GANIL RF system

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GANIL* RF SYSTEMS

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Abstract

Final studies on a model were made simultaneously for the three types of GANIL resonators : separated sector cyclotrons[1], injector cyclotron[2] and buncher n° 1[3]. These investigations have permitted complete definition of the main parameters of these resonators (size, tolerances, current and voltage distribution, losses, coupling and tuning). Mechanical studies for the three resonators are nearly finished. Technological studies on sliding contacts have been made at full current. Phase and amplitude regulation systems have also been tested. The values measured fully satisfy GANIL tolerances. Construction of the first two resonators of CSS, C0 and buncher will start in July 1979. At the same time the prototype of a 100 kW RF transmitter has been satisfactorily tested and construction of the first three amplifiers will begin soon.

1. Separated sector cyclotron resonators

1.1 Model measurements

Q-value, frequency variation with capacitive panel, voltage distribution along the gap, coupling loop and tuning methods have been investigated on the 1 : 3 scale model (Fig. 1). These results are in good agreement with those calculated. The 1 : 3 model has also been used to define current distribution in the inner and outer conductors, especially in the region of the movable capacity stem where a uniform density of the current in the sliding contacts is very important. From these measurements total power losses have been re-evaluated and the size of the movable capacity stem has been adjusted to reduce the maximum current density at 20 A/cm. For 250 kV at 14 MHz, the maximum power will be less than 80 kW and for 100 kV at 6 MHz, less than 60 kW.

Fig. 1

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1.2 Mechanical studies

The external OFHC copper wall, divided into three removable parts, is supported by a stainless steel structure which allows the copper to expand and keeps the geometrical relation between dee and anti-dee constant. These structures are connected together to a support, which is placed on three jacks mechanically insulated from the vacuum tank.

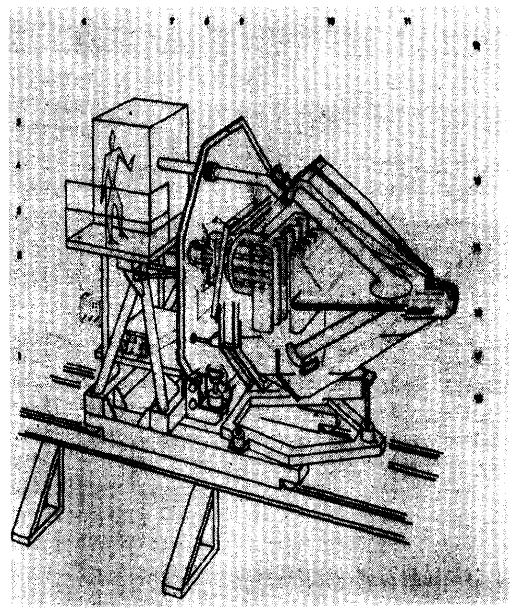

Fig. 2

The three-dimensional calculations using the finite elements method[4], including the thermal field action and the stainless steel structure, have shown that the maximum displacement of the anti-dee lips is in the order of 0.6 mm in the vertical direction (Fig. 3).

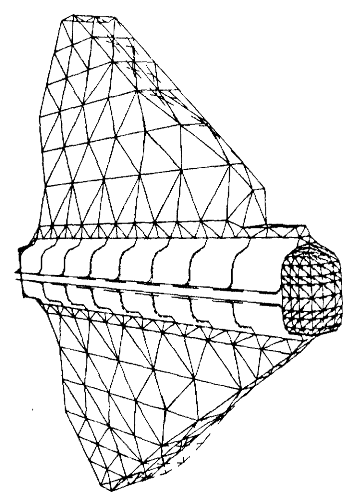

Fig. 3

The movable capacitive panel is moved by a hydraulic jack with an internal drive. Movement resolution is less than 1/100 mm.

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1.3 Power amplifier and coupling

As the inductive coupling loop is fixed, its impedance varies with the frequency : 25 Ω at 6 MHz and 100 Ω at 14 MHz. To match this impedance with the load impedance of the tube, we use a tunable plate tank circuit (π) with two variable capacitors. The RF power on the grid of the final stage (1.5 kW) is given by another single tetrode tube with a π in the plate circuit. The impedance ratio is 2000/50 with 650 pF on the grid circuit. This circuit uses only one variable element (impedance). The grid of the pre-amplifier is driven by a wide-band amplifier (100 W). The actual prototype amplifier[5] has delivered more than 120 kW in the range 6 to 14 MHz (Fig. 4).

