SUPERCONDUCTING RF CAVITY ON THE BASE OF NB/CU FOR THE ACCELERATOR SVAAP

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Introduction

Federal Problem Lab at IHEP deals with the superconducting accelerator for irradiation of High Tc ceramics. This accelerator is known as the Superconducting Vertical Accelerator for Applied Purposes (SVAAP) [1,2]. The basic characteristics of accelerator SVAAP are given in table 1.

Table 1

№	The name of parameter	Value
1	Max. output energy, MeV	7.5
2	Power disorder of particles, %	0.5
3	Energy of injection, keV	80
4	Current , μA	10
5	Mode of operation of the accelerator	continuous

1. TOPOLOGICAL SCHEME OF SVAAP

As one can see Fig. 1 the accelerator consists of two parts, horizontal and vertical.

The injector (1) remains in horizontal part of the accelerator and it consist of an electron gun and high voltage source of power (17). The injector generates continuous electron beam with the energy of 80 keV and beam current of 400 mkA.

The units that follow the injector (2...8) are related to the system of preliminary beam forming. The system includes three focusing lenses (2,9), a bending magnet and three collimating cells (4,6,7). Taking into consideration that there is no beam focusing witling the limits of the accelerating cavity, it is necessary to take measures excluding of particles coming to the surfaces of the superconducting cavity. It is achieved by means of using of RF-chopper and collimating slots.

After passing the cavity the basic part of the beam remains on the vertical diaphragm, located just before the bending magnet, the rest of the beam passed through the magnet, bends by 90 degrees and is thrown on the collimating slot.

The scheme is ended by a vertical cryostat (12) with the superconducting cavity (SCC) inside it (11). The accelerating and chopper cavities are electrically coupled through their feeding and phasing systems (14) [3].

On the base of these investigations the injection energy and geometry of accelerating cavity of 14 cells at the frequency 3 GHz, which provides the beam energy of 7 MeV, has been chosen.

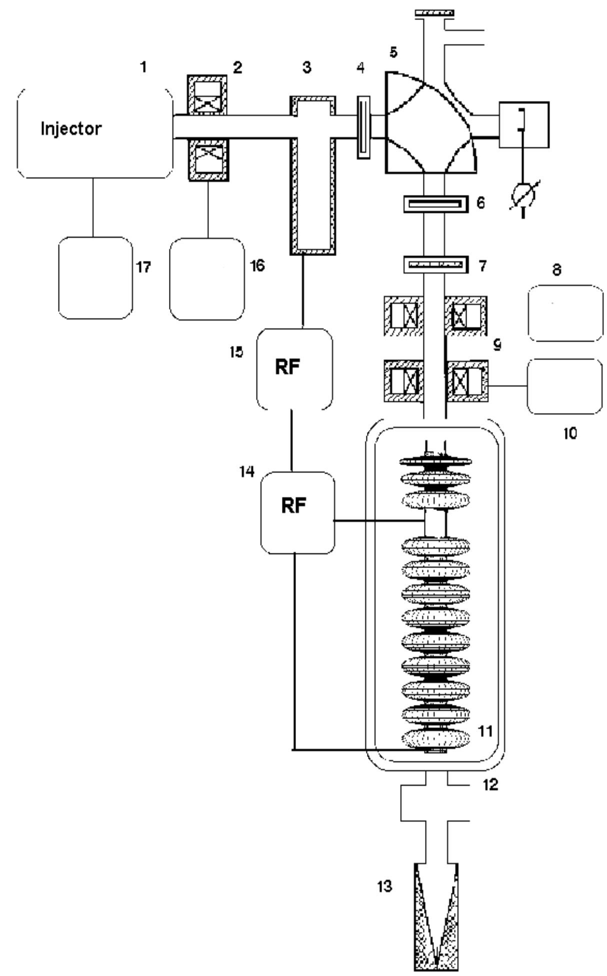
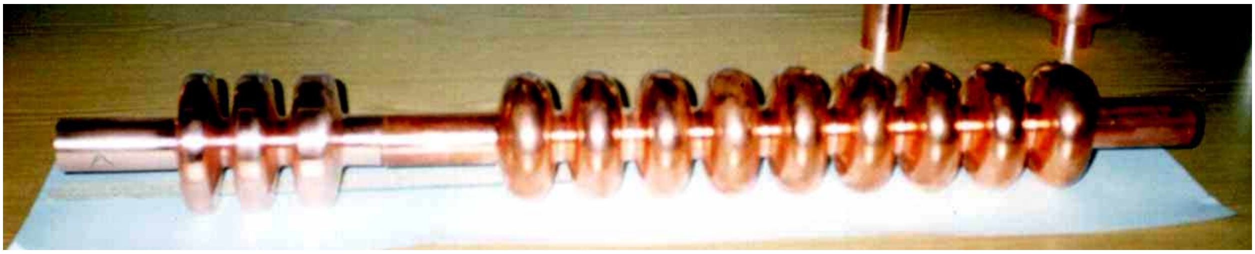


