THE INFLUENCE OF THE INJECTION ENERGY ON THE ACCELERATION RF STRUCTURE GEOMETRY AND THE BEAM DYNAMICS OF SVAAP

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Abstract

At the Federate Problem Lab for Technology and Study of Superconducting Cavities at IHEP the project of the Superconducting Vertical Accelerator for Applied Purposes (SVAAP) is under developing. In this report the accelerator topological scheme is given and the main technological systems are described. The particular attention is paid to the choice of geometry and superconducting RF cavity technology. The influence of injection energy in the range of 40-250 keV on accelerating RF structure geometry and technology adaptability to manufacture is shown. The electron beam dynamics for horizontal and vertical accelerator channels, including beam phase portraits in different accelerator cross-sections, emittance, acceptance, particles trajectories etc. On the base of these investigations the injection energy and geometry of accelerating structure of 14 cells on the frequency 3 GHz, which provides the beam energy 5-7 MeV, has been chosen. The manufacturing technology of RF structure elements on the base of niobium or High Tc, sputtered on the copper shells, is tested. It was decided to use the galvanoplastical formation and magnetron sputtering methods in order to manufacture superconducting RF structure.

1. INTRODUCTION

The development of the new resource-saving technologies for SC cavities of CM-band is carried out at our lab since 1993 [1]. The technology of SC cavities on the base of niobium films and High T_c films sputtered on the copper shells of complicated geometry with TESLA-shape attracts the attention of accelerator technique specialists due to its adaptability to manufacture and low prices.

This kind of technology is used in the project of Demonstration Model of the Superconducting Electron Linac. The project realisation is carried out by the Institute of Nuclear Physics at the Moscow State University, Joint Institute for Nuclear Researches (Dubna), Institute for High Energy Physics (Protvino) and Moscow Radiotechnical Institute [2]. Moreover, this technology was used in the project of SC linear electron accelerator on the energy 5 MeV with beam current 10 µA for fundamental researches under the High T_c

ceramics radiation. This project is developed within the bounds of agreement with Atomic Ministry of Russian Federation together with the department «Electrophysical Facilities and Accelerators» of Moscow Engineering and Physical Institute [3].

2. SCHEMATIC VIEW OF SVAAP

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

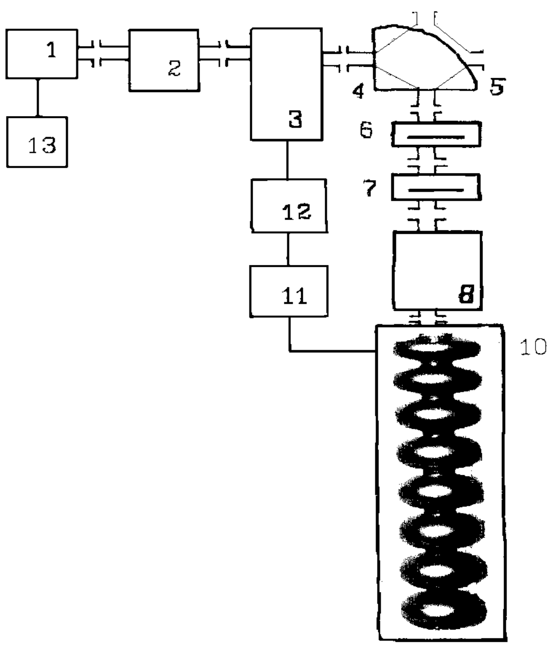

Fig. 1. The topological scheme of SVAAP: 1 - injector, 2 - electron-optical focusing system, 3 - prismatic chopper cavity, 4 - collimating slot, 5 - bending magnet, 6, 7 - collimating slots, 8 - electrostatic lens, 9 - SC accelerating cavity, 10 - cryostat, 11, 12 - RF feed system of SC cavity and chopper cavity.

The injector (1) generates continuous electron beam up to 2 mA beam current. Elements (2...8) create the preliminary beam forming system. The beam transportation from injector and its focusing in front of the chopper is realised by the special electron-optical system (2).

After the chopper cavity the part of beam passed through the slot is 90 grades is bent by the bending magnet (5) and drops onto the collimating slot (6). Electron-optical system matches the beam emmittance to the accelerator beam channel transverse acceptance.

At the accelerator end there is a cryostat in vertical position (10) with the superconducting cavity (SCC) inside it (9). The accelerating and chopper cavities are electrically coupled through their feeding and phasing systems (11 - 12).

