INSTALLATION AND INITIAL RESULTS OF THE "DRAGON-I" INDUCTION LINAC

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Abstract

The "DRAGON-I" accelerator is an induction linac with designed electron energy up to 20MeV, and beam current more than 2.5kA at the exit. The accelerator is mainly composed of subsystems such as, pulsed power system, induction cavities, injector, transportation system, alignment system, diagnostic system, monitoring and controlling system, and supporting system as well. The "DRAGON-I" induction linac was installed entirely and tuned initially, this report will outline this accelerator and present the latest measurement result.

INTRODUCTION

With the advantage of accelerating high brightness and high intensity beam of kiloAmpere, linear induction accelerator can be used in the field of flash X-ray photograghy, inertial fusion, two beam accelerator and so on. The history of research traces back to 1980s' on induction linac in Institute of Fluid Physics of CAEP. By the end of 1993, an electron linear induction accelerator, LIAXF, was built with energy up to 10MeV, output beam current of about 2.0kA, which was a breakthrough in our procedure to explore induction linac technology. After that success it was put forward to develop an induction linac with higher energy, 20MeV, together with better beam property and reliability, as shown in fig.1.

OUTLINE OF "DRAGON-I"

Similar to LIAXF, the "Dragon-I" induction linac is mainly composed of a pulsed power system, induction accelerating cavities, an injector, a beam transporting and focusing system, and some other subsystems. But seeking for higher performance, quite a few technique breakthrough was achieved and integrated in this accelerator, which will be covered in detail as follows.

Pulsed Power System

The pulsed power system converts the net power to high voltage pulses with pulse width of 90~120ns (FWHM) and voltage magnitude of 250~300kV.

8 Marx generators, 48 Blumlein pulse forming lines, 9 synchronizers, and other parts make up the whole system.

Wide flattop(±1%) of 70ns of high voltage pulses is obtained, which owes to such improvement as Blumlein with longer electric length and higher output impedance, switches with lower inductance, longer charging period to Blumlein and higher resistivity of water filled inside Blumlein.

Different from the transmission line in LIAXF, 48Ω and 24Ω cables are used to feeds the induction cavity from pulsed power system. One blumlein feeds one cavity in injection section, whereas one blumlein two cavity. in acceleration section.

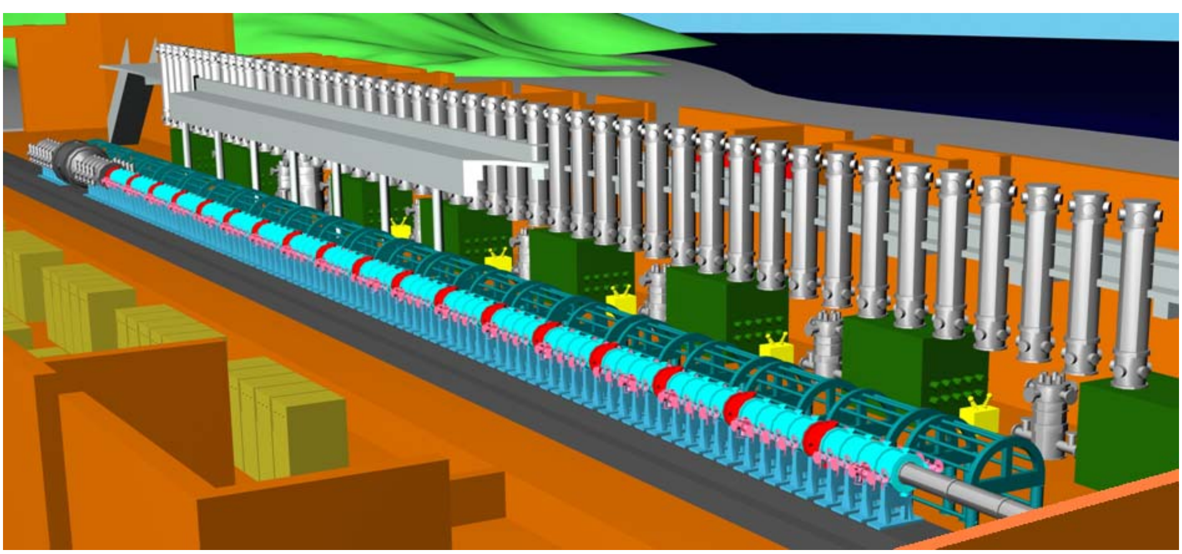

Figure 1: 3D view of "DRAGON-I" induction linac.

Induction Accelerating Cavity

In the accelerating section there are 72 induction cavities which transform the input voltage pulses from pulsed power system to accelerating voltage pulses. Each cavity is assembled as a ferrite loaded transmission line in favour of the pulse flattop, inside each cavity are housed 11 ferrite toroids with 237mm ID, 508mm OD, 25.4mm thick, which demonstrates flux swing greater than 0.7T.

