UNDULATOR FOR THE LCLS PROJECT – CHANGES IN THE MAGNET STRUCTURE DESIGN*

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Abstract

The design modifications of a new hybrid-type undulator with a fixed gap of 6.8 mm, a period of 30 mm and a length of 3.4 m are presented. The prior pole design included side "wings,s" which were used for precise positioning, and clamps to fasten the poles to the magnet base. This design has been replaced by a more straightforward assembly, where the pole is attached to the magnet structure base using only two screws. Tests were performed on the vanadium permendur pole material to prove that the threaded holes are easy to fabricate and are able to successfully withstand the torque required to hold the pole in place. A fixture was also developed to ensure the precise location of the poles on the base during assembly. In addition to the pole modifications, the magnet-structure base is now manufactured as one piece as opposed to three, which greatly eases assembly. Finally, a small section of the original prototype had these changes successfully implemented, and the test results are presented.

MAGNET STRUCTURE DESIGN FOR THE LCLS PROTOTYPE UNDULATOR

The design of the new undulator for the LCLS project was already presented [1]. The upper and lower magnetic structures of the LCLS undulator consist of two short end sections ~190 mm long and three identical 1005-mm-long middle sections that are mirror-image symmetrical. The total length of the whole magnetic structure is roughly 3400 mm. A number of changes were made from the prototype design to the final version, and these are outlined below.

Initial Design

In order to obtain the maximum undulator peak field, the poles were made of vanadium permendure Vacoflux 50. The magnet design required a pole overlap on three sides, so it was necessary to locate each pole precisely, not only in the beam direction but in the transverse direction as well. The initial design of the LCLS magnetic structure used poles with attached titanium wings (see Figure 1), which extended beyond the magnets in the transverse direction. These wings were used as precise pole locators as well as clamping sites. The poles were manufactured by grinding the wings and vanadium permendur pieces together to ensure that they had exactly the same thickness. During assembly, the wings were placed inside precisely machined grooves on both sides of the aluminum magnet structure base. The base consisted of three parts, which was required to machine the slots for the pole wings into the side bars. Titanium was selected for the wing material because it has thermal expansion properties similar to the vanadium permendur, which allowed a final annealing process after grinding. This annealing step is necessary to get the best magnetic performance from the pole material.

Initially all 450 poles for the LCLS prototype undulator were made using this approach, and the required magnetic performance according to the specifications was attained.

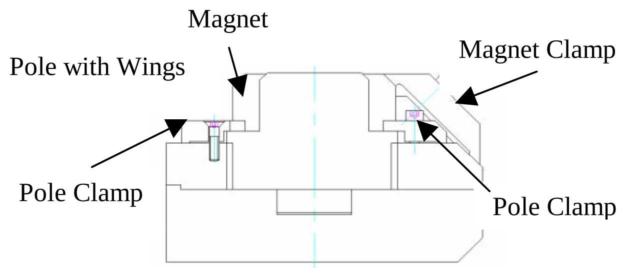

Figure 1: Initial LCLS magnetic structure design.

Current Design

Preparation is underway for full-scale LCLS undulator production, which will include 40 full-length undulators and roughly 19200 poles. Due to the large quantities, efforts were made to simplify the pole design without sacrificing location tolerances. A new design with the wings removed (Fgure 2), shows the poles fastened to the base by two #6 screws, which allow the aluminum bases to be manufactured as one piece instead of three. This both simplifies and reduces the amount of machining needed to fabricate the poles and bases, making them more cost effective.

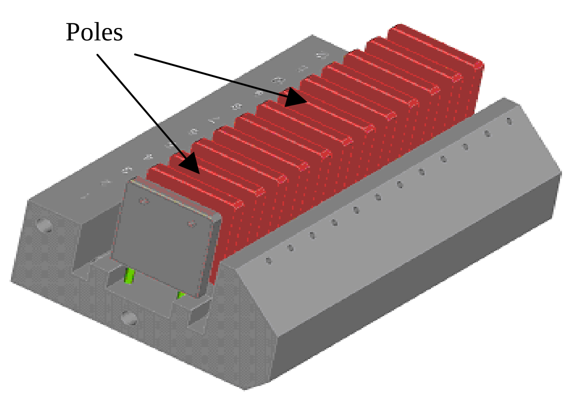

Figure 2: Current LCLS magnetic structure design (poles and base only).

