LCLS-II FUNDAMENTAL POWER COUPLER MECHANICAL INTEGRATION

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Abstract

LCLS-II is a planned upgrade project for the linear coherent light source (LCLS) at Standard Linear Accelerator Centre (SLAC). The LCLS-II linac will consist of thirty-five 1.3 GHz and two 3.9 GHz superconducting RF continuous wave (CW) cryomodules that Fermilab and Jefferson Lab will assemble in collaboration with SLAC. The LCLS-II 1.3 GHz cryomodule design is based on the European XFEL pulsed-mode cryomodule design with modifications needed for CW operation. The 1.3GHz cryomodules for LCLS-II will utilize a modified TTF3 style fundamental power coupler design. Due to CW operation heat removal from the power coupler is critical. This paper presents the details of the mechanical integration of the power coupler into the cryomodule. Details of thermal straps, connections, and other interfaces are discussed.

INTRODUCTION

SLAC is responsible for the power coupler order (280 total). The Engineering Specification document (ESD), the Interface Control Document (ICD), and the Production Readiness Review (PRR) have been completed. The award for coupler production has been given to two vendors. Each vendor to produce 8 prototypes for evaluation. Prototypes are to be delivered by Sept-Oct 2015. The balance of the order will be distributed equally (132 couplers each). Expected production rate will be 16 couplers/month for each vendor. Serial production is expected to start in summer 2016, and the completion of order January 2017. Couplers will be delivered (ready to use) to the partner labs FNAL and JLAB.

COUPLER DESIGN

The coupler design basis (for production cryomodules) is as follows. A TTF3 type coupler with some modifications was originally proposed to the vendors and the vendors submitted value engineering proposals. Figure 1 presents components of the TTF3 coupler.

The following changes were made to the TTF3 ILC design: On the cold end the antenna length was shortened by 8.5mm. The CF100 55K interface mounting surface was improved by increasing the diameter from 64mm to 78mm almost doubling the mounting area. Mounting bolt size was increased from M4 to M6 to improve clamping force (> 2x). Holes for temperature sensors were added to CF100 flange. The warm end was improved by increasing the Cu plating thickness on the inner conductor from 30 micron to 150 micron in order to reduce the bellows temperature. An additional threaded hole was added to facilitate mounting a transportation support.

For the prototype production two slightly different variants will be produced by the two vendors. Both variants will be functionally equivalent. The goal is for both manufacturers will produce the same design coupler for the production CMs. There are currently licensing issues that are being worked out, but these details are beyond the scope of this paper.

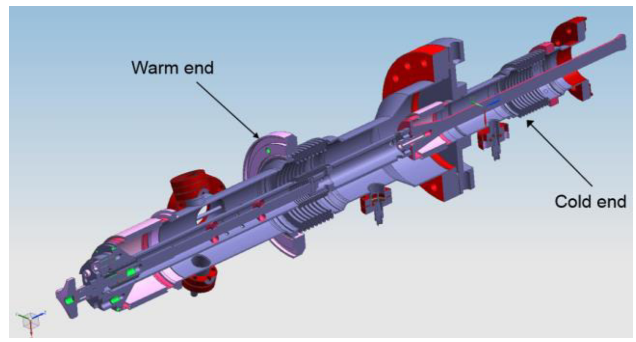

Figure 1: TTF3 Components.

COUPLER CONFIGURATIONS

For the coupler cold ends, there will be a total of 3 different configurations. Due to time constraints, for the 2 prototype cryomodules (pCMs) 16 ILC type cold ends were modified by the original manufacturer for use. It is planned that for the serial cryomodule (CM) production there will be two cold end variants, 8 of one variant from original prototype production and the remaining 272 to be the same. There will be two variants for the warm ends, with one pCM containing 8 from one vendor and the remaining cryomodules having 272 of the same warm end variation. All couplers will be functionally equivalent. Due to the variations in coupler combinations, there will be 4 different configurations of CMs. Performance of the cryomodules is expected to be the same because the couplers are functionally equivalent. Couplers will be integrated into the CM in the same way with only minor detail differences related to the different variations.

COUPLER INTEGRATION INTO CM

Integration of the coupler into the cryomodule is similar to ILC and XFEL integration. The coupler overall geometry is the same as ILC and XFEL. The lengths of cold and warm sections are also the same. The flanged connections are the same and the installation procedure is very similar to that of ILC type and XFEL. The couplers are functionally interchangeable. Coupler warm end vacuum is provided by common pumping line. Figure 2 depicts geometry similarities of the integration.

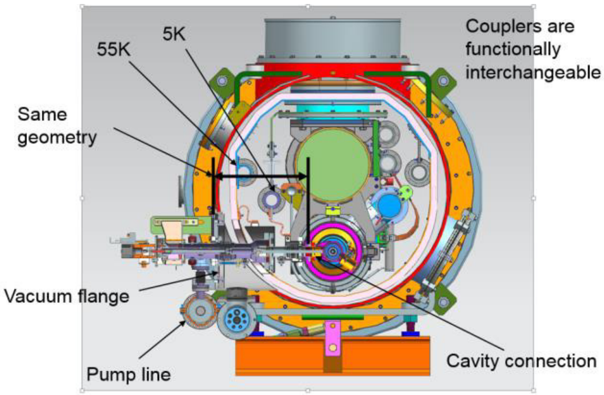

Figure 2: Integration geometry.

