General Design of the Layout for New Undulator-Only Beamline Front Ends

Deming Shu, Mohan Ramanathan, and Tuncer M. Kuzay

Advanced Photon Source
Argonne National Laboratory
Argonne, Illinois 60439, U. S. A.

Abstract. A great majority of the Advanced Photon Source (APS) users have chosen an undulator as the only source for their insertion device beamline. Compared with a wiggler source, the undulator source has a much smaller horizontal divergence, providing us with an opportunity to optimize the beamline front-end design further. In this paper, the particular designs and specifications, as well as the optical and bremsstrahlung ray-tracing analysis of the new APS front ends for undulator-only operation are presented.

1. Introduction

Since 1996, forty front ends, which include twenty bending magnet (BM) beamline front ends and twenty insertion device (ID) beamline front ends, have been completed and became operational at the Advanced Photon Source (APS). The original design of the ID beamline front end was based on compatibility with various ID devices, including undulators and wigglers. These front ends are standardized and modularized, which reduced both cost and engineering effort [1]. They are easy to install and are reliable with respect to both maintenance and operations.

However, since the standard APS ID device, undulator A, achieved an excellent performance in generating high-intensity x-ray radiation in the spectral range 3.2 keV to 45 keV continuously by using the first, third, and fifth harmonics of radiation [2], a great majority of the APS users have chosen an undulator as the only source for their insertion device beamline. Compared with a wiggler source, the undulator source has a much smaller horizontal divergence, providing us with an opportunity to optimize the beamline front-end design to a new level.

2. Design specification

The front end designed for APS 32-ID is a prototype for new undulator-only beamline. We call it a version 1.5 undulator-only front end. As shown in fig. 1, the front end includes a pre-fixed mask that confines the photon beam and protects the downstream components from a mis-steered beam. Two V-shaped photon shutters intercept the photon beam and protect the safety shutters and vacuum valves from thermal load. Three bremsstrahlung collimators and two heavy-metal safety shutters

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provide radiation protection in the downstream experimental area. Two x-ray beam position monitors (XBPMs), which are combined with two fixed masks, provide beam position signals to users.

The major design improvement in this new version is its higher thermal loading capacity with better beam collimating. The new front end is designed to be capable of withholding a maximum total beam power up to 9 kW with 0.8 kW/mm^2 power density, which is about 35% more than the thermal loading capacity of the original version 1.2 undulator/wiggler front end. Furthermore, the first and second photon shutters in this new front end are prototypes of a new V-shaped compact photon shutter with a thermal loading capacity of 12 kW total power with 1.2 kW/mm^2 maximum power density. It is capable of handling the maximum beam power and power density emitted from a 4.8-meter-long double undulator A with APS operating at 100 mA.

In this new design, we have kept design uniformity with the original front ends design in following areas:

- The unity of safety philosophy for the APS front-end design was kept. That is, from the point of view of operations, there is no schematic difference between the new front end and the original undulator/wiggler front ends as described in reference 1;
- The same enhanced heat transfer technology [3] has been used for the design of new front-end high-heat-load components which was well developed in the past years;
- The same source mis-steering parameters have been applied to the new front end ray-tracings.

As shown in table 1, the new front end has a smaller exit optical aperture [3 mm (H) x 2 mm (V)] and an in-vacuum heavy-metal bremsstrahlung collimator aperture [14 mm (H) x 7 mm (V)] for a single beryllium window configuration. These new apertures provide better beam collimation to both synchrotron radiation and bremsstrahlung, as shown in figs. 2 and 3. It simplifies the downstream beamline component design for users.

3. New components

There are three new high-heat-load component prototypes that were developed in this new front end with thermal loading compatibility from a 4.8-meter-long doubled undulator A.

- A V-shaped compact photon shutter P2-30 with a box-type explosive bonding structure;
- A x-ray beam position monitor combined with a fixed mask;
- A polished white beam beryllium window.

