650 MHz coupler, couple of new ideas

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Power requirements for 650 MHz coupler:

Project-X requirements: \( \approx 18 \text{ MV} \times 1 \text{ mA} + \text{overhead} + \text{safety margin} \approx 30 \text{ kW} \)

Project -X, 5 mA upgrade: \( \sim 100 \text{ KW} \)

PIP – II: \( \approx (18 \text{ MV} \times 2 \text{ mA} + \text{overhead} + \text{safety margin}) \times \text{duty factor} \approx \)
\( \approx 50 \text{ kW} \times 0.01 \approx 0.5 \text{ kW} \)

PIP – II CW upgrade: \( \approx 50 \text{ kW} \)
Design approach:

- Simplest vacuum part, without bellows and, if possible, without copper coating.

- HV bias for multifactor suppression.

- High impedance to reduce losses in outer conductor (connected to 2K) and move multipactor zone to higher power.

- Air cooling of antenna.

- Single window.

- Similar design for 325 MHz and 650 MHz coupler to use the same proven solutions and technology.
Based on this approach 325 MHz and 650 MHz couplers were designed:
Current structure of 650 MHz coupler
Since that time two new ideas appeared:

1. How to avoid copper coating.
2. How to make double window.

For 50 -100 kW, 650 MHz coupler, a pure stainless steel is not solution – too big RF losses. SS has to be coated with thing layer of copper.

But copper coating has several drawbacks:
1. Copper coating is not stable sometimes. Couple of times the copper flakes were found in 1.3 GHz cavities.
2. Coated copper has a lower RRR than ingot copper usually.
3. Copper increases the thermo-conductivity of structure. It increases static cryogenic load.
How to avoid the copper coating? - Use copper shield for SS.

Idea started from this simpler geometry:

Coupler has a better performance than coupler with copper coating:
~ 0.7 power flow to 2K and ~ 0.8 power flow to 5K comparable to conventional coupler.
Performances are even better for these geometries:

Dynamic losses at 2 K are 50 times smaller than for conventional copper coated coupler.

Fields are zero in slot. There are no dynamic losses at 2K and 5K at all.
Modification of idea:

Idea:

- Low fields chamber
- SS

Heat flows through SS only, RF loss in SS < loss in Cu

No thermal contact between copper parts

~0.4 mm
~1 mm
With some combinations of dimensions of slot and chamber:

1) RF reflections < -35 dB
2) H-field at SS surface < 0.25 of H-field at Cu surface (losses at SS will be < losses at Cu)
Possible configurations of 1.3 GHz and 650 MHz were presented to TD experts (cleaning and assembling):

**1.3 GHz**

**650 MHz**

**Static cryo-loading:**

<table>
<thead>
<tr>
<th></th>
<th>2K</th>
<th>10K</th>
<th>100K</th>
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<tbody>
<tr>
<td>Static cryo-loads:</td>
<td></td>
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</tr>
<tr>
<td>2K</td>
<td>0.017 W</td>
<td>0.90 W</td>
<td>3.2 W</td>
</tr>
<tr>
<td>10K</td>
<td>0.021 W</td>
<td>1.25 W</td>
<td>4.8 W</td>
</tr>
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Conclusion was: “it is difficult to clean (re-clean) closed chambers”.

Possible configurations of 1.3 GHz and 650 MHz were presented to TD experts (cleaning and assembling):
Now we are proposing the dismountable configuration. It can be cleaned:

**Pro:** dismountable

**Con:** bigger number of flange
No multipactor in 0.8mm sots in operating power range (200W – 3.5 MW, TW)
Exploded view
We hope to make two versions of 650 MHz coupler for testing: with copper coating and with copper shielding. These parts will be interchangeable.
Double window.

We still have no solid answer how many windows coupler should have. Single window and two windows have their own advantages and drawbacks.

**Two windows**

**Pros:**
more reliable

**Cons:**
It is very difficult to provide antenna cooling for high power couplers (50 kW-100 kW). It is necessary to mount a vacuum tight connection with cooling channels in antenna size area (~ 0.5”-1”).

It is not clear how to detect reliably a possible crack of inner window for conventional two-window couplers. Vacuum is at both sides (window is cold, He has a low electric strength, good thermo-conductivity). Cold cavity works like a pump. It will be difficult to detect a leak. With small crack the window can RF operate without any sign of crack.
Singe window:

**Pros:** No cons of two windows

**Cons:** Less reliable.

It seems there is solution which combines pros of both approaches: Leonardo suggested to place two windows close to each other as much as possible and use it as one unite. Both window is warm, we can place $N_2$ between windows. In case of big crack of inner window some amount of $N_2$ will come to accelerator, $\sim 50\text{ cm}^3$, 0.06g, $\sim 5\text{e-4 bar}$ ($\sim 5\text{e-5 bar}$ in cryomodel). Hopefully it is not fatal to accelerator and $N_2$ will not reduce performance of cavity (A. Romanenko).
Two close positioned windows.
- Advantages: reliability as two windows, compact as single window.
- Appearance of ceramic cracks can be detected: increasing pressure in cavity indicates of crack in inner window, increasing pressure between windows indicates of crack in outer window.
- Any one crack is not fatal for accelerator.
Interesting solution was found for test cavity for 650 MHz coupler testing: compact (not expansive) and extremely wideband (not sensitive to geometrical sizes). Sizes was chosen to avoid multipactor.
Pass-band of 650 MHz test cavity:

~580 MHz at -30 dB!