

# HIGH POWER COUPLERS FOR PROJECT X\*

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## Abstract

Project X, a multi-megawatt proton source under development at Fermi National Accelerator Laboratory. [1]. The key element of the project is a superconducting (SC) 3GV continuous wave (CW) proton linac. The linac includes 5 types of SC accelerating cavities of two frequencies.(325 and 650MHz) The cavities consume up to 30 kW average RF power and need proper main couplers. Requirements and approach to the coupler design are discussed in the report. New cost effective schemes are described. Results of electrodynamic and thermal simulations are presented

## COUPLERS REQUERMENTS

Cavities parameters of 3 GeV Project X superconductive linac is presented in Table 1[2].

Table 1: Cavities parameters

| Cavity | Frequency | Number | Power*  | Cryo-loss |
|--------|-----------|--------|---------|-----------|
| SSR0   | 347 MHz   | 18     | 0.7 kW  | 1.3 W     |
| SSR1   | 347 MHz   | 20     | 1.7 kW  | 1.7 W     |
| SSR2   | 347 MHz   | 40     | 3.2 kW  | 3.7 W     |
| LB     | 672 MHz   | 36     | 11.5 kW | 24 W      |
| HB     | 650 MHz   | 152    | 17.5 kW | 25 W      |

\*Maximal power consumed by the beam.

Cavity parameters determine requirements for couplers, which have to provide reliable operation of cavities in CW regime at power level 6 kW at 325MHz and up to 30kW at 650MHz taking into account necessary overhead, and must sustain full reflection from cavities for short time. Cryogenic loads of couplers have to be less noticeable than the cryogenic loads of cavities. The couplers have to allow for assembly to cavities with a vacuum window in a clean room followed by installation in a cryomodule. At the same time, the couplers should remain simple in structure to keep them as cost-effective as possible.

## COUPLERS CONFIGUTATION AND PARAMETERS

To make coupler production more effective, an approach of maximum unification was chosen. Couplers for both frequencies should contain maximum number of common (shared) parts. Both couplers will have coaxial structures. The outer diameter of coaxial is determined by

compatibility with previously designed and built 325 MHz cavities. The outer conductor is made from standard seamless 3" stainless tube with its O.D. machined to obtain 0.8mm wall thickness and its I.D. coated with an ~10 micron copper layer. An inner conductor consists of 0.5" oxygen-free copper tube and is air-cooled. Scheme of 2K-300K vacuum part of coupler is presented at Fig.1. Both 325 and 650 MHz couplers have the same structure.

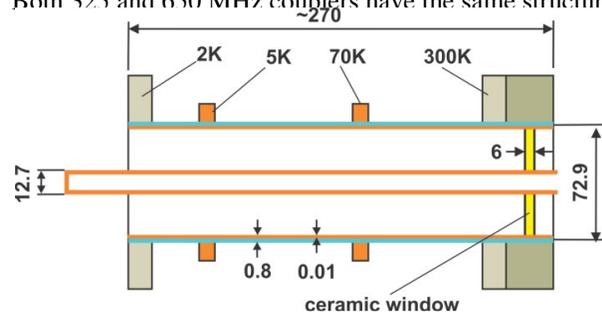


Figure 1: Structure of 2K-300K vacuum part of coupler.

The relatively small diameter of the inner conductor provides higher impedance of coaxial. (108 Ohm) High impedance has two advantages: it provides lower RF current for fixed RF power and, thus, lower RF loss in outer conductor which is connected directly to low temperature 2K structure. Second, high impedance leads to higher multifactor power threshold and moves it beyond the operating range. Nevertheless, coupler design allows the application of a voltage bias to suppress multifactor if necessary.

Couplers have a fixed coupling, Project X linac is CW machine, and a penalty for an error in the coupling is only extra RF power. As calculation shows that power is not sensitive to mis-coupling: it requires not more than 5% extra power if coupling is in range 0.65 - 1.55 (1.0 is optimal). It is suggested that cavities be overcooled from the beginning to decrease microphonic detuning effects.

An antenna tip of a new shape will be used for 650 MHz coupler, Fig. 2

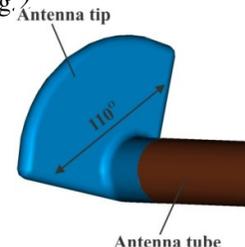


Figure 2: New shape of an antenna tip for 650 MHz coupler.

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This shape provides better coupling, has a smaller weight (it is important for horizontal position of an antenna), and allows tuning of the coupling by rotating the tip with respect to the cavity axis. 180° rotation change a coupling 4 times.

