LARGE FREQUENCY SWING RF CAVITIES FOR MIMAS

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Abstract

To face the acceleration of a large variety of ions (p, to, Xe) and energy range (187 keV/amu to 12 MeV/amu) the two MIMAS RF cavities must be able to be varied in frequency by a factor in excess of 16 (0.15 to 2.5 MHz). This very unique capability is obtained by variation of ferrite magnetic permeability. The general RF system including high power, drivers, gain and phase controls is described.

Introduction

The new injector MIMAS is a low energy (187.5 keV/amu) storage booster ring (12 MeV/amu) dedicated to polarized ions (p, d) and heavy ions, the RF system has been designed so as to accelerate the different beams in the range of 150 kHz to 2.5 MHz (harmonic number = 1) with a peak voltage of 4 kV during the extraction process. The highest ramp velocity is 14 MHz/sec. The repetition rate reaches 1 s. The main RF requirements on the MIMAS RF system are illustrated on fig. 1

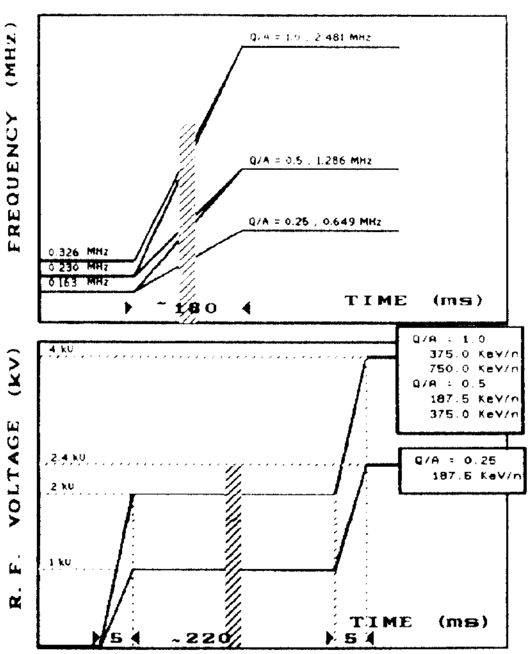

Fig. 1 a, b : frequency law (a) and voltage law (b) of the MIMAS RF system

The RF handling is divided into three stages :

- adiabatic trapping for gathering injected particles into one bunch,
- acceleration up to beam extraction,
- beam preparation on flat-top in view of transfer.

General description of the RF system

For maintenance considerations, the design of the MIMAS RF chains is quite similar to the SATURNE II one.

- 1) high level voltage system

The very large frequency range, and the low start frequency prescribed the use of resonant cavities loaded with high permeability ferrites. It will be seen later that the cavity has a low impedance and a very high induction level. Consequently, the voltage would be too high for only one cavity. Therefore the acceleration system consists of two identical ways, each provided with a ferrite cavity, voltage amplifiers and tune regulation. An intercavity phase servo loop maintains a 90° phase difference between the two ways during the frequency shift.

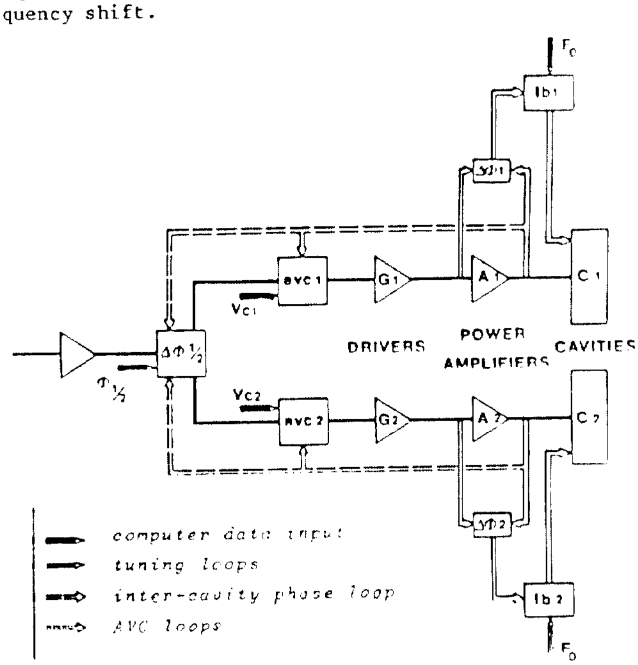

Fig. 2 : general layout of the high level voltage system

- 2) low level RF system

The block-diagram is shown on fig. 3.

