HIGH-FREQUENCY SYSTEM OF THE CYCLOTRON DC - 72

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Abstract

The basic parameters of a RF system of a cyclotron DC-72 are presented in the given article. The results are obtained by virtue of numerical calculations using the software package POISSON SUPERFISH and are checked in the series of measurements using the resonator model with the scale 1:1.

INTRODUCTION

The azimuthally varying field cyclotron DC – 72 accelerates ions from H to Xe over an energy range 2.5 MeV per nucleon for heavy ions like Xe^{+18} to 72 MeV for protons. The orbital frequency of ions ranges from 3.08 to 16 MHz. The ions are accelerated by two independent resonators with an acceleration voltage up to 60 kV in the 2_{nd}; 3_{rd}, 4_{th}, 5_{th} or 6_{th} harmonic mode. This requires a frequency range of 18.25 - 32 MHz for the RF system.

RESONATORS

The resonators are coaxial λ/2-cavities, which are symmetric with respect to the median plane and are located up and down in the yoke magnet. Dees are located in the valleys of the magnet poles.
The calculated main RF and mechanical characteristics are summarized in Table 1.

Table 1: Resonator characteristics

frequency range	[MHz]	18.25 - 32
cavity type:		coaxial λ/2
cantilever length	[mm]	2x2070
electrode angle	[°]	40
accelerating gap width	[mm]	10 at injection 40 at extraction
vertical aperture	[mm]	30 (20 at injection)
inner line diameter	[mm]	106
outer line diameter	[mm]	400
coarse tuning system		sliding short
sliding short displacement	[mm]	1200
fine tuning system		adjustable plate
coupling system		stable plate and variable capacitor
extraction radius mm	[mm]	1120
peak voltage range	[kV]	up to 60
Q factor		about 6000
maximum RF power	[kW]	19
RF probes		4 capacitives

RF CALCULATIONS AND MEASUREMENTS USING THE RESONATOR MODEL

RF calculations were performed with the software package POISSON SUPERFISH [1].

Drawing of the resonator model and the dee are shown on Figure 1.

For calculations we used equivalent scheme where dee was replaced with a cylinder. The capacitance of the equivalent cylinder and of the dee is the same.

Figures 2 to 4 show the calculated and measured resonant frequencies at different position of sliding shorts and Q factor and power dissipation at different frequencies respectively.

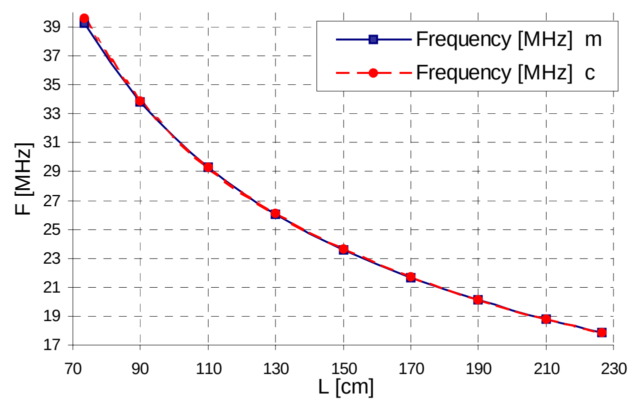

Figure 2: Calculated and measured resonant frequencies at different position of sliding shorts.

For variable sliding shorts at the distance of 735 to 2265 mm from median plane a resonant frequency range from 39.091 to 17.759 MHz for calculated and from 39.260 to 17.855 MHz for measured values.

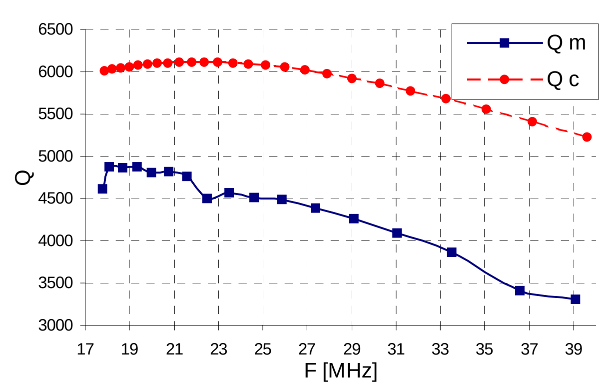

Figure 3: Calculated and measured Q factor at different frequencies.

