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DESIGN SYUDY OF THE SPIRAL BUNCHER CAVITIES FOR THE HIGH CURRENT INJECTOR AT IUAC

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Abstract

Two high-energy beam transport (HEBT) cavities are designed to provide the longitudinal beam bunching between drift tube linac and superconducting super-buncher of the superconducting linear (SC-LINAC) accelerator. A 48.5 MHz frequency was chosen for its broad acceptance of bunch width over 97 MHz. The spiral-type cavities were chosen over standard quarter wave-type geometry due to its higher shunt impedance. The TRACE-3D ion-optical codes have been used to determine the bunching voltage of the cavities. The two-gap RF cavity requires 80 kV/gap to provide the longitudinal beam bunching at the entrance of the superconducting super-buncher. The CST-MWS simulations were performed to design the spiral-type bunching cavities. The various parameters including shunt impedance, quality factor, average accelerating field, and total power loss were determined using CST-MWS simulations. The ratio of drift tube radius to the gap was optimized to achieve the maximum effective electric field with minimum field penetration within the gap. SolidWorks has been used to prepare a mechanical model for the fabrication.

INTRODUCTION

The Inter-University Accelerator Centre (IUAC), New Delhi is occupied with various types of accelerators in the range of a few keV to hundreds of MeV, which includes the 15 UD (unit double) Pelletron [1] accelerator and the niobium based superconducting linear accelerator operating (SC-LINAC) at 97 MHz [2]. Due to low current limitation and inability to provide a beam of noble gases of the existing system, the High Current Injector (HCI) is being built to overcome the restrictions [3]. The HCI will work as an injector to the SC-LINAC while Pelletron will work as a standalone facility. The HCI comprises a high-temperature electron cyclotron resonance (HTS-ECR) ion source, a multi-harmonic buncher that is being operated at 12.125 MHz frequency and uses a sawtooth waveform. The sawtooth wave has been designed and developed indigenously by the addition of the four harmonics at different phases and amplitude. Furthermore, the ion beam will be injected into the chopping and deflecting system [4-6] which will be capable of providing the chopped beam at various repetition rates to the experimental facilities of the IUAC. A Radio Frequency Quadrupole (RFQ) which is being operated at the 48.5 MHz frequency, the input and output energy of the RFQ is 8 keV/amu to 180 keV/amu, respectively. The output of RFQ will be injected into the medium energy beam transport (MEBT) spiral buncher cavity [7-9], which is capable of providing the longitudinal beam matching between RFQ and DTL. The MEBT spiral buncher cavity has been designed, developed, and tested indigenously. The cavity is being operated at 48.5 MHz frequency at 1 kW of input power. The voltage required to bunch the charged particles at the entrance of the DTL cavity is ~27 kV/gap. The compact diagnostic boxes are being used to measure the beam current and beam profile between the subsequent DTL cavities. The two buncher cavities are required to inject the output of the DTL into the superconducting super-buncher of the SC-LINAC. Finally, the HCI beam will be injected into the SC-LINAC for further energy boost as shown in Fig. 1.

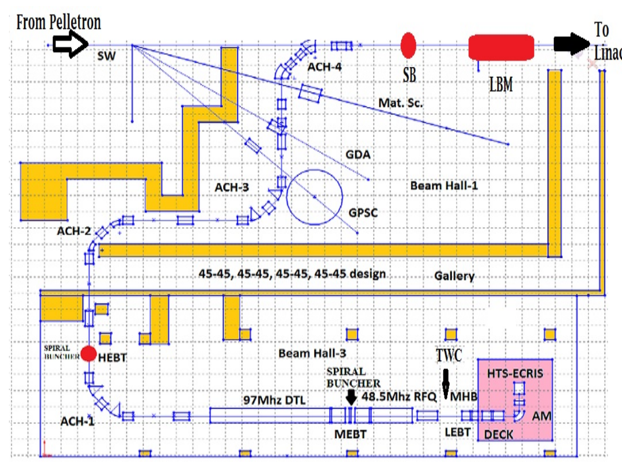

Figure 1: The pictorial layout of the high current injector accelerator.

DESIGN AND SIMULATIONS

Electrical Design

The spiral-type cavities were chosen for their high shunt impedance, compact structure, and mechanical stability. A CST MWS model has been prepared to simulate the electric field, magnetic field, and surface current inside the cavity. The endplates, stem, and central conductor have been designed of OFHC while the cylindrical cavity has been designed of copper-plated mild-steel. The cavity has been designed for the 2 kW of input power. The internal water connections have been provided to extract the heat out of it. Figure 2 represents that the electric field intensity is maximum near the end of the central conductor towards the open end. The drift tubes and RF gaps have been provided at the open end of the central conductor for the maximum beam acceleration due to maximum electric field intensity. The magnetic field intensity is maximum near the stem of the buncher cavity and minimum near the open end as

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shown in Figs. 3 and 4 demonstrates that the surface current is maximum near the stem and minimum near the open end. Therefore, the beam acceleration will take place from the open end and magnetic coupling will be provided near the stems to power the cavity.

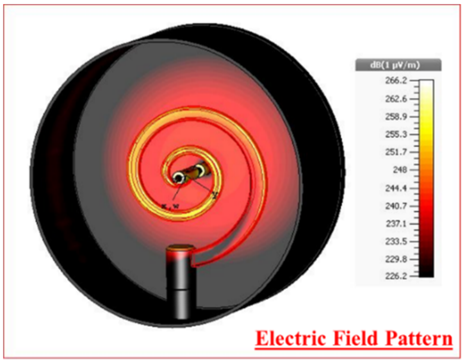

Figure 2: The electric field intensity along the spiral type central conductor.