In order to make the coupler simpler, a single window structure was chosen. Operation experience with high average power RF windows and couplers has shown that the single window can operate reliably with an average power flow density through ceramic up to 5.6 kW/cm<sup>2</sup> and more than 1MW of the total power flow in CW regime. [3-5]. By comparison, parameters of the Project X coupler window look moderate: 0.75kW/cm<sup>2</sup> power density, and 30kW total CW power. The window is made of 6 mm thick A<sub>2</sub>O<sub>3</sub> ceramic. Mechanical and thermal stress analyses show that it has enough safety margin. The window has a room temperature and should be placed at maximum distance from 2K structure. At the same time, position of window has to allow an assembled cavity (with a cold part of coupler) to be installed inside the cryomodule. Calculations show that two thermo-anchors at 5K and 70K are necessary to minimize total cryogenic load. Thermal parameters of coupler are presented Table 2.

Table 2: Thermal parameters of couplers

| Parameter       | 325MHz coupler | 650MHz coupler |
|-----------------|----------------|----------------|
| RF power        | 6 kW           | 30 kW          |
| Static loss, 2K | 0.029 W        | 0.029 W        |
| Total loss, 2K  | 0.033 W        | 0.058 W        |
| Static loss 5K, | 1.53 W         | 1.53 W         |
| Total loss 5K   | 1.55 W         | 1.68 W         |
| Static loss 70K | 8.76 W         | 8.76 W         |
| Total loss 70K  | 8.79 W         | 9.09 W         |
| Kryo-plant      | 610 W          | 670 W          |

Fig. 3 and Fig. 4 present the schematics for air parts of couplers. 325 MHz coupler has a standard 4-1/16" coaxial input. 650MHz - 11.5" x 1.5" waveguide input. Fig. 5 and Fig. 6 show simulated passbands.

