RECEIVED

JAN 18 2000

A New Gap Separation Mechanism for APS^{OSTI} Insertion Devices*

E. M. Trakhtenberg², V. G. Tcheskidov¹, P. K. Den Hartog², B. N. Deriy²,
M. Erdmann², O. A. Makarov², E. R. Moog²

¹*Budker Institute of Nuclear Physics, 11 Ac. Lavrentyev Prosp.
630090 Novosibirsk, Russia*

²*Advanced Photon Source, Argonne National Laboratory, Argonne IL 60439*

Abstract. A new gap separation mechanism for use with the standard Advanced Photon Source (APS) 3.3-cm-period undulator magnetic structures has been designed and built, and the first system has been installed in the APS storage ring. The system allows a minimum magnetic gap of 10 mm for use with the APS 8-mm insertion device vacuum chambers. The mechanism is a bolted steel frame structure with a simple 4-motor mechanical drive train. The control system uses servomotors with incremental rotary encoders and virtual absolute linear encoders.

INTRODUCTION

Twenty-three insertion devices (IDs) have been installed at the Advanced Photon Source (APS). Most are variable-gap, 3.3-cm-period IDs manufactured by STI Optronics (1). Thirty-five straight sections are available for insertion devices, and each straight section can accommodate one or two APS standard-length (2.4 m) IDs. Presently, twelve straight sections are unoccupied and nineteen straight sections could accommodate a second ID if the experimental program required a higher flux or a larger x-ray tuning range. Several new collaborative access teams (CATs) are now preparing to install new beam lines and several existing CATs are planning to add a second ID.

These current and future ID needs of the APS have led us to procure eleven new 3.3-cm-period magnetic structures from STI Optronics and to design a new gap separation mechanism (NGSM), which will be used with these magnetic structures. Since the design of the original APS IDs, a number of specification revisions made the design of a new mechanical system advisable. Primary among these was the elimination of the requirement that the device be useable with the strong attractive magnetic forces of long-period wiggler magnetic structures. The success of third-generation undulators, particularly the ability to generate high flux at high harmonics, has induced almost all APS beamlines to abandon wigglers in favor of undulators with

*Supported by the U.S. Dept. of Energy, BES-Materials Sciences, under Contract No. W-31-109-Eng-38

The submitted manuscript has been created by the University of Chicago as Operator of Argonne National Laboratory ("Argonne") under Contract No. W-31-109-ENG-38 with the U.S. Department of Energy. The U.S. Government retains for itself, and others acting on its behalf, a paid-up, nonexclusive irrevocable worldwide license in said article to reproduce, prepare derivative works, distribute copies to the public, and perform publicly and display publicly, by or on behalf of the Government.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, make any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

smaller attractive forces. Still another specification revision, the reduction in the vacuum chamber stay-clear area, was made possible by the successful fabrication of small aperture (5 mm) extruded chambers (2) which made provision for possible variable aperture chambers unnecessary. In addition, experiments and experience with the tuning of magnetic structures taught us that ferromagnetic materials could be placed closer to the undulator gap than was previously realized without adversely affecting the magnetic field on axis. These realizations had major implications for the design of the support and drive system. No minor redesign could take full advantage of these changes.

MECHANICAL DESIGN

Insertion devices must achieve precision positioning reproducibility under high magnetic loads. The design requirement for the APS NGSM is to reproduce the physical gap, at upstream and downstream positions, to within $6\text{ }\mu\text{m}$ for movements in one direction and to within $20\text{ }\mu\text{m}$ for approaches from the opposite direction. Reproducible gap positioning requires a rigid structure and accurate mechanical systems. The mechanical drive transmission between the upper and lower magnetic jaws of IDs is often a source of positioning error, and components are potential failure points that add cost. The increasing capability and simplicity of economical servomotor systems encouraged us to adopt a 4-motor servosystem that minimized the number of power transmission parts. Servomotors also have a much greater torque profile over the desired range of rotation speeds than stepper motors. Each end of each magnetic jaw is separately driven by an Animatics SmartMotor™ 3430 servomotor (3) with a built-in servocontroller that includes an incremental rotary encoder with a resolution of 4000 counts per revolution. A bolted structural steel frame achieves the required rigidity. The design is robust, cost effective, forgiving in terms of mechanical tolerances, and very simple to fabricate and assemble. The major mechanical specifications are given in Table 1.