Before proceeding with this design, a number of tests were performed on the vanadium permendur to verify

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thread quality (before and after annealing) and integrity. The first step was to ensure that machining of the threaded holes could be done easily and reliably. After trying several different types of taps, the "VEGA" formtap with a special cooling composition was found to make this operation dependable. The thread quality was tested before and after annealing on several pieces and was found to be acceptable in all cases.

Thread integrity was confirmed by tightening ten screws to 50 inch-pounds, which is 2.5 times above the required torque for a #6 stainless-socket head-cap screw. In all cases, the threaded hole inside the pole was not damaged, but the screw itself failed.

All the poles are identical except for the end ones, which include two additional threaded holes for the installation of "diving boards," which are used to adjust the field integral more precisely.

Assembly

The major challenge of the new design was locating the poles on the magnetic structure base with the same precision that was achieved with the side wing configuration. A fixture was fabricated with precisely machined slots that are used to align the poles in their proper locations (see Figure 3). Each base section has two threaded holes on the left side for attaching the assembly fixture. This fixture is the same for all bases because their cross sections are identical. Such an approach will simplify the manufacturing process significantly based on the large quantity of components required.

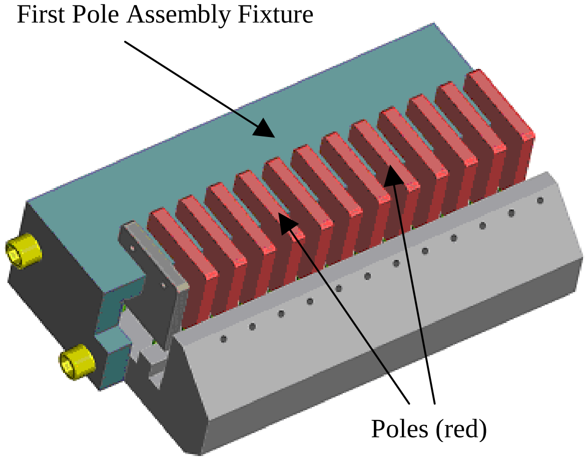

Figure 3: Magnetic structure with the first pole assembly fixture.

After pole installation, the fixture is removed, and the permanent magnets are inserted manually and affixed by one clamp. The fully assembled short magnet structure is shown in Figure 4. One short section of the magnetic structure was fully manufactured after the tests of all components.

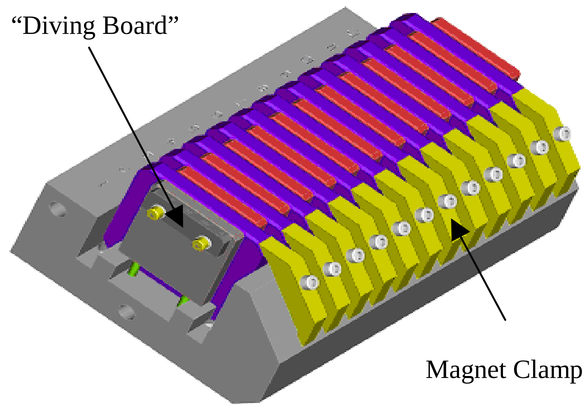

Figure 4: Fully assembled short magnet structure.

The long magnetic structure sections use a second installation fixture to complete the assembly. Initially, the first fixture is attached to the end of the base as before, and the first 13 poles are installed. The second fixture is then attached to the side of the base using the last four installed poles as location points (see Figure 5). When all the poles are installed in the second fixture, it is removed and reattached to the base further down, again using the last four installed poles as locations points. This process is repeated two more times until the base is completely filled with poles.

