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The Development of a Prototype Fundamental Power Coupler for CiADS and HIAF Half Wave Resonators

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Abstract

More than 100 Half-wave resonators (HWR) will be adopted for China Initiative Accelerator Driven System (CiADS) and High Intensity heavy-ion Accelerator Facility (HIAF) at IMP. Each HWR cavity equips with one variable coupling, dual-warm-ceramic fundamental power coupler (FPC). The FPC should be able to transmit up to 30 kW in CW mode. This paper will give an overview of the RF design of the 162.5 MHz CW power coupler. The coupler employs two warm ceramics in a 50 Ohm coaxial line to ensure operation reliability. The results of thermal and thermomechanical will also be reported. Two prototypes have been fabricated and the RF measurements with low RF power were carried out.

Introduction

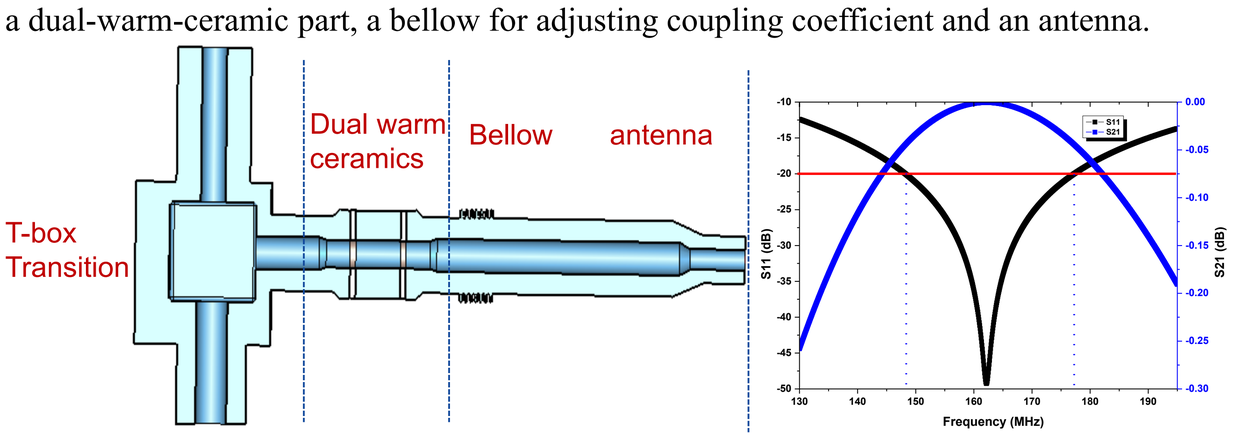
HIAF and CiADS accelerators desire not only high accelerating gradient, but also high operating efficiency and reliability. The fundamental power coupler is the critically important component of a superconducting (SC) accelerator. The primary function of the coupler is to delivery RF power from RF source, which located at room temperature and at atmospheric pressure, to a superconducting cavity sat at cryogenic temperature and vacuum. Based on the operation experience of China ADS, two-window coupler at SC cavities is the higher safety margin against window failure during operation. The two-warm-ceramic coupler will be adopted for the two SC linear accelerators.

The beam current of CiADS will be less than 2.5 mA in the first phase, and it will be upgraded to more than 10 mA in the future. The coupler should be variable to accommodate diverse beam loading at different phase to reduce the cost of power source. The main specifications of power coupler for CiADS and HIAF are listed in the table. It was decided that only one coupler design will be used for all the HWRs regardless of their diverse power needs. The prototype coupler should be able to operate up to 30 kW CW RF power at 162.5 MHz in travelling wave, but it should also be tested in total reflection mode.

