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MAGNET MODULE ASSEMBLY FOR THE APS UPGRADE*

K. J. Volin†, R. R. Bechtold, A. Jain, W. G. Jansma, Z. Liu, J. J. Nudell, and Curt Preissner
Advanced Photon Source Upgrade Project, Argonne National Laboratory (ANL), Lemont, IL, USA

Abstract

With the Advanced Photon Source Upgrade (APSU) well into the procurement phase of the project, the APSU assembly team has completed a "DLMA Practice Assembly", comprised of the support system and all magnets required to complete a module. The purpose of this test was to verify assembly and documentation procedures, ensure proper fit between mating components, and verify that alignment specifications can be met. The results of this exercise are presented. This test was completed on the ANL site and work continues in the APSU offsite warehouse where our first production plinths and girders have been shipped and where production modules are assembled. This space has been outfitted by ANL contractors and APSU assembly technicians with 1) five parallel DLM/FODO module assembly stations, each outfitted with a 3-ton overhead crane, retractable cleanroom, staging tables, and tools, and 2) two QMQ module assembly stations each outfitted with a 5-ton gantry crane, assembly support stands, staging tables, and tools. An overview of this production assembly space is also presented.

INTRODUCTION

A major part of the APS Upgrade [1] is the installation of a new Multi-Bend Achromat (MBA) storage ring. The MBA storage ring is comprised of 40 sectors. Each sector is approximately 27.6 meters long (path length) with mirror symmetry about the central Q-bend (transverse-gradient dipole) magnet. There are a total of 1320 magnets comprising the new MBA storage ring. Each storage ring sector consists of three large modules with two support plates, supporting three magnets each (QMQ), bridging between them. Figure 1 shows one of the 40 sectors of the storage ring. The upstream Doublet-L-bend-Multiplet (DLM) module A supports a quadrupole doublet, an L-bend, and a multiplet array of magnets. In the center of the sector is the curved Focusing-Defocusing (FODO) module which supports five large bending/focusing magnets. The down-stream DLM module B is a mirror image of the upstream DLM module A. Each module contains a concrete plinth grouted to the floor with an alignable support girder mounted on top, which in turn supports the individual magnet strings, vacuum system, and auxiliary hardware. In addition to the 200 magnet modules comprising the storage ring, a full sector mockup of 5 modules will be assembled and used for storage ring installation training.

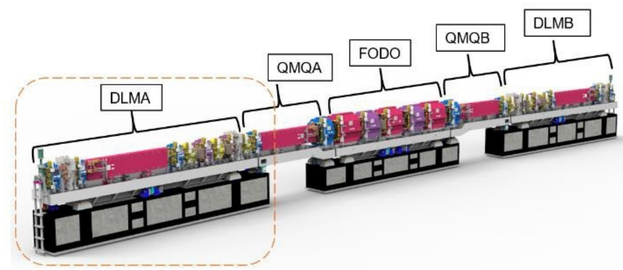

Figure 1: Typical APSU arc sector. DLMA Module (circled above) used for the first practice assembly.

MODULE ASSEMBLY OVERVIEW

To assemble the 123 DLMA, DLMB, and FODO magnet modules, 5 assembly stations were each outfitted with a 3-ton overhead crane, steel weldment tables for staging the magnets, stainless steel (SS) tables for staging the vacuum strings, and an ISO7 (Class 10,000) retractable clean room for installing the particle-sensitive open vacuum chambers. To assemble the 82 QMQA and QMQB magnet modules, two assembly stations were each outfitted with a 5-ton gantry crane, steel weldment assembly stands for mocking up the support ends of the DLMA/B and FODO plinths, steel weldment tables for staging the magnets, and SS tables for staging the vacuum strings. The QMQ magnet modules are assembled with complete, sealed, nitrogen backfilled, vacuum chambers. There is no need for a clean room environment for the QMQ.

DLMA Practice Assembly

With the arrival of the APSU vacuum system later than the bulk of the accelerator components, a first "practice assembly" was planned to use all magnets and support system components required to complete a DLMA assembly (see Fig. 1). The purpose of this activity was to verify assembly and documentation procedures, ensure proper fit between mating components, and verify that alignment specifications can be met.

Magnet Installation Extremely precise alignment of magnets within a module is necessary for achieving key performance parameters in the new machine. To achieve alignment specifications, we rely on precise machining of the girder and magnets, in conjunction with shimming.

Each magnet is fiducialized on a rotating wire bench before it is installed on a module [2]. This relates the magnet's magnetic center to its fiducials, as well as documenting offsets from the magnetic center to its X, Y, and Z reference

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† kjvolin@anl.gov

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Figure 2: Quadrupole magnet enroute via overhead crane to its final location in the DLMA module (Image by JJ Starr/Argonne National Laboratory).

mounting surfaces. Typical X and Y errors of a magnet's reference surfaces are less than 50 microns.

