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Fundamental Power Coupler Technical Development

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R0	June 29, 2018	Original release.

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1 Overview

The SLAC 'Linac Coherent Light Source -II' project (LCLS II) is a hard X-ray Free Electron Laser now under construction in support of photon-based material science.

LCLS II uses a superconducting linac design based on the twenty year-long TESLA- Technology development effort. The TESLA proposal, the European XFEL (EU-XFEL) project, and the ILC design employ a pulsed superconducting linac with roughly 0.5% duty factor. This aspect was changed for LCLS II so that the FEL could be operated continuous-wave (CW) namely with a 100% duty factor. Several critical changes to the linac design were required including RF power distribution, cryogenic heat-load management and cavity preparation. This note lists the changes required to the fundamental power coupler (FPC). All of these changes were made by the SLAC physics and engineering teams and reviewed by the cryomodule design lead (Fermilab) and international partners. Testing was done by the LCLS II cryomodule teams (Jefferson Lab and Fermilab). The SLAC LCLS II project team managed the design and procurement process.

The LCLS II fundamental power coupler design is based upon the DESY TESLA Test Facility (TTF-3) design. DESY shared their drawings with LCLS II and SLAC copied and modified them to meet the LCLS

II CW operation power and heat-load requirements. LCLS II had an external reviewer evaluate and compare SLAC drawings to EU-XFEL drawings. SLAC used the same industrial partners that EU-XFEL used.

