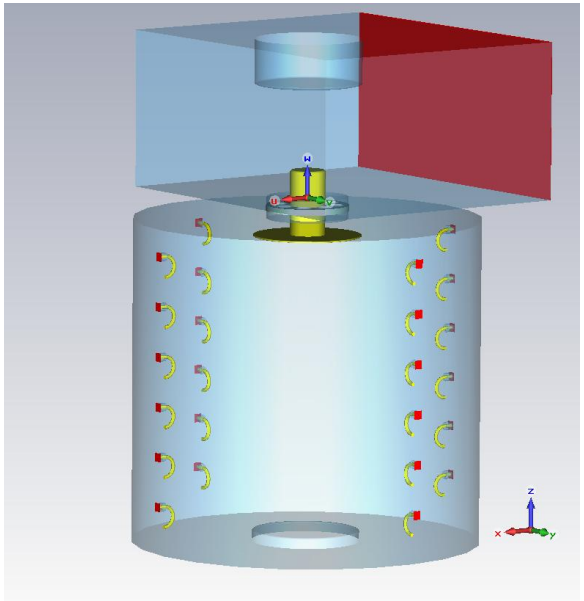
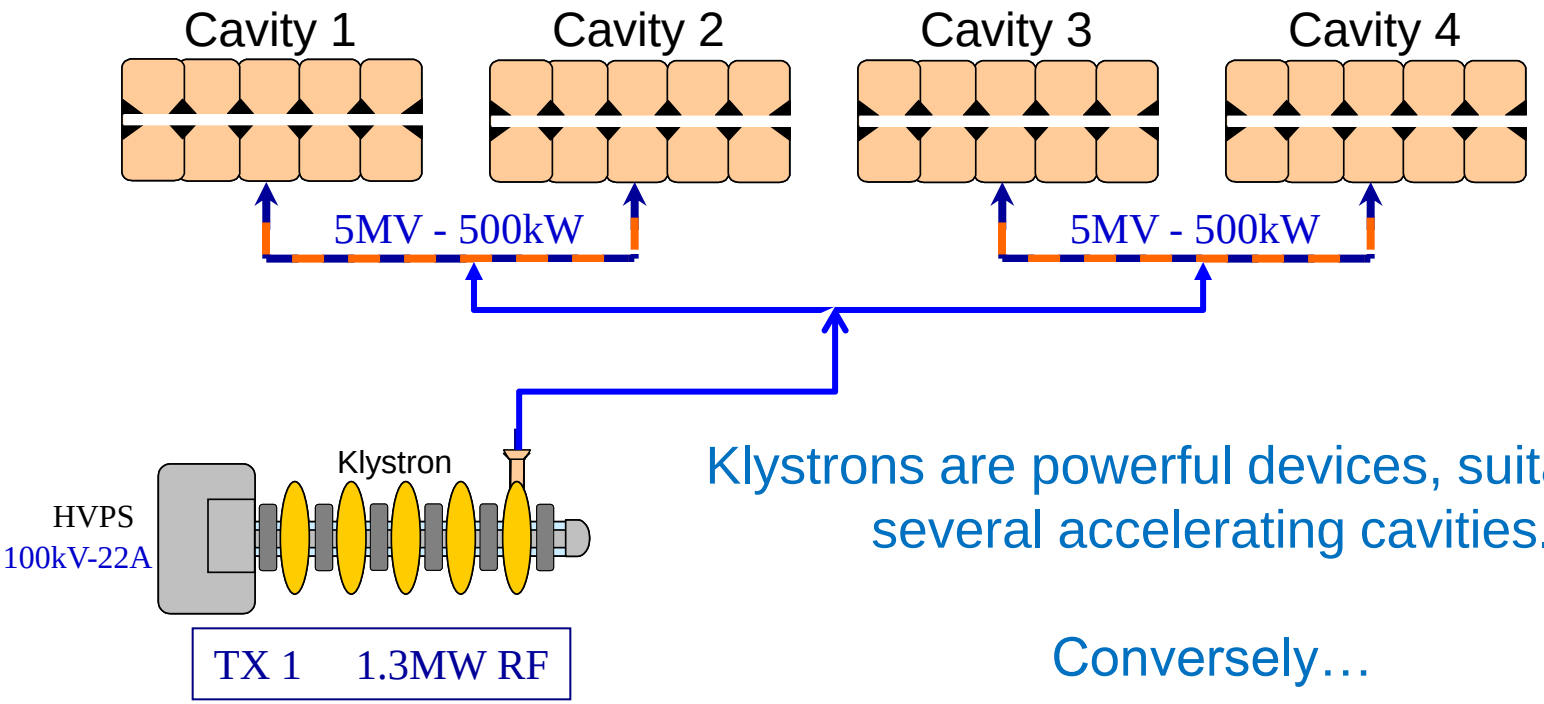
Cavity combiners for transistor amplifiers