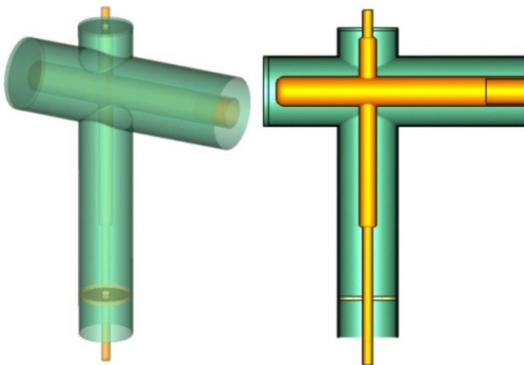


Figure 3: Schematics of air part of 325MHz coupler

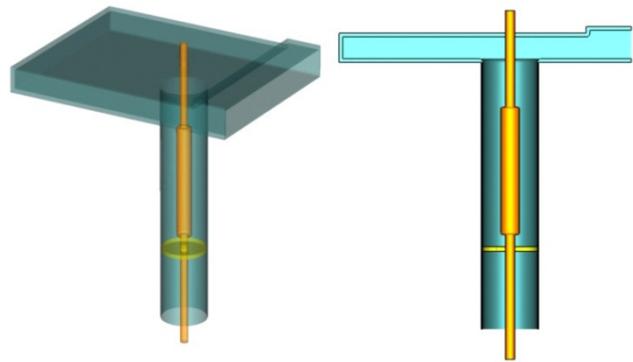


Figure 4: Scheme of air part of 650MHz coupler

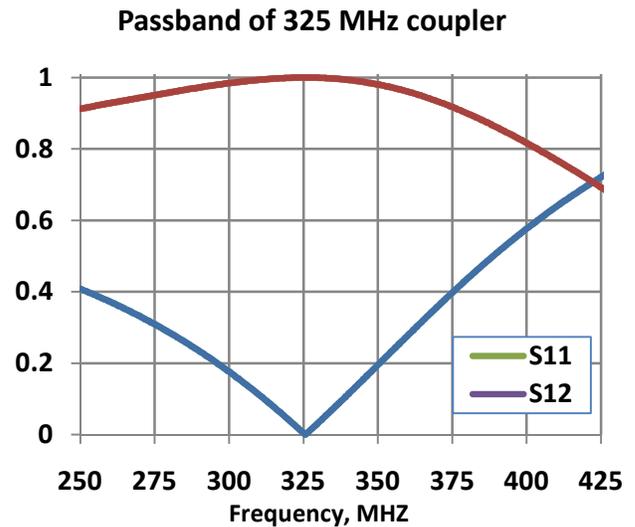


Figure 5: Passband of 325 MHz coupler

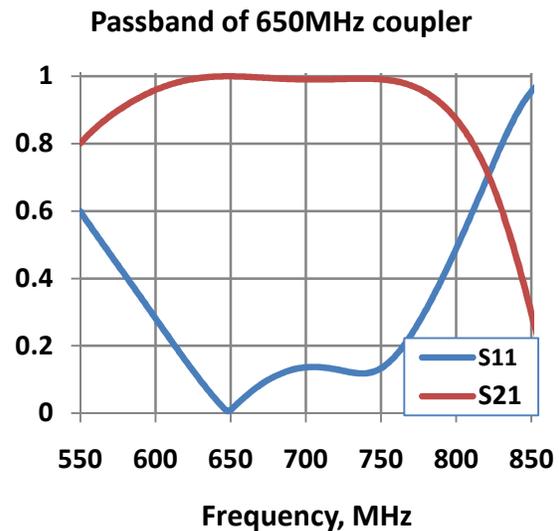


Figure 6: Passband of 650 MHz coupler

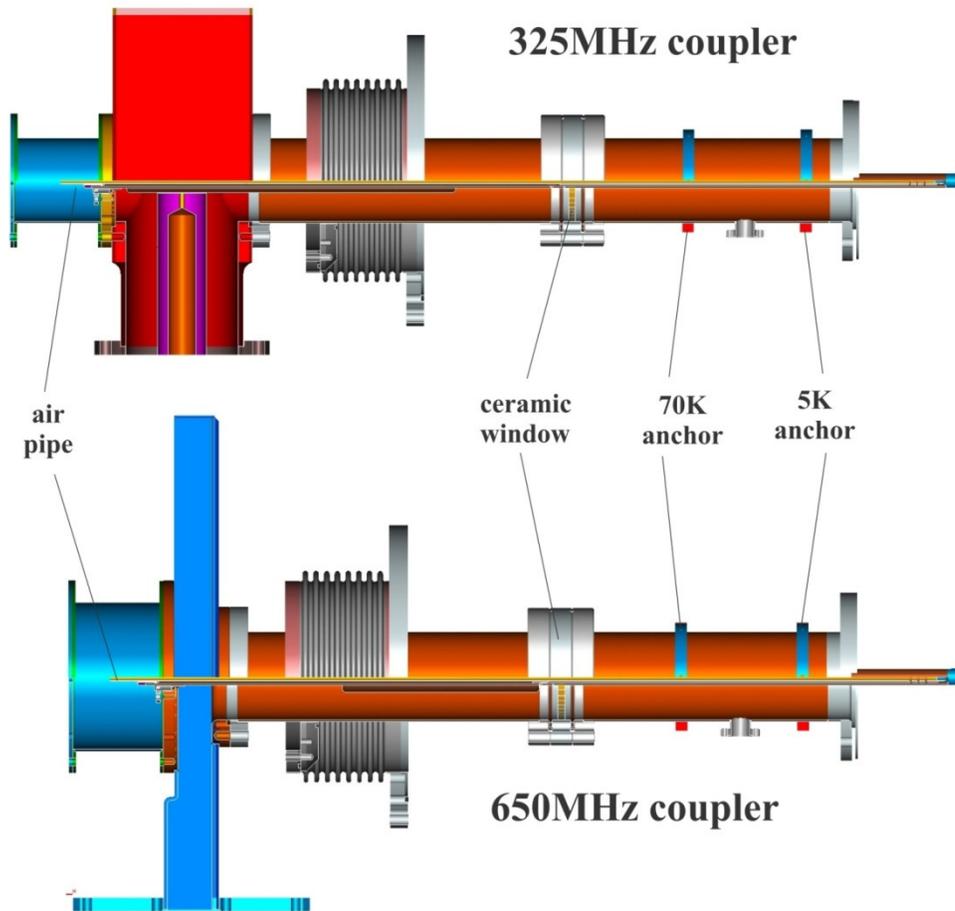


Figure 7: Conceptual mechanical design of 325 and 650 MHz coupler

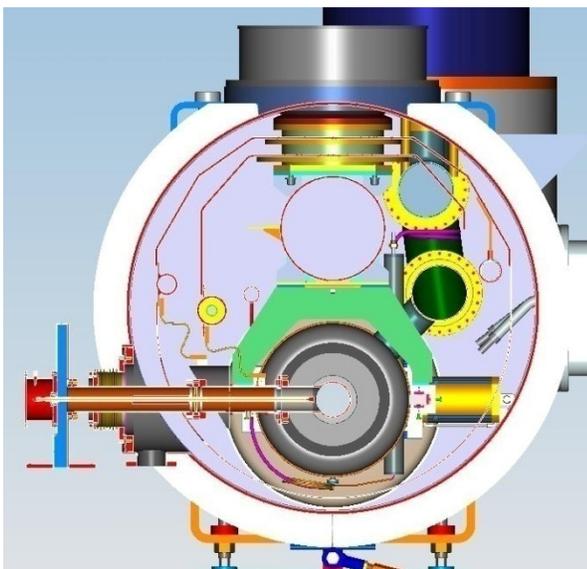


Figure 8: Drawing of 650MHz coupler installed in cryomodule

At present, the electrical, thermal and conceptual mechanical design of 325 and 650 MHz couplers for

Project X have been finished. The coupler prototypes are planned to be fabricated and tested in a year.

## REFERENCES

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