The main accelerator systems were described in [3, 4]. In this report special attention has been given to the accelerating RF structure: its technology and geometry.

3. THE GEOMETRY CHOICE FOR ACCELERATING RF STRUCTURE

The accelerating cavity form has the TESLA-shape. The determination of SC cavity geometrical sizes and its basic electrodynamical characteristics has been carried out on the base of the particles movement computer simulation. The preliminary variant has been chosen as a result of this study. The SC accelerating RF structure was calculated for different injection energies in the range of 50÷250 keV, because the SC accelerating structure with the injection energy 40 keV [3] chosen earlier was found more difficult to manufacture due to very narrow first three cavity cells. On the Figs. 2 and 3 the cavity cells geometry for 50 keV and 250 keV respectively is shown.

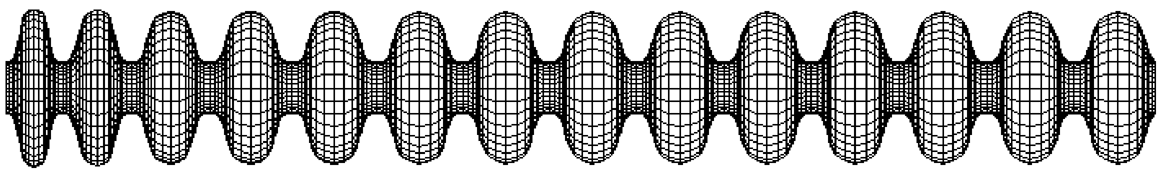

Fig. 2. The accelerating RF structure geometry of 14 cells at the injection energy 50 keV.

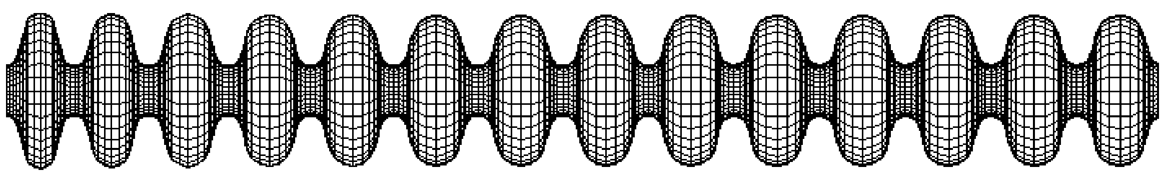

Fig. 3. The accelerating RF structure geometry of 14 cells at the injection energy 250 keV.

The first three cavity cells form the beam buncher system and the rest form accelerating cells. The SVAAP accelerating structure geometry at the energies 50 and 250 keV respectively is shown on the Figs. 2 and 3.

The obtained sizes correspond to the required electromagnetic field distribution on the cavity axis.

The size increasing for the cavity cells on 51.4% at 250 keV allows to use the developed SC cavity technology on the base of film materials.

4. THE DEVELOPMENT OF THE TESLA-SHAPE ACCELERATING STRUCTURE TECHNOLOGY OF 14 CELLS.

The galvanoplastical formation method developed at our lab [1, 5] doesn't require the high price equipment. If one has the very pure electrolytes and very clean rooms it is possible to manufacture the copper shells of SC cavity like those which are made from oxide-free copper. The SC films are obtained by means of axial magnetron sputtering. On the Fig. 4 the 14 cells copper cavity is given.

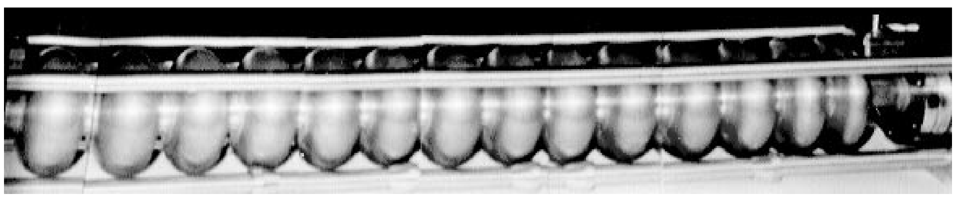

Fig. 4. The view of SC RF cavity structure.

The main difficulty in the manufacturing such kind of structure with many cells lays in the obtaining the uniform thickness of copper layer and SC films. Now at our lab the new technology of many cells SC cavity manufacturing is developed with use of planar magnetron sputtering instead of axial magnetron one.