M.Langlois, J.Jacob, J.M. Mercier



Motivation

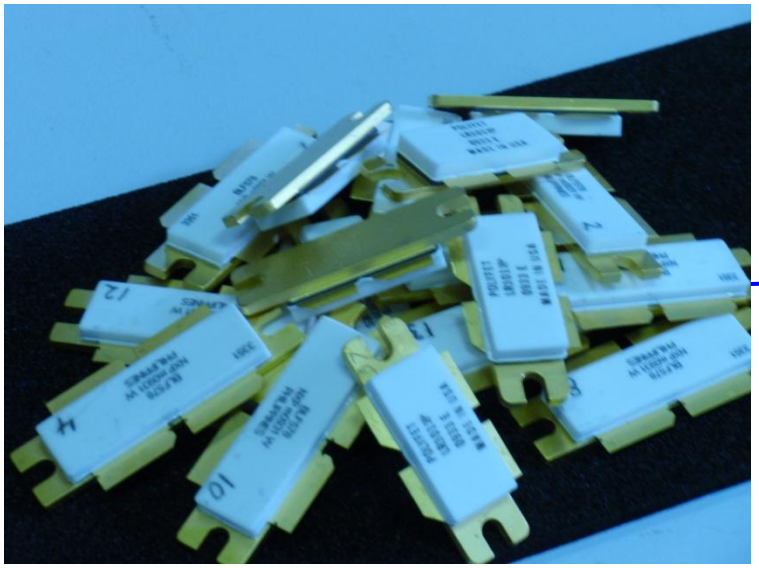


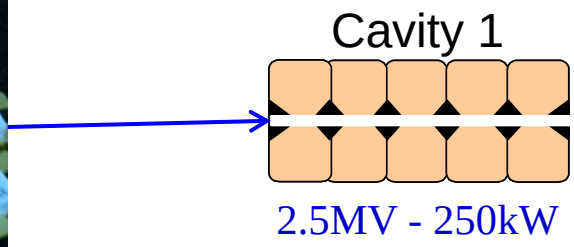
Klystrons are powerful devices, suitable for several accelerating cavities.

Conversely…

Motivation

It takes quite a handful of MOSFETS to feed just one cavity.

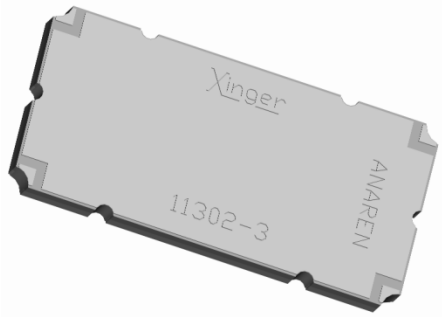




Hence, combiners play an important part!

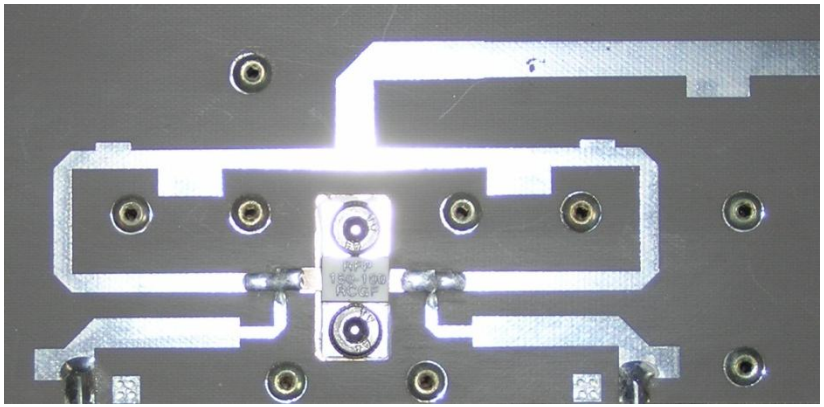
State of the art

1. PCB hybrids



e.g:100W surface mount from ANAREN

2. PCB Wilkinsons

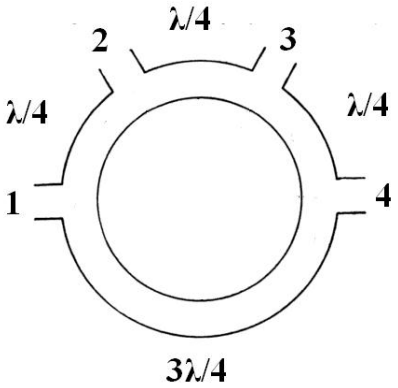


e.g: 700W from TED

Courtesy THALES

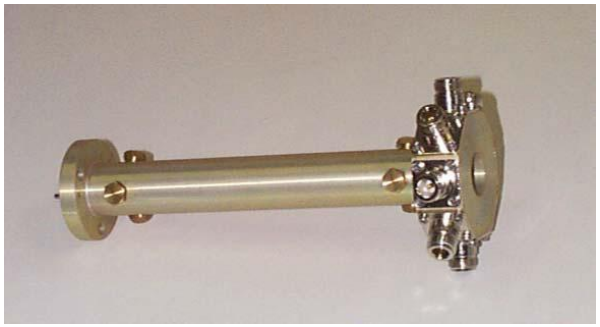
State of the art

3. Rat-race



$$S = \frac{-i}{\sqrt{2}} \begin{pmatrix} 0 & 1 & 0 & -1 \\ 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 \\ -1 & 0 & 1 & 0 \end{pmatrix}$$