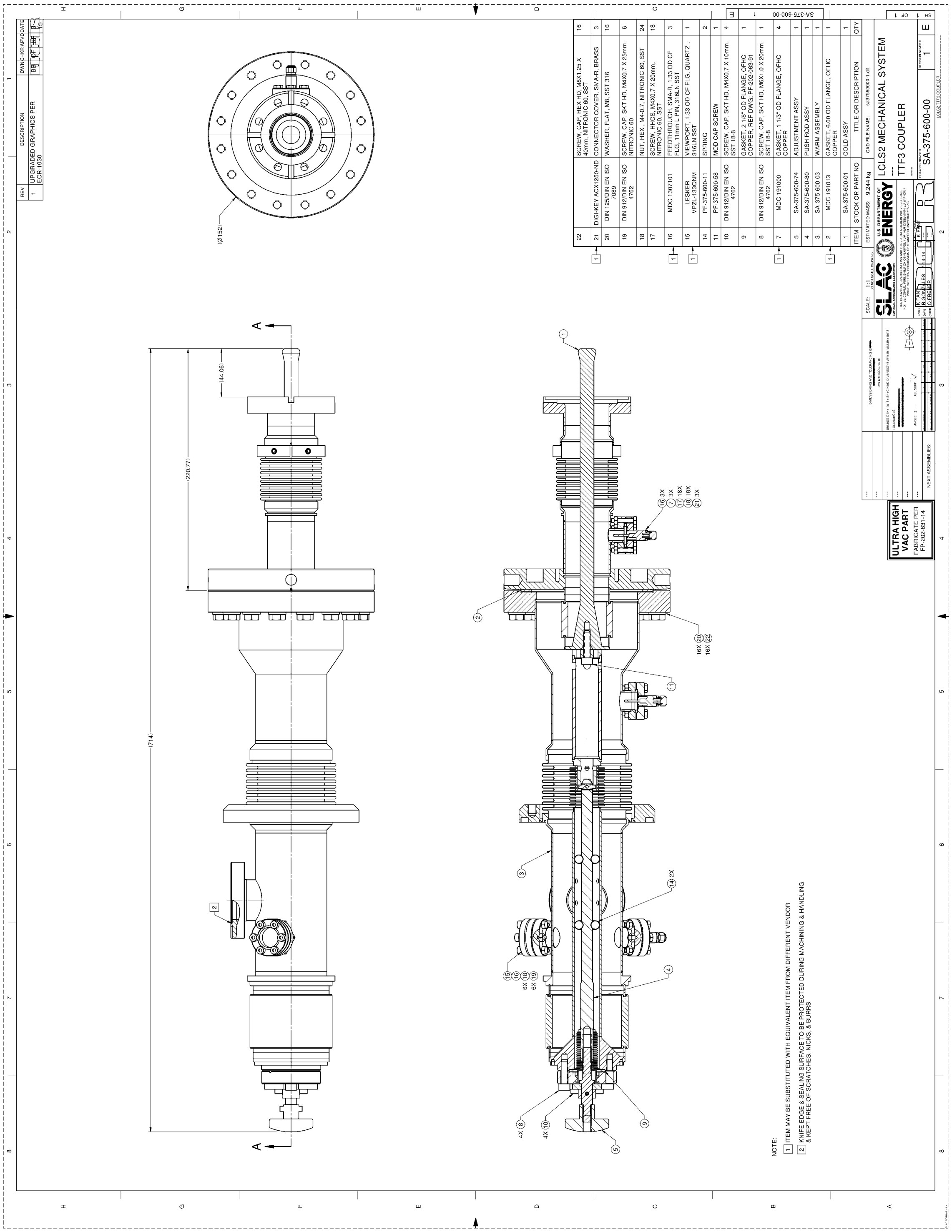

Figure 1: The LCLS II Fundamental Power Coupler Sub-Assembly drawing, produced by SLAC in 2014 at the start

of the LCLS-II Project. The figures below show the specific items labelled 1 (cold assembly, SA-375-600-01) and 3 (warm assembly, SA-375-600-03).

2 Technical Development

During the procurement process, SLAC's FPC vendors (RI/Thales and CPI) requested incorporation (merging) of the relevant EU-XFEL changes that had been made to the original TTF-3 design. Final LCLS II manufacturing design was provided by the vendors and approved by SLAC. SLAC drawings were not updated to reflect the vendor changes as the vendors drawings are the final design (per the basic premise). There are some differences between the RI/Thales and CPI couplers, and differences from the EU-XFEL design.

The EU-XFEL (modified TTF) fundamental power coupler did not meet to the following critical LCLS II requirements:

a) The cavity-coupling is incorrect for CW operation. The coupler tuning range doesn't cover the required nominal Qext = 4.e7

b) There is an overheating of the internal bellow in the warm section of the coupler at 7 kW CW input power and full reflection (effective power ~14 kW).

The SLAC-led LCLS II Cryogenic Systems group did the needed development.[1]

Two modifications were proposed to address these problems as part of a coupler R&D and test program:

- Cut the cold-assembly antenna at 8.5mm for increasing the nominal Qext value. (See figure 2 and 3)
- Increase the thickness of copper plating on the internal inner conductor of the warm-assembly section from 30 µm to 100 - 150 µm and eliminate overheating (See figure 4).

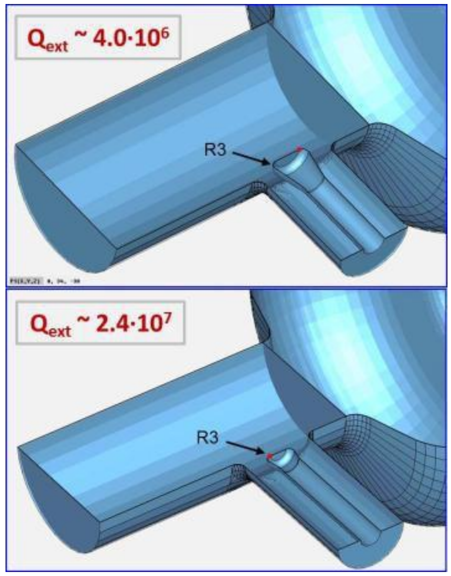

Figure 2: Coupler center-conductor (antenna) inside the cavity envelope, before (top) and after (bottom) the modification.[2]

Figure 3 below shows the modified antenna of the cold assembly (item #3, PF375-000-28) as needed to match the coupling to the LCLS-II requirements, a) above.