Fig.1.The Topological SVAAP scheme [3].

However, in the accelerating RF structures from the large number of cells (N> 9) the parasitic modes of high order occur that influence negatively. And we decided to allocate in the separate section first three cells, responsible for a capture of particles and their preliminary acceleration till 1.0-1.2 MeV, but to place together with base accelerating RF cavity in the same cryostat.

In this report special attention has been given to the RF cavity, its geometry, mechanical stresses, HOM and technology.



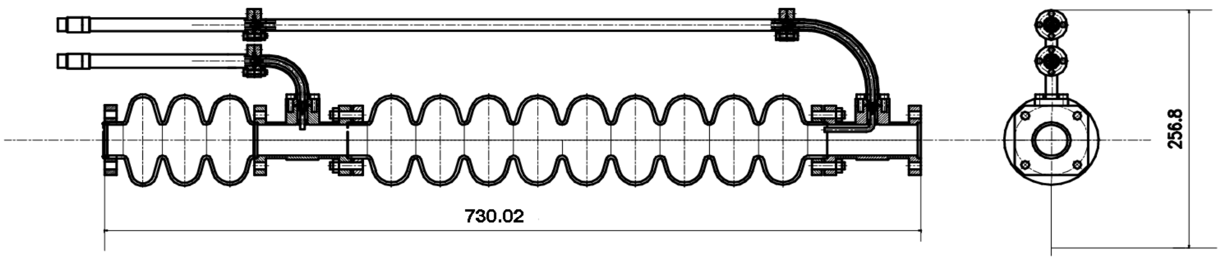


Fig.2. RF superconducting structure for SVAAP

2. GEOMETRY OF ACCELERATING SUPERCONDUCTING RF-CAVITY

RF cavity for accelerator SVAAP consists of two resonators: accelerating and grouping (Fig.2).

Earlier in [3] the choice of the geometrical sizes of accelerating RF cavity and calculation of the basic RF characteristics cavity (Table. 2) is shown.

Table 2

№	The name of parameter	Value
1	Accelerating field, MV/m	12
2	Q_0–factor	$10^9 – 10^{10}$
3	Frequency MHz	2950

Definition of geometrical parameters was based on the analysis of the calculation results of particles dynamics [3] and definition of cells radiuses and the iris radiuses from conditions of adjustment to the given working frequency (2.95 GHz) and distribution of an electromagnetic field to axes of cavity.

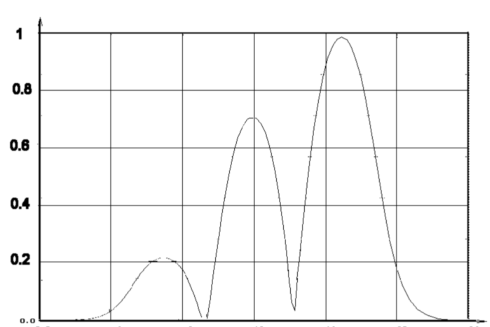


Fig.3. Distribution of EM field along the axes of grouping cavity

The cavity of capture consists of three cells with β equal 0.74, 0.78 and 0.9 accordingly.

Fig. 3 shows field distribution along the grouping cavity.

On Fig.4 (a curve 1) distribution of an electric field to axes of such structure is shown.

The numerical analysis of characteristics of fluctuations without variations of a field on an azimuth is made with the help of program PRUD-0. Working frequency is 2950 MHz.

The accelerating cavity consists of nine cells with β equal 1 and uniform distribution of accelerating field to axes (see Fig.4).