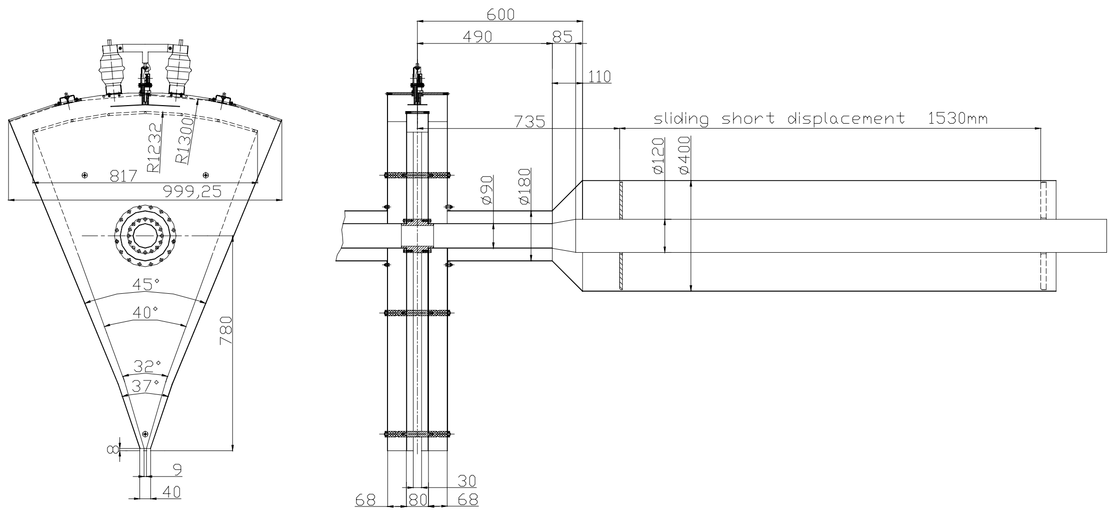

Figure 1: Drawing of resonator model with the scale 1:1.

Q factor was measured with a delta mode method (see Eq. 1). Q factor is 6115 to 5225 in the case of calculation and 4875 to 3310 for measurement at different frequencies.

$$Q = \frac{F_r}{F_2 - F_1} \quad (1)$$

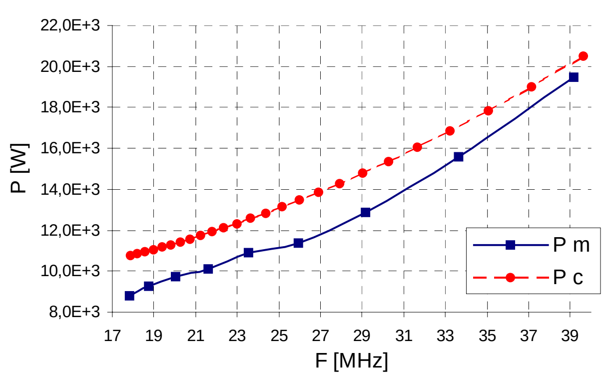

Figure 4: Calculated and measured power dissipation at different frequencies.

The value of measured power dissipation was calculated with an equivalent capacitance of resonator and Q factor (see Eq. 2, 3, 4).

Equivalent capacitance is:

$$C_{eq} = \frac{F_r \cdot \Delta C}{2 \cdot \Delta F}, \qquad \Delta F = F_r - F_{rC}, \quad (2)$$

where ΔC is a appended capacitance, F_r is a resonant frequency and F_{rC} is a resonant frequency with an appended capacitor set on the dee at maximum value voltage.

Shunt resistance is:

$$R_{Sh} = \frac{Q}{2 \cdot \pi \cdot F_r \cdot C_{eq}}. \quad (3)$$

Power dissipation is:

$$P = \frac{U_{dee}^2}{2 \cdot R_{Sh}}. \quad (4)$$

Power dissipation is calculated for U_{dee} = 60 kV and range from 10.75 to 20.50 kW for calculation and from 8.6 to 19.5 kW for measurement at different frequencies.

COMPARISON OF CALCULATIONS WITH MEASUREMENTS

Frequency Range

In the case of calculation two-dimensional cylindrical equivalent gives the best results compared with measured values.

Q Factor

Q factor depends on quality of electrical contacts and material properties of resonator. Difference between measured and calculated values was mainly due to ideal electrical contacts used in equivalent scheme.

Power Dissipation

Indirect method measurement of the power dissipation results in an accumulation error consisted of Q factor measurement and equivalent capacitance measurement.

CONCLUSIONS

RF system of a cyclotron DC – 72 was designed by ue of computer simulation and measurements using the resonator model with the scale 1:1. In the near future series of cold measurements and the first power tests for the RF system will be carried out in resonators.

REFERENCES

[1] James H. Billen and Lloyd M. Young, POISSON SUPERFISH LA-UR-96-1834, The Regents of the University of California. Copyright, 1985-2001