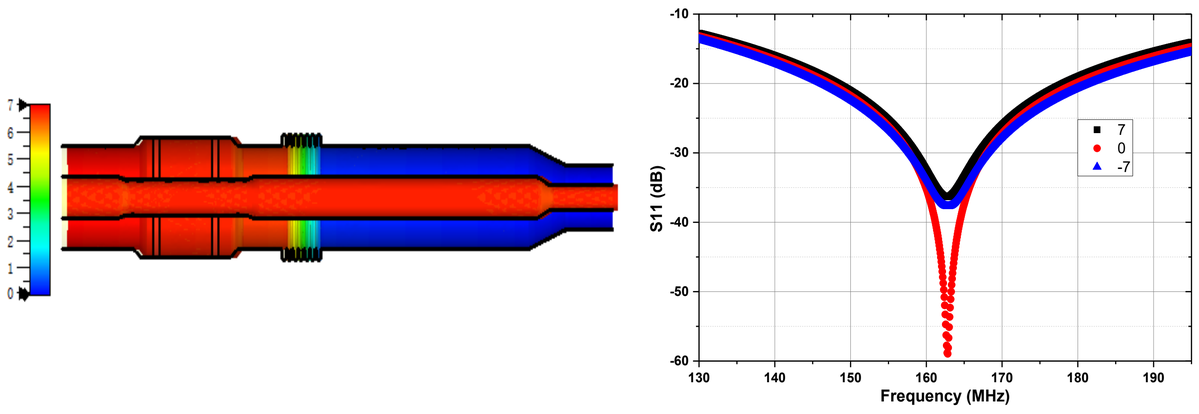
	HIAF				CiADS		
	QWR007	HWR015	HWR010	HWR019	DSR042	Ellip062	Ellip082
Frequency (MHz)	81.25	162.5	162.5	162.5	325	650	650
Quality	30+5	66+6	9	24+6	40+4	40+4	24
Qe(10^6)	0.18~0.61	0.36~0.92	0.36~1.02	0.54~1.18	1.08~5.17	2.17~6.64	2.95~5.61
stroke(mm)	-	6	6	6	6	6	10
Operation power (kW)	3	4	7	24	42	88	92
Power at Test Stand (kW)	6	6	10	30	60	100	110

EM design

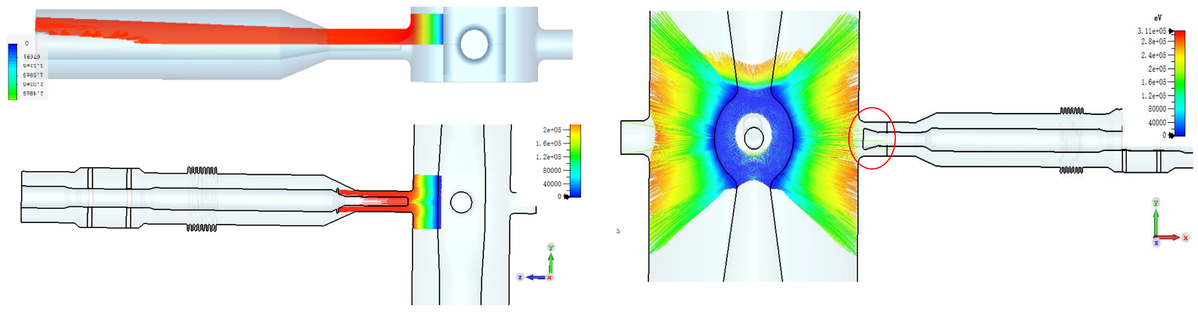
A general overview of the coupler set is shown below. The coupler has a coaxial geometry, which is connected between the HWR and a “T” transition box. It constituted of a dual-warm-ceramic part, a bellow for adjusting coupling coefficient and an antenna.



The change in coupling is made by axial movement of the antenna through pulling or pushing the bellow. The effect on the different position of bellow is simulated. The passband is not sensitive to the outer conductor‘s displacements.