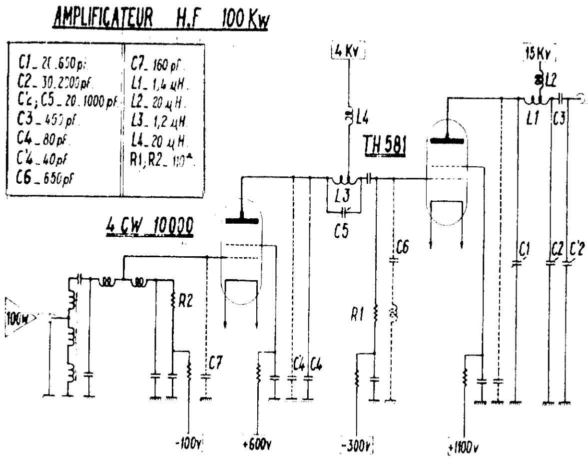


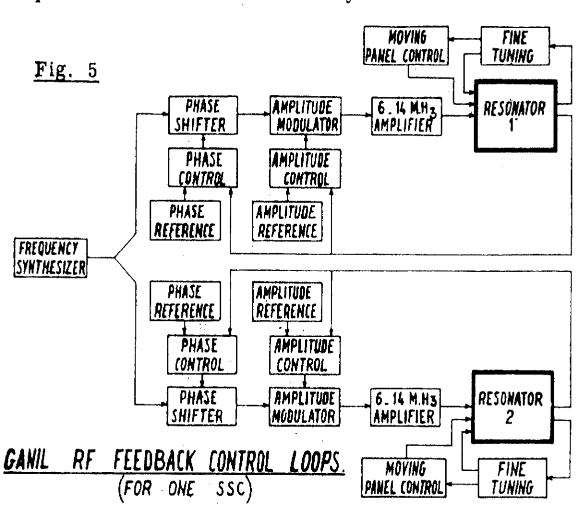
Fig. 4

1.4 Phase and amplitude regulation

Fig. 5 shows the GANIL RF control system (for one SSC). We expect the following values for the accuracy of the dee voltage :

- fast self-tuning system : phase accuracy ± 1° RF phase with a bandwidth for small detunings greater than 20 Hz and a slew-rate of 120° RF per second
- amplitude stabilization : less than $\pm 5.10^{-5}$ for $\Delta V/V$, long-term drift and ripple. A special dynamic filter will certainly be necessary to reduce parasitic AM introduced by the 50 Hz harmonics, especially the 1st, 2nd and 6th harmonics
- phase stabilization : less than ± 0.15°. A special beam phase input signal has been made to reduce the energy spread after each SSC if necessary.

Fig. 5



1.5 Experimental studies

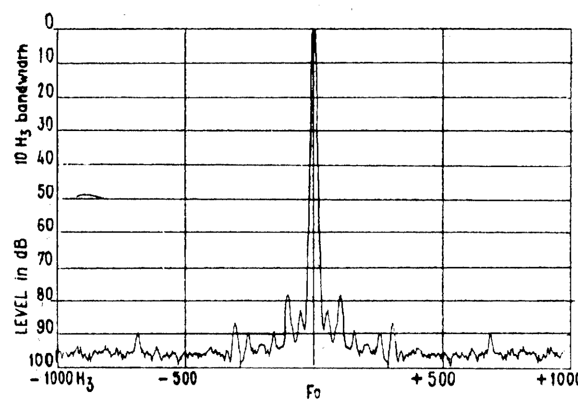
1.5.1 Experimental resonator

All the experiments described here were made with our 3 meter quarter-wave resonator powered by a 25 kW RF amplifier. On the variable capacity, current and voltage as high as 170 kV peak and 1100 A peak can be reached to test sliding contacts or sparking problems. Tuning, phase and amplitude regulation systems were also tested.

1.5.2 Amplitude and phase regulation

For the amplitude regulation, numerous tests were made with a classical compensation network. This feed-back control systems has a unity gain bandwidth at 4000 Hz. A special phase shifter has been designed for the phase regulation[7]. Its essential characteristics are : very low harmonic distortion, low phase noise (< 0.01°), bandwidth (small signals) greater than 25 kHz, phase shift capability ± 40°, RF output voltage constant and independent of the phase shift, frequency range 6 to 20 MHz.

Included in the phase loop control system of the test tank (unity gain bandwidth near 60 kHz up to 100 Hz) a residual parasitic phase modulation less than ± 0.03° has been obtained (at 16 MHz for this test). Fig. 6 shows the spectrum analysis of the RF voltage at 16 MHz (scan width 100 Hz/div.), which is characteristic of the residual phase modulation and noise (the AM main spikes are 12 dB down).



SPECTRUM ANALYSIS at 16 MHz

Fig. 6

1.5.3 Sliding contacts

For the GANIL resonators the mechanical tolerances are such that we need a contact with a transversal elongation in the range of ± 1 mm and with a current density around 20 A/cm. Small movements with the RF on are also necessary to correct thermal expansion of the resonators. Various types of commercial sliding contacts have been tested, but they are not able to meet all our requirements. In collaboration with CGR-MeV we are therefore developing a special type of contact using silver graphite contacts (95 % silver) and bronze beryllium or cobalt beryllium bronze blades. The first results are good, both for current density and lifetime. (Fig. 7).