The smaller horizontal optical apertures on the fixed masks allowed us to design a V-shaped compact photon shutter (P2-30). This new photon shutter is made from Glid-Cop and stainless steel with an APS-developed box-type explosive bonding technique [4]. Compared with the original P2-20 photon shutter [5], P2-30 provides 150% thermal loading capacity with more than 50% manufacturing cost savings.

The smaller optical apertures on the front end masks also create design challenges for the x-ray beam position monitor (XBPM). We have developed a new prototype of an

XBPM that is combined with a fixed mask. We are continuously testing the XBPM with different CVD diamond-blade configurations.

The 500-μm-thick polished single beryllium window has been designed and tested under a 4.8-meter-long double undulator A white beam with an 11 mm gap and APS 100 mA operating condition without any filtering.

Based on the installation and operation experiences from the original front ends, many design improvements have been made in the details of these new version components, such as a lead collimator for shielding wall penetration, an in-vacuum heavy-metal collimator, and supporting structures for front-end components.

4. Discussion and conclusion

During the past year, the 32-ID front end has been fully commissioned at the APS and is now operational. The new front end presented a good vacuum performance during the commissioning as shown in fig. 4. The construction of three more undulator-only front ends v.1.5 is in progress.

Further experimental studies on the V-shaped box-type explosive bonding structure will provide us with more design information for our new fixed mask design, which is based on such a structure. Once we update the fixed masks to the next version, the new front end will become fully compatible with the 4.8-meter-long double undulator A with the APS operating at 100 mA.

Acknowledgments

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References

[1] D. Shu and T.M. Kuzay, Nucl. Instrum. and Methods. A347 (1994) 584-590.

[2] R. J. Dejus, B. Lai, E. R. Moog, and E. Gluskin, Argonne National Laboratory Report, ANL/APS/TB17 (1994).

[3] T. M. Kuzay, J. T. Collins, A. M. Khounsary, and G. Morales, Proc. ASME/JSME Joint Conf., Book No. I0309E-1991, pp.451-459.

[4] D. Shu, J. Chang ,T. M. Kuzay and D. G. Brasher, to be submitted to SRI-2000.

[5] D. Shu, H. L. T. Nian, Z. Wang, J. Collins, D. Ryding, and T. M. Kuzay, SPIE Vol. 1739 (1992) 218.

TABLE 1. Comparison of the front end aperture parameters

Aperture (mm x mm)	Front end v.1.2	Front end v. 1.5
Pre-fixed mask (input)	N/A	38 (H) x 26 (V)
(output)	N/A	20 (H) x 12 (V)
1st fixed mask (input)	38 (H) x 26 (V)	24 (H) x 16 (V)
(output)	24 (H) x 12 (V)	11 (H) x 6 (V)
1st photon shutter	70 (H) x 16 (V)	20 (H) x 20 (V)
Lead collimator (optical)	62 (H) x 20 (V)	32 (H) x 20 (V)
(shielding)	68 (H) x 26 (V)	38 (H) x 26 (V)
Fast valve	70 (H) x 18 (V)	70 (H) x 18 (V)
2nd fixed mask (input)	66 (H) x 18 (V)	21.5 (H) x 14 (V)
(output)	54 (H) x 6 (V)	12.7 (H) x 5.2 (V)
2nd photon shutter	70 (H) x 16 (V)	20 (H) x 20 (V)
Wall collimator (optical)	72 (H) x 20 (V)	32 (H) x 20 (V)
(shielding)	78 (H) x 26 (V)	38 (H) x 26 (V)
Exit fixed mask (input)	40 (H) x 12 (V)	21 (H) x 11 (V)
(output)	4.5 (H) x 4.5 (V)	3 (H) x 2 (V)
Exit Be window	5 (H) x 5 (V)	3.6 (H) x 2.6 (V)

Figure Captions

Fig. 1. Schematic layout of the APS version 1.5 undulator-only front end. Beam enters from the left and travels to the right. B7-60: BM mask, M1-40: ID mask, B2-60: first XBPM/mask, P2-30: first photon shutter, K1-44: collimator, VAT-S: UHV valve, VAT-F: fast valve, B2-70: second XBPM/mask, P2-30: second photon shutter, S3-20: safety shutter, K1-43: wall collimator, M4-40: exit mask for Be-window, W1-82: single Be-window, K5-20: in-vacuum collimator, M7-20: exit mask for differential pumps.

