DESIGN OF RF POWER INPUT PORTS FOR IPHI RFQ

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Abstract

The IPHI RFQ will be fed through four input ports driving 400 kW RF power each. These ports are the link between the WR2300 half height waveguide and the RFQ cavity wall. Special care has been taken to design these elements in order to satisfy the following requirements: RF matching, negligible perturbation on cavity voltage, convenient coupling coefficient, moderate operating temperature and stress, reasonable overall dimensions. The result is a modular system including a glidcop taper equipped with stainless steal flanges and a re-machinable iris that will be brazed on the taper after final adjustment

1 INTRODUCTION

RF input ports in a high power CW RFQ like IPHI is a critical issue from a thermal point of view. Coupling a waveguide inherently implies a hole in the cavity wall. To ensure enough coupling, the hole must extend longitudinally and rather looks like a slot. Current lines are deviated by this slot and a high peak power spot appears at the slot ends where current lines are concentrated. As experienced in Los Alamos during the first LEDA operation, this phenomenon could lead to iris melting [1]. It is important to notice that high power dissipation is not due to the power traveling through the RF ports, but rather to the standing wave at the cavity limit. Consequently, increasing the number of RF inputs would make no difference.

2 TAPER

The 8-m IPHI RFQ will be fed by four RF input ports situated in the two upper quadrant of the 4th and 7th meter of the structure. Because of the small transverse dimension of the cavity, a WR2300 waveguide cannot be directly connected to it. A taper with a constant cutoff frequency will transform the half-height WR2300 into a ridged waveguide with much smaller external dimensions (fig. 1). The small end of the taper is connected to the RFQ through a slot and two holes in a 21.5-mm thick iris (fig. 2). Assuming that the taper is a smooth transition, we do not include it in the study of RF matching. We use simple ridged waveguide of constant cross section in the MAFIA simulation (next section).

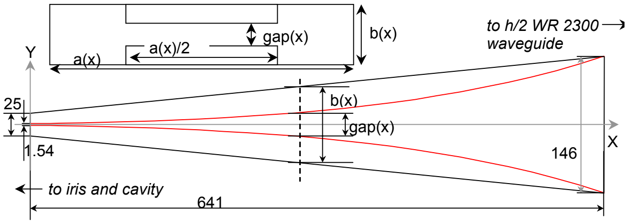

Figure 1. Taper dimensions.

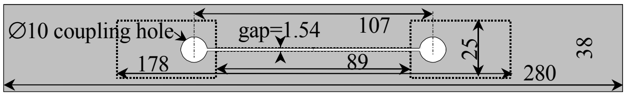

Figure 2. Iris dimensions.

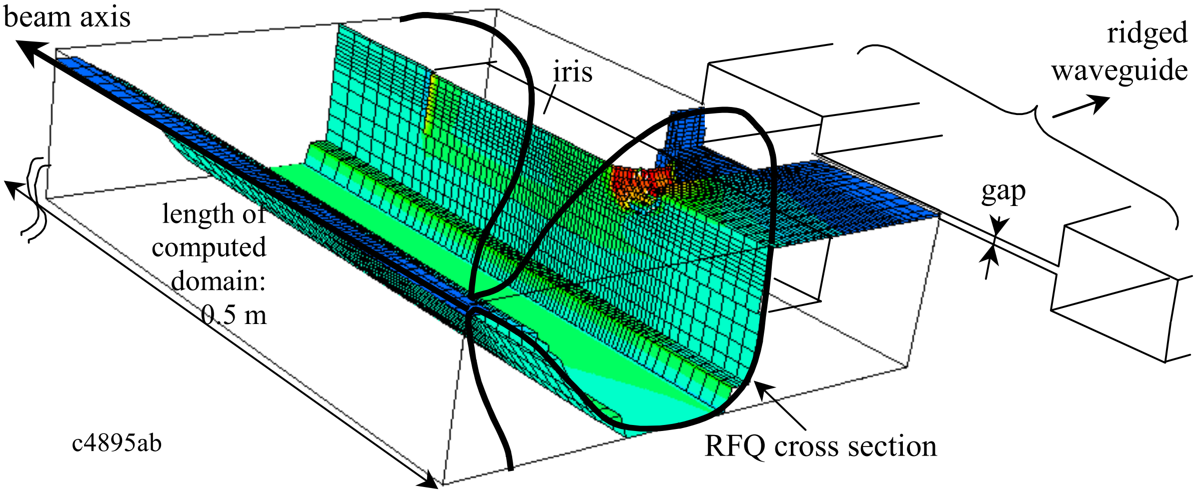

Figure 3. MAFIA simulation of the RF input port.

