THE SUPERCONDUCTING ACCELERATING STRUCTURE GEOMETRY AND BEAM DYNAMICS OF SVAAP

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Abstract

In this report the results of the further SVAAP (Superconducting Vertical Accelerator for Applied Purposes) Project development are presented. It is given the RF superconducting structure geometry choice and also to the electron beam dynamics simulation with the use of program products URMEL-T, PRUD, LIDOS, PARMELA. The recent information concerning the RF accelerating structure technology on the base of the film material sputtered on the copper shells is given in this report. The accelerating RF structure of 14 cells is to be manufactured by the means of the galvanoplastic forming technique and the planar magnetron sputtering.

1 INTRODUCTION

At the Federal Problem Lab of Technology and study of the Superconducting Cavities the SVAAP accelerator project is under developing. The accelerator will be used for the radiation of the High Tc ceramics in order to stabilize its stoichiometry composition.

Originally the project was simulated for the energy of 5 MeV with the beam current 10 μA at the injection energy 40 keV [1, 2].

Afterwards the injection energy was increased up to 250 keV [3] due to the technological difficulties in the manufacturing of the superconducting accelerating RF-cavity with the frequency of 3GHz on the base of superconducting films, sputtered on the weldless copper shells. Moreover, it was necessary to increase the output energy of the beam up to 7.5 MeV in the continuous regime.

2 SVAAP SCHEMATIC VIEW

Injector (1) consists of electron gun with 40 kV and electrostatic column and generates continuous electron beam with 250 keV nominal energy and up to 2 mA beam current. Elements (2 ...9) create the preliminary beam forming system. The beam transportation from injector and its focusing in front of the chopper is realized by solenoid lens (2). After the chopper cavity (3) the part of beam passed through the slot (4) is bend on 90° by the bending magnet (5) and drops onto the collimating slots (6,7). Two solenoid lenses (8, 9)match 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 (11).

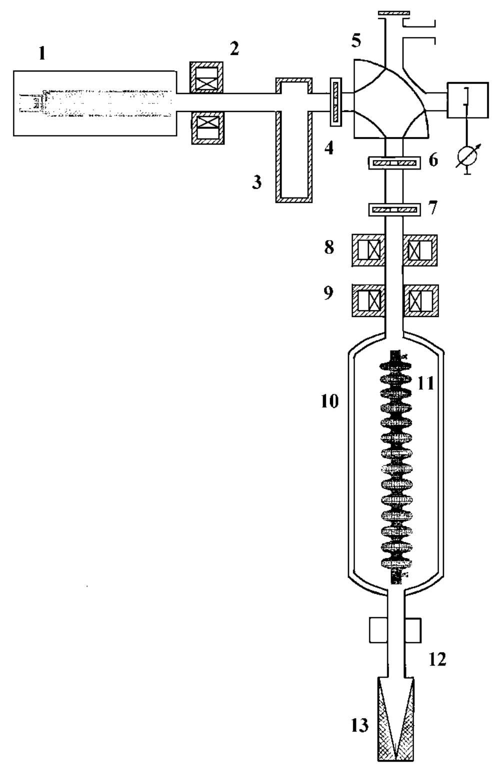

Figure 1. Schematic view of SVAAP:
1 - electron gun with electrostatic column; 2 – solenoid; 3 – prismatic chopper resonator; 4 – collimating slot; 5 – bending magnet; 6 ,7 – collimating slots; 8,9 – solenoid lenses; 10 – cryostat; 11 - SC cavity; 12 - beam diagnostic system; 13 – collector.

The project SVAAP authors took part in the project "Demonstration model of the SC Electron Linac on the energy 5 MeV " carried out by the Institute of Nuclear Physics of the Moscow State University, Joint Institute for Nuclear Researches, Institute for High Energy Physics and Moscow Radiotechnical Institute [2]. Taking in to account this work and new requirements to SVAAP accelerator on the energy 7.5 MeV the detailed analysis of injection channel of SVAAP is given in the paper [4] presented on this conference.

