PROTOTYPE OF THE ACCELERATING RESONATOR FOR THE SUPERCONDUCTING SECTOR DEUTERON CYCLOTRON

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Summary

A fullscale prototype of the accelerating cavity for the superconducting deuteron sector cyclotron at the energy 100 MeV is described.

The fundamental frequency and the distribution of the radiofrequency voltage along the accelerating gap were calculated by the RFC3D programme for calculating of 3-dimensional components of the electromagnetic field. The rf measurements proved the validity of the calculations with the accuracy better than 5% for the cavity fundamental frequency and 10% for the voltage.

Introduction

The structural features of the DC-1 sector cyclotron |1| required a halfwavelength resonator with a Δ-electrode as an accelerating element. The Table lists the main parameters of the RF system of DC-1 |2|.

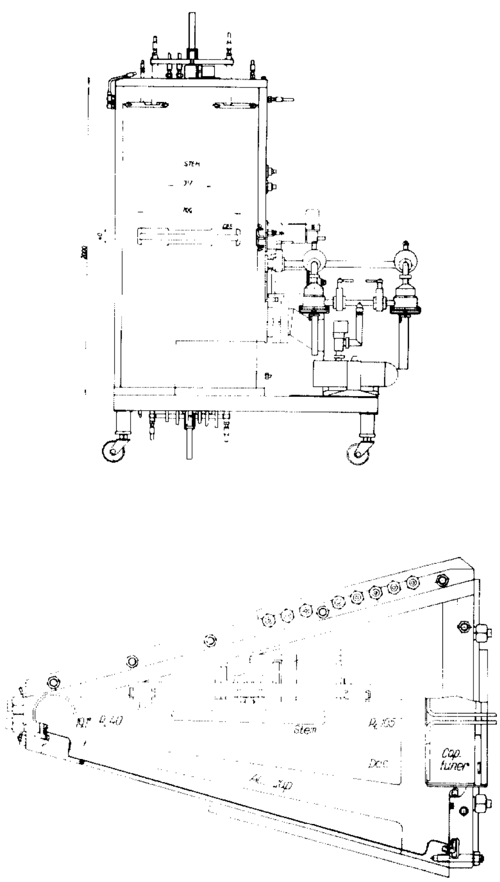

Fig. 1. The general view and median cross section of the resonator.

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Table

Number of cavities	2
RF frequency	74.25 MHz
Harmonic number	6
Mean injection radius	40 cm
Mean extraction radius	115 cm
Accelerating voltage	300 kV
Azimuth dimension of resonator	30°
Losses in one resonator	40 kW

The main structural features

The resonator is a right-angle prism about 2 m high, its base being a trapezium with equal sides. The general view and median cross section of the resonator are shown in Fig. 1.

The resonator walls are made of aluminiumalloy with copper cladding inside. The space for the resonator in the cyclotron is 30° and is limited by two neighbouring magnet sectors. The side walls of the resonator are as thin as possible to keep the necessary internal volume. It is the magnet cryostat walls that are of the supposed to carry atmospheric load. The gaps between the side walls of the resonator and the cryostats are pumped down to rough vacuum. Other resonator walls are 50 mm thick and withstand the atmospheric load.

To tune the resonator and to achieve the necessary behaviour of the variation of the accelerating voltage in the acceleration zone, there are movable panels and a trimmer capacitor that changes the capacitance between the outer end of the Δ-electrode and the resonator wall. The contacts of the panels are made of copper foil 0.3 mm thick pressed to the walls by sending air under pressure into a rubber hose placed in a slot under the contact tabs. The hose is a vacuum tube with the inner hole 4 mm diameter and walls 4 mm thick. The design pressure is up 14 atm. The necessary pressure was determined in a direct experiment. The natural frequency of the resonator changes within 100 kHz as a function of the pressure in the contact opening system. The minimal working pressure is 10 atmospheres and the quality factor is 10000.

The copper cladding is cooled by water under pressure running in soldered on copper tubes. The water reaches the panels and the trimmer capacitor through guide rods.

The resonator is supposed to be evacuated by two electric discharge pumps. To prevent oil fumes from penetrating in the initial vacuum system, adsorption traps will be used.

Measurements of resonator characteristics

The main resonator characteristics measured at a low power level are the quality, the range of tuning with the trimmer capacitor, the accelerating voltage distribution along the accelerating edge.

Fig. 2 shows the resonance frequency plotted as a function of the gap between the short-circuiting panels of the resonator. The theoretical and experimental values are given. The discrepancy is 5%.

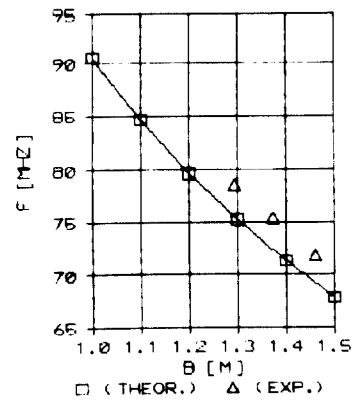

Fig. 2. Resonance frequency vs cavity height.

The calculation was performed by means of the programme RFC3D |3| for calculation of 3-dimentional components of an electromagnetic field. Fig. 3 shows the possible range of resonator frequency tuning with the trimmer capacitor for the maximum and minimum gap between the resonator tuning panels.

