DRAGON-I LINEAR INDUCTION ACCELERATOR

J. Deng#, B. Ding, L. Zhang, H. Wang, G. Dai, N. Chen, Z. Dai, K. Zhang, J. Shi, W. Zhang, J. Li, X. Liu, Y. Xie, M. Wang, L. Wen, H. Li, J. Wang, Z. Xie, M. Wang , Institute of Fluid Physics, CAEP, Mianyang, Sichuan, 621900, P.R. China

Abstract

The best quality induction linac in the world, named Dragon-I, has been built at Institute of Fluid Physics, China Academy of Engineering Physics. It can produce 2.5~3kA high current electron beam with energy of 20MeV and pulse width of 70ns.The spot size of about 1mm diameter has been achieved with beam current greater than 2.5kA.The design of Dragon-I facility is introduced briefly. The commissioning and results of Dragon-I are presented in the paper.

INTRODUCTION

The linear induction accelerator (LIA) technologies have been used in many research areas in the past four decades such as radiography, free electron laser, high power microwave, heavy ion fusion and so on. The linear induction accelerator technologies have been developed at Institute of Fluid Physics since 1970's and a series of induction accelerators have been constructed at IFP [1, 2, 3]. Recently, a new LIA named Dragon-I, the world best quality LIA, was built at Institute of Fluid Physics, China Academy of Engineering Physics (CAEP). The Dragon-I facility is a high current induction linac and can produce an electron beam of 2.5 kA, 20 MeV with pulse width of 70 ns (FWHM). Brief description about the Dragon-I has been introduced in the first section. In section two, the measurements of beam energy, current and spot size are presented. Emittance measurements have been conducted using two different methods and good agreement has been achieved. Time-resolved measurement of beam envelop has been made by Cerenkov radiation method. Time-resolved emittance has been measured as about 2060π.mm.mrad during the flattop of the beam by modified three gradient method. The time integrated emittance has been measured as 2935π.mm.mrad by OTR (Optical Transition Radiation) method. The time-resolved beam centroids have been obtained by Cerenkov radiation with frame camera. The variation of the beam centroid during the flattop is less than 0.5mm. In the last section is the summary of the paper.

DESCIPTION OF THE DRAGON-I

The Dragon-I linear induction accelerator is designed [4] and built at Institute of Fluid Physics, China Academy of Engineering Physics. The Dragon-I facility is an electron linac and consists of a -2.0MV/+1.6MV bi-polarity inductive adder injector, 72 accelerating cavities, pulsed-power system, beam-transport, control and auxiliary systems. It can produce an electron beam of up to 3 kA, 20 MeV with pulse width of 70 ns (FWHM).

Injector

The injector of the Dragon-I is a typical inductive adder which consists of 12 induction cavities [5].There are seven cavities in the cathode side and five cavities in the anode side (see Fig. 1). 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 at 300 kV with pulse width of 90 ns. So the cathode voltage is -2.1 MV and the anode voltage is +1.6 MV. And the total voltage between the diode is 3.6 MV. The cathode emitter is velvet and the anode is a hollow stainless steel pipe. The gap between cathode and anode is about 17cm.

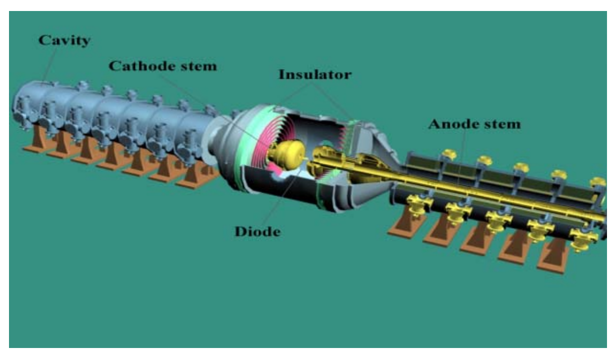

Figure 1: The injector of Dragon-I.

Accelerating Section

The accelerating section consists of 72 cavities and is divided into 18 subsections by four cavities plus one multi-function cavity. The multi-function cavity is 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. In order to reduce the beam energy spread and get high beam quality, the output of electron beam from the injector is designed to be synchronized with the flattop of the accelerating voltages, i.e. the beam pulse is just put in the middle of the accelerating voltage pulses. Therefore the pulse width of the accelerating voltage for each cavity in the accelerating section is 120 ns (FWHM) instead of 90 ns. The accelerating cavity is designed to generate 250 kV voltage pulse with 70 ns flattop with +/-1% variation. The maximum operating voltage for each accelerating cavity is 300 kV.

#djjleap@my-public.sc.cninfo.net

Focusing Section

There are ninety solenoids arranged periodically in the accelerating section to confine the beam in the accelerating section. In the focusing section several solenoids and two thin magnetic lenses are used to focus the beam to the targets. Each solenoid is supplied by a DC current source.