Fig. 2. Synchrotron radiation ray-tracing schematic for APS version 1.5 undulator-only front end.

Fig. 3. Bremsstrahlung ray-tracing schematic for APS version 1.5 undulator-only front end.

Fig. 4. Vacuum pressures measured in the APS version 1.5 undulator-only front end. Data series 1 is measured at the P2-30 photon shutter, which stops the beam.

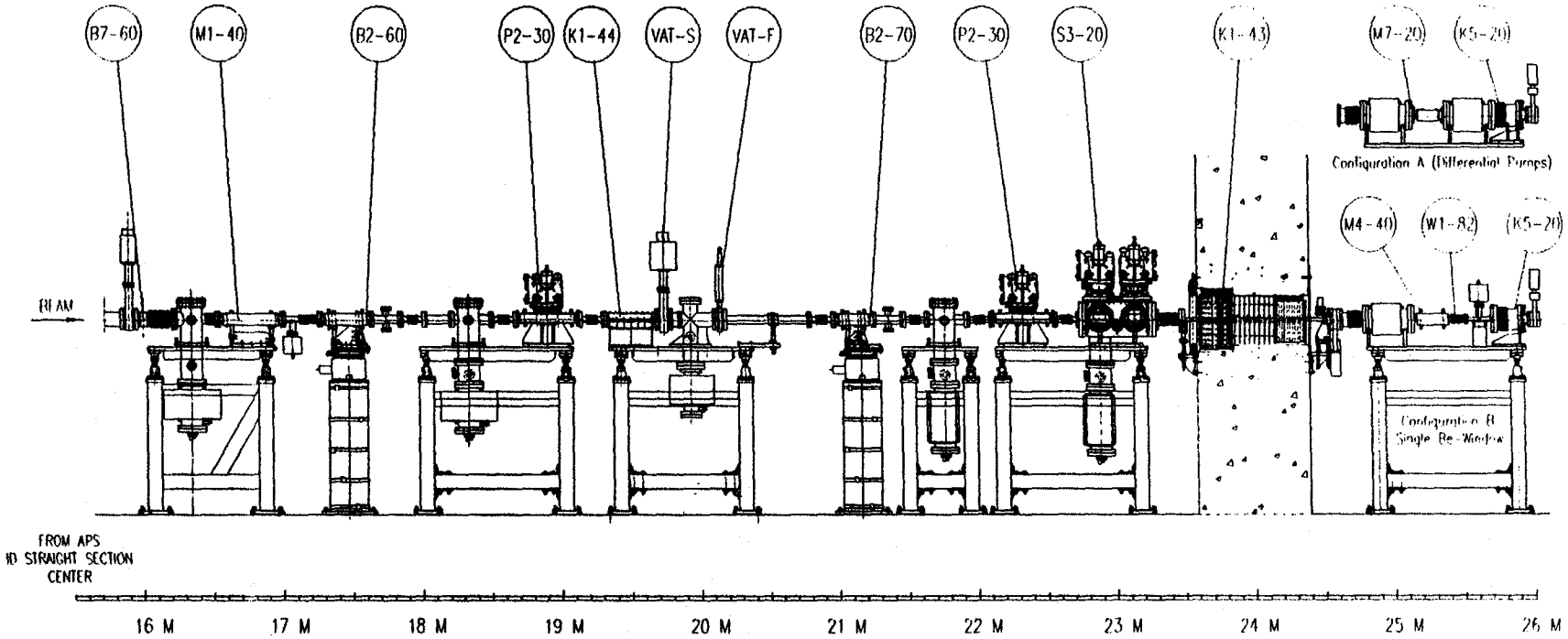
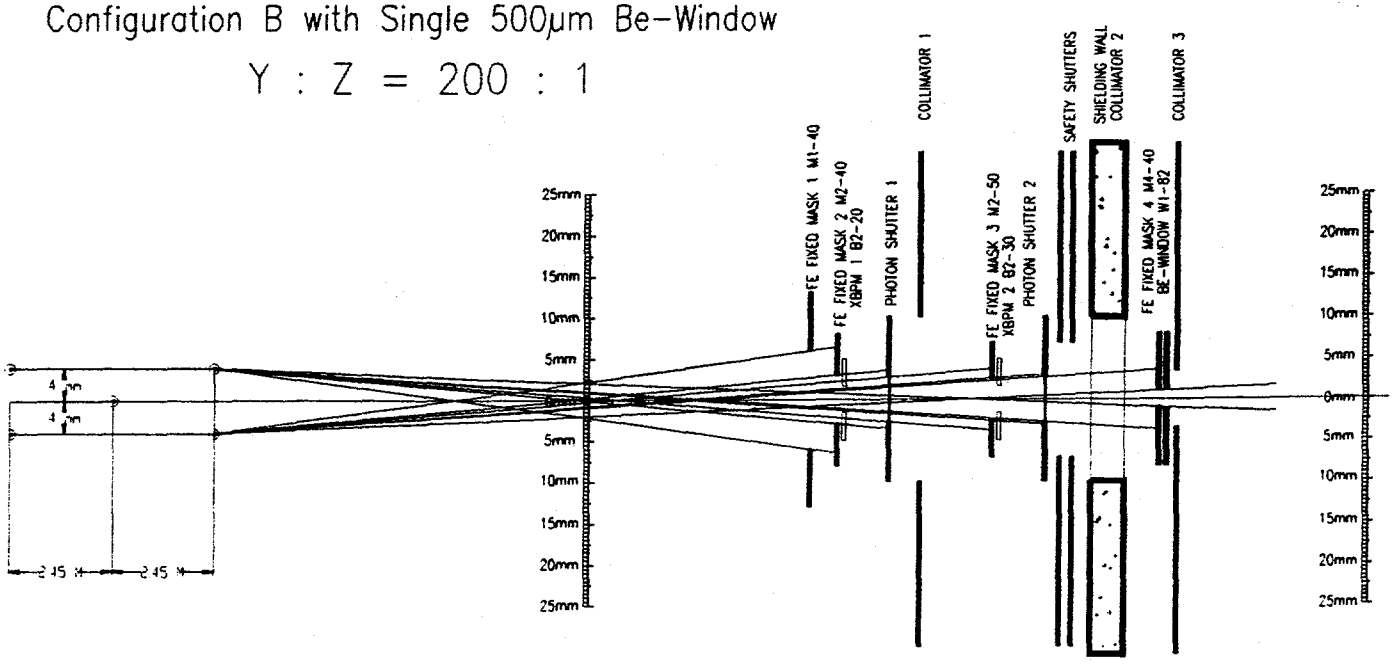