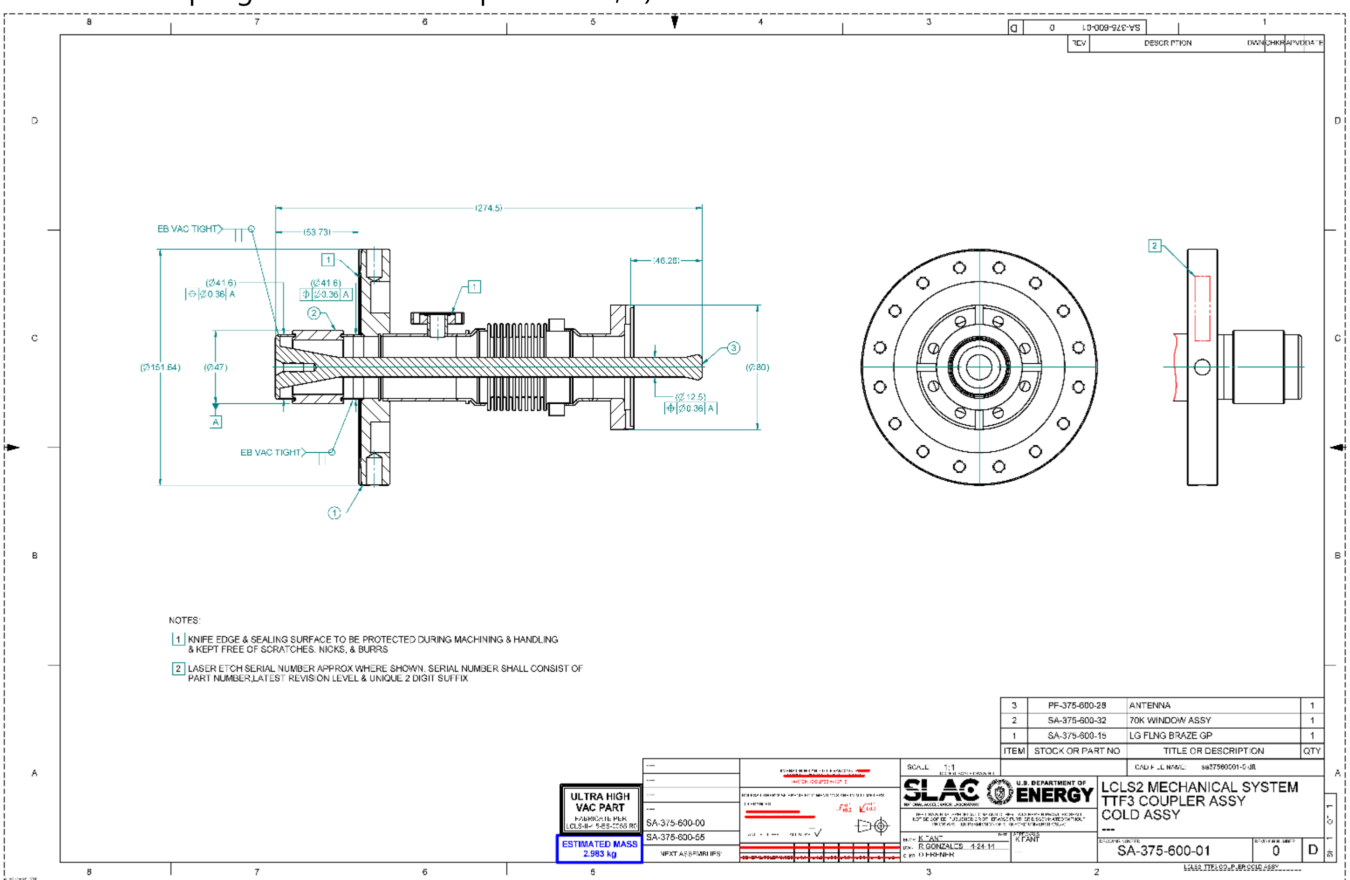

Figure 3: LCLS II Coupler Cold Assembly, showing the central-conductor antenna

Figure 4 shows the LCLS II Coupler Warm Assembly. For CW operation, the shortcoming b) above was addressed through thermal and microwave power-flow analysis. It was necessary to add thermal heat-flow path capability through very thick copper plating. In addition to analysis this required technical development and testing. SLAC has expertise in this, (from work on normal conducting accelerator systems), and was able to contribute substantially. SLAC infrastructure is well adapted to the difficult task of plating copper on stainless steel, a necessary step.