Location of thermal intercepts on the couplers has not changed from TTF3 type. There are two coupler thermal interfaces to the cryomodule: a 5K intercept on cold end (between bellows and cavity flange), and a 55K intercept on the cold end CF100 flange. CW operation requires improved heat transfer away from coupler, from both the 5K and 55K intercepts. Figure 3 shows the intercept locations.

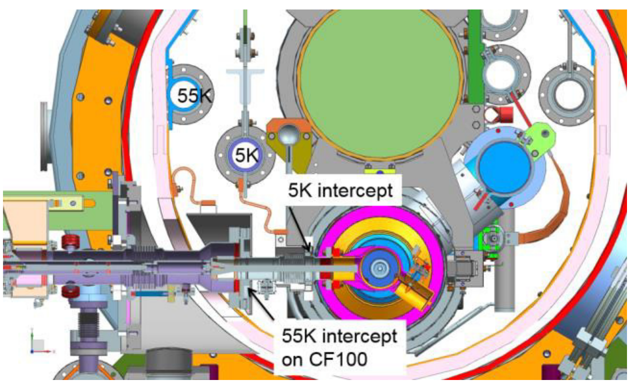

Figure 3: Intercept locations.

For the 55K intercept interface the design concept is similar to that of the ILC type and XFEL design. The interface consists of a 6061aluminium shield bolted to the back of the CF100 flange using M6 screws. The design will use high performance engineered OFHC Cu straps. Two (2) straps take heat to the 55K outer shield. Bolted connections will utilize indium for better thermal contact. Figure 4 depicts the 55K interface details.

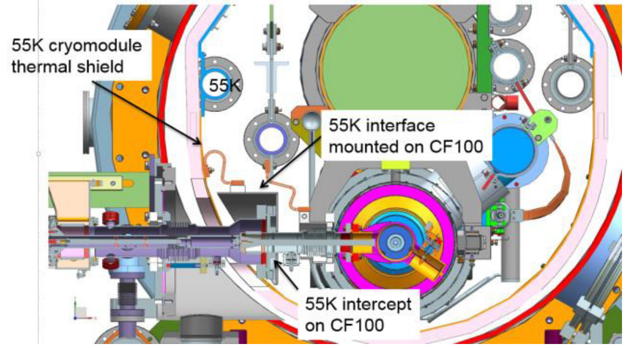

Figure 4: 55K Interface.

There are some minor differences in the 55K interface attachment to CF100 flange, depending upon variant. The same shield design to be used for all types, with the only difference being the mounting bolt pattern of the shield to the CF100 flange. There should be similar thermal performance between types. The 2 pCMs that use the modified ILC type cold ends will utilize an additional copper sink to enhance heat transfer. See Figure 5. This design has been tested at FNAL in the horizontal test stand (HTS). The thermal strap connections and geometry are the same for all 3 variations, except for bolt pattern differences of the intercept.

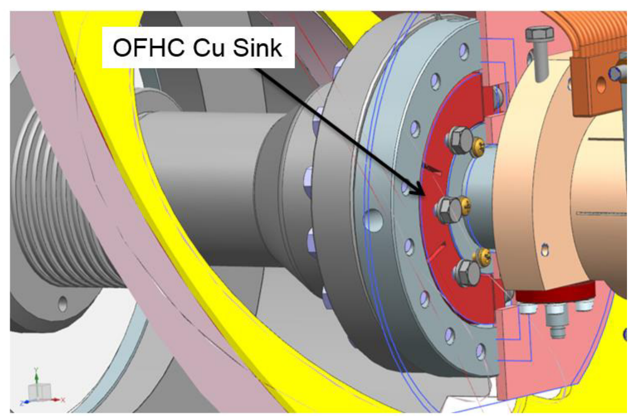

Figure 5: Cu sink added on modified ILC colds.

The 5K coupler interface is clamped to the coupler intercept (copper ring) that is brazed to the cold end just inside the bellows. This is similar to the ILC and XFEL mounting. Material is 6061 aluminium. The design will use the same high performance engineered OFHC Cu straps as used on the 55K interface. Two (2) OFHC Cu straps take heat to 5K line via bolted connections that will utilize indium for better thermal contact. Figure 6 depicts the 5K interface.