B7-60
M1-40
B2-60
P2-30
K1-44
VAT-S
VAT-F
B2-70
P2-30
S3-20
K1-43
M7-20
K5-20
Configuration A (Differential Pumps)
M4-40
W1-82
K5-20
BEAM
FROM APS
ID STRAIGHT SECTION
CENTER
16 M
17 M
18 M
19 M
20 M
21 M
22 M
23 M
24 M
25 M
26 M

Fig. 2

Configuration B with Single 500μm Be-Window

Y : Z = 200 : 1



0M 2M 4M 6M 8M 10M 12M 14M 16M 18M 20M 22M 24M 26M 28M 30M 32M

FROM CENTER OF STRAIGHT SECTION

Fig. 3

Configuration B (with Single 500μm Be-Window)

Y : Z = 200 : 1

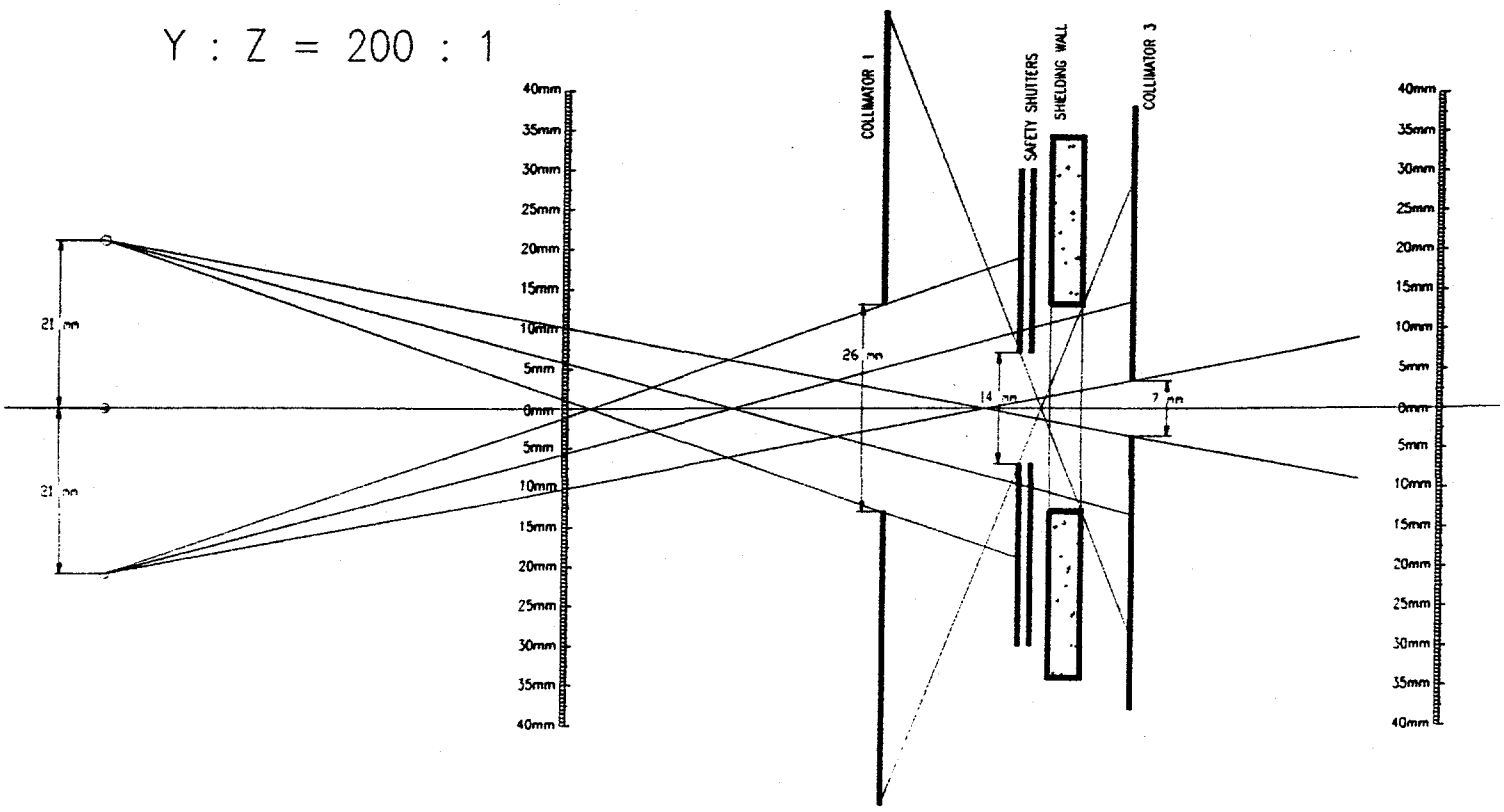
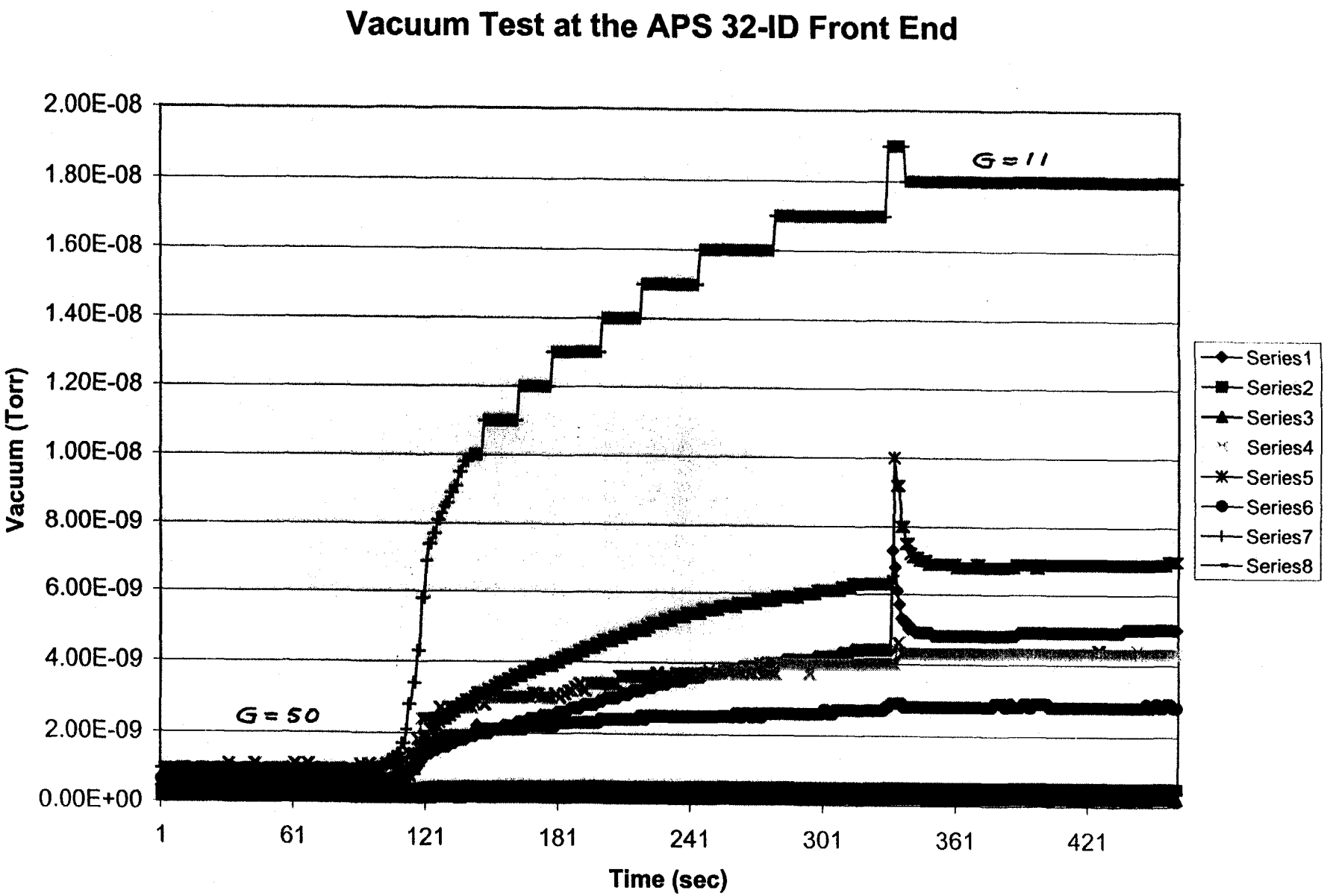


Fig. 4


Vacuum Test at the APS 32-ID Front End
2.00E-08
1.80E-08
1.60E-08
1.40E-08
1.20E-08
1.00E-08
8.00E-09
6.00E-09
4.00E-09
2.00E-09
0.00E+00
Vacuum (Torr)
1
61
121
181
241
301
361
421
Time (sec)
G = 11
G = 50
Series1
Series2
Series3
Series4
Series5
Series6
Series7
Series8