4. λ/4 transformers



e.g: 2.5 kW from SOLEIL

5. Hybrid waveguide

e.g: WR1500 from μcom

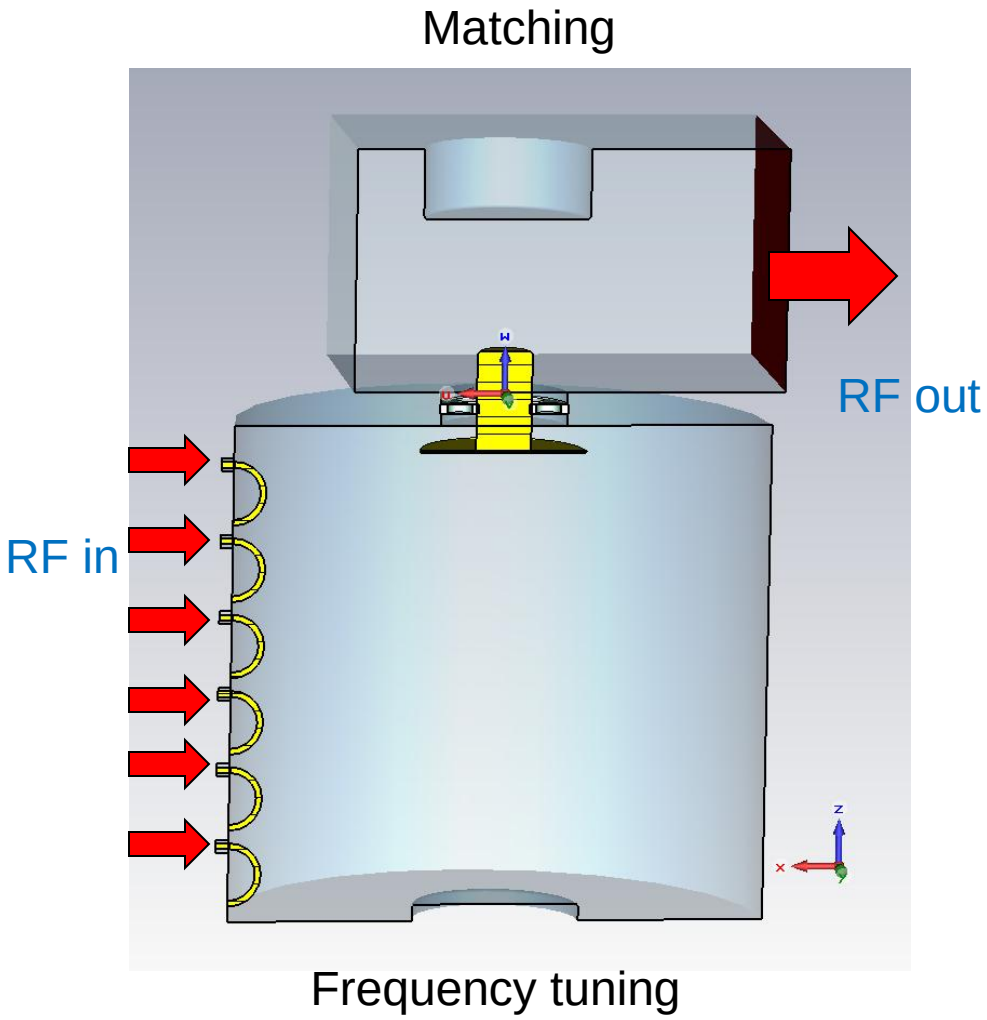
State of the art : common features

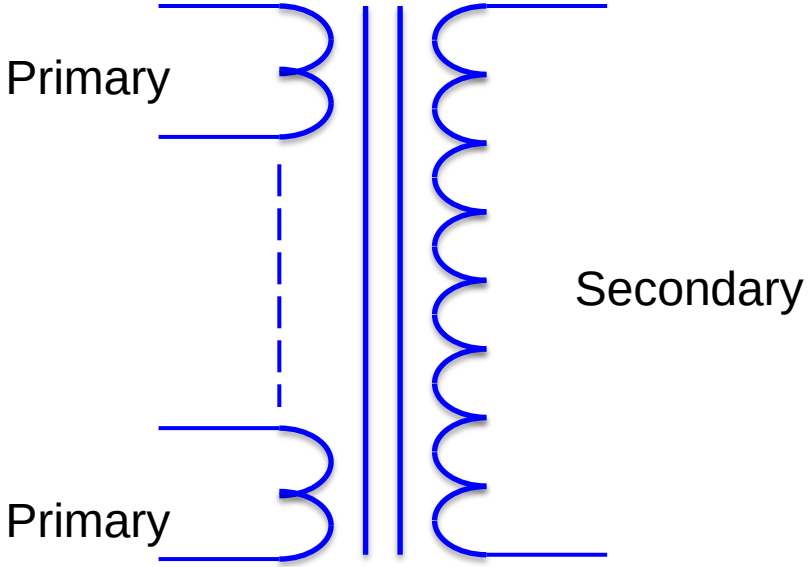
1. Limited number of inputs

2. The number of inputs is set at design stage.

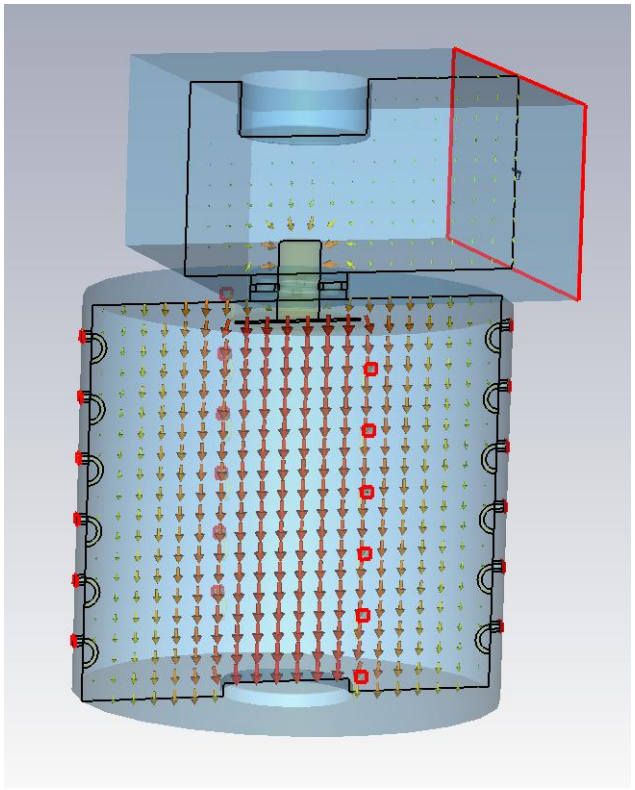
3. Comparatively high losses due to coaxial or striplines except for (bulky) waveguide couplers

