DESIGN OF THE DRAGON-I LINEAR INDUCTION ACCELERATOR

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Abstract

This paper describes the design of the Dragon-I linear induction accelerator (LIA) being built at Institute of Fluid Physics, China Academy of Engineering Physics (CAEP). The Dragon-I facility is an electron linac and consists of a -2.0MV/+1.5MV bi-polarity inductive adder injector, 68 accelerating cavities, pulsed-power system, beam-transport, control and auxiliary systems. It can produce an electron beam of 3 kA, 20 MeV with pulse width of 90 ns (FWHM). Good accelerating voltage pulse for each cavity with width of 120ns (FWHM) and up to 70 ns flattop within +/-1% variation have been obtained for high beam quality.

1 INTRODUCTION

The linear induction accelerator is capable of producing high power, high current pulsed beam and has many applications such as high power microwave, flash X-ray radiography, free electron laser, heavy ion fusion and so on. This paper introduces the design of the Dragon-I linear induction accelerator being built at Institute of Fluid Physics, CAEP. The Dragon-I LIA consists of a 3.6 MV bi-polarity inductive adder injector with –2.1MV cathode voltage and +1.5 MV anode voltage, accelerating section made of 68 accelerating cavities, pulsed-power system, beam-transport, control and auxiliary systems. It can produce an electron beam of 3 kA, 20 MeV with pulse width of 90 ns (FWHM).In the second section of this paper the injector was described. The design consideration of the accelerating cavity was given in the third section. The pulsed power system and the beam transport design were introduced in section 4 and 5 individually.

2 THE INJECTOR

The injector of the Dragon-I is based on the principle of inductive adder and composed of 12 induction cavities each can generate 300 kV high voltage with pulse width of 90 ns (FWHM). The voltages of the first seven cavities are added through a cathode stem and provide -2.1 MV on the cathode of the diode. Likewise the voltages of the other five cavities are added through an anode stem and provide +1.5 MV on the anode. So the total voltage of the diode of the injector is 3.6 MV. The design parameters of the injector is as follows:

Energy ： 3.6 MeV;
Flattop width of voltage pulse with +/-1% variation: 60ns；
Beam current ： 3.0 kA;
Pulse width of output beam：90 ns (FWHM);
Transverse displacement of output beam centroid：1mm;
Normalized brightness: 3×10^{8}A/(m rad)^2;

The cathode emitter is velvet and the anode is a hollow stailless steel pipe. The gap between cathode and anode is about 17cm.

The injector is powered by two Marx generators each charges six Blumlein pulse forming lines (PFLs) through high voltage cables. Each Blumlein PFL drives one induction cavity. The details of the injector is given by K.Z. Zhang at this conference [1].

3 THE ACCELERATING CAVITY DESIGN CONSIDERATION

In order to reduce the beam energy spread and get high beam quality, the output of electron beam from the injector was designed to be synchronized with the flattop of the accelerating voltages, i.e. the beam pulse was just put in the middle of the accelerating voltage pulses. Therefore the designed pulse width of the accelerating voltage for each cavity in the accelerating section is 120 ns (FWHM). The accelerating cavity was designed to generate 250 kV voltage pulse with 60 ns flattop with +/-1% variation. The maximum operating voltage for each accelerating cavity is 300 kV. The accelerating section consists of 68 cavities and was divided into 17 subsections by four cavities plus one multi-function cavity. To get maximum 300 kV voltage with 120 ns pulse width, 11 pieces of ferrite toroids was used in each cavity. The dimension of the ferrite toroids is 508 OD,237 ID with 25 mm thickness. B_s is 4000 Guass, B_r 3000 Guass. The multi-function cavity was designed for bridging the beam transporting magnetic field between adjacent accelerating subsections, vacuum pumping, monitoring the beam current and position, and detecting the beam profile. Two kinds of accelerating cavities was designed and tested. One is to put the ferrite in the vacuum and another is to put the ferrite in the transformer oil separated by an insulator. Both work well and the design with insulator was chosen for the final accelerating cavity. Fig. 1 shows the inductive voltage pulse of the accelerating cavity. The flattop width with +/-1% voltage variation reaches 74 ns.

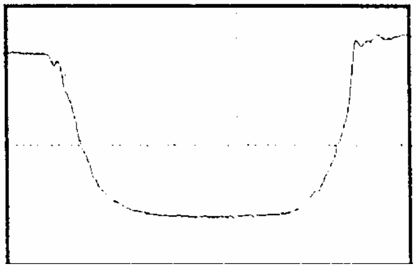

Figure 1.Voltage pulse of the accelerating cavity

4 DESCRIPTION OF THE PULSED POWER SYSTEM OF THE DRAGON-I LIA

The accelerating section is energized by six Marx generators each powers six Blumlein PFLs. Each Blumlein PFL is designed to drive two cavities through a pair of HV cables in the accelerating section. The main switch of the Blumlein PFL is gas-insulated cylindrical field-distortion spark gap and operating at about 300 kV. The time jitter of the main switch is about 1 ns (rms). The thirty-six Blumlein switches are triggered in turn by two-stage triggering system. One first-stage switch triggers six second-stage switches each then triggers six Blumlein main switches in turn when the Blumlein PFLs are charged to the its peak voltages.(see Fig.2)