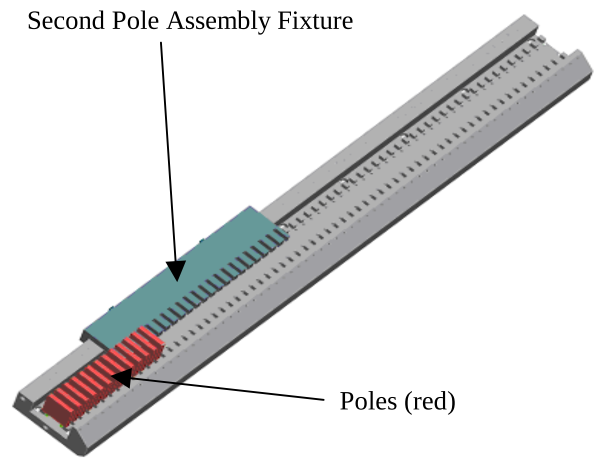

Figure 5: Long magnetic structure with second pole assembly fixture.

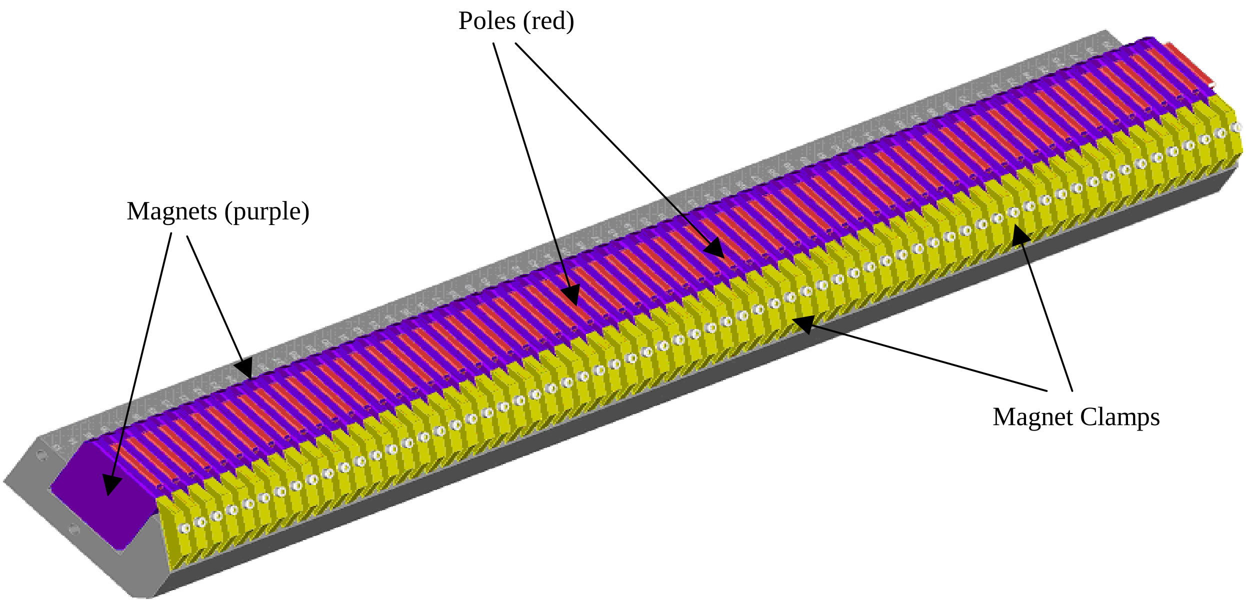

Figure 6: Fully assembled long magnet structure.

As with the short section, the permanent magnets are inserted manually and affixed by one clamp. The fully assembled long magnet structure is shown in Figure 6.

CONCLUSION

The LCLS undulator design has been simplified and is more cost effective than the initial prototype. Modifications to the poles and magnetic structure bases reduce the amount of machining needed to fabricate them while improving the ease of assembly. One short section of the magnetic structure was fully manufactured after the tests of all components. With these improvements, a significant cost savings can be expected (about $25K per device) during full-scale LCLS undulator production.

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REFERENCES

[1] Isaac Vasserman, Roger Dejus, Patric Den Hartog, Elizabeth Moog, Shigemi Sasaki, Emil Trakhtenberg, Marion White. “LCLS Undulator Design Development,” FEL-2004 International Conference, Trieste, Italy, http://www.jacow.org.

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