The cavity combiner and its low frequency equivalent

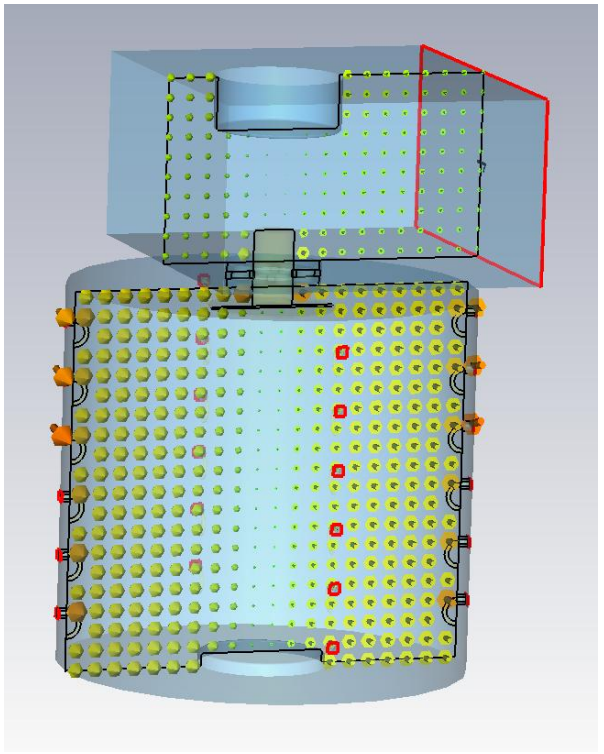




The cavity combiner : field patterns



E010 mode

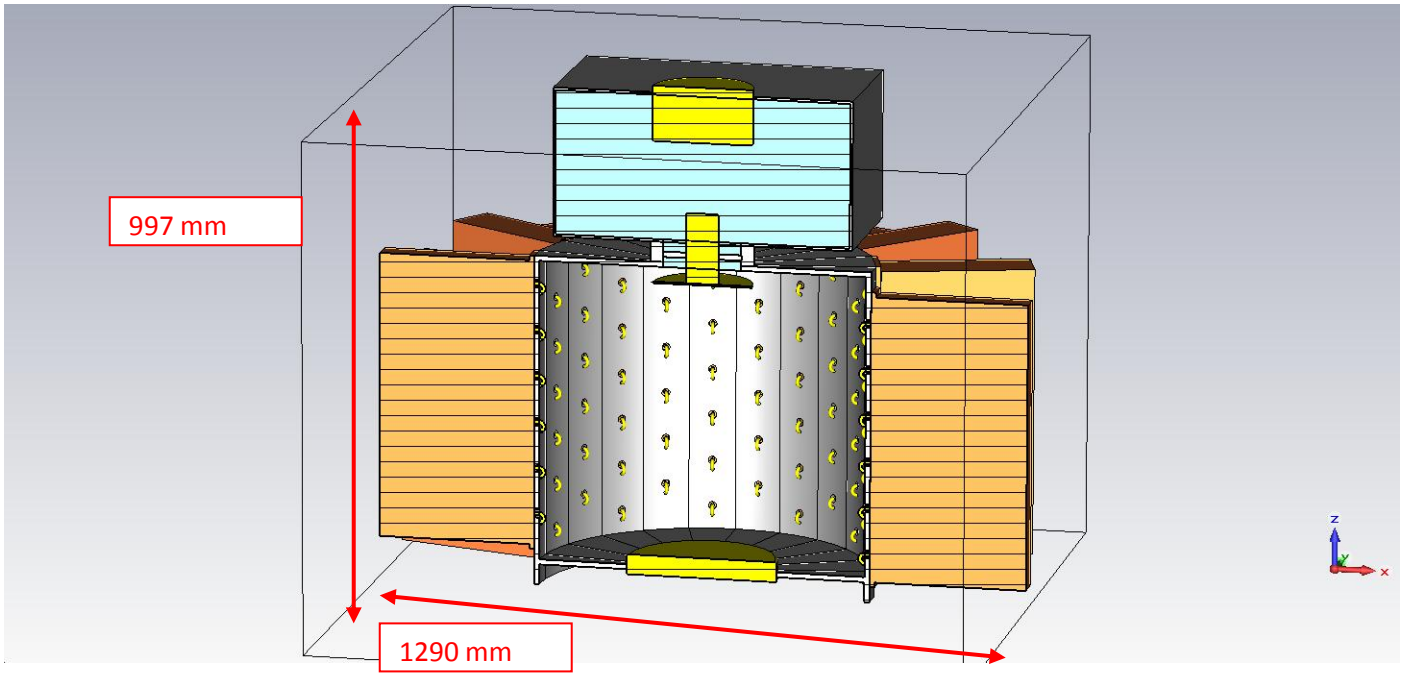


E field

H field

The cavity combiner : advantages

1. Small footprint



e.g: 6*22 modules of 600 W~ 75 kW

The cavity combiner : advantages

2. Galvanic insulation

Each pallet is connected to a loop protruding inside the cavity. Live conductors from each pallet are thus insulated from each other.

3. Flexible

In the event of an overrating of the power, it is possible and easy to connect a fraction of the available openings, blinding the other ones with short-circuits. Adjusting the number of modules to the power need enhances efficiency since each module is used at nominal power and not at reduced power.

2. Efficient

One stage of coupling, moreover in waveguide mode, generate less losses than multiple stages.

3. Proven

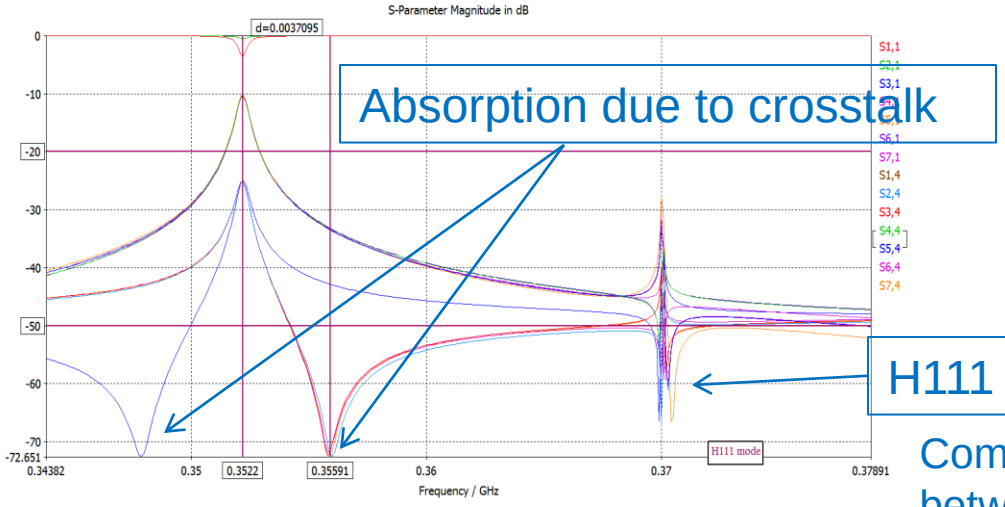
A combiner for 2 IOT's,150 kW, 500 MHz has been designed, manufactured and tested at THALES for ALBA.