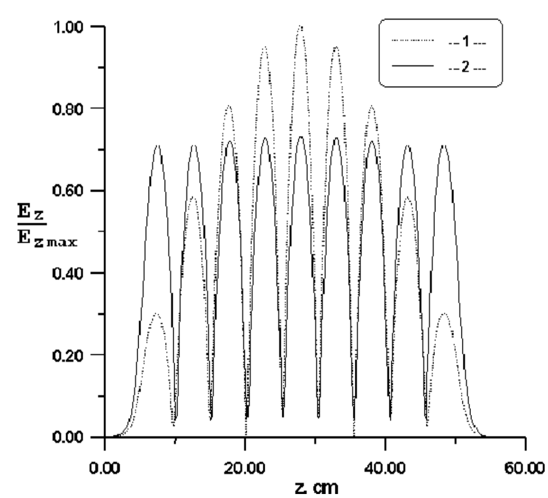


Fig.4. Distribution of EM field along the axes of accelerating cavities: 1–before tuning; 2– after tuning

3. THE HOM IN ACCELERATING RF CAVITY

Necessity of research of dynamic characteristics of modes with one variation of a field on an azimuth arises owing to high Q-factor of these modes in SCC and, hence owing to much attenuation of electromagnetic fluctuations of cross emission and in case of the big currents may cause the effect Beam Blow Up.

In order not to allow the instability to arise it is necessary to lower cross impedances of the connection of the maximum styles to some threshold sizes. For this purpose it is necessary to investigate not only working, but also the maximum types of fluctuations in SCC in a range of frequencies up to $3f_0$, where f_0 - frequency of working fluctuation.

The numerical analysis of RF characteristics of accelerating cavity is made with programs URMEL-T and URMEL.

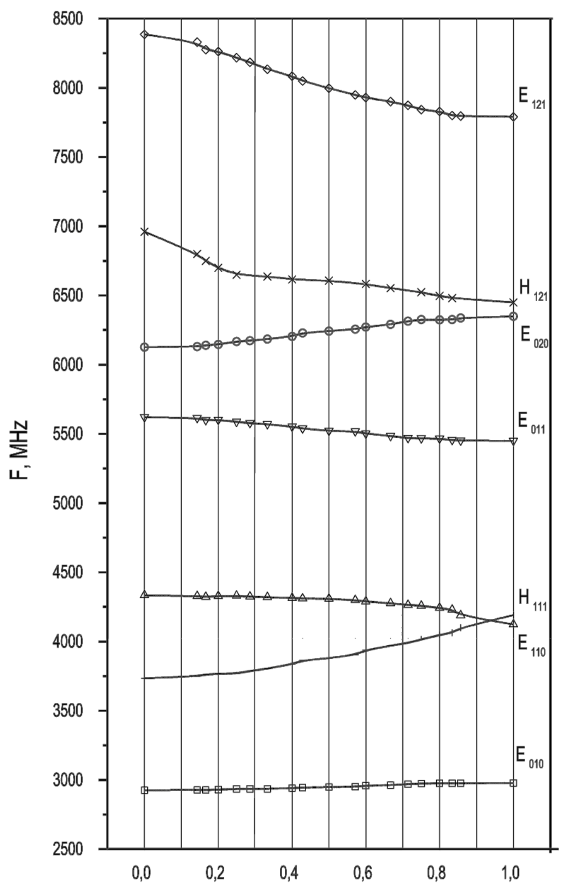


Fig.5. The depressive characteristic of RF cavity.

The depressive characteristic of accelerating cavity is shown on fig 5.

The special attention was given to such parameter, as Rsh/Q because the power of electromagnetic fluctuations at the high frequencies is directly proportional to this parameter. As it is show on fig 6 it is fluctuation number 6 that represents danger.

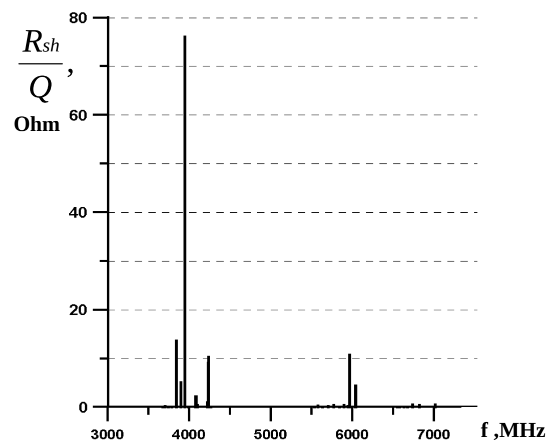


Fig.6 The spectrum of HOM.