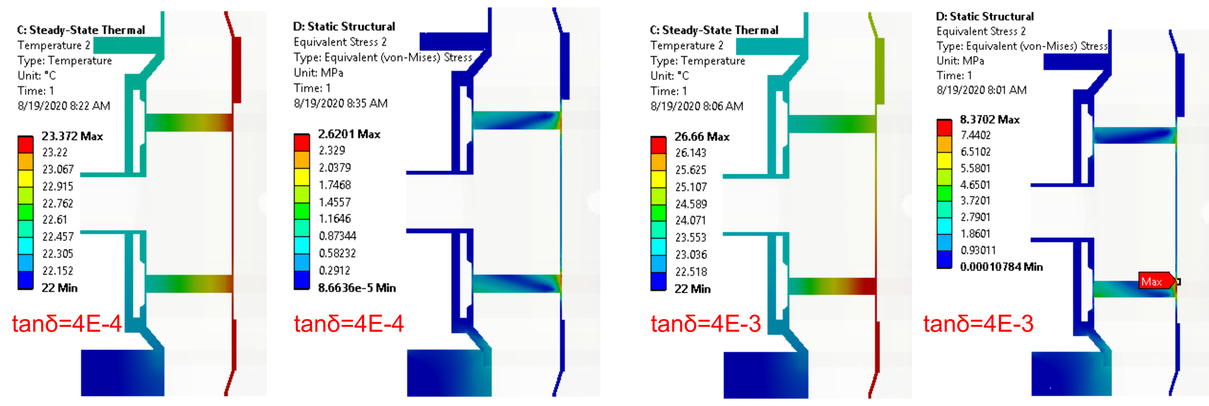
The field emission electrons from SC cavity can hit on the ceramic for HWR010 cavity. The design includes the shields in the inner conductor to protect the ceramics from charged particle. The shields also match the tapered coaxial component.



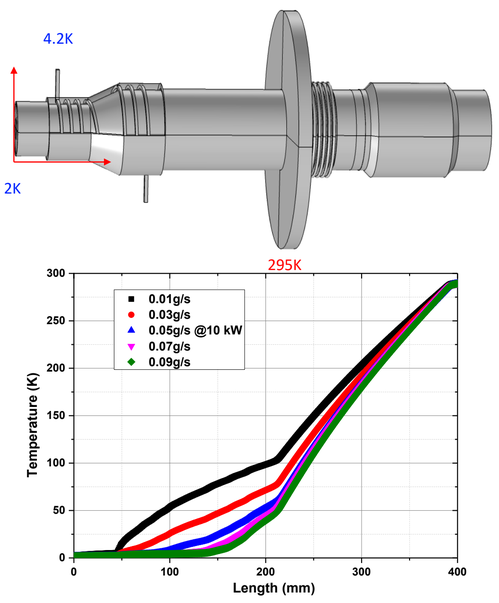
HWR010 HWR015&HWR019

Thermal-Mechanical simulations

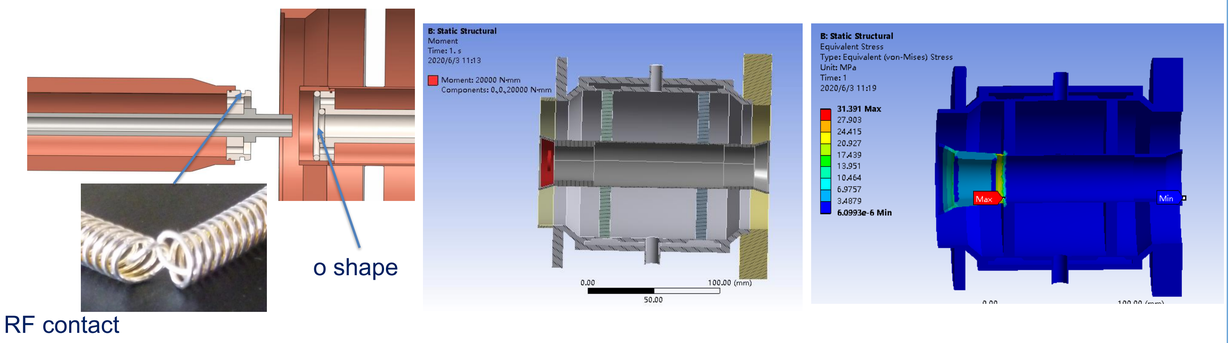
Thermal stress for different loss tangent of ceramic at 10 kW has been simulated to ensure the safety of dual-warm-ceramic part.