The cavity combiner : implementation

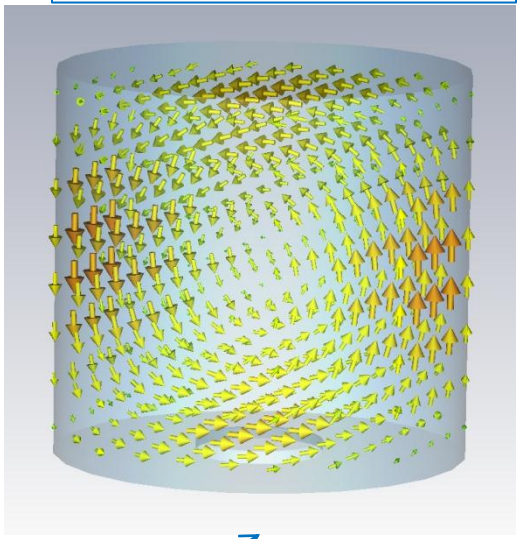
The number of modules is limited by the available cavity wall area and the possible crosstalk between adjacent loops.

- The diameter depends on the operation frequency.
- The height is limited by the H111 mode.
- The crosstalk depends on the distance between adjacent loops.

6 staggered rows of 22 modules appears as a suitable compromise: 6*22*600W=79 kW



H111 mode, H field



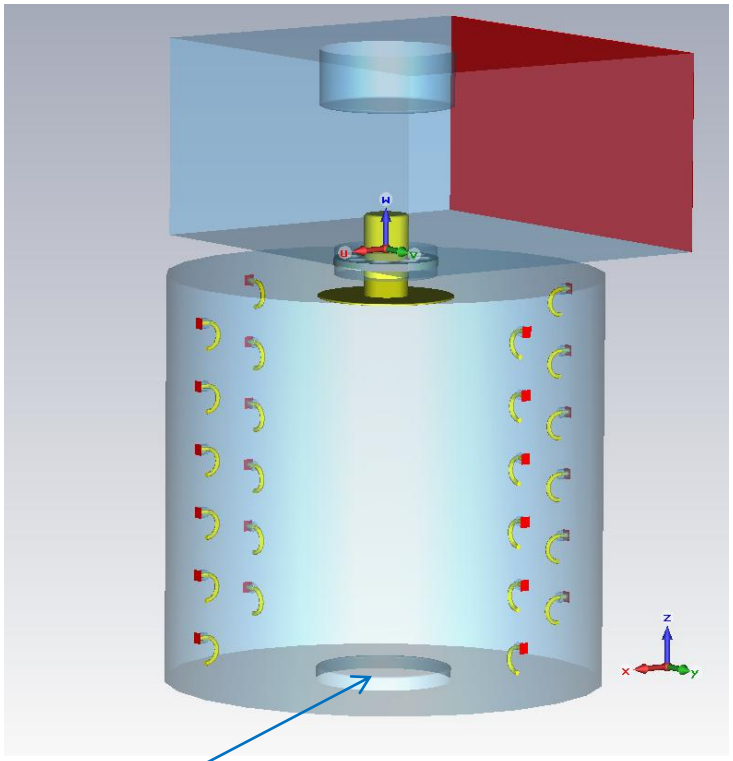
H111 mode, 370 MHz

Computation with 6 inputs, the distance between loops matching the 6*22 loops case

The cavity combiner : tuning

A tuner ensures that resonant frequency is adjustable, thus coping with manufacturing tolerances.

