500 MHZ COAXIAL TRANSITION BETWEEN THE ELETTRA INPUT COUPLER AND THE TRANSMISSION WAVEGUIDE

C. Pasotti, A. Fabris, M.Svandrlik, Sincrotrone Trieste, Trieste, Italy

Abstract

The investigations have shown that the 500 MHz ELETTRA Input Power Coupler (IPC) can safely sustain more than 150 kW. The critical component limiting the increase of the transmitted RF power is the connection element between the input power coupler and the transmission line. An optimized design has been studied to overcome this limit. During the optimization process, the entire RF chain (input power coupler, connection element and transition to the standard waveguide WR1800) has been verified. The analysis has been carried out to check the performances of the whole lay out in terms of efficiency of transmitted power and sensitivity to any signal coming from the cavity.

INTRODUCTION

ELETTRA* is a user dedicated synchrotron radiation light source running at 330 mA /150 mA at 2 GeV / 2.4 GeV. The injection energy is 0.9 GeV and the beam energy is ramped in the storage ring.

A project of upgrading the existing RF system is in progress. The goal is to raise the power delivered to the cavity from 60 kW to 150 kW [1]. The present 6 1/8" 50 Ω EIA coaxial lines will be replaced with WR1800 waveguides. The vacuum side of the IPC to the cavity will remain unchanged, since the simulated and measured data have shown it can sustain this power level [2]. A transition between the coaxial input power coupler and waveguide (WG) is required. The operational experience and the analysis of the present connection element have shown that this lay out is strongly sensitive to Higher Order Modes (HOMs) of the cavity.

Table 1: ELETTRA Cavity's HOMs parameters

Mode	**Freq.** MHz	**R/Q$_o$** Ω	**Q$_o$**	b_e	**P$_c$** kW	**P$_{IPC}$** kW
L1	946.6	27.9	44000	1.1	51.2	55.6
L2	1057.6	0.98	45800	0.2	4.0	0.9
L3	1419.5	5.04	41800	0.1	1.3	0.2
L4	1511.6	5.00	48700	2.8	0.1	0.4
L5	1606.3	11.6	45900	15.7	0.4	6.2
L6	1874.3	0.31	32000	1.0	0.5	0.5
L7	1945.6	1.72	60300	1.5	2.5	3.7
L9	2122.8	7.28	32000	14.2	0.2	2.6

* Further details on this machine can be found at the Internet address "http://www.elettra.t rieste.it"

The 500 MHz ELETTRA cavities are not equipped with dedicated HOMs dampers. At the user's operating energy, longitudinal stability is achieved by proper shifting of the cavity HOMs and by tuning of the third harmonic superconducting cavity. A controlled coupled bunch mode (CBM) longitudinal instability is allowed during the injection and ramping phase of the storage ring to facilitate the completion of these procedures, relaxing the optics. The study of the coaxial transition between the IPC and the WG also takes into account the possible extra-power induced by the beam current source on the IPC.

The longitudinal HOMs parameters measured on the IPC port with the cavity completely closed are reported in table 1. P_c is the maximum power that each mode may dissipate in the cavity's walls when excited by a current source of 300 mA in the worst case [3]. The power on the IPC and connection element load is $\beta_e \cdot P_c$. Therefore a significant power can flow through the IPC and connection element if an instability is driven by the beam in the HOMs.

COAXIAL ELEMENT

Figure 1 shows the IPC and the coaxial transition element. This has been simulated with Ansoft HFSS v 9.1 as a unique structure.

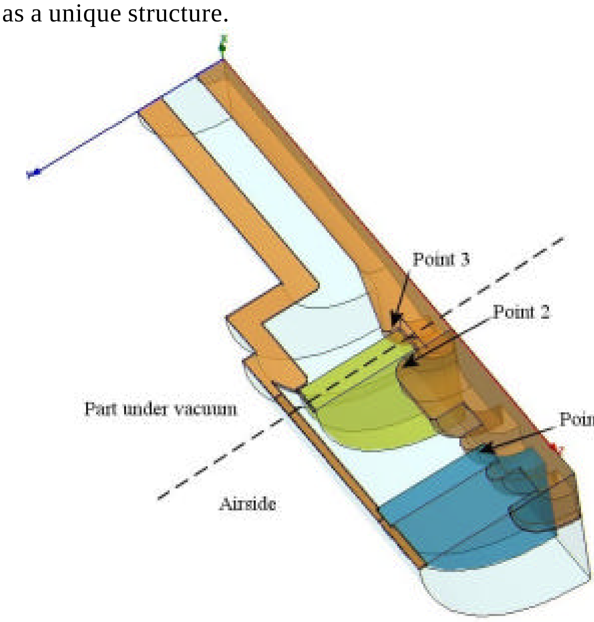

Figure 1: ELETTRA's IPC coupler and transition element.