FIGURE 1. Difference between gap readings made with the linear encoders and those made with a laser interferometer, for both opening and closing scans.

TABLE 1. Major Technical Specifications for the CPU

Description	Value	Units
Minimum pole gap	10	mm
Minimum pole gap (upgrade)	8.5	mm
Maximum pole gap	200	mm
Working gap range	10-50	mm
Opening time to 50 mm	40	sec
Opening time to 150 mm	1.8	min
Maximum operating taper	5	mm
Maximum taper w/o damage	Full	
Attractive force limit for 10-mm gap	22,560	N
Attractive force limit for 8.5-mm gap	31,380	N
Magnetic jaw weight	400	kg
Total undulator weight	2500	kg
Main gearbox ratio	60:1	
Motor gearbox ratio	3:1	
Motor torque (continuous)	1.1	N-m
Motor torque (peak)	4.1	N-m

The magnetic gap is measured with four full-travel Gurley Virtual Absolute™ linear encoders (4) with 1.0 μm accuracy and 0.25 μm resolution. The encoders use a glass scale with a 64- μm period, which is electronically sub-divided into 256 parts. An additional scale pattern with a 12-bit position code enables absolute position determination after a translation of at least 0.768 mm (12 x 64 μm). Four precision (1- μm reproducibility) home switches are included for redundancy.

TEST RESULTS

Tests were run to measure the position reproducibility. Two laser interferometer channels measured the gap at upstream and downstream positions. The interferometer readings were set to match the linear encoder reading at 11.5 mm. Figure 1 shows the difference between the interferometer and encoder readings for a gap scan with 0.05-mm steps. The large slope at small gaps and the $\sim 100 \mu\text{m}$ difference at large gaps is

FIGURE 2. Difference between gap readings made with the rotary encoders and those made with the interferometer, for both opening and closing scans. Same scan as in Fig. 1.

due to flexing of the structural frame—the encoders make measurements relative to the top and bottom of the structural frame, whereas the interferometer measured the gap directly. This deformation is due to the larger magnetic force at smaller gaps but is elastic and reproducible and can easily be compensated. Oscillations with a 5-mm period and 10- μ m amplitude are caused by a misalignment between the axes in the screw-nut pairs. The few-micron hysteresis is caused by friction forces, probably from the two air springs on the lower jaw, which compensate the weight of this jaw. In figure 2, the difference in the gap readings between those obtained with the interferometer and those obtained with the rotary encoders is shown. The slope at small gaps and the ~ 500 - μ m difference at larger gaps includes both stretching of the lead screw and frame deformation under magnetic forces. The significantly larger hysteresis of ~ 40 μ m, compared to figure 1, is caused not only by friction forces but also by backlash in the drive system: motor, gearbox, clutch, and nut-screw pair.

Another comparison of interferometer with linear and rotary encoders was done with considerably smaller 5- μ m steps. Frequent oscillations with peak amplitude of about 2 μ m and with a 64- μ m period were seen. This is exactly the period of the incremental scale of the linear encoders. Although within the encoder specifications, the amplitude of the oscillations limits the gap adjustment precision. Another very small (0.5 μ m) oscillation was found with a period 60x smaller than that of the nut-screw axis misalignment, due to misalignment between the input drive shaft axis and the axis of the 60:1 right-angle gearbox.

SUMMARY

A new gap separation mechanism has been designed and built for the APS IDs. The first system has been installed in the storage ring and is being used for shielding validations of a new beamline. Six additional structures are being assembled. Test results have identified several sources of positioning error but all are within design tolerances. The new mechanism provides a cost-effective support structure, and all of the design goals have been satisfied.

REFERENCES

1. Gluskin, E., *J. Synchrotron Rad.*, 5, 189-195 (1998).
2. Den Hartog, P., Grimmer, J., Trakhtenberg, E., Wiemerslage, G., Xu, S., "Advanced Photon Source Experience with Vacuum Chambers for Insertion Devices," *Proc. PAC '97*, Vancouver, B.C., 3556-8, (1997).
3. Animatics Corporation, 3050 Tasman Drive, Santa Clara, California 95054-1116 USA, (408)748-8721, <http://www.animatics.com>.
4. Gurley Precision Instruments, 514 Fulton St. Troy, NY 12181 U.S.A, (518) 272-6300, <http://www.gurley.com>.