Prior to mounting magnets on the first article, shims for each magnet were chosen based on magnetic measurements and placed on the girder mounting surfaces to account for the slight errors in position of the magnet's X and Y reference mounting surfaces. Then, each magnet was lifted into position using an overhead crane and bolted into place on the girder (Fig. 2).

Survey Results Fiducials on 9 out of 11 magnets of the DLMA array (excluding Fast Correctors) were measured from 5 stations using a Leica AT930 laser tracker [3]. Data was analysed using the Spatial Analyzer software package. Temperature was not controlled during the ~2 hour measurement.

A Spatial Analyzer file was developed which contains the ideal locations of each magnet center or vertex point in the DLMA array [3], based on the Lattice File. Once the measurement of each magnet fiducial in the array is complete, the individual magnet fiducialization data is imported and fitted using Least Squares to the new measured fiducial locations of that magnet in the array. Then, the X, Y, and Z offsets (difference in location between the ideal magnet center points and measured magnet center points) may be extracted and plotted.

The magnet alignment specifications and results in the X and Y directions are shown below in Table 1 and Figs. 3 and 4. The magnet alignment in the critical X and Y directions far surpasses the 30 microns RMS tolerance.

Table 1: DLMA Practice Assembly Survey Results

	X-Offsets	**Y-Offsets**
Specification	30 µm, RMS	30 µm, RMS
Measurement	9 µm, RMS	13 µm, RMS

The magnitude of measurement error is estimated to be 7 µm RMS. The magnitude of the alignment error in X and Y is 16 µm RMS. RMS error is derived using a best-fit line through the measured magnet center offsets from ideal position in X and Y. Overall, the alignment is exceptionally good on the DLMA practice assembly, and the magnet positioning scheme is deemed a success. The completed practice assembly in ANL Building 375 is shown in Fig. 5.

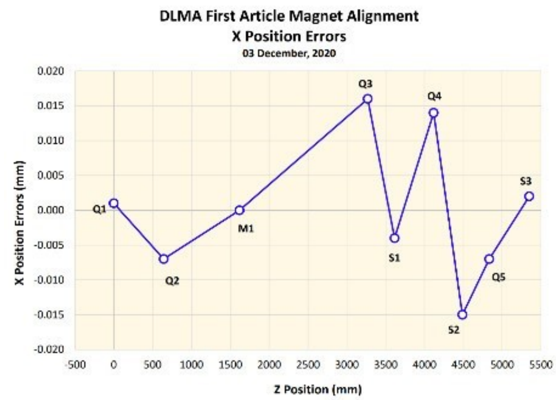

Figure 3: DLMA first article, magnet X-position errors.

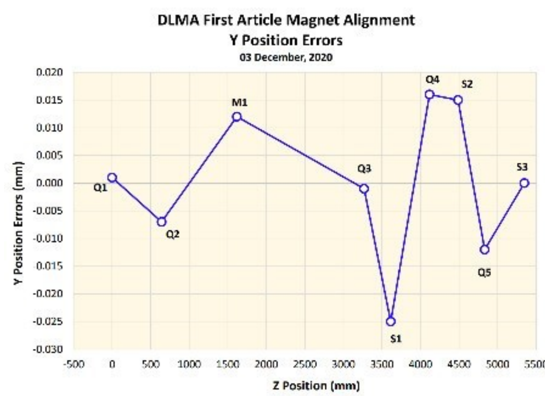

Figure 4: DLMA first article, magnet Y-position errors.

Assembly Update

Outfitting of the off-site Assembly Area is complete. As of this writing, twenty-one (21) production support systems

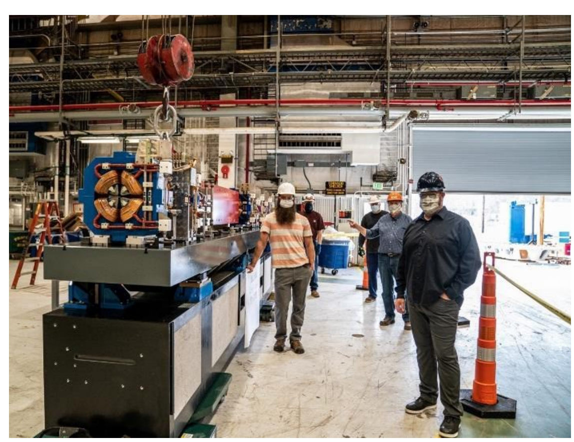

Figure 5: The completed DLMA practice assembly.

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Figure 6: Picture showing the off-site Module Assembly Area including overhead cranes, retracted cleanrooms, and several modules in the magnet mounting process.

have arrived, and fiducialized magnets are available to complete the magnet portion of Module Assembly. Thus, production work has begun on training technicians, and mounting and aligning magnets on Support Systems (see Fig. 6).

CONCLUSION

The preparation for the assembly and testing of the accelerator magnet modules is nearly complete. A first article practice assembly involving the mounting of all magnets onto a DLMA support system showed achievement of magnet alignment goals stated in the APSU Functional Requirements Document. The APSU Project has begun building partial production storage ring modules as we await arrival of the vacuum systems.

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