3 EXTERNAL Q

The external Q characterizes matching between taper and cavity. To compute it, we use our method, already described in [2,3]: we simulate a cavity connected to a waveguide of an arbitrary length successively ended by the two limit conditions. We showed that:

$$Q_{ext} = \frac{\omega}{c}\left(\frac{\lambda_g}{\lambda}\,\frac{\iiint_{cavity}|E|^2 dv}{\iint_{port}|E|^2 ds} + \frac{\lambda}{\lambda_g}\,\frac{\iiint_{cavity}|B|^2 dv}{\iint_{port}|B|^2 ds}\right).$$

Volume integrals are on the whole cavity, and surface integrals are only on the input port (line end cross section). The first term (with electric field) is computed with the $E_\perp=0$ condition (magnetic wall) on the input port, and the second term (with magnetic field) is computed with the dual condition: $B_\perp=0$ (electric wall) on the input port. The guided wavelength λ_g is given by the waveguide cutoff frequency f_c: $\lambda_g/\lambda=[1-(f_c/f)^2]^{-1/2}$.

Matching occurs when the internal Q (including beam) equals the external Q. The expected Q_0 is about 8100 without beam, and will drop to 5700 with a full current beam (100 mA): this is the goal value for the global external Q. In the simulation, we computed only 1/16 of a 1-m section (fig. 3). With the symmetries, it represents a 1-m section equipped with one port in each quadrant, i.e. 32 ports for the whole 8-m RFQ, instead of 4 ports as in the real RFQ. This brings the Q_{ext} goal value of the simulation to 5700× 4/32=715.

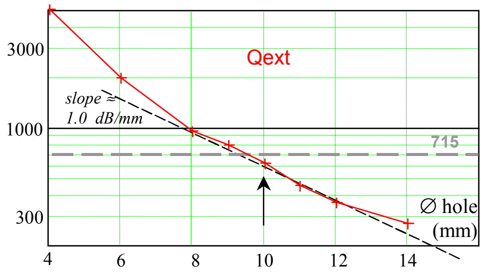

Figure 4. Simulated Q_{ext} values

In our simulation, Q_{ext} value depends on the hole diameter with a 1 dB/mm slope. The goal is reached with a ∅10 mm hole (fig. 4.. Practically, matching will be obtained by adjusting the iris hole diameter around 10 mm in a ±2 mm range, corresponding to a 4 dB range for Q_{ext}.

4 FIELD AND LOSSES

The frequency shift caused by the input port is cancelled by a 1.5 mm penetration of the iris toward the cavity. This dimension will be adjusted after RF measurements. The bead-pull measurement should exhibit a somewhat perturbed magnetic field (±2.5%), but the actual vane voltage perturbation should be negligible (<0.25%) as seen on figure 5.

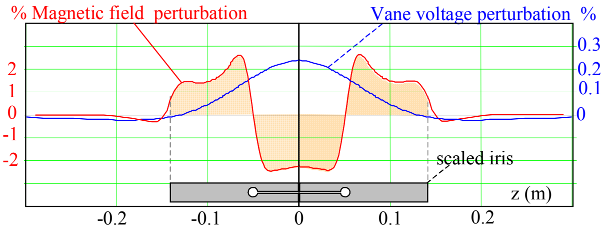

Figure 5. Perturbations caused by the RF input port

RF losses have been computed with the new algorithm of the MAFIA post -processor [4], for the most critical RF input (in the 7th meter of the RFQ). In this region, power loss densities are about 16 W/cm^2 in the current cross section (far away from RF input and vane ends). RF losses densities in the iris are about the same values, except in the hole region where local power density reaches 120 W/cm^2. Global losses in the whole iris are about 3260 W, including 600 W for each of the two holes (fig. 6).

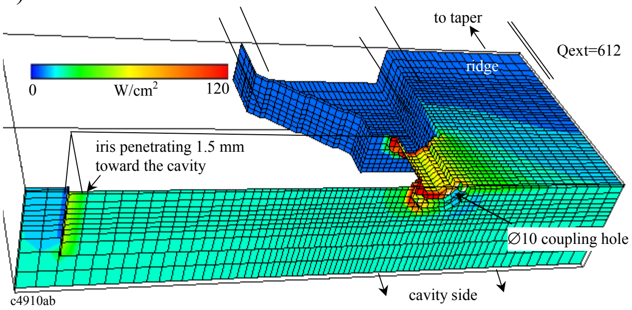

Figure 6. RF losses in iris

5 MECHANICAL DESIGN

The desired characteristics of this RF input are:

- Modularity (for RF tunings).
- Small overall dimensions.
- Low thermo mechanical deformation to avoid resonant frequency shift.
- Stresses below yield point.
- Good RF contacts.
- Accurate positioning.

