THE INJECTION SYSTEM CALCULATION FOR SVAAP

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Abstract

The injection system for the Superconducting Vertical Accelerator for Applied Purposes (SVAAP) calculation results are presented in this report. The injection system includes the electron gun of 250 keV, chopper, bending magnet and focusing elements. The injection channel characteristics were obtained by using the PARMELA, LIDOS and SUPERFISH analytical methods. Albeit still preliminary the results show the good correlation between different programs. The main attention has been given to the calculation of the bending magnet parameters which construction has been chosen from this simulation.

1 INTRODUCTION

The SVAAP project was originally developed for the injection energy of 40 keV [1]. Then due to the technological requirements for superconducting accelerating RF structure of 14 cells with the working frequency of 3 GHz it was necessary to increase the injection energy up to 250 keV [2] in order to obtain optimal structure geometry. The injection channel elements parameters were also changed according to these requirements.

2 GENERAL DESCRIPTION OF SVAAP INJECTION CHANNEL

The schematic view of SVAAP accelerator is given in the paper presented on this conference [3]. Accelerator is divided on two parts - horizontal and vertical. Horizontal part of accelerator contains injector, optical system, chopper cavity, collimating slot and bending magnet. Vertical part includes collimating slots, optical system and cryostat with SC accelerating RF structure of 14 cells with the output energy of 7.5 MeV.

2.1 Injector complex

SVAAP injector contains the electron gun and electrostatic column. The electron gun provides continuos electron beam with the energy of 40 keV and transverse emittance of 6 mm×mrad. The electron gun is planned to be with long focus, the gun crossover location will be changed in the range of 1 m. The relatively low energy is preferable because of simple construction and the increasing of work stability and feeding system of electron gun.

In order to accelerate the beam up to required energy of 250 keV it was proposed to use the electrostatic column similar to that of TESLA Test Facility Injector [4].

Moscow Radiotechnical Institute and Federate Problem Lab at IHEP now develop both electron gun and electrostatic column.

The electron gun and column are supposed to be fed by two independent power supplies for 40 kV and 300 kV respectively. The technical characteristics of the power supplies for the electron gun on 40 keV are presented in the table 1. At the electrostatic column output the beam current will be approximately 2 mA in order to obtain the 10 μA beam current at the output of SC accelerating RF structure.

Table 1. Technical characteristics of power supply for electron gun on the energy of 40 keV.

N	Technical characteristics	Values
1	Sizes, mm	160×220×400
2	Working power, W	30
3	Output voltage, kV	40
4	Load current, mA	0.5
5	Output voltage pulsations, %	0.1

2.2 Beam forming system

The beam forming system was chosen on the base of beam dynamic calculations for 250 keV beam injection energy. It consists of 3 focusing lenses, chopper cavity, bending magnet and 3 collimators. In the previous injection channel scheme the electrostatic lenses were chosen as focusing elements, but as a result of injection energy increasing they were replaced by solenoid lenses because of high potential (about 50 kV) on electrostatic lens electrode necessary for this energy. In the process of operation tuning of accelerator it is planned to use also the beam diagnostic equipment.

After the injector the electron beam has the diameter of approximately 1 mm and divergence of 10 mrad and is focused by solenoid lens before the chopper cavity. The chopper cavity is intended to form the beam bunches of 20° phase length from the continuos electron beam of 2 mA in order to capture practically all the particles and accelerate without beam current losses.

The chopper cavity design and fed system were described in [1]. The main parameters of prismatic chopper cavity are shown in table 2.

Table 2. Chopper cavity main parameters.

N	Parameter	Value
1	Wave type	H101
2	Walls length, mm	76
3	Beam divergence angle, rad	0.2
4	Loss power, kW	0.85
5	Electrical field in the cavity center, kV/cm	20
6	Quality factor	1.04×10^4

Before the chopper the beam has the azimuth symmetry, after the chopper the axial symmetry is spoiled and the 20° bunches are formed from the low part of the beam.

Then the main part of the beam drops on the vertical collimating slot situated just before the bending magnet, parallel to the X-axis. The distance between the slot and bending magnet is about 6 mm. All the collimating slots have the width along Y-axis 2.5 mm and along the Z-axis about 5 mm. The rest part of the beam passes through the bending magnet, turns on 90° and drops on to the horizontal collimating slot in the vertical part of the channel. In the calculation of injection channel the magnet field is supposed to be of 0.005 T, poles dimensions 200 mm and gap of 25 mm [5].

The bending magnet works also as drift tube and allows to center the beam with vertical channel axis. The collimating slots in vertical part of the channel are situated on 65 and 130 mm from the bending magnet respectively. The second horizontal collimating slot can be replaced by beam position monitor during the accelerator tuning. The main part of the particle losses is concentrated on these slots.