3 THE GEOMETRY CHOICE FOR ACCELERATING RF STRUCTURE

For SC accelerating RF structure geometry optimization the following were taken into account:

- the influence of injection energy on the geometry and beam dynamics;
- the influence of accelerating gap length on the over-voltage coefficient of magnet and electric field and beam dynamics;
- the manufacture technology of SC accelerating RF structure on the base of film materials, sputtered on the weldless copper shells.

During the development of technology of accelerating RF structure with injection energy of 40-50 keV [1, 2] we faced the difficulties due to the small gap dimensions and distances between cells for the first 3 cells.

After the increasing of injection energy up to 250 keV the cavity cells dimension increased on 51.4% [3] and that allowed us to use the technology of SC cavity on the base of SC films, sputtered on the weldless copper shells.

The optimization of geometric sizes of single cell is carried out on the base of numerical analysis of oscillation characteristics for different relation of accelerating gap dimension to the cell period. Studying the electrodynamical characteristics this parameter is varied from 0.1 to 0.9, the other parameters were changed so that the frequency 3 GHz remained constant for the main oscillation types.

On the Fig. 2 the dependence of coefficients overvoltage of electric (a) and magnet (b) field from the Gap/Period parameter is shown. The optimum value of parameter Gap/Period is 0.78.

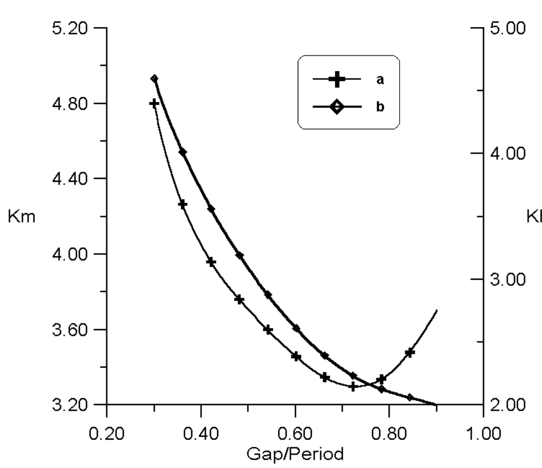

Figure 2. The dependence of overvoltage coefficients of electric field (a) and magnetic field (b) from the Gap/Period parameter.

As a result of geometry choice, injection energy and Gap/Period parameter the optimal configuration of accelerating RF structure were obtained. This configuration provides the required beam dynamics.

4. ELECTRON BEAM DYNAMICS SIMULATION

The beam dynamics simulation for SVAAP was carried out for injection channel including 3 solenoid lenses and bending magnet [5] and accelerating structure in the vertical cryostat.

On the Fig. 3 one can see the beam envelope along the injection channel for X and Y planes. The lens forces and bending magnet field were chosen according to focusing channel optimization procedure. The results of these simulations are presented in the paper [4].

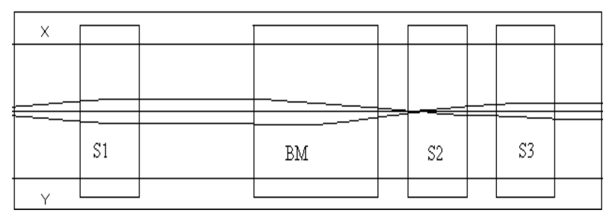

Figure 3. Electron beam trajectories along the injection channel (S1, S2, S3 – solenoid lenses, BM – bending magnet).

The accelerating field amplitude distribution is calculated through the cavity channel of 14 cells in which the beam is accelerated up to 7.5 MeV. The normalized dependence of electric field E_z along the accelerating structure is given on the Fig. 4.