Tuning efficiency:175 KHz/mm

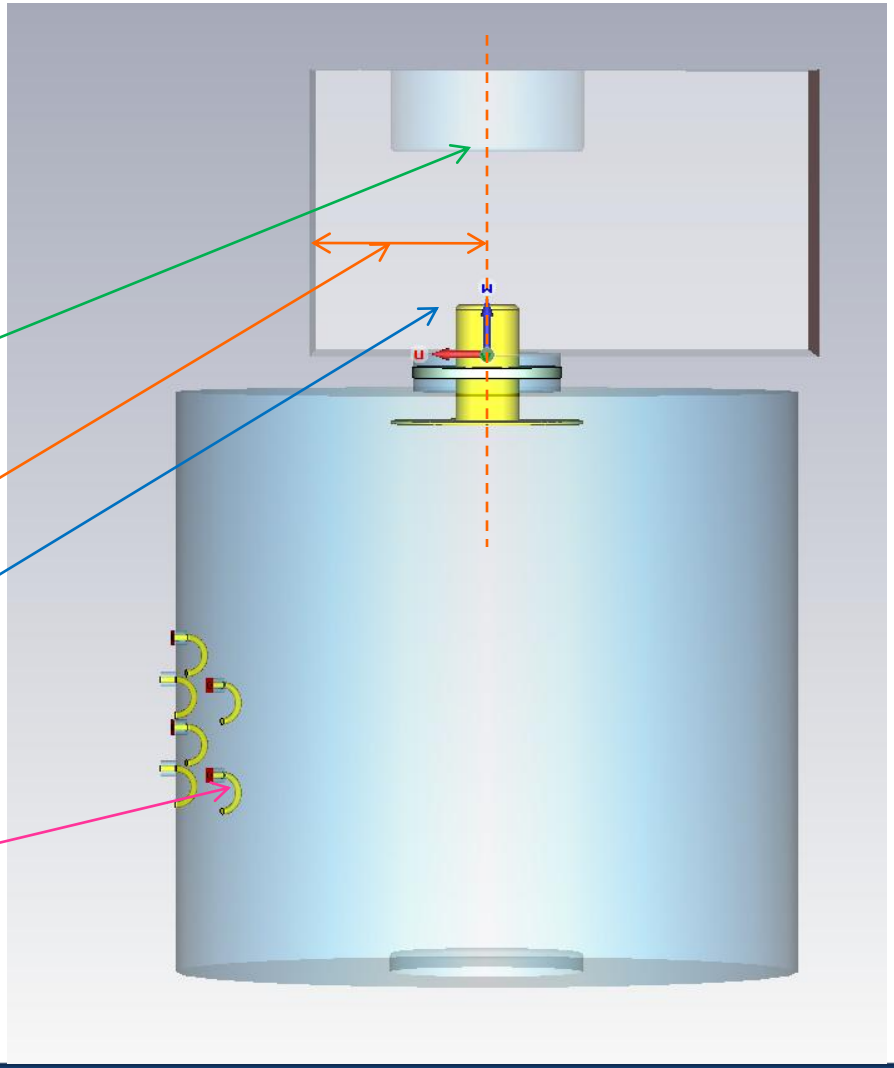


The cavity combiner : matching

Matching condition:
$N_{loop} * \beta_{loop} = \beta_{output} >> 1$

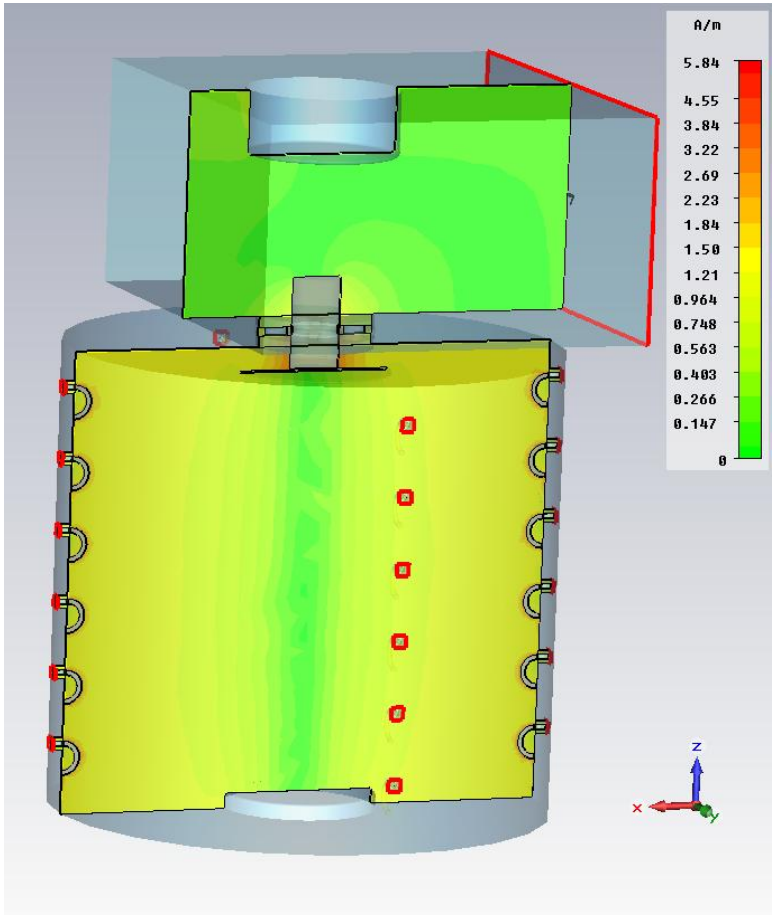
4 parameters have a major influence on the matching:

1. The height of the matching piston
2. The distance from the post to the waveguide short