Two solenoid lenses in vertical channel match the beam emittance with the SC accelerating RF structure channel.

The Faraday cylinder will be placed between collimating slot and first of the two solenoids in order to measure the bunch length before the SC accelerating RF structure.

The bending magnet vacuum chamber with 4 windows will give the possibility to investigate the work of all the elements in horizontal part of accelerator in the independent regime, to carry out the optical adjustment of accelerating cavity, solenoid lenses and collimating slots and also to organize the vacuum pumping of beam forming elements.

3 FOCUSING CHANNEL SIMULATION

On the Fig. 1 the schematic diagram of focusing channel is shown. In beam trajectories simulations the 3 solenoid lenses and bending magnet were taken into account. The input parameters for injection channel are presented in the table 3.

The focusing element parameters were chosen accordingly to the beam dynamic of injection channel and optimization procedure.

The Fig. 2 presents the graphical results of this simulation. X- and Y- beam envelopes are indicated on the backgrounds of the channel focusing elements and the aperture (solid horizontal lines).

The optimization procedure consisted in changing the focusing element fields so that the mismatching factors T_x and T_y were close in value to the preset ones. In our case the T_x and T_y were obtained on the base of this optimization equal to 1.84 and 1.79 respectively.

Table 3. Injection channel parameters

N	Parameter	Value
1	Injection energy, MeV	250
2	Beam emittance, mm×mrad	6
3	Aperture, m	0.02
4	Beam current, A	0.001
5	Total channel length, m	1.323
6	The distances along the channel, m	
	1-1	0.10
	2-2	0.17
	3-3	0.343
	4-4	0.10
	5-5	0.25

The output beam phase portraits are visually compared with the required ones as shown on the Fig. 2 (upper 3 graphics) during the optimization procedure. These phase portraits are presented for (X,X')-plane, (Y,Y')-plane and (X,Y)-plane and show that the beam emittance (inner ellipse) is matched with accelerating structure channel acceptance (external ellipse).

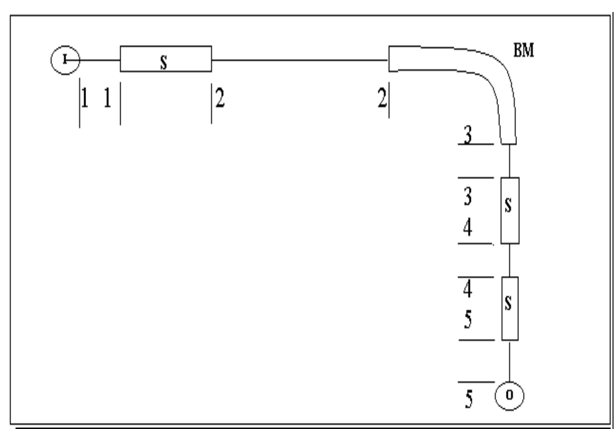

Figure 1. Schematic view of SVAAP focusing channel (S - solenoid lenses, BM - bending magnet, I - input point, O - output point, 1-1…5-5 – the distances (see table 3)).

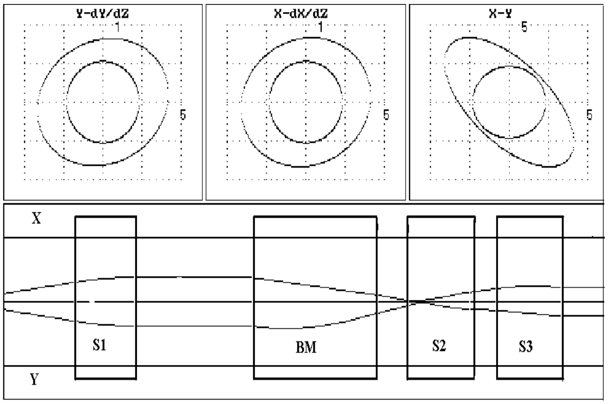

Figure 2. Phase ellipses and beam envelopes of SVAAP injection channel as given by LIDOS simulation code.

The focusing elements main parameters calculated during optimization procedure are given in the table 3.

Table 3. Solenoid lenses parameters

N	Solenoid lens	Length, m	Field, T
1	S1	0.12	0.0082
2	S2	0.12	-0.0181
3	S3	0.12	0.0084

In the simulation of SVAAP injection channel focusing elements the LIDOS program code [6] for the optimization and beam focusing was used.

4 CONCLUSION

At the present time the calculation of injection channel for Superconducting Vertical Accelerator for Applied Purposes is finished in general. The power supplies for electron gun on the energy of 40 keV are developed and manufactured. The electron gun on the energy of 40 keV and electrostatic column on the energy of 250 keV is now developed together with Moscow Radiotechnical Institute.

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