Measuring of the accelerating voltage is the most labour-consuming process and required special equipment and measuring devices. To solve this and similar problems, a multipurpose measuring complex has been developed on the basis of the personal computer. The perturbation method was used for measurement |4|. The perturbing body was a copper ball 6 mm in diameter fixed to a capron thread. Since the ion trajectories in the Δ-electrode are close to a straight line perpendicular to the axis line of the electrode, radii were measured from this axis, and the systems that guided the movement of the thread with the ball were parallel to this axis.

In measurements we registered the output analogue signal from the phase voltmeter, which was proportional to the variation of the RF field phase in the resonator caused by the perturbing body: $\Delta\varphi \sim E$ (E is the value of the electric field at the perturbation point), and the voltage from the multiturn potentiometer connected to the motor that moved the ball. The preliminary software processing of the characteristics consisted in removal of the experimental errors (temporal thermal instability of instruments and the resonator itself, deviation from the zero level). Then the dependence of the accelerating voltage on the radius U(R) was calculated. In Fig. 4 one can see this dependence compared with the calculated one.

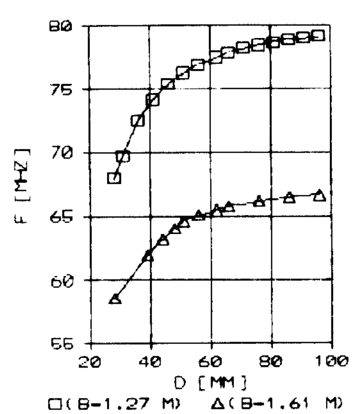

Fig. 3. Resonance frequency vs trimmer capacitor gap for max and min cavity height.

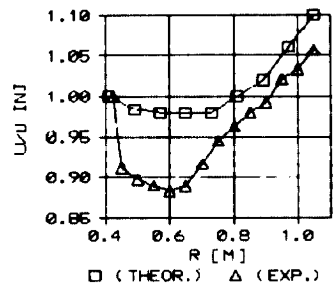

Fig. 4. Accelerating voltage vs radius.

The non-compensated capacitive coupling was used for excitation of the resonator. Since there was coupling capacitance (C_c), the frequency tuning of the resonator should be slightly shifted from its own resonance toward the capacitance region. Considering the equivalent resonator coupling system circuit, we can obtain in this case that $C_c = [2\pi f(Z_{in}R_{sh})^{1/2}]^{-1}$, where Z_{in} is the input resistance of the coupling system, R_{sh} is the shunt resistance of the resonator, f is the frequency. The resonator has such parameters that they allow $Z_{in} = Z_{0f}$ (Z_{0f} is the wave resistance of the feeder). The coupling system design allows stepless variation of the coupling capacitance for fine matching tuning. Retuning goes on without violating the vacuum. The impedance and the input phase of this coupling system are shown in Fig. 5.

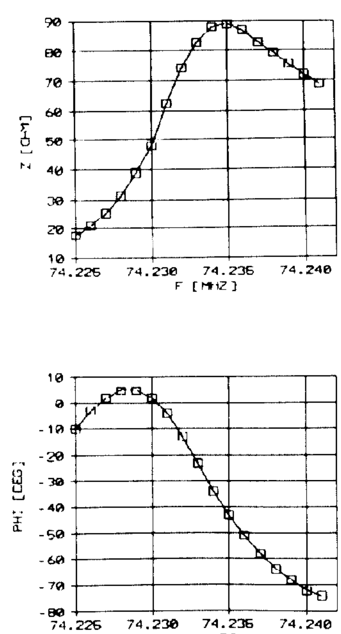

Fig. 5. Impedance and input phase of coupling system.

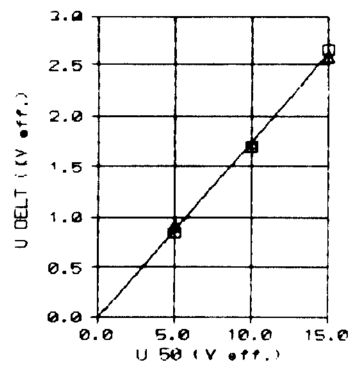

Fig. 6. Accelerating voltage vs coupling system input voltage.

Fig. 6 shows the dependence of the voltage at the accelerating Δ-electrode in the region of the injection radius U_Δ on the input voltage of the matched ($Z_{in} = R_{in} = 50$ Ohm) coupling system U_{50}. The dependence was measured with the help of the calibrated measuring loop. Using the obtained result one can find out that the power of the Δ-resonator will be about 40 kW at the accelerating voltage $U_{delt} = 300$ kV.

A 100 kW self-excited oscillator with the intrinsic feedback has been developed for experimental excitation of the resonator. Coaxial circuits and flat film capacitors are used here. The initial excitation of the resonator performed according to this scheme in the air allowed 10 kV at the Δ-electrode. This oscillator is planned to be used in a pulsed mode of operation.

References

1. A.A.Glazov et al. JINR, R9-81-734, Dubna, 1981.
2. A.T.Vasilenko et al. JINR, R9-90-176, Dubna, 1990.
3. A.N.Bespalov et al. Proc.of the 10th All-Union Conference on Accelerators, JINR, D9-87-105, Dubna, 1987, v. 2, p. 257.
4. L.B.Mullet. AERE G/R 883, Harwell, 1957.