The reduce the R/Q relation for these frequencies it is necessary to apply the HOM devices of damping which are filters for these frequencies

4. INFLUENCE OF EXTERNAL FACTORS ON RF CHARACTERISTICS OF THE CAVITY

It is known, that deviations of the geometrical sizes from the calculated sizes can cause two undesirable effects [4]:

- the speed of a wave changes and there is an additional sliding of the bunch in its relation towards a wave
- the amplitude of the accelerating wave decreases

These both processes result in reduction of energy by an output of the accelerating wave-guide.

Accelerating cavity settles down in cryostat in vertical position that results in deformation of cells, by gravity. Change of the geometrical form of cells conducts to change of its resonant frequency and may result in change of distribution of a field on an axis of structure. Hence, it is necessary to estimate influence of deformation of the resonator on shift of working frequency of the resonator and its influence on distributions of a field on axes of the resonator.

Some variants of fastening of accelerating structure in cryostat (fig 7) and the deformations appropriate to them are considered at various values of thickness of walls:

·1. accelerating structure has one free flange (top or bottom), and another is rigidly fixed;

· 2. both flanges are fixed.

On fig. 7 change of geometry of cells of the resonator by gravity is shown. The initial form of a cell is represented by a line 1, and deformed by a line 2.

As we can see from the figure, the border of a cell is described by the arches of circles and the pieces being their tangents.

Analyzing deformation of a cell, it is possible to draw a conclusion, that change of geometry of a cell occurs due to change of the period of a cell. The greatest contribution to change of the period of a cell makes change of angles of an inclination of the forming cells.

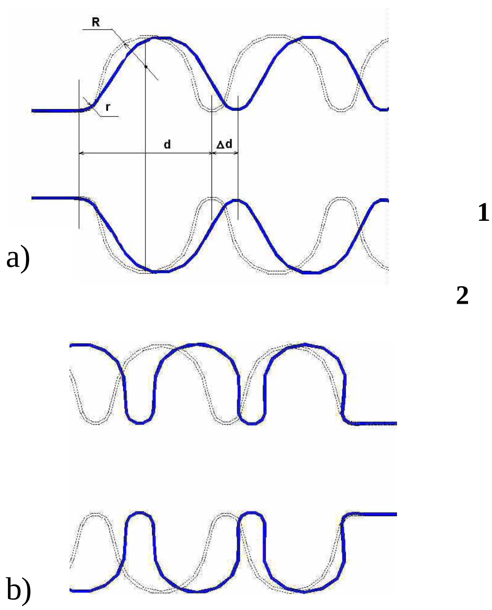


Fig.7 Change of forms of the deformed cells of the cavity a) extension of cells; b) compression of cells.

As a result of numerical modeling the set of absolute deformations of geometry of structure for various values of thickness of its walls (fig. 8) is received.

The resonator with thickness of a wall of 1 mm corresponds to the greatest change of length (about 9 microns).

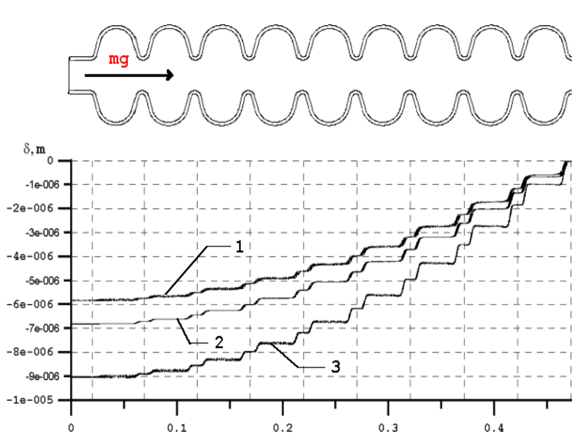


Fig. 8 Deformation of accelerating cavity with the fixed bottom flange at various values of thickness of a wall

On Fig. 9 deformation of the resonator for a case when the resonator is rigidly fixed from two sides is shown. In this variant the general lengthening of the resonator does not occur, and lengthening of the top cells is compensated by the compression of the lower cells. And, if in the first the variant at deformation shift of own frequencies of each cell was one mark then in the second variant one half of cells increases its own frequency, and another half of cells reduces that frequency.

