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RECENT EXPERIENCE WITH MAGNET SORTING FOR APS-U HYBRID UNDULATORS*

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Abstract

At the Advanced Photon Source (APS) we have assembled, measured, and analyzed 14 new undulators of the exact same mechanical design, some of them with sorted magnets and some unsorted. The performance differences appear to be insignificant in meeting the tight APS Upgrade (APS-U) undulator requirements.

SORTING

It is worth mentioning that sorting of the magnets assumes that we know the most important sources of the errors. Very different types of errors affect the performance of an undulator, mainly: errors in sizes of the magnets, location of the magnets between the poles, differences in the pole gaps, and magnet recesses [1-4]. Justification of the fact that sorting is not perfect comes from the fact that with the same sorting techniques (simulated annealing, total moment, many points of the magnet field data, etc.) results are different. An important fact to mention is the quality of permanent magnets, which has been improved considerably. One of the ways to see how the sorting affects the performance is to compare the results with and without sorting.

Magnet sorting at the APS was made on the total magnetic moment (M) using either the nominal magnet block volume or the real magnet block volume. Sorting using the nominal volume is equivalent to sorting of the total moment, and sorting using the real volume is equivalent to sorting on the total moment density. Previously, the horizontal component of the total moment M_x was included in the procedure, and sometimes the result led to unwanted changes in multipole components (see Fig. 1).

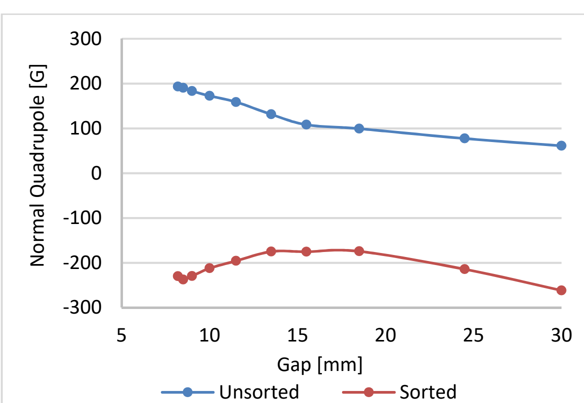

Figure 1: Comparison of normal quadrupole components with M_x sorted and unsorted for the APS27#3 device (a 27-mm-period undulator).

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One of the 28-mm-period undulators, APS28#13S, was used for specific testing. It was first assembled using sorted magnets and then disassembled and reassembled with unsorted magnets (the magnet keepers and the so-called super-strongbacks were unchanged). Sorting did not consider either of the transverse components M_x or M_y, or the difference in field from the north and south faces of the magnets.

The comparisons are shown in Figs. 2 and 3 for the sorted and unsorted cases, respectively. Any differences noted, whether before or and after tuning, including tuning efforts and the number of shims used, are not essential.

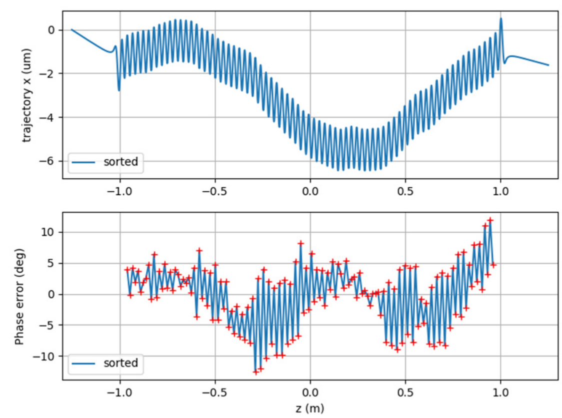

Figure 2: Computed as-assembled trajectory at 6 GeV (top) and RMS phase errors (bottom) before tuning for the sorted case for the APS28#13S undulator at 8.2-mm gap. The as-assembled RMS phase error was 4.88°.