The transition element has to compensate for the sharp change of the diameter of the IPC's conductors and has to match the IPC towards the 50 Ω standard line as much as possible. At 500 MHz this element works properly. The

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peak values of the electric field are located near the steatite disk (point 1), the alumina window (point 2) in the air side of the IPC and near the round profile of the inner conductor under vacuum (point 3) (see fig. 1).

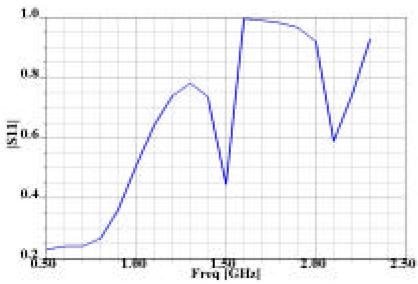

Figure 2: Reflection coefficient of the original IPC and connection element versus frequency.

The reflection coefficient of the original IPC is shown in figure 2. The plot shows two singularities of the magnitude of the reflection coefficient at 1.5 GHz and 2.1 GHz. Preliminary studies have shown that the problem can be lessened optimizing the connection element with minor modifications [2]. Two shapes, IPC6 and IPC7, meet the specification at 500 MHz and reduce the HOMs sensitivity (see fig. 3).

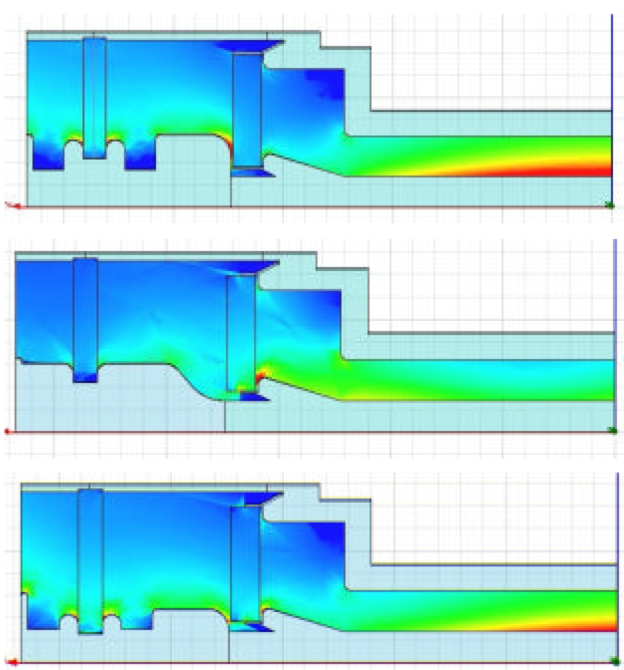

Figure 3: From top to bottom: original IPC, IPC6 and IPC7 profiles and peak electric field at 500 MHz. The colour scale is the same.

The smooth IPC6 profile avoids the huge field in point 2, but, at the same time, the mismatch due to the IPC diameter change, is moved back to the vacuum part of the structure, resulting in the increasing of the field in point 3. IPC7 realizes a compromise, as shown in table 2. The power dissipations are shown in table 3 and table 4 as a function of the different load due to the stored beam. The data confirm the need of cooling down the airside coaxial part of the structure. This will be realized using a forced cooling fluid, flowing along the inner conductor of the coaxial transition.

The alumina window dissipation of IPC7 is 40% higher with respect to the original shape for 300 mA, while the loss of IPC6 for zero mA is almost doubled in comparison with the others. The reduction of the total dissipated power of IPC6 is clear with the only drawback of the alumina's losses. IPC7 is less efficient, but does not stress of the area near point 3 at 500 MHz.

Table 2: 500 MHz peak electric field (V/m) for 1 W input power when there is no beam (higher mismatch).

	Point 1	Point 2	Point 3
IPC_orig	**2123**	1491	496
IPC6	882	249	**1367**
IPC7	1950	904	839

Table 3: Losses on IPC's part with 500 MHz 150 kW of input power, 300 mA of stored beam.

	Losses (W)		
	IPC_orig	IPC6	IPC7
Alumina window	10.4	13.4	14.4
Steatite disk	264.9	190.8	216.0
Inner cond. (vacuum)	50.2	40.3	47.0
Outer cond. (vacuum)	18.7	15.6	19.7
Inner cond. (air side)	26.1	18.1	20.7
Outer cond. (air side)	4.6	5.4	3.6

Table 4: Losses on IPC's part with 500 MHz 150 kW of input power, 0 mA of stored beam.

	Losses (W)		
	IPC_orig	IPC6	IPC7
Alumina window	9.1	20.1	11.1
Steatite disk	393.8	132.1	347.6
Inner cond. (vacuum)	63.8	46.4	53.4
Outer cond. (vacuum)	23.6	18.8	22.4
Inner cond. (air side)	18.3	19.7	14.0
Outer cond. (air side)	3.8	5.9	2.8

Concerning the effects of HOMs, the electric field along the IPC structure is not purely transverse as the frequency increases. The reflection coefficient of the two new shapes is shown in figure 4.