The master oscillator is mainly constituted by a voltage to frequency converter fed by :

- a) a phase-locked loop which gives the capture frequency according to the accelerated ion. The accuracy is better than 10^{-4}.

- b) a vector generator which builts up the frequency law from : $\frac{dF}{dt} = \frac{dF}{dB} \cdot \frac{dB}{dt}$. The different values of $\frac{dF}{dB}$ for each ion are tabulated in a memory, and $\frac{dB}{dt}$ is given by a coil inside a main magnetic field dipole.

- c) a network compares the wanted radius and the beam displacement measured with a ΔR PU electrode,

- d) an analog network which measures the phase difference between the RF and the center of gravity of the bunch detected by a PU electrode stabilizes the radius loop.

Finally the VCO TTL output whose frequency is twice the wanted one is changed into sine waves.

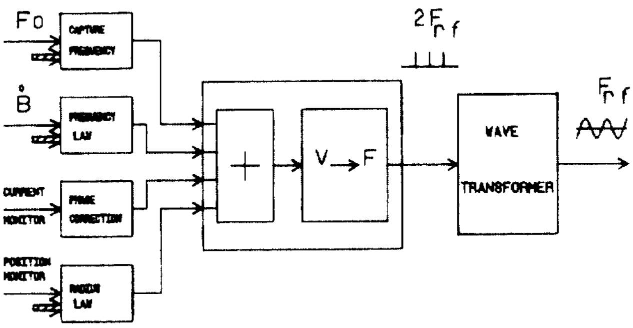

Fig. 3 : low level RF system.

Ferrites choice

For the main part, the cavities and amplifiers caracteristics depend on the ferrite qualities. We conducted a large number of experiments to test and measure several samples from different origins for which we built a reduced-size cavity. We finally selected a TDKC4 SY7 ferrite. Their main data for MIMAS cavity are :

outer diameter : 510 mm
inner diameter : 355 mm
thickness : 25 mm
remanent μ_R : 2500
dielectric constant ϵ_R : 10
quality factor, 150 kHz: 6
quality factor, 2.5 MHz: 40
polarisation field for $\mu_R/280$: 2150 At/m
Curie point : 90° C

RF cavities

Each cavity is composed of one $\lambda/4$ coaxial resonator, by one acceleration alumina gap, and is loaded by two separate blocks of 20 ferrite rings. Each couple of ferrite-rings is sandwitched by cooling copper discs.

The resonator ferrites are polarized with a 6 turn-copper rod winding connected to a 0-400 A bias current power supply. The cavity is designed so that the inside vacuum chamber can be baked up to 300°C

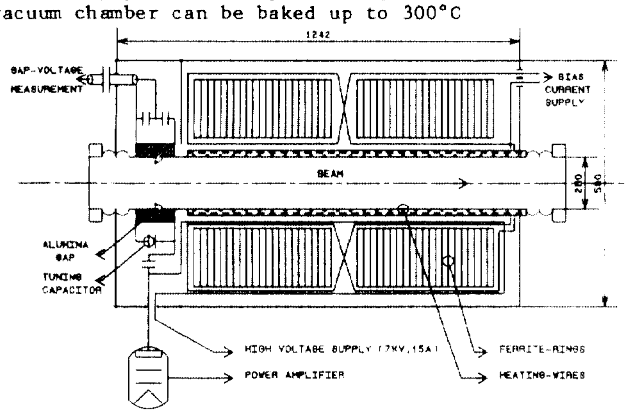

Fig. 4 : scheme of one cavity.

The electrical caracteristics are 240 pF/m and 175μH/m which means 800 kHz for the resonance frequency. The low frequency required to accelerate beam is adjusted by a 6000 pF capacitor on the gap.