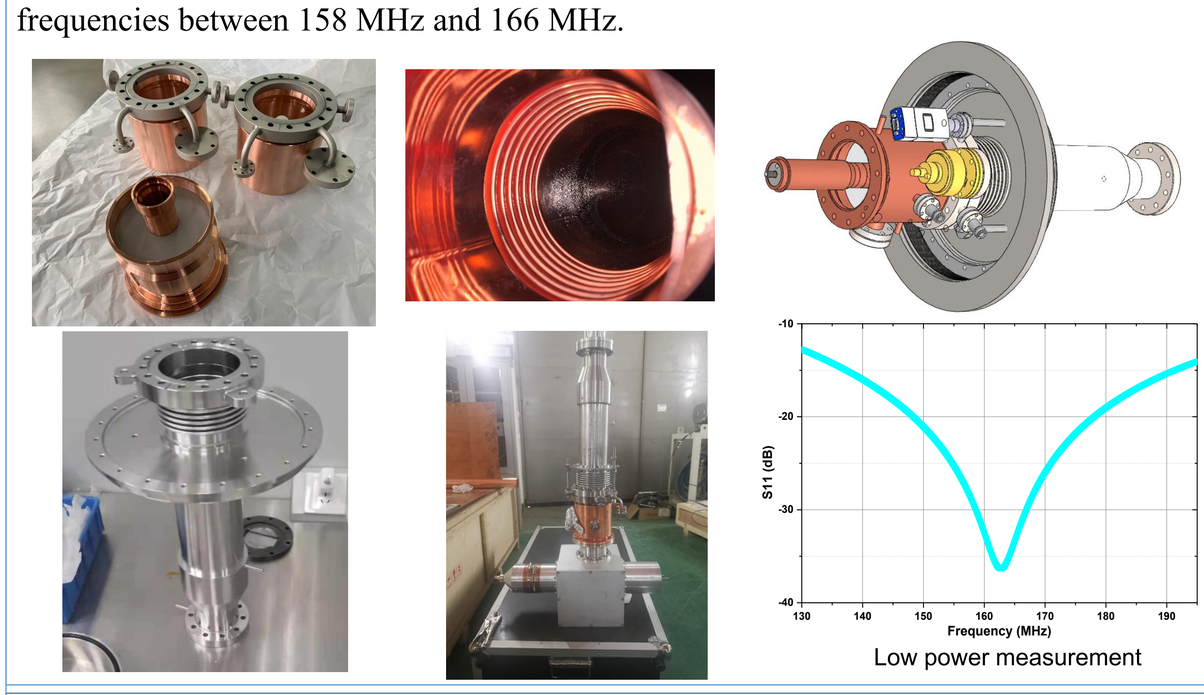
The double-wall tube is applied to ensure a thermal gradient between low temperature cavity and the ambient temperature (window level) and to be used as the external conductor for the RF coaxial line. A cooling circuit (helium) is used to obtain the required thermal gradient. In order to recycling to the refrigerating machine, the output temperature of the helium gas should be less than 75 K.



Power(kW)	2K heat load(W)	Gas flux(g/s)	Output temp.(K)
0	3.894	0.01	91.9
10	4.100	0.01	93.6
20	4.314	0.01	95.2
30	4.529	0.01	96.9
0	0.324	0.03	64.9
10	0.382	0.03	66.3
20	0.442	0.03	67.6
30	0.505	0.03	69.0
0	0.070	0.05	46.5
10	0.084	0.05	47.5
20	0.097	0.05	48.4
30	0.113	0.05	49.4



The stress of connecting the inner conductor was analyzed, the max. equivalent stress is less than 32 MPa, which is beyond the weld strength of the ceramic joint. A prototype has been fabricated and low power measurement was carried out. The measurements fulfill the acceptance condition and demonstrated a low return loss values less than -30 dB for all frequencies between 158 MHz and 166 MHz.



Low power measurement

Conclusion

A two-warm-ceramic coupler has been designed for HWR cavities of CiADS and HIAF. Two coupler prototype sets were manufactured. Acceptance tests are on-going. The reception of couplers is planned for autumn 2021. The high-power processing will be the next major validation stage.