Type	Elongation	P N	N finger /cm	Intensity A/finger	Temp/ finger °C	Remarks
CGR1	± 1 mm		2	11.5	< 60	no dammage after
CGR1	± 1 mm	< 10	1	23	< 80	> 60 hours

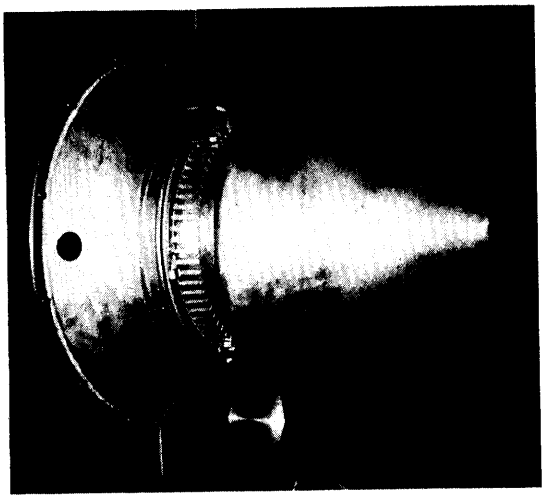


Fig. 7

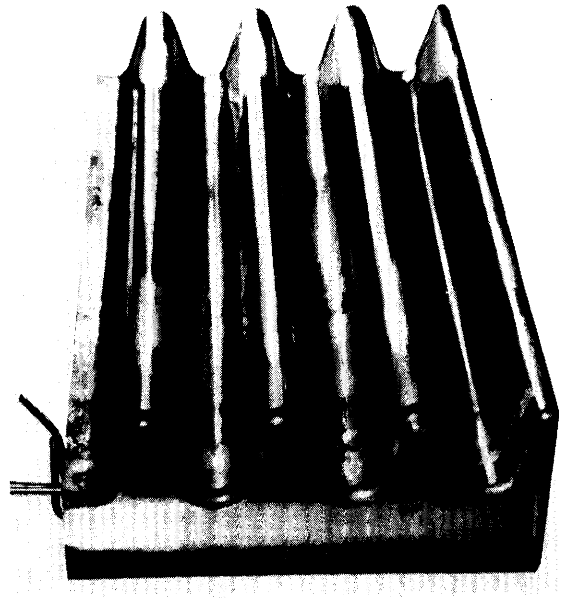


Fig. 9

2. Injector cyclotron resonators

The same studies have been made on the 1 : 4 model as for the SSC resonators. Compared with the calculations, minor modifications have been included in the stem length and size. Most of our measurements have been devoted to the density current in the sliding contacts and to the choice of the shape of the movable stems. The profile given on Fig. 8, which also shows the maximum current density lower than 23 A/cm, is a good compromise.

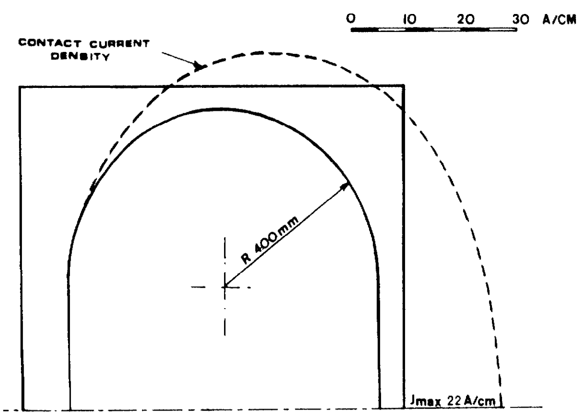


Fig. 8

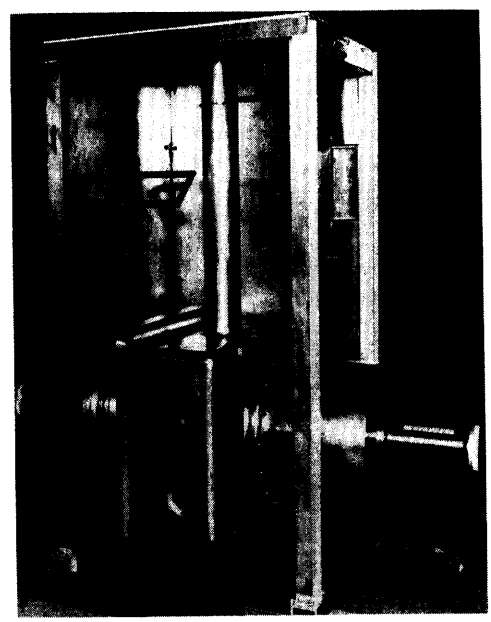


Fig. 10

Mechanical studies will be finished in two months and Fig. 9 shows a full-scale model of the "waved" panel[6].

3. Buncher n° 1

This buncher is placed between the injector cyclotron and the first SSC. A 1 : 2 model has been built and the results are in good agreement with the calculations, Fig. 10.

The main characteristics are :

- maximum voltage on the electrode : 130 kV to 14 MHz
- frequency range 6 to 14 MHz by symmetrical movement of flat capacitive panels
- maximum power losses : 20 kW
- amplitude stability ± 1 %
- phase stability ± 0.5°.

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