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# VERY WIDE RANGE AND SHORT ACCELERATING CAVITY FOR MIMAS

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#### Abstract

The frequency ranges of electrical accelerating field for heavy ions synchrotrons have to be often very wide. And their dynamics are limited by the physical characteristics of the magnetic load in the resonant structures.

We built an accelerating system, with only one gap, using amorphous material, able to replace the two actual MIMAS Cavities (the Saturne II booster), in order to make free a part of the ring. The frequency range can be swept at 4 kV. The RF voltage can be increased up to 10 kV, and the frequency to 12 MHz. The geometrical sizes was chosen to minimize the operation troubles during the cavities permutation on the machine.

## I. INTRODUCTION

Mimas is the storage booster for the synchrotron Saturne II, on the National Laboratory SATURNE from Saclay (F). It was dedicaced to operate protons, deuterons and heavy ions (up to krypton to day) at 12 MeV/amu.



Fig. 1 a, b : frequency law (a) and voltage law (b) of the MIMAS RF system

For that, the accelerating RF system uses two ferrite loaded cavities, at 2 x 2kV peak with a frequency range from 150 kHz to 2,5 MHz. The requirements are illustrated on fig. 1.

Some projects on Saturne and Mimas, mainly to cool the beam inside the booster, needed to make free a part as long as possible of the vacuum pipe.

On the other hand we started a test program on amorphous magnetic materials and arrived at several optimistic conclusions concerning use in accelerating RF structures.

### II. MAIN RESULTS OF VAC 6025 TEST

The main differences between ferrites and amorphous, for the RF structure use, have been seen in the permeability, the losses and  $\mu$ QF product, the behaviour with frequency, RF induction, bias field and temperature.

This test was made around the Mimas frequencies, on an VACUUMSCHMELZE material 6025 F.

 $1^{\circ}$ ) - <u>Permeability</u>: at 150 KHz,  $\mu$  is 10 time higher than the ferrite SY 7 one. It decreases with the frequency, to the value of the ferrite at 10 MHz, insuring a quasi-self tuning.

 $2^{\circ}$ ) - <u>The losses</u>: They cannot be given by the traditional  $\Delta F/F$  Q factor, because the large permeability variation with frequency. But these losses are greater. The product  $\mu QF$ , where  $\mu$  is higher and Q lower, is higher than the ferrite one.

 $3^{\circ}$ ) - <u>Bias current</u>: the magnetic sensitivity of  $\mu$  is 20 to 40 time higher than ferrites. It means that the current requirements and the turns-number are 20 to 40 time lower (fig. 2).

 $4^{\circ}$ ) - <u>RF</u> induction : the Q and  $\mu$  values are quasi independant of the RF induction and we did not see the Q loss effect in the Mimas range, like we saw with Phillips or TdK ferrites (fig. 2). It is possible to increase the RF voltage by a factor and changed from a TH 120 - 40 kW Tetrode to a more than 4 (the limit was given by the power push pull using 2.10 kW TH 541 tetrodes. dissipation in the small test-cavity).

 $5^{\circ}$ ) - <u>Power Dissipation - temperature</u> : In ferrite, the  $\mu$  increases by 2 every 30° C. With VAC, the sensivity is very low, not appreciable. But the limit temperature is low, and destructive (90°).

The VAC is metal. The power can be extracted up to more than 1 W/cm3.



Fig. 2 - Small Test cavity Impedance for different voltages Frequency V. bias current

 $6^{\circ}$ ) - <u>Cost</u>: the price of the VAC for the same volume is two time this for the ferrite : but one half of the volume is used for the same result. The total price is the same. But the environment is less expensive (power supplies, amplifier, used space, a.s.o...)

#### III - REAL SIZE LOAD BUILDING

It was possible to think built an alone cavity for MIMAS, to replace the two necessary in operation, and, so, make free 1, 5 meter on the vacuum chamber.

We chose the same size,  $(1, \emptyset \text{ int.}, \emptyset \text{ ext.})$  for the cavity, the gap and all the components of the magnetic load, but the structure was built in two symetrical push-pull quasi-resonators (fig. 3). The amplifiers was adapted at this new configuration,



Fig. 3 - Push Pull resonators

Magnetic load :

-	Vitrovac 6025	F
-	$\emptyset$ ext. :	510 mm
-	Ø int.	355 mm
-	e/core :	25 mm
-	e ribbon	: 25 μm
-	ring number:	2 x 12
-	l magnetic	: 60 cm
-	Bias current µ	./400 : 4A/4 turns
-	cooling	: copper rings and water

<u>Cooling system</u>: the amorphous metal is inclosed inside a C form alumina box, insulated by a capton film. A sandwich of two magnetic cores, back to back on the two faces of a new designed copper ring in witch flowes the cooling water make an independant module (fig. 4).

Six modules of this type are aligned around the beam pipe for each quasi-resonator.

We tested the cooling up to 2 kW per ring.





## Fig. 4 - Cooling module

## IV. TEST OF THE CAVITY

 $1^{\circ}$ ) - <u>Impedance - Tuning</u>: we measured the cavity shunt impedance on the total structure, with an Impedance Analyser Hewlett Packard N° 4194 A. The two resonators appear in parallele and the read impedance has to be multiplied by two. The impedance, at the natural tuning 600 KHz is near 500  $\Omega$ , and the tune is possible at 10 MHz with 40 Amperes in the 4 bias windings. The impedance decreases at 300  $\Omega$  at 2,5 MHz and 230  $\Omega$  at 10 MHz (fig. 5).



Fig. 5 - Tuning and impedance

 $2^{\circ}$ ) - <u>Voltage</u>: the 4 kV peak needed by the Mimas operation was reached on this alone gap, in the used range. Some small parasitic resonances (2 dB losses), due to the coopling loop and bias windings are now in correction.

To obtain this voltage, only an 300  $\Omega$  impedance is necessary with the used amplifiers. It can be obtain out of the tune of cavity. Like that, it is not necessary to load the structure with VAC up to

150 KHz tuning. The large  $\Delta F$  (the low Q) permits to decrease the frequency without excessive impedance losses.

Like that, the frequency dynamic of the load in our configuration, is greater than 20 with 300  $\Omega$  impedance, an than 100 with 230  $\Omega$ .

 $3^{\circ}$ ) <u>Cooling</u>: the Mimas frequency range and voltage program, in operation configuration and at 1 Herz of repetition rate, gave an temperature elevation of  $2^{\circ}$  C. on the external face of Vitrovac.

## V. CONCLUSION

The initial goal is touched : it is possible to replace the two old Mimas cavities by one, and use the free place for other operation. The last work on the model is to put the vacuum chamber inside the cavity internal pipe, and connect the accelerating alumina gap, if the decision to make free the space on Mimas is taken.

This work will be continuated by and for new needs.

An european collaboration, between German, Italian and French Laboratories, Universities and Industries is today in study, in order to sum the different "know-how" and capabilities to the same goals.

Two european synchrotron projects will try o use the gain given by this kind of materials, and extend their use at higher frequencies.

This technic can be used today on several existing accelerators.



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