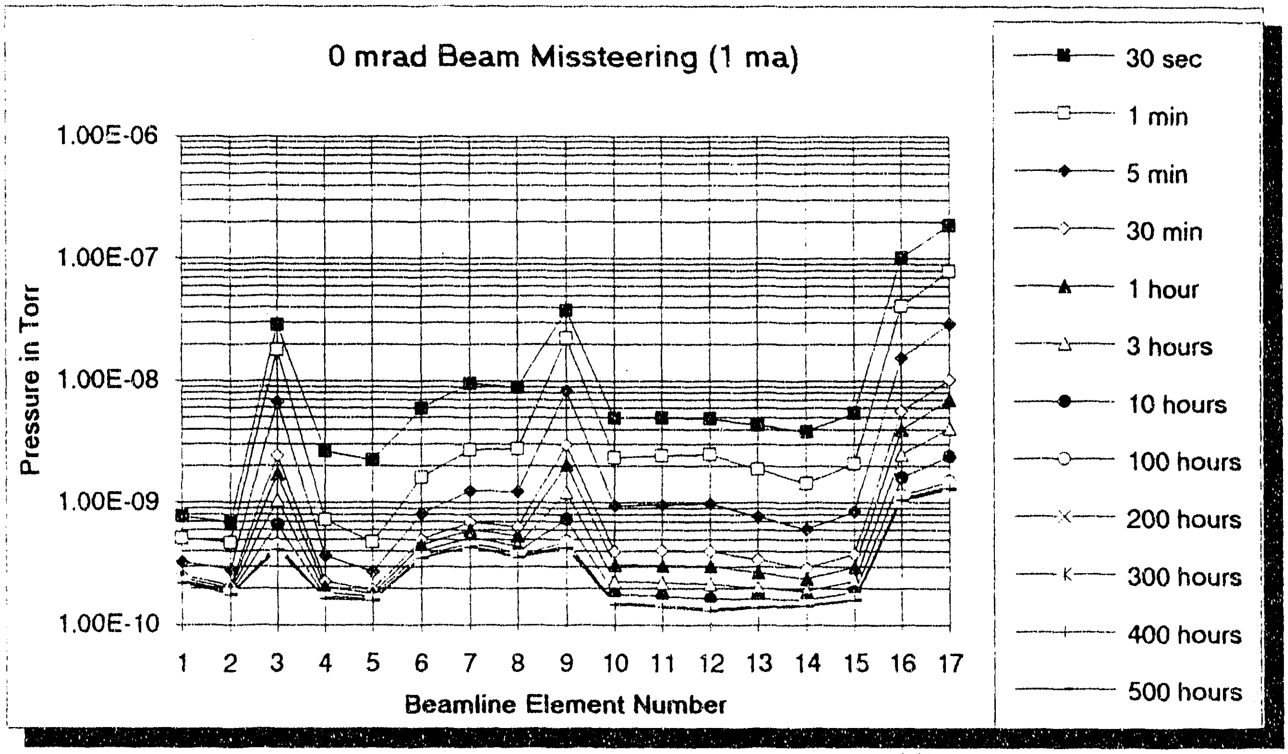
100 ma Stored Beam (No Missteering)

Figure 3



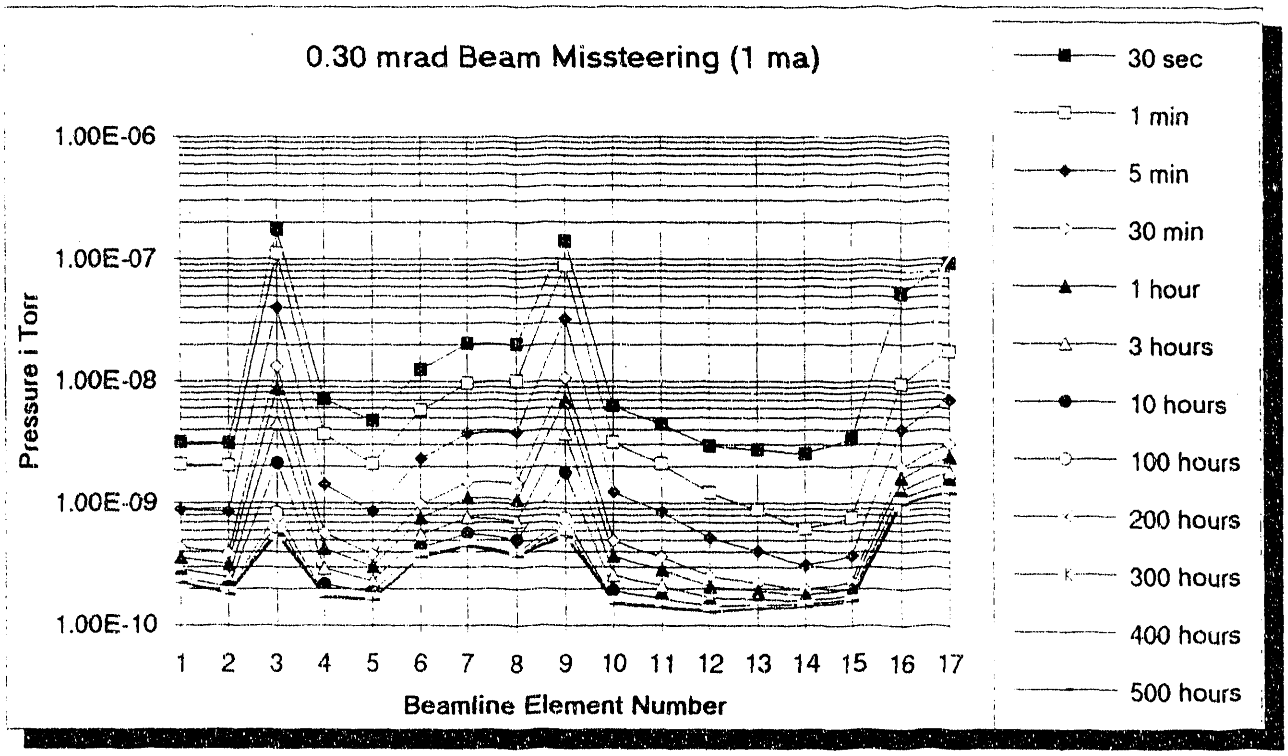
100 ma Stored Beam (0.30 mrad Missteering)

Figure 4



1 ma Stored Beam (No Missteering)

Figure 5



1 ma Stored Beam (0.30 mrad Missteering)

Figure 6

DISCLAIMER

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