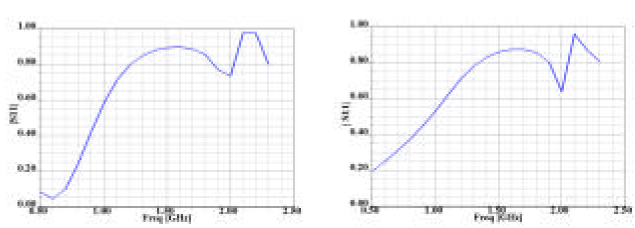

Figure 4: Reflection coefficients of IPC6 and IPC7.

The first singularity of the reflection coefficient results in a huge increase of the peak electric field in the "triple

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point: metal, air and alumina" located near the brazing area of the alumina ceramic window (point 2). This is a very critical point, since any discharge here can metalize the ceramic window, reducing thus its electrical insulation. In the worst scenario, damage to the brazing ring can occur and this could gradually lead to a vacuum leak. IPC6 and IPC7 shapes overcome this problem. IPC6 reduces the strength of the electric field due to the concave shape. IPC7 keeps constant the inner conductor radius between the vacuum and air sides, reducing the mismatch and, at the same time, shields the brazing area.

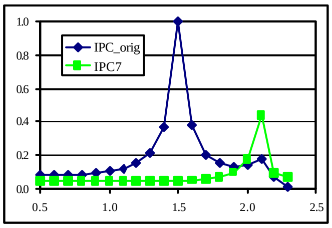


Figure 5: Electric peak values (V/m) in point 2. The maximum in point 2 is 4 times greater than in point 3.

The electrical peak values versus frequency have been evaluated. For the original profile, the worst case is still the resonance in point 2 at 1.5 GHz (see fig. 5). The IPC7 shape shows a significant field increase in point 1 at 2.0 GHz and in point 3 at 2.1 GHz, (see fig. 6).

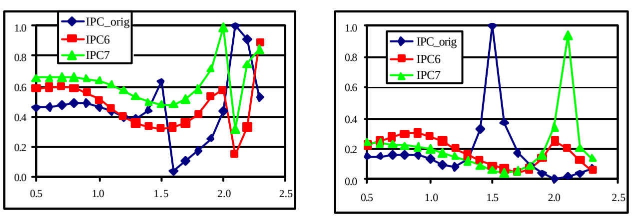


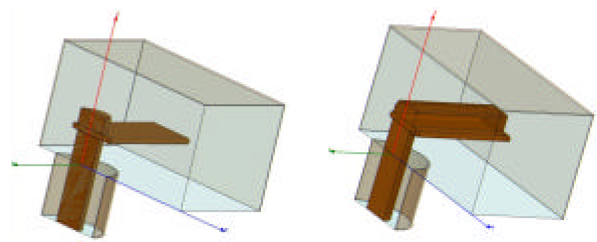
Figure 6: Electric peak values (V/m) normalized to the maximum for point 1 and in point 3. The maximum in point 3 is 1.4 times greater than in point 1.

The maximum electric field value in point 3 is 513 kV/m for 1 kW of incident power from the IPC port towards the cavity (original profile).

It seems that the singularities of the scattering matrix of the IPC can not be completely avoided due to the discontinuity of the dielectric constant of different insulators: air, alumina and steatite. For this reason diagnostic devices will be introduced. An optical fibre arc detector will be placed on the outer conductor of the transition element, looking toward the alumina disk. Its signal will be monitored and used as interlock for the RF input power. An inductive loop, strongly undercoupled, will be also installed in the transition element. Its RF signal will be filtered, rejecting the component at 500 MHz frequency. This detection will be correlated to the machine operation and the incidence of HOMs. The strength of this signal could be used as a threshold to limit the coupling with HOMs, allowing the needed CBM excitation during the injection and ramping phases, protecting against excessive fields.

WAVEGUIDE TRANSITION

The transition from the coaxial line to WG has to realize the connection with the IPC structure minimising the insertion loss and to allow the cooling of the inner conductor of the coaxial element. The spoiler of a standard WG transition has been enlarged for this purpose (see fig. 7) [4].



a b

Figure 7: WG transition: standard (a), and modified (b).

At 500 MHz the modified shape has a VSWR less than 1.03 in a 25 MHz bandwidth.

The simulations of the whole RF front end (IPC and WG transition) in the HOMs range have confirmed the need of lowering the resonances of the IPC to avoid a dangerous increase of the peak electric field and insulator losses. The phase rotation due to the physical length of the line plays an important role too: the transition to the WG could act as short circuit for an incident signal at higher frequency if it arrives at that plane with the wrong phase. However the physical length is not a completely free parameter since it has to take into account the constrains of the existing machine.

CONCLUSION

The requirements to interface the existing IPC to the WG system have been analyzed both at the fundamental as well as at the HOMs frequencies. The two proposed solutions are a good compromise between 500 MHz performance and good behaviour in HOMs frequency range. A straightforward way to water cool the inner coaxial element in the airside of the IPC can be realized by simple modification of the transition to the WG.

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