Modularity, required for minimizing cavity frequency perturbation and for RF matching, deals with position and dimension of the iris (in particular, hole diameter). Transverse dimension is limited by the cooling channel of the cavity. Longitudinally, long dimension brazing should be avoided.

These requirements led to an RF input made of 3 copper pieces: the taper (split in "high" and "low" parts) and the iris. The iris is 20 to 25 mm thick to dissipate power. A first aluminium iris will be made for RF measurements and tunings. Eventually, a copper piece will be machined at the same dimensions.

Two stainless steel flanges with helicoflex grooves are brazed with these 3 pieces (fig. 7). So, modularity needed for RF tunings is provided by the iris piece, which is easy to machine or to change. No machining is needed on the two other pieces.

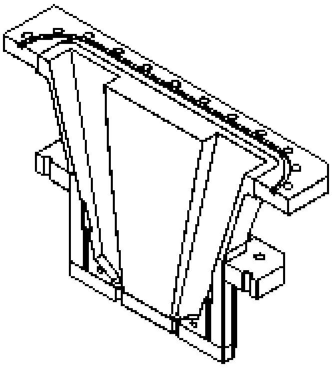

Figure 7. Iris and low part of the taper.

6 THERMO MECHANICAL CALCULATIONS

As the automatic transfer software [5] was not available at the time we made these calculations, we divided manually the whole surface in zones of approximate constant power density to compute the temperatures. Results presented here were made with early estimations of the peak power density on the iris (200 W/cm^2), which were rather pessimistic.

The cylindrical geometry around the coupling hole is favorable for cooling: maximum temperature remains below 85°C (fig. 8). The deformation profile exhibits a maximum value of 25 µm in vertical direction.

Stress is maximum in the iris hole (fig. 9); this high value (110 MPa) makes the use of glidcop necessary. The peak local stress would certainly be lower with a more realistic value of peak power density, but probably not enough with respect to the necessary margin below the elastic limit of the copper. So, glidcop will be kept.

7 CONCLUSIONS

With its modular design and from the Q_{ext} predictions, we expect from our RF input ports a fast tuning procedure and an efficient behaviour.

Authors thanks all their colleagues from Los Alamos for sharing their very helpful experience, particularly Lloyd Young, Dale Schrage and Frank Krawczyk.

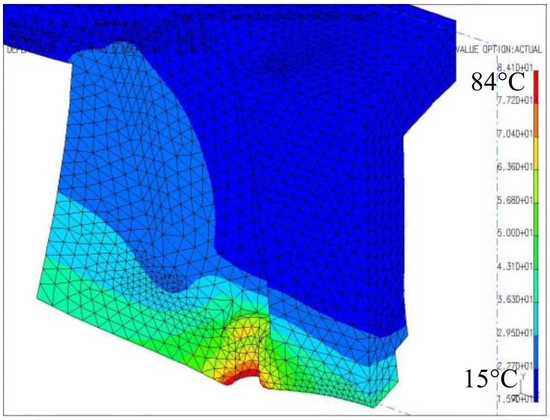

Figure 8. Temperatures (°C) on the RF input.

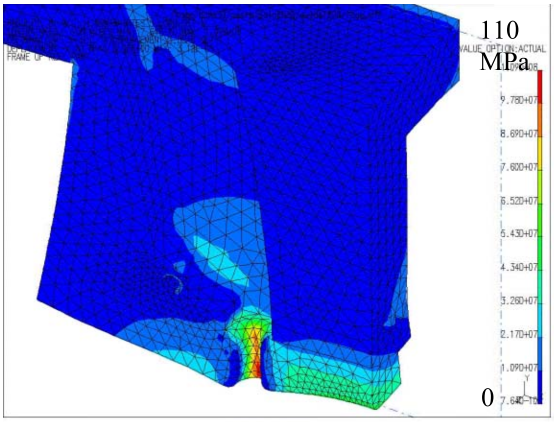

Figure 9: Stresses (color scale in Pa) and (magnified) displacements.

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