Ferrite toroids are immersed in dielectric oil which is separated from vacuum by an insulator. The maximum electrical fields calculated on the electrode surface are 185kV/cm and 70kV/cm in the insulator at operating voltage.

To damp transverse impedance of the cavity, accelerating gap was designed as transmission line like structure, with width of 20mm. Together with other measures, such as the corner ferrite, which reflects the EM wave to the ferrite toroids to be absorbed. The impedance is reduced as estimation with highest value to be 800Ω/m of TM_{130}.

A 3D view of the induction accelerating cavity and the measured dependence of transverse impedance on frequency are depicted in fig.2.

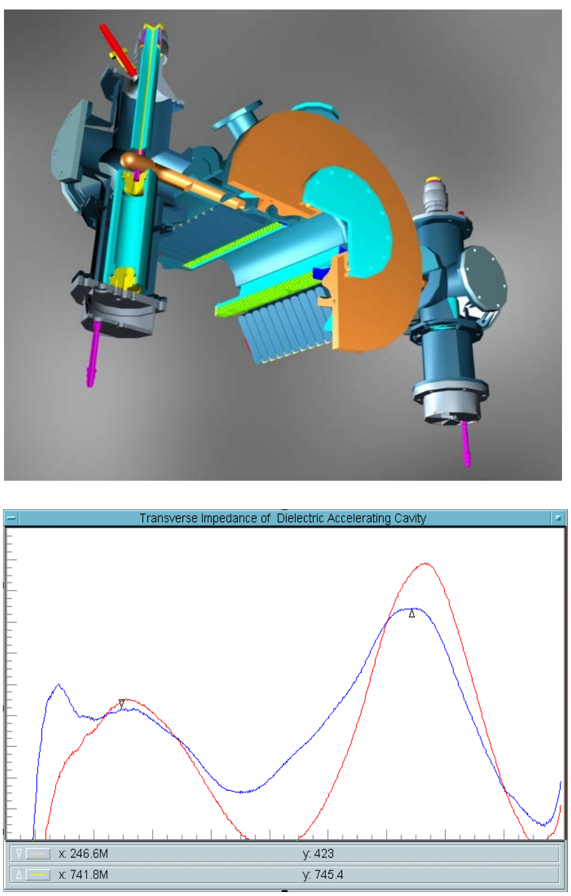

Figure 2: Induction accelerating cavity(upper) and measured transverse impedance(lower)

Injector

The injector comprises 12 induction cavities, which is shown in fig.3. With 13 ferrite toroids with 800mm OD inside, each cavity provides a high voltage pulse with magnitude of 300kV, and pulse width of 90ns(FWHM). The cavities are added together in series through a cathode stem and an anode stem respectively, to provide a high voltage pulse greater than 3.5MV across the diode.

The diode include a large flat cathode with velvet embedded in the center as emitting material, and foiless anode with 120mm bore, the distance between cathode and anode is adjustable about 160mm. Simulation on the diode shows the highest electric field of 270kV/cm at some point along the surface of cathode, it is a little dangerous.

Inside cathode and anode are placed 3 magnetic coils respectively which shape the guiding magnetic field distribution along beamline, with highest value of 0.12T near the anode, and zero along the surface of emitting materials. The anode pipe is made up of 2 layers in consideration of leading conduction lines of coils to the power sources.

Two radial insulated supports are used to keep the center of cathode and anode along accelerator axis respectively.

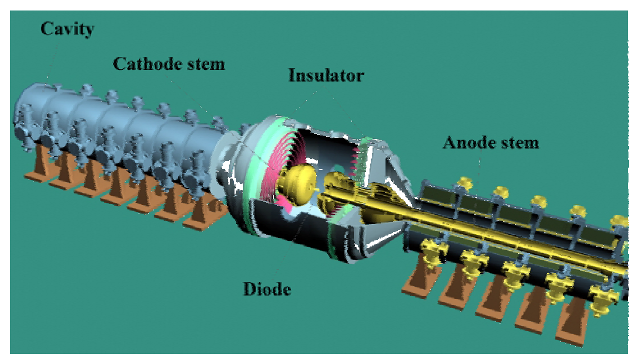

Figure 3: 3D view of the injector

Beam transportation and focusing system

Each induction cavity (except 7 in the cathode part of injector) contains a solenoid magnet. The solenoid will produce magnetic field up to 0.2T along its axis to transport electron beam from injector to the exit of accelerator.

The solenoid design features bifilar winding to reduce field errors due to winding geometry, iron homogenizer rings within the solenoid to greatly reduce the effects of winding errors. Printed board dipole trim magnets inside the solenoids to correct any remaining field misalignment. Fig.4 shows the picture of solenoid and dipole trim magnet respectively.

Between every five induction cavities an inter-cell is placed to provide vacuum pump ports, beam propert measurement interfaces, and to smooth magnetic field distribution along axis.