5. THE ELECTRON BEAM DYNAMICS CALCULATION IN VERTICAL CHANNEL OF ACCELERATOR

As has been mentioned earlier the first accelerator section is the beam buncher with variable phase velocity. At the beginning of this section the beam bunch is formed and the energy is increased. The other sections with β = 1.0 in general are identical and they serve for relativistic electrons acceleration up to final energy.

In order to provide the maximal acceptance coefficient the accelerating field amplitude should not be very big at the beginning and then should increase in length (Fig. 5). This requirements for the accelerating field are obtained on the base of the results of the geometry sizes simulation given earlier.

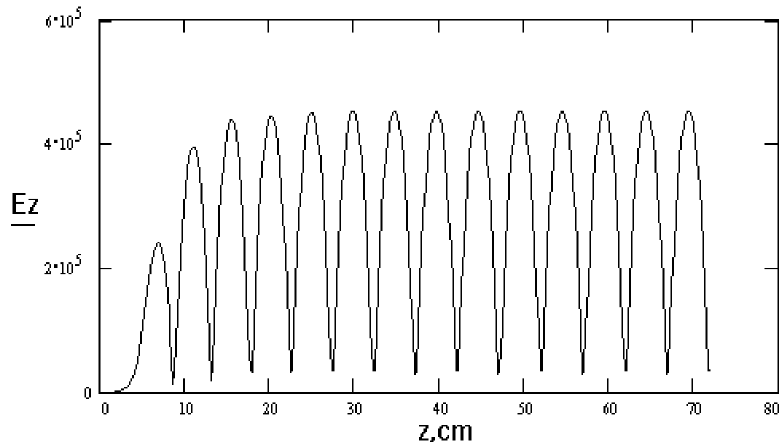

Fig. 5. The accelerating field amplitude along the cavity axis.

The computer analysis of oscillation characteristics without field variation on the azimuth has been carried out with the use of the URMEL-T and PRUD programs. This program complex is intended for the calculation of azimuth-uniform modes in the axial-symmetrical cavities and periodic structures and also the critical frequencies in longitudinal-uniform guides.