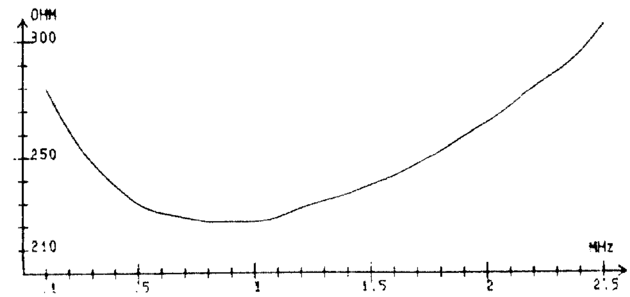

Fig. 5 : impedance of a cavity

Amplifiers

The final RF power stage is located below the cavity and use a water cooled tetrode (Thomson CSF TH 120 - maximum power : 50 kW) working in class AB. The voltage gain is close to 20. This vacuum tube is driven by a wide band transistorized amplifier (100 kHz - 30 MHz, 200 W).

Tuning and regulation

The cavity is automatically tuned to the accelerating frequency shift by adjusting the magnetic biasing field on the ferrite. This servo loop is designed so that the phase difference between the grid and plate of the TH 120 tetrode is detected (and maintained close to 180° during the accelerating cycle) to feed the biasing power supply of the ferrites.

At the same time, the gap voltage is regulated better than 1% in 5 kHz range by a 55 dB (100 kHz - 25 MHz) AVC.

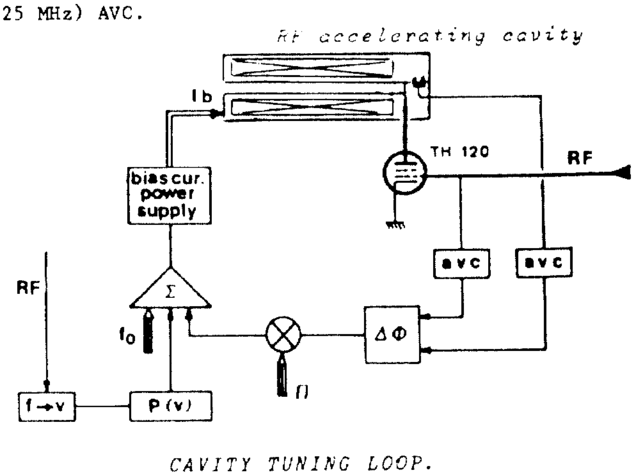

fig. 6 : block diagram of the tuning and regulation system

Present status of the RF system and acceleration

All the operating parameters are connected to the general computer network for the control and monitoring, by a home-made CAMAC controller. This RF system has been working for one year with a large variety of ions without trouble. Nevertheless some investigations have been made to point out the RF system limitations. These ones are induced by the maximum voltage on the gap, and the duration of the flat top voltage (Fig. 7a and 7 b) during the extraction process.

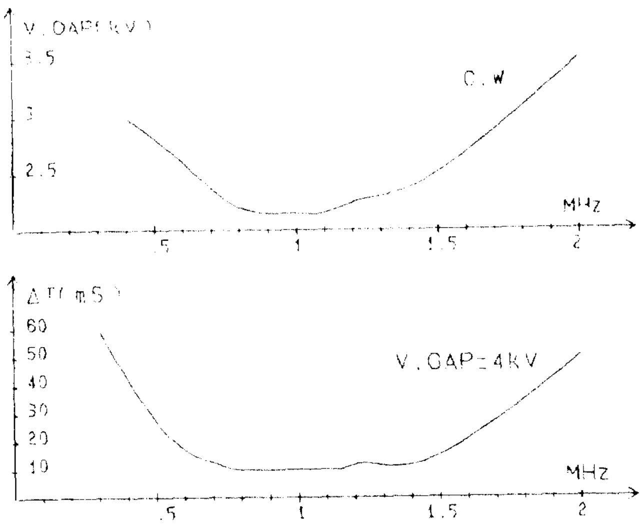

Fig. 7a, b : maximum gap voltage, maximum duration of this voltage

At last, with the described RF system, MIMAS accelerate 2.10^{11} polarized deutons (or protons) and for example C^{6+}, O^{8+}, Ne^{10+} and Ar^{16+} in the heavy ions field.

Acknowledgements

Many people of the RF group have contributed to th construction of the RF system for MIMAS. We will than them, all. We particularly acknowledge the contribution of J. PEYROMAURE, J. LEPINAY, A. MILLO, G. CHAUVET an E. GELLOZ.

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