Immediately after the exit of accelerating setion there is a drift section which will be used to adjust the beam current profile before focus. Two solenoids with relatively high field strength, and lower aberration are placed at the end of the accelerator to focus the intense electron beam to tiny size.

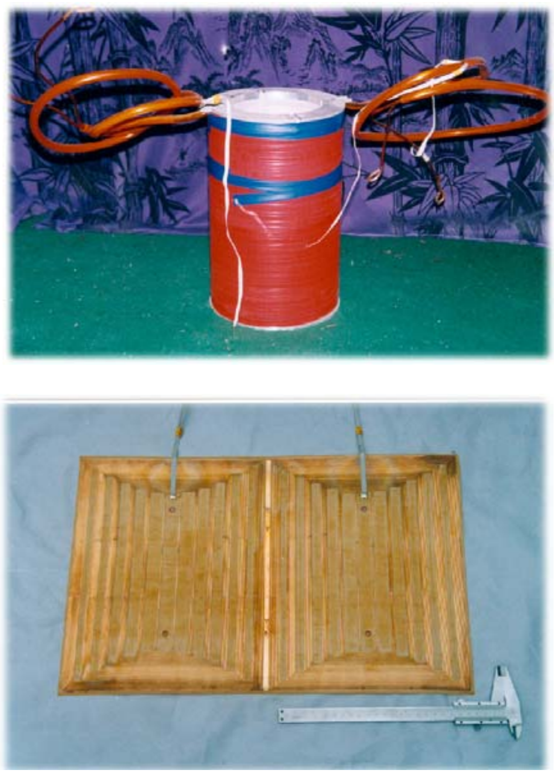

Figure 4: Picture of solenoid (upper) and printed board dipole trim magnet (lower)

INSTALLATION

Each of the 72 cavities was tested under high voltage of 300kV, which drove at verifying high voltage property of cavities, especially the insulated ring placed inside the gap.

Magnetic field distribution of each solenoid is measured through pulse wire method both in bench and inside induction cavity, and proper correcting field is provided to balance the transverse magnetic field component near its axis. After every 4 cavities and an intercell connected together as a block, the field distribution of blocks is measured and modified. The measurement result shows that, after correction, the mean value of tilt error of each cavity is -0.0051mrad along X axis, and -0.11mrad along Y axis; offset is 0.034mm along X, and -0.021 along Y. The measurement result before and after correction is shown in fig.5 respectively.

An alignment adjustment system is developed which bases upon a laser tracker system, including adjustable foundation tables underlaying the main body of accelerator, and additional target markers. This system helps us to control the alignment error of the beam line within 0.2mm.

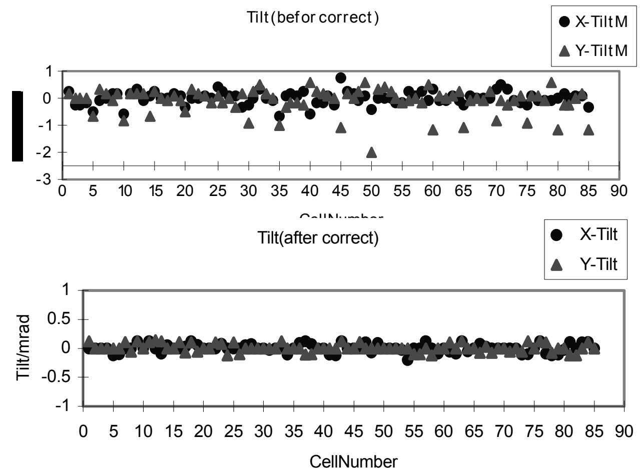

Figure 5: Distribution of tilt of magnetic axis along accelerator axis before and after correction

INITIAL RESULTS

After tuning for a short period of time, the properties measured of beam current output from the injector got closer to the goal.

The current intensity of the output beam was more than 3.1kA, and energy up to 3.5MeV, the energy sweep is nearly ±2.5%, and the normalized emittance is about 2500π·mm·mrad.

Some parts of the injector was modified soon because the emittance was not so good as expected.

The flat cathode was replaced by a Pierce type one with surface finely machined, and the AK gap was enlarged to 170mm.

Normalized emittance decreased to 1000π·mm·mrad, and the output current lowered to 2.8kA as a result of above improvement.

CONCLUSION

The induction cavities have been fabricated and tested at full voltage at test bed. The magnetic distribution for each and every five-cell block was measured using pulsed wire method. Installation of the whole machine has finished. And the injector runs as expected.

According to the plan, tuning of the whole accelerator will be accomplished by the end of this year, and output electron beam with perfect properties will be achieved from “D DRAGON-I”.

REFERENCES

[1] Deng Jianjun, et al., “Design of the DRAGON-I Linear Induction Accelerator,” Proceedings of the 2002 international linear Accelerator Conference.

[2] Zhang Kaizhi, et al., “3.5MeV Injector for an Induction Linac,” Proceedings of the 2002 international linear Accelerator Conference.