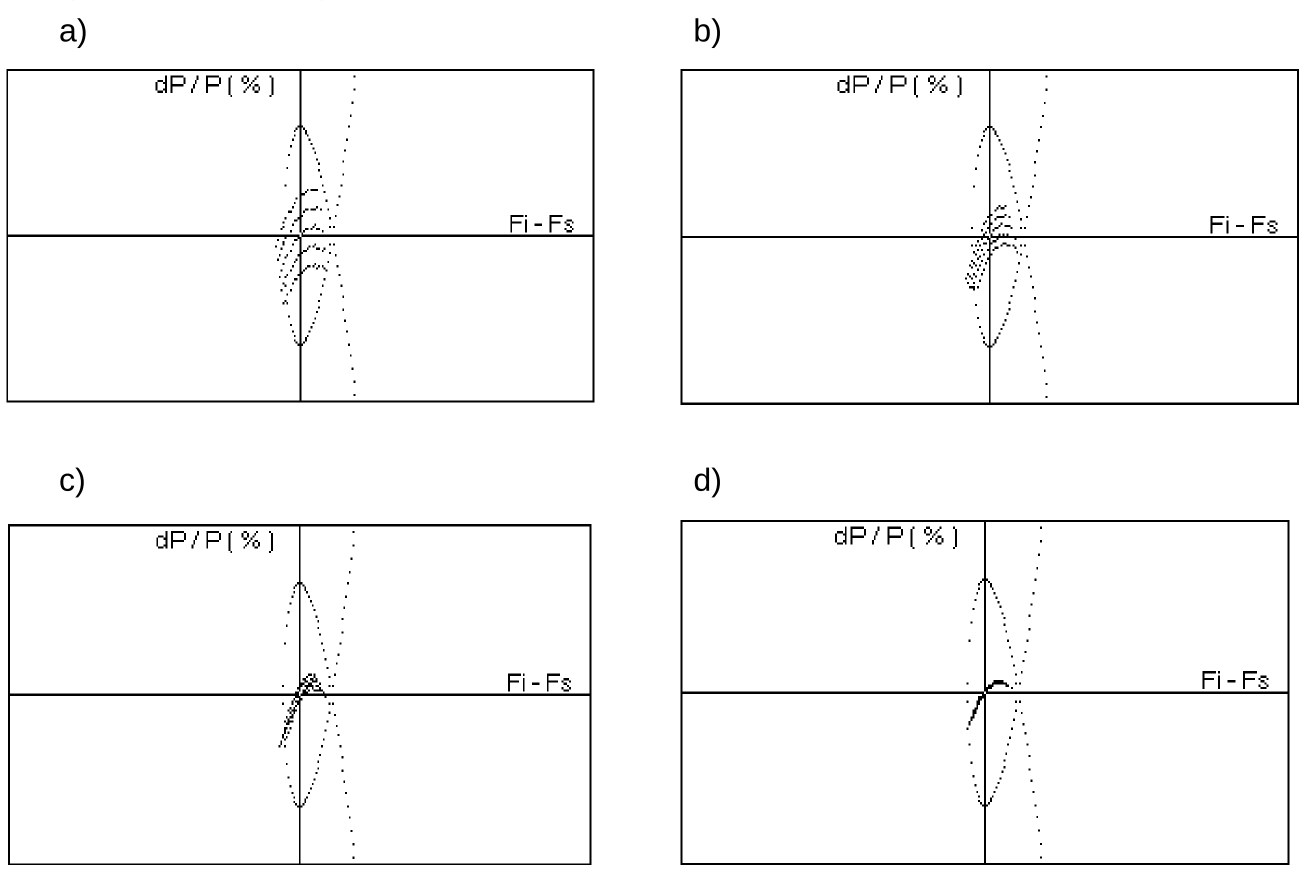

Fig. 6. The beam longitudinal phase portrait at the (dP/P, $\varphi-\varphi_s$) - plane on the background of separatrice for injection energy 250 keV: a) - cell No 1, E=0.389 MeV, L=0.039 m; b) - cell No 3, E=0.636 MeV, L=0.082 m; c) - cell No 5, E=1.373 MeV, L=0.176 m; d) - cell No 14, E=5.262 MeV, L=0.669 m.

On the Fig. 6 (a-d) one can see the results of the longitudinal motion simulation in different cavity cells at the injection energy 250 keV. The pictures confirm that in the first 3 cells (Fig. 6 a and b) the beam bunching occurs. And at the further cells the beam is accelerated up to 5.262 MeV with the beam parameters improving.

The phase ellipse at the output of accelerating structure and the beam trajectories are shown at the Fig. 7 a) and b) respectively.

a) b)

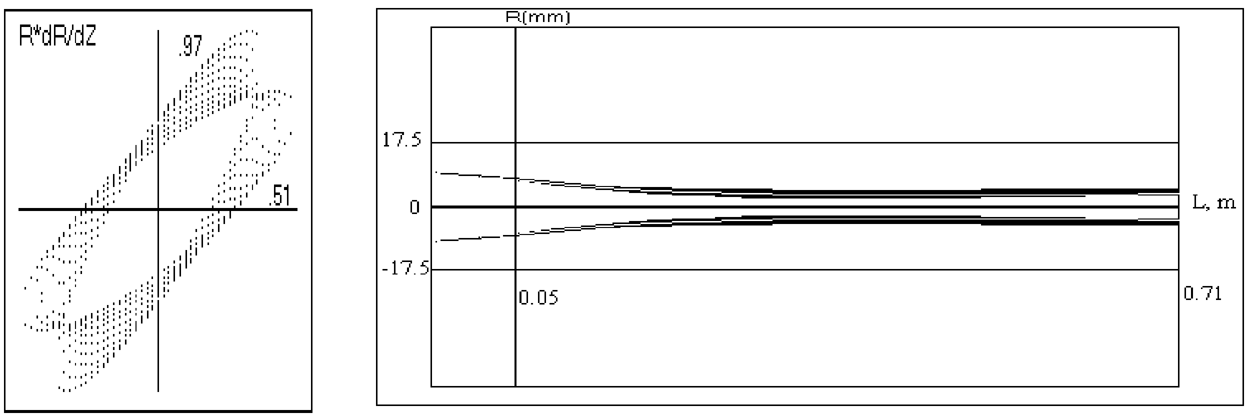

Fig. 7. The transverse dynamic simulation for SVAAP: a) - phase ellipse on the (R, R')-plane; b) - the beam trajectories along focusing channel.

For the longitudinal and transverse beam motion simulation the program LIDOS (Linac's Ion Dynamics Optimisation and Simulation), modified for the case of SC electron linear accelerator [6].

6. CONCLUSION

The project SVAAP is under design now. It is necessary to study the accelerator stability diagram and also to develop the horizontal channel and calculate the parameters of the bending magnet. The SC accelerating cavity technology development on the base of planar magnetron sputtering is also continued.

References

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