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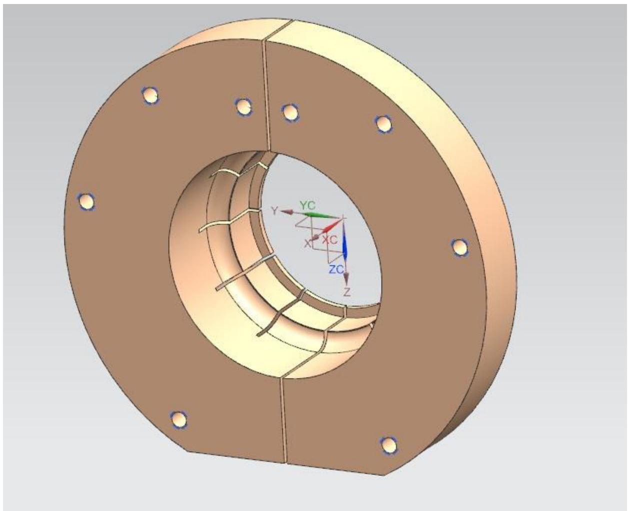

Figure 6: 5K interface.

High performance engineered OFHC Cu (101 copper) straps will be used. OFHC copper was chosen for high conductance properties at low temperatures. Straps for the prototype will be a standard part from company catalogue, length and mounting holes to spec. The straps were chosen for good flexibility and durability. Solder free construction should result in very low outgassing. Performance will be better than straps made from ordinary copper (110 copper). Strap thermal performance is expected to be about .33W/K for each (measured at room temperature by manufacturer). Low temperature performance will be measured in the next horizontal test at FNAL. Figure 7 shows strap configuration in cryomodule.

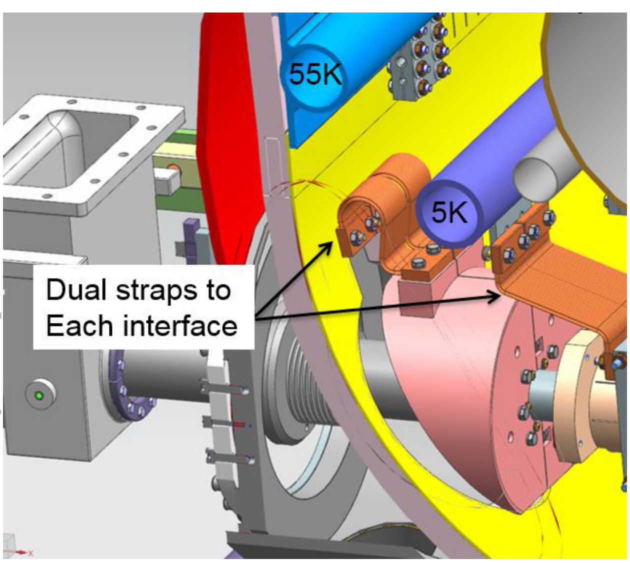

Figure 7: Dual straps to each interface.

SLAC is responsible for waveguide design and procurement. The same waveguide interface configuration as ILC and XFEL is used. Due to tunnel constraints the coupler waveguides are oriented facing upwards. Similar waveguide mounting brackets to XFEL and ILC were used. The waveguide has been value engineered by SLAC in order to reduce cost. The new design material for the waveguide is aluminium with a protective coating. Waveguides will be procured separately from couplers. The waveguide will fit on both variants of the coupler warm ends. Figure 8 details the waveguide installation.

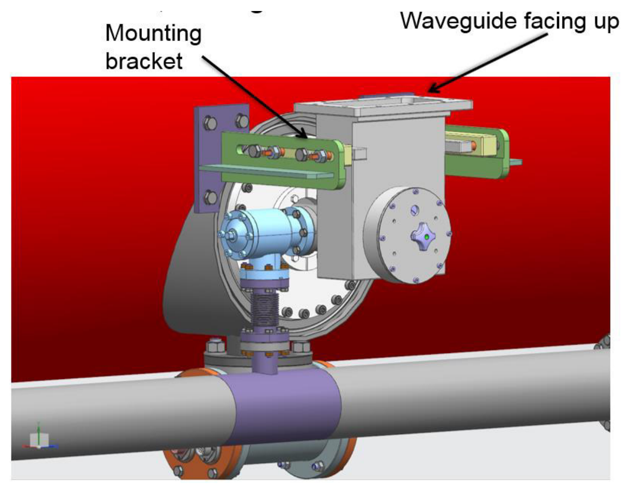

Figure 8: Waveguide and pumping port configuration.

There is 1 pickup port (e-pickup) on the cold end located inside the insulating vacuum. Depending on warm end variant, there is either be 1 pickup port inside insulating vacuum, and 1 pickup port outside, or 1 pickup port inside insulating vacuum, and 2 pickup ports outside. Cables to inside ports will be routed through the vessel vacuum space and terminate at feedthrough flanges. Cables inside the insulating vacuum will be the same regardless of coupler variant.

CONCLUSION

Coupler design complete and prototypes should be delivered Sept-Oct-Nov. There are 3 cold end variations, and 2 warm end variations. All variations are functionally interchangeable. There are 4 cryomodule configurations (Re: coupler combos), with 2 different pCM configurations and 2 different production CM configurations. There should be no function and performance differences between variations. Coupler integration into the CM the same for all configurations. Tooling and installation procedures are the same for all configurations. Thermal interfaces are nearly the same, and thermal straps have been selected. There are slight variations in 55K interface mounting hole patterns. However, the same thermal strap connection and geometry is used for all variations.