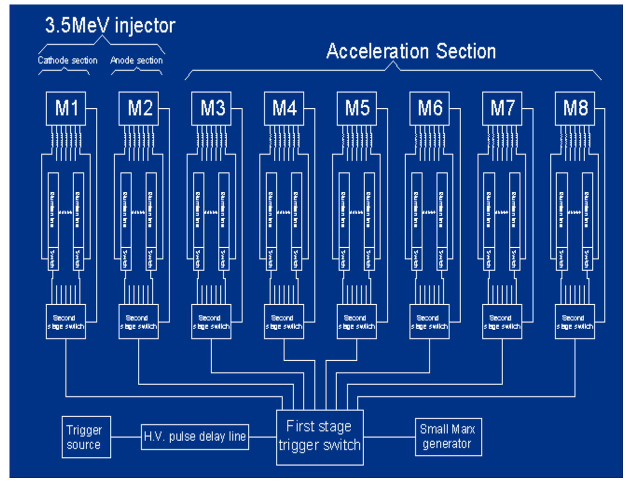

Figure 2. Pulsed power system of the Dragon-I LIA

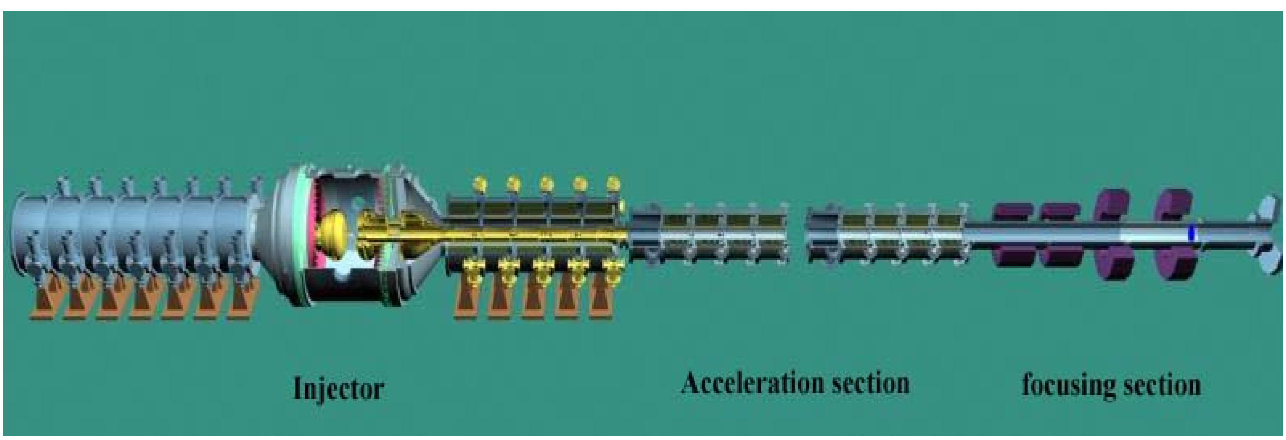

Figure 3: Drawing of the Dragon-I linear induction accelerator

5 BEAM TRANSPORT SYSTEM

The beam transport system can also be divided into three section. i.e. the injector section, accelerating section, focusing section. As shown in Fig. 3. There are nine solenoids arranged in the injector section to extract and match the beam from diode to the accelerating section. There are ninety solenoids arranged periodically in the accelerating section to confine the beam in the accelerating section. In the focusing section two solenoids and two thin magnetic lenses are used to focus the beam to the targets. Each solenoid is supplied by a DC current source. A print-circuit dipole is designed to compensate the transverse field of each solenoid.

After compensation the offset and tilt of the solenoids are in the range of o.2mm and 1mrad individually. The peak magnetic field is 2500 Guass. Fig. 4 is the schematic of the solenoid.

The focus lenses is a short solenoid surrounded by pure iron with a narrow gap. The Maximum magnetic field could reach 6000 Guass. The electron beam is gradually focused to the targets. The designed spot size is about 1.5mm in diameter.

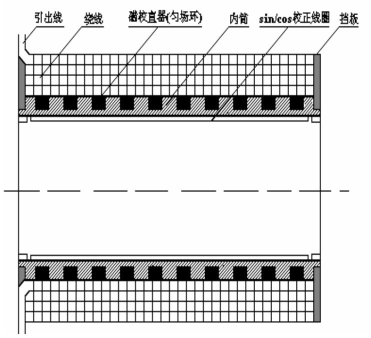

Figure 4 Schematics of the solenoid

6 END

Initial high voltage test on the cavity and measurements on the magnetic axis of the solenoid showed that the cavity does work and can generate good pulse for acceleration and the solenoids made satisfied the design requirements.

7 REFERENCES

[1 K.Z.Zhang, "3.5MeV injector", this conference , LINAC2002, Gyongju, Aug. 2002

[2] W.W Zhang, "Measurement of the magnetic axis of the solenoid", High Power Laser and Particle Beams, No.3, Vol. ,2002