Demonstration Model of the Superconducting Electron Linac with the Energy 1-5 MeV.

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Abstract

Status of the demonstration model of continuous wave superconducting electron linac with the energy 1-5 MeV is described. The accelerator consists of 50 keV long focus electron gun, chopper, and nine cells graded β superconducting cavity placed into the cryostat. π -mode accelerator structure optimised for effective capture of 50 keV electrons at different levels of accelerating field is niobium-sputtered copper cavity made by galvanoplastic technique. The accelerator has been assembled at Dubna, beam optic and chopper resonator tuning, low temperature tests of copper made cavity are in progress.

1. Introduction

The aim of the present continuous wave (CW) superconducting (SC) linac project, which started in 1991 is twofold.

First - demonstration of feasibility of a SC accelerator structure based on the weldless technique.

Second - construction of a prototype of CW SC linac for applied researches and medicine with a good beam quality which requires much less RF power and can be much shorter than the normal conducting CW linac with the same energy. The schematic view of accelerator is shown on the Fig. 1 and the main project parameters are given in the Table I.

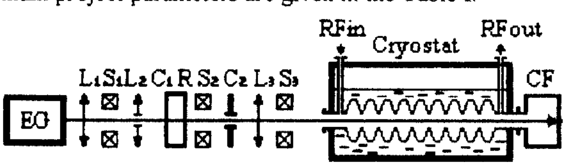

Fig. 1. Schematic view of CW SC linac. EG - electron gun; L - solenoidal magnetic lens; S - steering coil; C - collimator; CF - Faraday cap.

Table I. The main project parameters of CW SC linac.

Injection energy	50 keV
Output energy	1 - 5 MeV
Operating frequency	2973 MHz
Klystron power	50 W
Accelerated beam current	40 - 8 mkA

Accelerator consists of the next main systems: long focus 50 keV electron gun, chopper, focusing and steering coils and accelerator cavity placed into the cryostat. Below the description of accelerator systems and present status of project are given.

2. Electron gun and chopper

Long focus 50 keV electron gun similar to that one developed for Moscow State University CW RTM project [1] with the normalised beam emittance about 2 mmxmrad is used. Maximum beam current which can be obtained with the 3 mm diameter tungsten impregnated cathode is limited by power of high voltage supply to 2 mA.

Lens L1 and collimator C1 are used for matching electron gun emittance with accelerator acceptance.

To avoid beam losses in accelerator structure during capture and acceleration of 50 keV electrons chopper system consisting of chopper resonator and collimator was elaborated. Chopper ensures about 9 degrees bunches preparation from continuous beam.

The principles of chopper operation are the next. Two orthogonal TM110 oscillations are exited in cylindrical chopper resonator through the coaxial connectors from two klystrons driven by the same reference RF signal. By proper tuning the resonator and choosing phases and amplitudes of the oscillations an elliptical beam pattern can be obtained at the collimator C2 placed about 0.5 m after the resonator. Collimator has a horizontal slot with the height 1 mm and width about 4 mm. Height of the slot is close to the beam diameter at the position of collimator with the chopper resonator switched off. To get phase length of bunches about 9 degrees after the chopper, klystrons power must be adjusted so as to have length of the elliptical beam path at the collimator about 40 mm. Inclination in horizontal plane to the axis of 1/40 part of the beam passed through collimator is compensated by steering coil placed immediately after chopper resonator. Adopted chopper scheme makes it possible to get electron bunches with the mean current up to 50 mkA and with small growth of transverse emittance.

3. Accelerator Structure Optimisation

The next requirements were taken into account in the process of accelerator structure type choice and its optimisation.

1. The form of the accelerating cells must ensure the absence of multipacting.

2. Fifty keV electrons must be captured and accelerated to the energy from 1 to 5 MeV at different accelerating gradient without focusing solenoid superimposed on the cavity. The possible values of accelerating gradients were considered to be from 5 to 15 MeV/m (for relativistic beam in $\beta = 1$ cells)

As a prototype π-mode accelerator structure optimised taking into account multipacting [2] was taken. The accelerating cell dimensions were scaled to operation frequency 2973 MHz. To ensure 50 keV electrons capture and acceleration to 1 - 5 MeV at different accelerating gradients cavity was constructed as 9 cells graded β section. The values of β of different cells chosen as a result of beam dynamics simulation with "RTMTRACE" [3] code are the next: 0.7; 0.8; 0.9; 0.95; 0.98; 1.0; 1.0; 1.0; 1.0. Though being non-optimal from the point of view of energy gain and energy spread for low and high accelerating gradients this values enable to accelerate beam without losses by proper choice of accelerating field phase for the gradients from 5 to 15 MeV/m. Cells with $\beta < 1$ differ from $\beta = 1$ cell by their length and external radii which were chosen to get proper distribution of π-mode on-axis electric field at operating frequency. Maximum values of the on-axis electric field were taken to be equal at the centres of the cells. So on-axis voltages decrease approximately linearly with the β. Procedure of cavity tuning at π-wave was modelled using "PRUD-0" code [4] and field sensitivity factors to changes of different cavity dimensions have been calculated.

4. The Structure Fabrication Technology and Tuning Procedure

The weldless SC structure fabrication technology developed at Institute of High Energy Physics, Protvino, [5] consists of the next steps:

- the frame fabrication;
- galvanoplastic shaping of the SC structure's from copper;
- removing of the frame;
- coating of inner surface by niobium film.

The frame was fabricated by numerically controlled lathe with the accuracy about some mkm. The frame fabrication includes such procedures as burning, normalisation and other technique for stress annealing.