COMMISSIONING RESULTS

In the commissioning stage, all the main parameters such as energy, beam current, beam envelop, beam centroid, emittance have been measured for the injector and the whole accelerator. The results were used for tuning of the injector and whole accelerator individually.

Time-resolved Energy Measurement

The output energy of the injector was measured by two methods. One is measuring the voltage cross the diode. The other is using magnetic analyzer combined with quartz screen. Cerenkov radiation light emitted from the screen was record by streak camera (see Fig. 2). Both results are in good agreement. The energy of the injector was measured at 3.5 MeV. The total energy at the exit of the accelerator was 19.4 MeV by adding the voltage of each cavity.

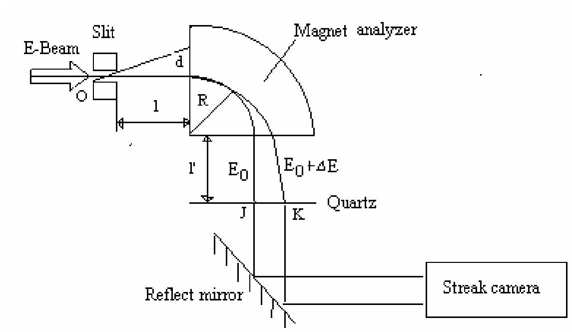

Figure 2: Schematic of time-resolved energy measurement.

Beam Current Measurements

The emitting current is measured by B-dot probe. The beam current and beam centroid are measured by current view resistor (CVR). There are twenty CVRs along the accelerator to monitor the beam current transportation. Each CVR is located in the multi-function cavity to monitor the current after 4-cell transportation and provide information for magnetic field tuning.

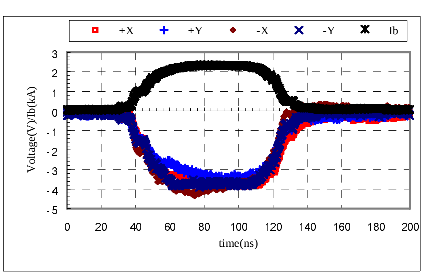

Figure 3: Beam current on the target (upper).

The emitting current is measured at 2.65kA with pulse width of 90 ns, the output beam current at the exit of the accelerator is 2.6 kA and the beam current at the target is 2.54 kA with pulse width of 70 ns (see Fig. 3).

Time-resolved Emittance Measurements

The emittance of beam was measured with two different methods, modified three gradient method and OTR method. Fig. 4 is the schematic of the modified three gradient method. By measuring the time-resolved beam envelop at different magnetic fields, the time-resolved emittance can be obtained according to the beam envelop equation Eq. (1)

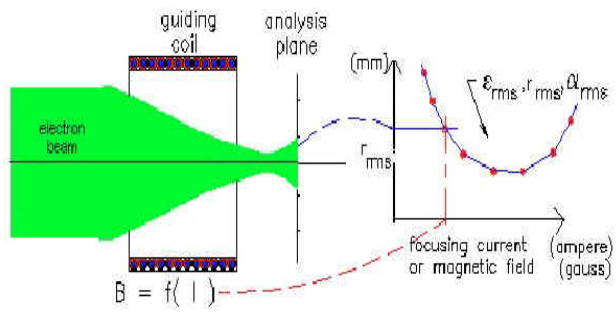

Figure 4: Schematic of the modified three gradient method.

$$R'' + \frac{k^2}{4}R - \frac{K}{R} - \frac{\varepsilon^2}{\beta^2\gamma^2 R^3} = 0 \qquad (1)$$

Here $K = \dfrac{2I}{17.045\beta^3\gamma^3}$ (I, kA), $k = \dfrac{ecB_z}{\beta\gamma mc^2}$

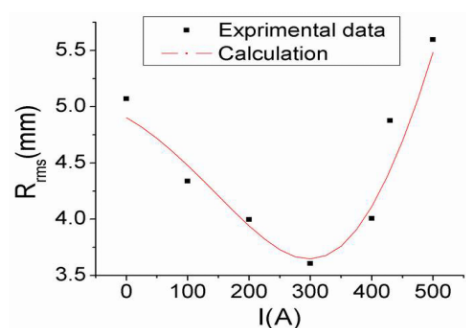

Figure 5: RMS beam radius at different magnetic fields.

According to the experiment data, the measured normalized edge emittances during the flat-top of the beam pulse are about the same as 2060π.mm.mrad.

Fig. 6 is the calculated distribution of OTR at different divergence angles of beam at energy of 20MeV. As long as the distribution of OTR is measured (see Fig. 7), the integrated emittance can be obtained (see Fig. 8) at 2935π.mm.mrad.