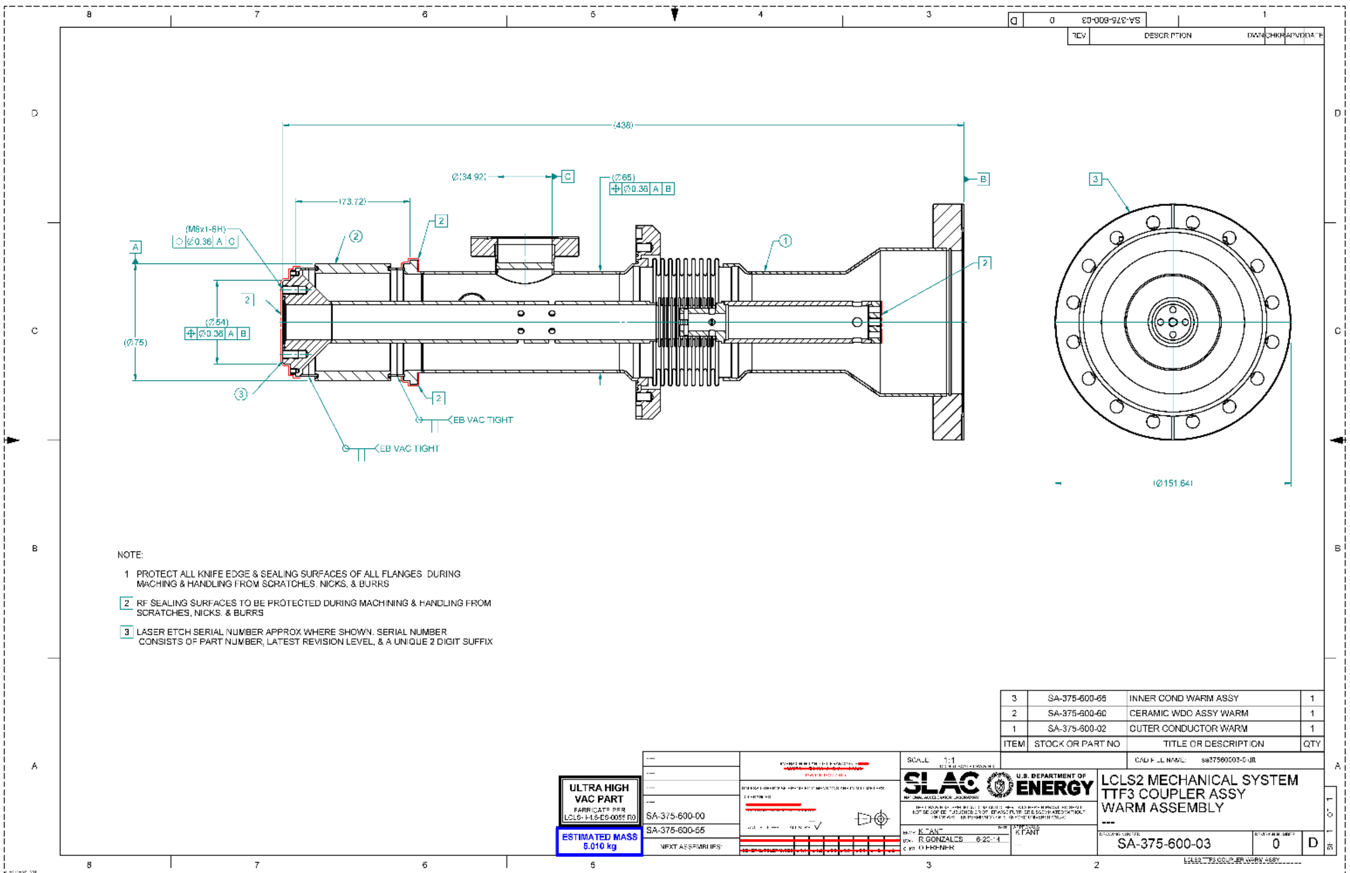

Figure 4a: LCLS II Coupler Warm Assembly showing the thickly plated bellows, part of item #3, SA-375-600-65 (4b).

