Superconducting Radio-Frequency (SRF) elliptical bulk niobium cavities (f=700 MHz) will be used as accelerating structures in the high energy section (185MeV-600MeV) of the proton LINAC driver in Accelerator Driven System. The power coupler (PC) needed for these resonators should transmit a 150 kW CW RF power to a maximum 20mA protons beam. The estimated average values of the RF losses in the coupler are 130 W (respectively 46 W) in the inner (respectively outer) conductor in SW mode. Due to such high values of RF losses, it is necessary to design very carefully and optimize the cooling circuits in order to efficiently remove the generated heat and to reduce the thermal load to the cavity operating at T=2 K.

An experiment simulating thermal interaction between the power coupler and a 700 MHz SRF five cells cavity was performed in the CRYHOLAB test facility in order to determine the critical heat load that can be sustained by the cavity without RF performance degradation. Experimental data are compared to numerical simulation results obtained with the finite element code COSMOS/M. These data also allow us to perform in-situ measurement of thermal parameters (thermal conductivity, thermal contact resistance) and they were used to validate numerical simulations of PC thermal model.

Study of thermal interaction between a power coupler and a 700 MHz superconducting cavity

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Abstract

Superconducting Radio-Frequency (SRF) elliptical bulk niobium cavities (f=700 MHz) will be used as accelerating structures in the high energy section (185MeV-600MeV) of the proton LINAC driver in Accelerator Driven System. The power coupler (PC) needed for these resonators should transmit a 150 kW CW RF power to a maximum 20mA protons beam. The estimated average values of the RF losses in the coupler are 130 W (respectively 46 W) in the inner (respectively outer) conductor in SW mode. Due to such high values of RF losses, it is necessary to design very carefully and optimize the cooling circuits in order to efficiently remove the generated heat and to reduce the thermal load to the cavity operating at T=2 K.

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Main objectives of the experiment:

- Determination of the amount of heat loads that can be sustained by the 700 MHz cavity without any degradation of RF performance.
- Measurement of some thermophysical properties like beam tube thermal conductivity and thermal contact resistance in coupler port.
- Validation of 3D finite elements thermal computations using the COSMOS/M code.
- Evaluation of heat quantities Q1, Q2 and Q3 from experimental data and thermal simulation results.

Study of the thermal interaction between the PC and the SC 700 MHz elliptic cavity

Main Characteristics of the coaxial Power Coupler (PC)

<table>
<thead>
<tr>
<th>Frequency (MHz)</th>
<th>700</th>
</tr>
</thead>
<tbody>
<tr>
<td>RF Power (PC)</td>
<td>130 W</td>
</tr>
<tr>
<td>Dependance (d)</td>
<td>58</td>
</tr>
<tr>
<td>Material</td>
<td>Cu/S.S</td>
</tr>
<tr>
<td>Diameter</td>
<td>35 mm</td>
</tr>
<tr>
<td>Wall Thickness</td>
<td>2 mm</td>
</tr>
<tr>
<td>Inner Conductor</td>
<td>OFHC copper</td>
</tr>
<tr>
<td>Outer Conductor</td>
<td>RRR=40, Cu/S.S</td>
</tr>
</tbody>
</table>

GOAL: Transmission of 150 kW CW RF power at f= 700 MHz to a Protons Beam

Average RF losses (Total Heating):
- Inner Conductor(TC): PIC= 65 W (TW mode) and 130 W (SW mode)
- Outer Conductor (OC): POCC= 23 W (TW mode) and 46 (SW mode)

Average dielectric RF losses in the window: \( P_{\text{Heater1}} = 12 W \)

Static losses (static conduction) from room temperature to 2K circuit: \( P_{\text{static}} = 7 W \)

Maximum heat flux by thermal radiation from CE to CO: \( F_{\text{max}} = 8 W \)

Design and calculation of 2 cooling circuits to remove heat loads
1) Water circulating Circuit at 288K in an annular space around the IC
2) Supercritical Helium in a coil brazed around the OC with the appropriate flow

Thermal Conductivity Measurements

Experimental data are compared to numerical simulation results obtained with the finite element code COSMOS/M. These data also allow us to perform in-situ measurement of thermal parameters (thermal conductivity, thermal contact resistance) and they were used to validate numerical simulations of PC thermal model.

Normalized Scattering Matrix (NORM)

Thermal contact resistance measurement (NORM)

\[ R_t = \frac{T_1 - T_2}{P_{\text{Heater1}}} \]

Relative deviation between experimental and simulation temperature values of He/LHe

Validation code by comparison between experimental and simulation temperature values of He/LHe

Temperature distribution with Heater 1 for TW mode and heater 3 for SW mode

Axially symmetrical model with Heater 3 for TW mode and Heater 2 for SW mode

Thermal balance at the junction Beam tube/LHe Tank/Cavity Iris

Thermal balance at the junction Beam tube/LHe Tank/Cavity Iris

Thermal contact resistance measurement (NORM)

\[ R_t = \frac{T_1 - T_2}{P_{\text{Heater1}}} \]

Relative deviation between measured and computed temperature field is less than 25 % for most thermometers.

Thermal shell model describes the thermal behavior of the simulated system with a sufficient accuracy.