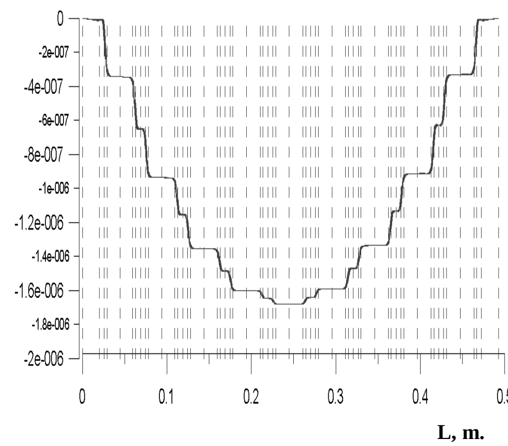


Fig. 9 Deformation of accelerating cavity with the fixed bottom and top flange at the thickness of a wall of 2 mm.

The shift of frequency of a cell will result in change of amplitude of an electromagnetic field in these cells and consequently distribution of a field to axes of the resonator will change also. Hence, it is necessary to define(determine) values of allowable changes in geometry of structure which will not result in gross infringements in distribution of an electromagnetic field to axes of the resonator.

The analysis of influence of deformation of accelerating resonator on its electrophysical parameters has shown, that change of the period of a cell caused by a gravity results in change of resonant frequency of a cell and amplitude of an electric field on an axis of the resonator. However, these changes are so small, that they can be neglected at the analysis of factors influencing on a shirt of working frequency

5. DEPENDENCE OF QUALITY FACTOR FROM ACCELERATING FIELD

Now special interest to technology of accelerating rf cavities is shown on the basis of superconducting materials as films, put on copper environments without welded seams.

The assembling had place in clean room, showed on Fig. 10 with class only 1000.

On fig. 11 results research of dependence of the cavity versus of accelerating field for superconducting cavity on the base Nb/Cu for accelerator SVAAP made with use of a method galvanoplastic sharing technique and axial magnetron sputtering.

Fig.10. The clean room with class 1000.

The copper shells have thickness about 3 mm and superconducting film (niobium) have thickness 1.5 – 3.0 microns .

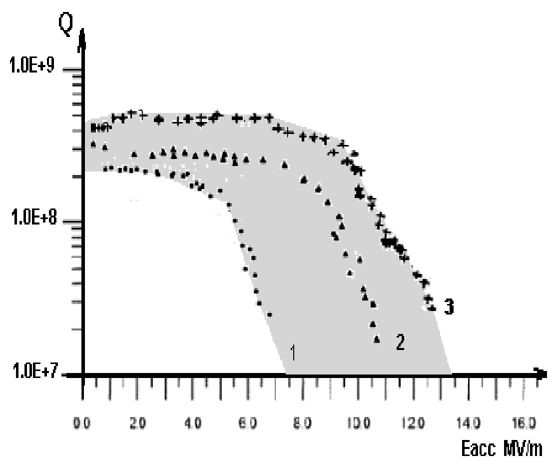


Fig.11. Dependence for Q =f(E acc) of the SVAAP-shape cavity (1,3) for 3 GHz, 2-for 2.45 GHz and TJNAF-shape cavity (5) for 1.3 GHz.

It is necessary to note that the results of the SCC investigation at 3 GHz carried out by us during the recent 7 years are located between the curves 1 and 3 on the hatched space. The obtained results are to a certain extent lower that the results for SCC at 1.3-1.5 GHz. and it can explain by technological difficulties at use magnetron sputtering (axial) because of the small sizes. We hope, that use of new setup for complex magnetron sputtering (axial and planar) will allow us to improve this situation. As opportunities of improvement of technology of manufacturing, processing and assembly of super-conducting cavities, and, hence, are clear to us ways of increase of accelerating fields for project SVAAP we have chosen quite achievable size of 12 MV/m which used in calculations of dynamics of particles and geometry of a superconducting accelerating cavity.

Results of research have shown perceptivity of the technology developed in the Federate Problem Lab for Technology and Study SC Cavities at the Institute for High Energy Physics.

6. ACKNOWLEDGEMENTS

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