The galvanoplastic shaping of cavities makes it possible to avoid surface irregularities caused by welding. Shaping regime is repeatedly changed with the aid of stable controlled power source as the copper coating thickness growth. The final thickness of copper structure walls is about 5 mm. Mechanical and thermal properties of copper produced by this method correspond to oxygen free copper properties which is usually used for RF cavities fabrication.

A special facility for a SC coating deposition on the inner surface of copper cavity was developed which consists of a vacuum chamber holding a heater, temperature probes, a thermal shield and a cooled cathode. The operational gas filling-in system consisting of the leakage spring, the argon purifying device and the compressed gas cylinder is attached to the vacuum chamber. The coating by niobium of the copper structure placed to the vacuum chamber is carried out in pure argon by means of abnormal DC smouldering discharge.

Fig. 2 shows copper cavity made by the galvanoplastic technique in the framework of the present project. It includes also ports for input RF power and output of control signal.

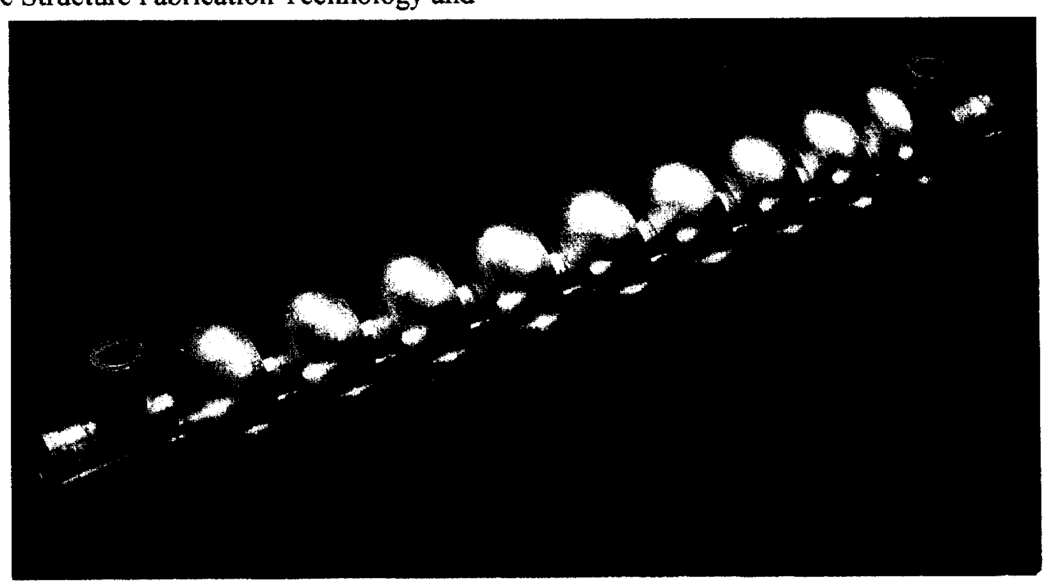

Fig. 2 Nine cells graded β copper cavity made by electroplating technique.

Copper cavity parameters before niobium film sputtering was measured and cavity was tuned using methods well developed at the Moscow Radiotechnical Institute [5]. The difference between measured resonance frequency of the π-mode for copper cavity and frequency calculated by "PRUD-0" appeared to be within accuracy of fabrication and calculations. Required on-axis electric field distribution was obtained by small walls deformation with specially constructed tools

5. Cryostat

The cryostat characteristics are given in Table 2.

Table 2. The cryostat characteristics.

Length	1280 mm
Width	650 mm
Height	1735 mm
Helium vessel volume	160 l
Helium screen basin volume	7.5 l
Nitrogen screen basin volume	10 l
Operational temperature	1.7 - 4.2 K

The view of cryostat installed in accelerator facility is shown in Fig. 3.

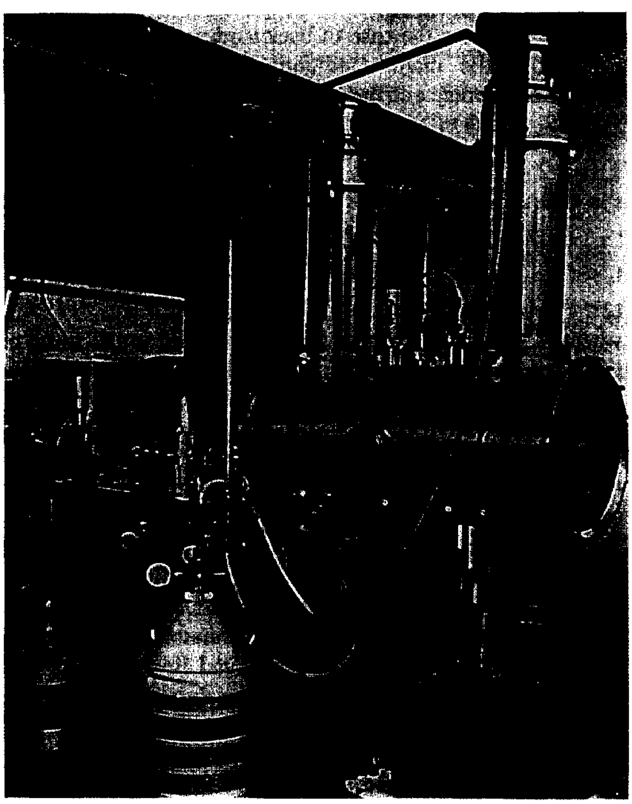

Fig. 3. The view of cryostat.

6. Conclusion

Up to the present moment all main components of accelerator have been fabricated and accelerator was assembled at Joint Institute for Nuclear Researches, Dubna. Development of control systems, beam optic tuning of 50 keV beam and cold tests of copper cavity are in progress.

7. References

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