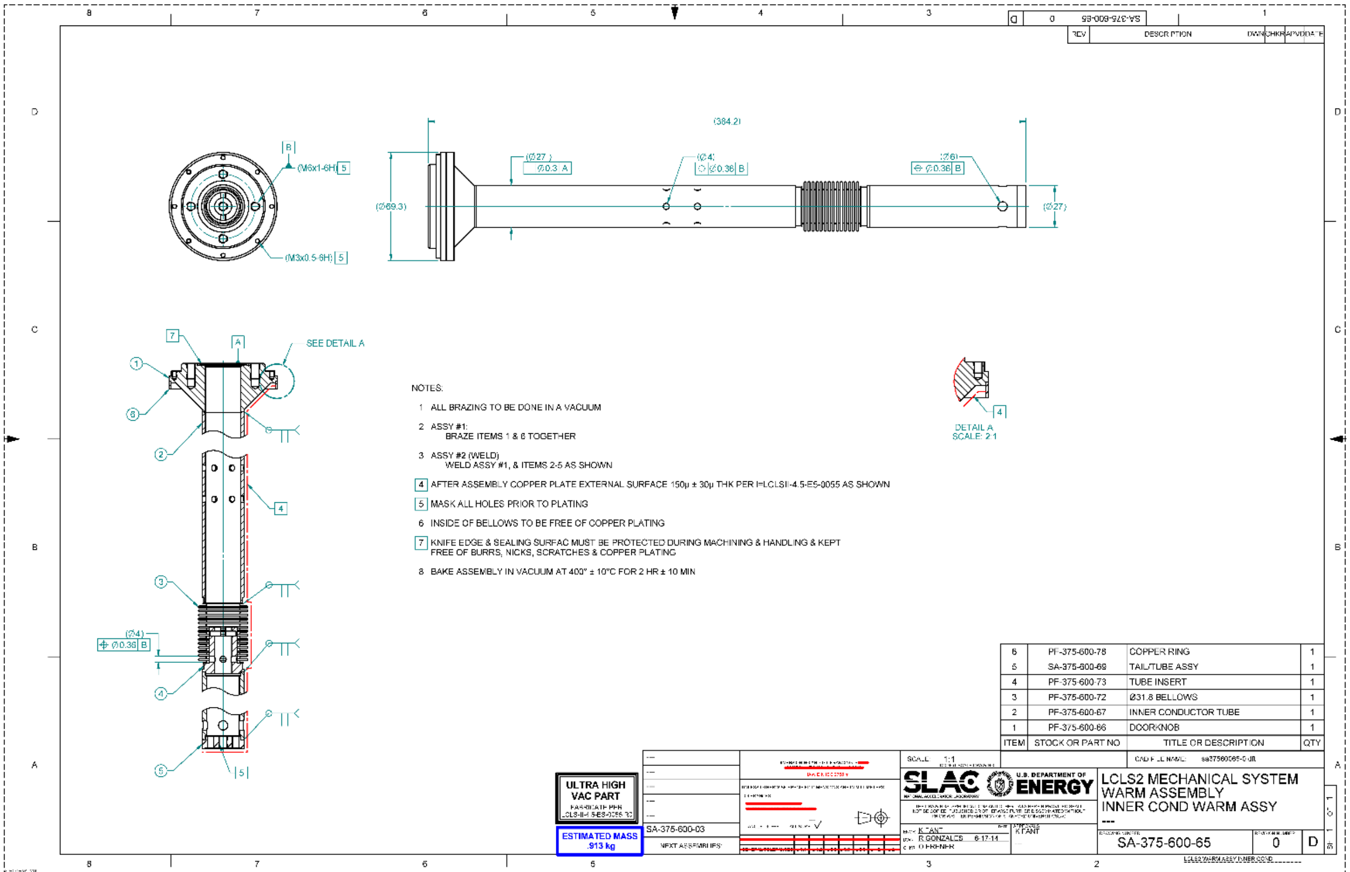

Figure 4b. Coupler Warm Assembly inner conductor bellows, with thick 150 micron copper plating on stainless steel.

Figure 5: Sectioned Coupler Warm Assembly bellows following thick copper plating done at SLAC to demonstrate the design. The plating thickness is equal to the initial base-metal stainless steel thickness.

Further, to lower cost and improve performance as compared to the EU-XFEL coupler, the copper waveguide box that attaches to the warm window will be replaced by one machined from a single block of aluminum, without RF matching posts. Also the capacitor ring that allows HV hold-off will be replaced by a copper flex ring to provide a better RF seal between the waveguide and the coupler body.

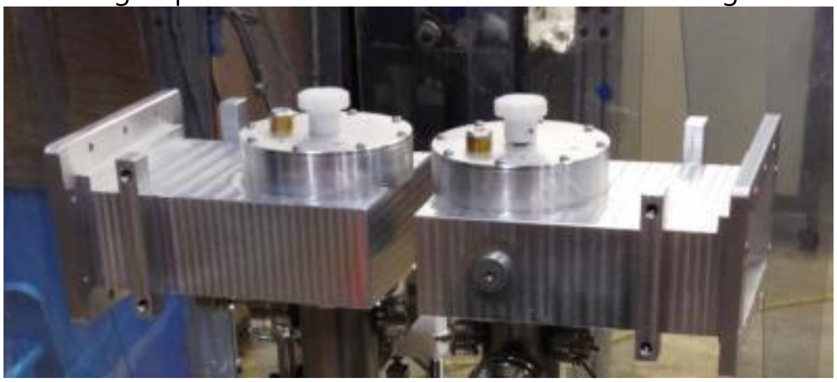

Figure 6: Block-machined coupler to waveguide adapter, developed following SLAC-experience with RF adapters.