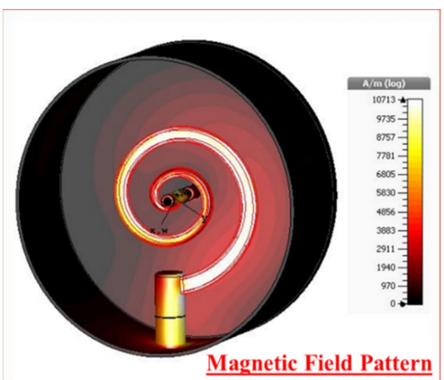

Figure 3: The magnetic field intensity along the spiral type central conductor.

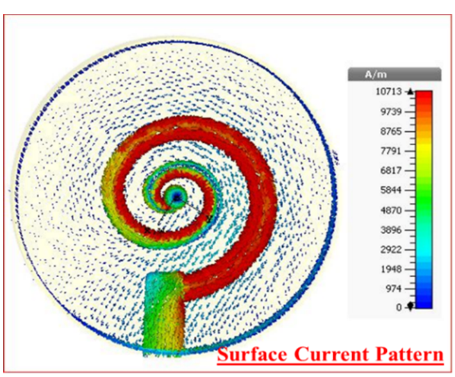

Figure 4: The surface current intensity along the spiral type central conductor.

An electric field scan was taken in the CST-MWS software to validates the design as shown in Fig. 5. The optimization of the various RF parameters was carried out by varying the physical dimension of the various components which are listed below in Table 1.

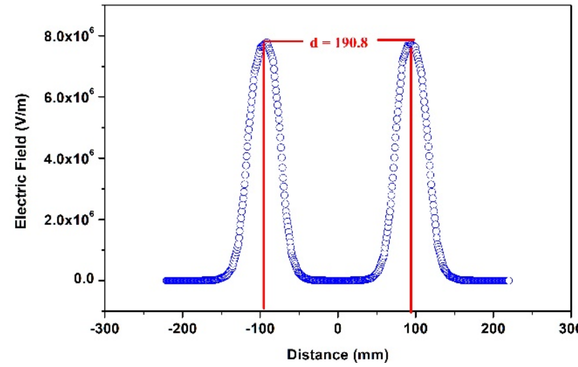

Figure 5: The electric field pattern along the beam direction of the buncher cavity.

Table 1: Simulated RF Parameters of Buncher Cavities

Frequency	48.50 MHz
βo (v/c)	0.06
d = βλ/2	190.8
Shunt Impedance	~ 13 MΩ
Quality Factor	~8000
Required Voltage	~ 80 kV/Gap
Stored Energy	~ 290 mJ
Peak Electric Field	~ 20 MV/m
Power Requirement	~ 2 kW

Figures 6 and 7 reveal that the electric field intensity is maximum and field penetration is minimum when the gap is 40 mm and inner radii are 10 mm, respectively. The various simulations were performed to optimize the RF parameters of the cavities which include the shunt impedance, quality factor, average effective electric field, peak electric field, and Kilpatrick limit.

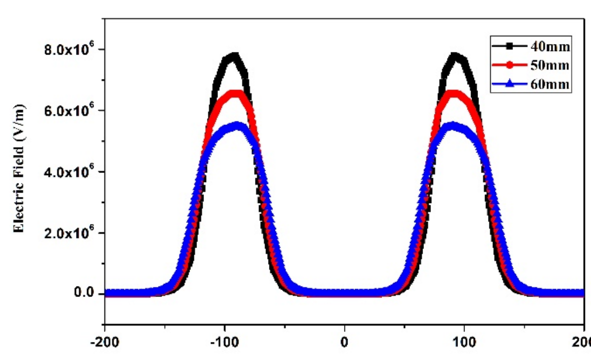

Figure 6: The electric field pattern along the beam direction when the gap has been varied from 40 mm to 60 mm.

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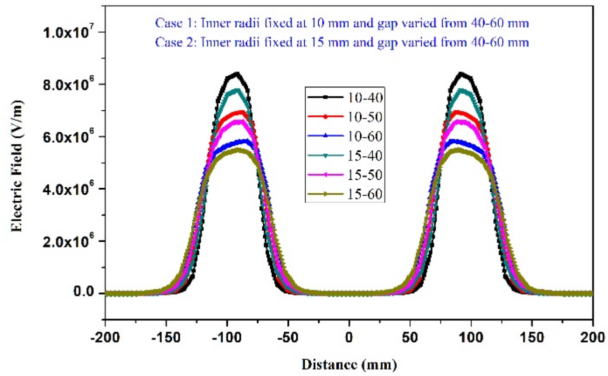

Figure 7: The electric field pattern along the beam direction when the inner and outer radii have been varied.

The physical dimensions of the cavity have been locked as listed below in Table 2.

Table 2: Simulated Physical Parameters of Buncher Cavities

RF Parameters	Case Study
Gap (mm)	40 mm
Drift Tube IR (mm)	10 mm
Drift Tube OR (mm)	20 mm
d = βλ/2	190.8 mm

RESULTS AND DISCUSSIONS

The two HEBT spiral buncher cavities have been designed in CST-MWS. It was observed that the spiral type central conductor provides higher shunt impedance which generates a higher voltage across the RF gaps, with the same input power. The various RF parameters have been optimized to achieve the highest figure of merit of the cavity. The cavities have been designed at 48.5 MHz with 2 kW of input power. The analytically calculated and simulated values match quite well with simulated values. The simulated quality factor and shunt impedance are ~8000 and 13 MΩ, respectively. SolidWorks modeling and fabrication will proceed shortly.

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