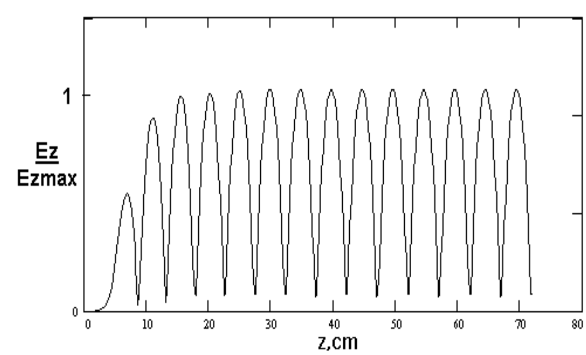

Figure 4. The accelerating field distribution along the SC accelerating RF structure.

The accelerating cavity cells are divided on 2 types: in the first 3 cells the particles are grouped and accelerated up to 0.7 MeV, the other 11 cells accelerate the beam up to nominal value 7.5 MeV. Fig.5 shows the results of longitudinal beam motion simulation at the output of the 14th accelerating cavity cell for the injection energy of 250 keV and optimal Gap/Period parameter of 0.78.

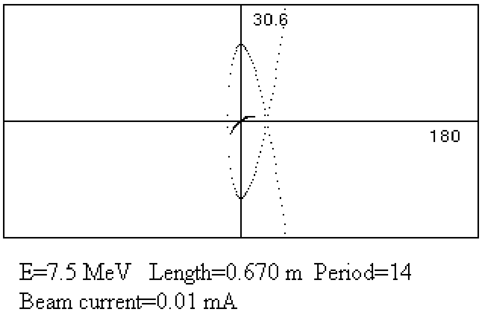

Figure 5. Beam phase portrait at the output of SC accelerating RF structure as given by LIDOS simulation code.

The accelerating RF structure parameters obtained from beam dynamics simulation are shown in the table 1.

Table 1. Accelerator structure parameters.

N	Parameter		Value
1	Electron maximum output energy	MeV	7.5
2	20 grade bunch energy spread	%	0.5
3	Injection energy	keV	250
4	Accelerated particle current	µA	10
5	Working frequency	GHz	3
6	Accelerating structure length	mm	670
7	Accelerating field	MV/m	12
8	Cavity cells number		14

5. RF ACCELERATING STRUCTURE TECHNOLOGY

Project authors were intended to manufacture the SC accelerating RF structure using the low cost technology. The complicated configuration of accelerating RF structure of 14 cell and requirement to manufacture this structure without welding by electron beam in vacuum caused the using of galvanoplastic copper shells forming technology which is developed in our Lab since 1993 [6], and also the axial magnetron sputtering technology and planar magnetron sputtering of film materials.

The our equipment for magnetron sputtering allows to sputter SC films on the structures of length up to 720 mm.

Together with MEPI we develop the planar magnetron sputtering technology. The equipment allows to sputter the films on the structures about 500 mm long.

On the Fig. 6 the accelerating structure with the optimal geometry (a) and the structure of 14 cells developed by described earlier technology.

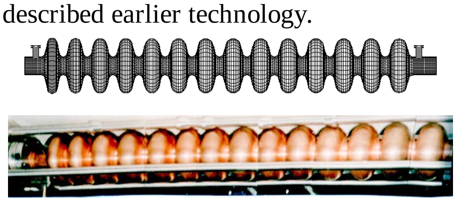

Figure 6. SC Accelerating RF structure.

Authors hope to reach in the future the accelerating field of 12 MV/m in such a structure.

2 CONCLUSION

So, on the base of beam dynamics simulation the optimum structure geometry was chosen for the SVAAP accelerator, the accelerated RF structure manufactured on the base of Nb/cu by means of galvanoplastic technique and magnetron sputtering.

The works on SC accelerating RF structure technology on the base niobium films, H2B allow films and High Tc material films are carried out.

We have goal to study technological possibilities of manufacturing the superconducting RF cavities based on High Tc material spread on the copper surface by means of magnetron sputtering.

High ceramics for this technology is developed jointly of our lab. All Russian Research Institute for Chemical Technology and the State Enterprise “Polymetal” Moscow Plant [7].

7 REFERENCES

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