3. The height of the capacitive post
4. The loop size and their number



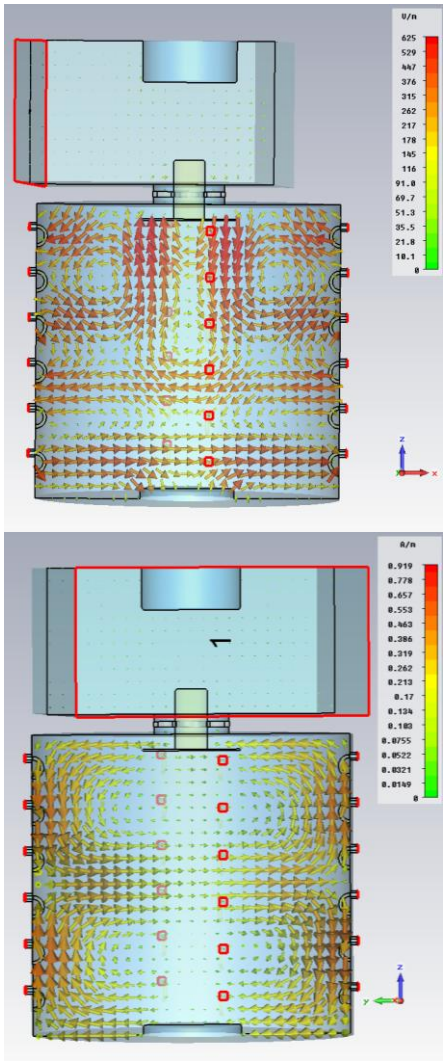
The cavity combiner : losses

Most of the losses are due to the current in the cylindrical wall.
In our case, it was found 1.35 kW for 75 kW output (conductivity:$5*10^7$ S/m). It does not depend heavily on the number of input loops.
It means 0.08 dB insertion loss.