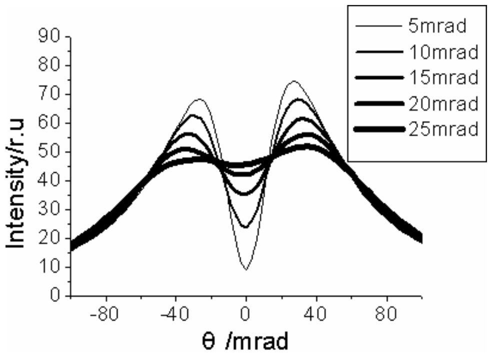

Figure 6: Distribution of OTR at different divergence angles of beam at energy of 20MeV.

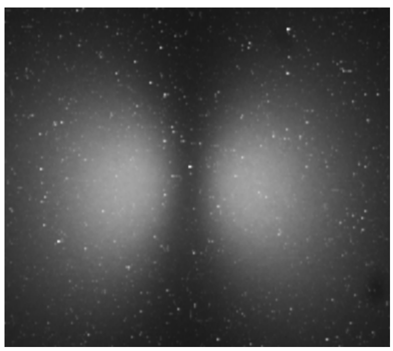

Figure 7: Experiment image of OTR.

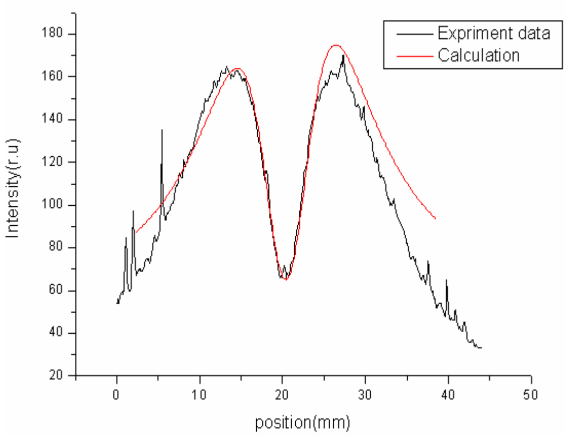

Figure 8: Scanned and fitted distributions of Fig. 7.

Time-resolved Beam Centroid Measurement

The time-resolved beam profiles were taken by fast frame camera with time interval of 10 ns and exposure time of 3 ns. Fig. 9 is the eight pictures taken at one shot. The fourth picture to the eighth picture correspond to the flat-top of the pulse. The variation of the beam centroid during the flat-top is in the range of 0.5 mm.

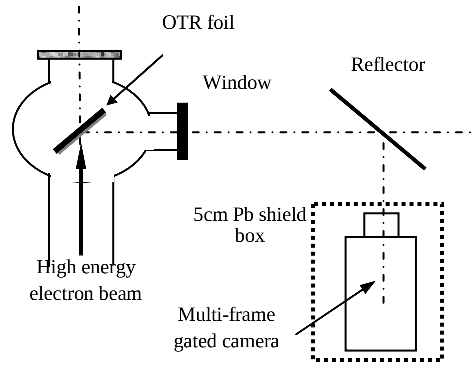

Figure 9: Experiment setup for beam centroid measurement.

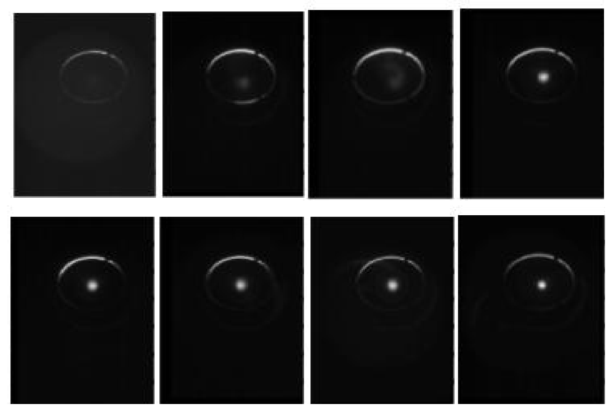

Figure 10: Beam profiles taken with frame camera.

SUMMARY

The Dragon-I LIA has been described briefly and its results have been presented in the paper. High current beam of 2.54 kA with pulse width of 70 ns at energy of 19.4 MeV has been obtained. Experimental results show that the Dragon-I facility has fully reached its design parameters and has very good stability and reliability.

REFERENCES

[1] Shouyun Zhang,et al. 1.5MeV Induction Linac. Proc of 7th IEEE Pulsed Power Conf.,1989
[2] Nianan Chen, et al, High Power Laser and Particle Beams,Vol. 4 (3). 1992
[3] Bonan Ding, et al, Proc. of 10MeV LIA, 1993.
[4] Jianjun Deng et al, Proc. Of LINAC2002, Gyongju, Korea, 2002, p40-42
[5] Kaizhi Zhang et al, Proc. Of LINAC2002, Gyongju, Korea, 2002, p37-39