3 Summary

The following is a summary listing of the design changes from EU-XFEL to LCLS II:

1) The antenna was shortened, (to fix point a), above,

2) the warm assembly copper plating was increased to 150um,

3) the waveguide box was redesigned using single piece aluminum,

4) the capacitor ring was replaced with a copper ring,

5) improved bellows retainer,

6) used larger cold flange diameter with TTF 3 hole pattern,

7) changed 4K tie in to solid copper ring,

8) changed orientation of warm mounting holes,

9) and removed thread,

10) removed on e-pickup,

11) added hole for structural tie for warm assembly,

12) EU-XFEL style push rod on RI/Thales which are not interchangeable with CPI or TTF3 design,

13) added holes on warm conflat on tuning rod,

14) removed thread on warm center conductor screw.

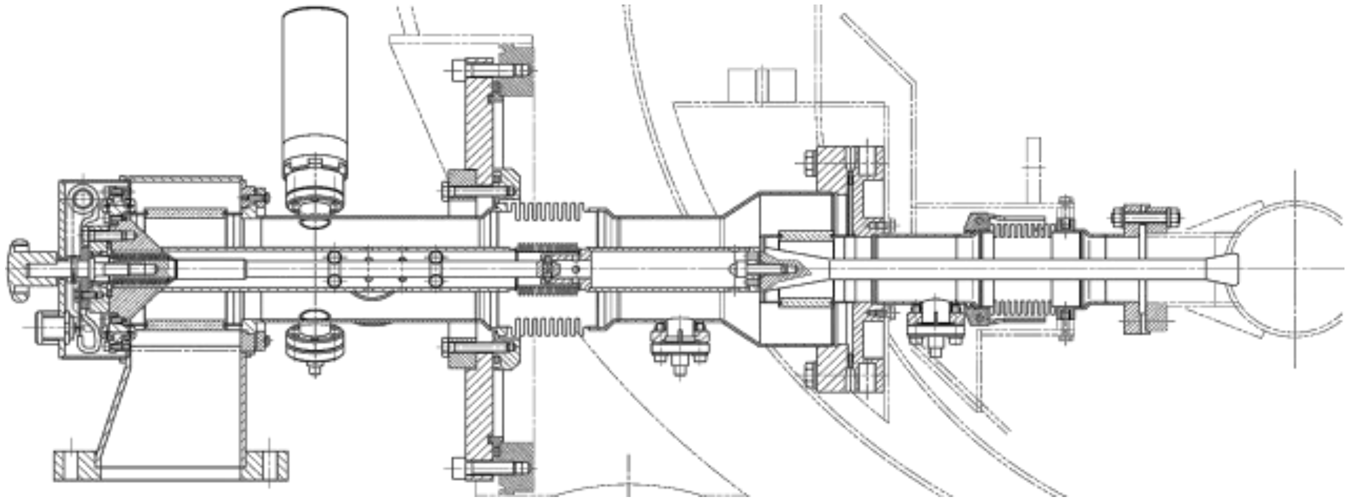

Figure 7: Fully assembled LCLS2 Fundamental Power Coupler installed in the cryomodule [3].

4 References

[1] L. Xiao, C. Adolphsen, Z. Li, C. Nantista, T. Raubenheimer, N. Solyak, I. Gonin, "TTF3 Power Coupler Thermal Analysis for LCLS-II CW Operation", SLAC-PUB-16285 (2015)

[2] C. Adolphsen, K. Fant, Z. Li, C. Nantista, G. Stupakov, J. Tice, F. Wang, L. Xiao, I. Gonin, K. Premo, N. Solyak, “Modified TTF-3 Couplers for LCLS-II”, Proceedings of SRF2015, Whistler, BC, Canada.

[3] K. Premo, T. Arkan, Y.Orlov, N. Solyak, “LCLS-II Fundamental Power Coupler Mechanical Integration”, Proceedings of SRF2015, Whistler, BC, Canada.