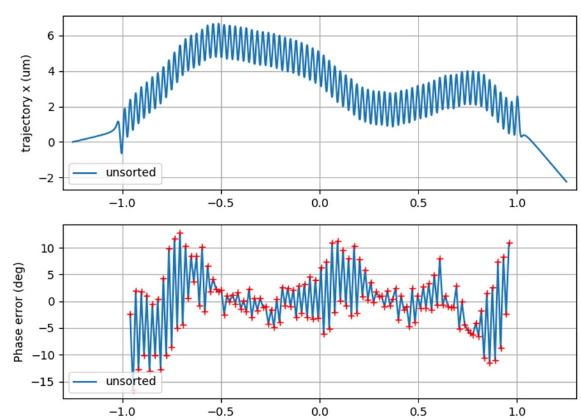

Figure 3: Computed as-assembled trajectory at 6 GeV (top) and RMS phase errors (bottom) before tuning for the unsorted case for APS28#13S undulator at 8.2-mm gap. The as-assembled RMS phase error was 5.51°.

The final RMS phase error achieved was 2.64° for the sorted case and 2.67° for the unsorted case at 8.2-mm gap.

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As seen in Fig. 4 there is large difference in the average top-bottom jaw total moment distribution for the two cases. The RMS value for the sorted case is about 30 times smaller than for the unsorted case. Nevertheless, clearly the end results of the tuning are very close for both (see Fig. 5).

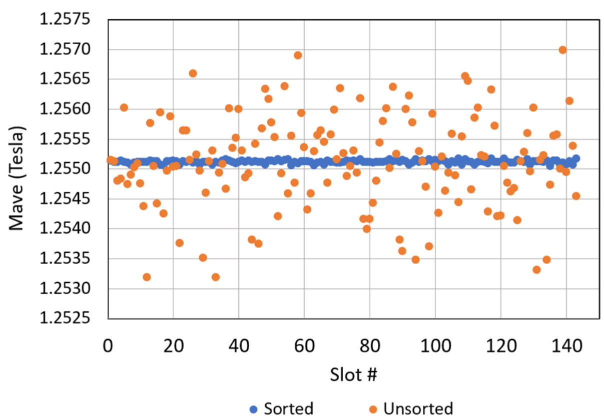

Figure 4: Average top-bottom jaw total moment distribution of device APS28#13S for sorted and unsorted cases. The RMS value is 2.54×10^{-5} Tesla for the sorted case and 7.73×10^{-4} Tesla for the unsorted case.

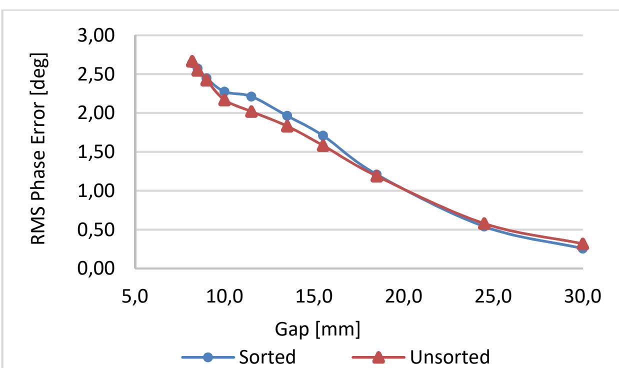

Figure 5: Comparison of RMS phase errors vs. gap for the APS28#13S undulator with sorted and unsorted magnets after final tuning. The RMS phase error requirement for the APS-U is less than 3°.

Table 1 lists all new undulators tuned to date, with magnet sorting status indicated, including two recently assembled shorter-period devices, and the achieved RMS phase errors after tuning.

Table 1: Comparison of All Tuned New Undulators

Device ID	RMS Phase Error [Deg]	Sorting Status
APS28#1S	2.6	Unsorted
APS28#2	2.6	Sorted
APS28#3S	2.7	Sorted
APS28#4S	2.5	Sorted
APS28#5S	2.9	Sorted
APS28#6S	2.8	Sorted
APS28#7	2.7	Sorted
APS28#8	2.4	Sorted
APS28#9S	2.4	Sorted
APS28#10S	3.1	Sorted
APS28#11S	2.4	Sorted
APS28#12S	2.1	Sorted
APS28#13S	2.6	Sorted
APS28#13S	2.7	Unsorted
APS25#1S	2.1	Unsorted
APS21#1S	1.6	Unsorted

CONCLUSION

Any differences between using sorted and unsorted rare earth permanent magnets from Kyma and Shin-Etsu (magnet vendors) appear to be insignificant in meeting the tight APS-U undulator requirements. Therefore, we have decided not to sort the magnets for the remainder of the new undulators to save time and effort.

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