The cavity combiner : 2nd and 3rd harmonic

The cavity combiner has modes of oscillation in the vicinity of second and third harmonic.
Some are shown here.
The modules, class B operated, deliver 2nd and 3rd harmonic. The circulator included in each module is narrow band and a good barrier to avoid exciting the cavity modes lying too close to 2nd or 3rd harmonic.



E field at 1054.3 MHz
Similar to E014

3*352.2 MHz=1056.6 MHz

H field at 1066.9 MHz
Similar to H112

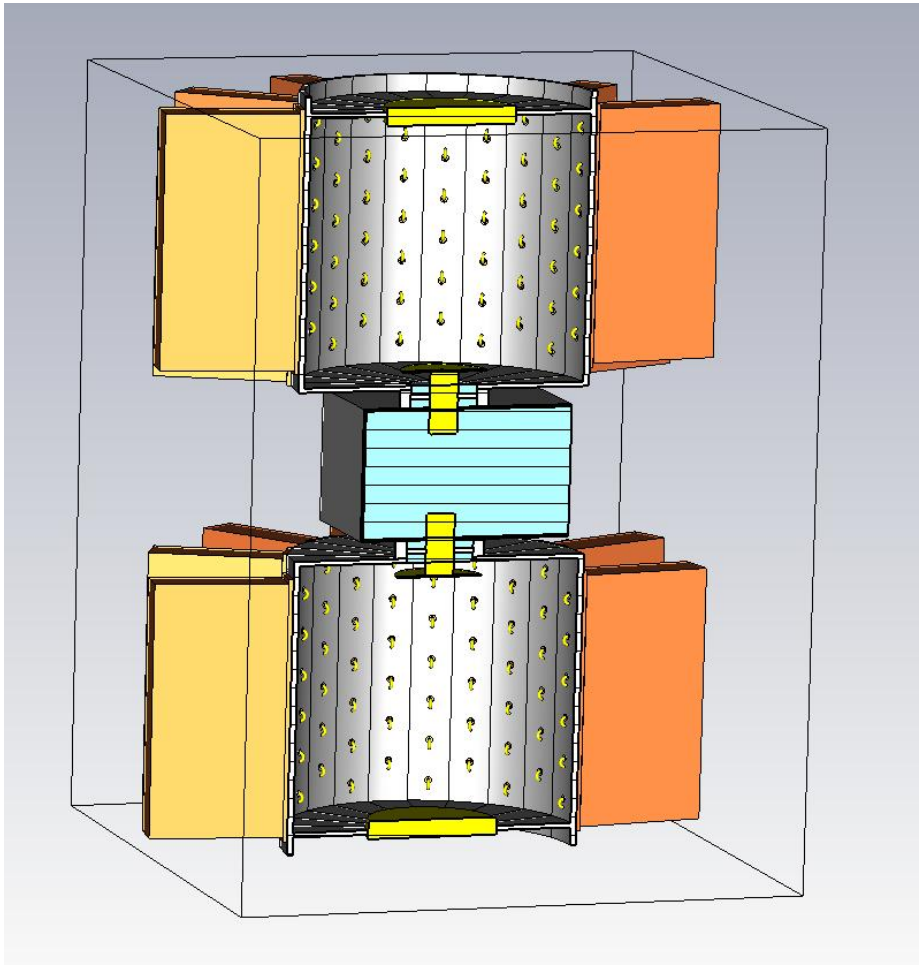
The cavity combiner : next step

ESRF launched this year a project to assess the feasibility of such a design.

The German company CRYOELECTRA has been selected to cooperate on this topic. The outcome will be a 12 kW, 350 MHz amplifier featuring a cavity combiner.

The transistors will be 50V LDMOS from either NXP or FREESCALE.

The cavity combiner : outlook



75 kW is not enough to power a cavity.
But 2 cavity combiners could probably be coupled together

The cavity combiner : outlook

In order to increase the area available for modules, it may be possible to squeeze the useful E010 mode between unwanted ones.

Frequency	mode
310 MHz	H111
352.2 MHz	E010
381.5 MHz	E011

These are the frequencies obtained with a combiner 1m high

The cavity combiner : outlook

Direct matching of the output transistor impedance to that of the loop. This would preclude the use of circulators inserted in each module. How tough should the transistors be?

Thanks!

•To my colleagues, for their support and putting up with me
•To Francis, for having the guts to try such a new concept
•To Thales, which in those times, was ready to risk such a development.