Alignment techniques for DRAGON-Ⅰ LIA

DAI Zhi-Yong(代志勇)[1)] XIE Yu-Tong(谢宇彤) LI Hong(李洪) ZHANG Wen-Wei(章文卫)
LIU Yun-Long(刘云龙) PAN Hai-Feng(潘海峰) ZHANG Lin-Wen(章林文) DENG Jian-Jun(邓建军)

(Institute of Fluid Physics, CAEP, P.O.Box: 919-106, Mianyang 621900, China)

Abstract DRAGON-Ⅰ designed and manufactured by CAEP is a linear induction accelerator which can produce a 20 MeV-3 kA-60 ns electron beam. The high performance required for the machine is determined by the beam quality and thus is greatly dependent on the accelerator alignment. In order to reduce the chromatic effect of the beam, the stretched wire technique has been developed to measure magnetic axes of the cells precisely, and the dipole steering magnets have been equipped into each cell to correct its magnetic axis misalignment. Finally, the laser tracker has been used to examine the installation error of the accelerator. In this paper, different alignment techniques and the primary results are presented and discussed.

Key words LIA alignment, beam quality, stretched wire technique

PACS 29.90.+r, 41.85.Gy

1 Introduction

The DRAGON-Ⅰ LIA consisting of a 3.5 MeV injector, 72 induction cells[1] and 18 multifunctional cavities, is capable of producing an 18 MeV-3 kA-60 ns electron beam. In each cell there is a solenoid focusing magnet[2] and a pair of X, Y dipole steering magnets to transport the beam. The cells are assembled into 18 blocks each containing 4 induction cells and one multifunctional cavity. The high beam quality requires small emittance and low energy spread. To achieve such objectives, the mechanical and magnetic alignment[3] must be taken care of to minimize the chromatic effects[4, 5]. The goal is to enclose all the magnetic axes of the cells in a 0.4 mm diameter cylinder with an angle spread lower than 1mrad.

In this paper, we will present and discuss the method used to reduce the alignment errors, including solenoid magnet design, alignment fixing of the solenoid, measurement and correction of magnetic axes of cells, pre-alignment of blocks and mechanical installation of the whole accelerator.

2 The solenoid magnet

Solenoid magnet design and machining are very important for accurate alignment. It is the basis for the accelerator alignment to limit the magnetic field errors of the solenoid within a very small range.

The solenoid magnet is equipped with homogenizer rings mechanically and dual wire running in parallel around the solenoid to minimize the field errors. The misalignment of the solenoid magnet is measured by using the stretched wire technique. The magnetic misalignment of each solenoid must be limited in the 1 mrad(tilt)/0.2 mm(offset) range and the solenoid magnetic axis is the reference to the mechanical one with high accuracy. These two axes are considered the same in the alignment procedure.

3 Fixing the solenoid

One solenoid magnet is fixed into a cell to obtain an unabridged cell. An additional discrepancy will generate during this process. The fixing precision mainly depends on the highly accurate match of solenoid design and machining. (The maximum matching tolerance is less than 0.05 mm.) The tilt and offset of this misalignment are less than 1.15 mrad and 0.14 mm, respectively.

4 Measurement and correction

The test stand is shown in Fig. 1. A Be-Cu alloy wire of ϕ0.1 mm, whose two end points are fastened

Received 28 October 2008

1) E-mail: dzycaep@yahoo.com.cn

on adjustable trestles, is centered on a cell mechanical axis. If the axis is different from the magnetic one, a transverse magnetic field will occur and act on a current passing through the wire to cause Lorentz force which will vibrate the wire. This vibration which is propagating at nearly the sound speed towards the two end points can be detected by two optical monitors located at a certain distance from the cell.

The typical data measured are offset and/or tilt of the wire relative to its own magnetic axis. The two types of waveforms shown in Fig. 2 are so different that they are easily distinguished.

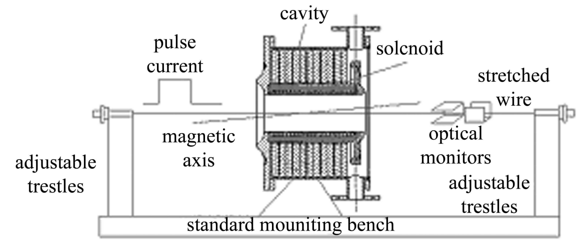

Fig. 1. The stretched wire technique.

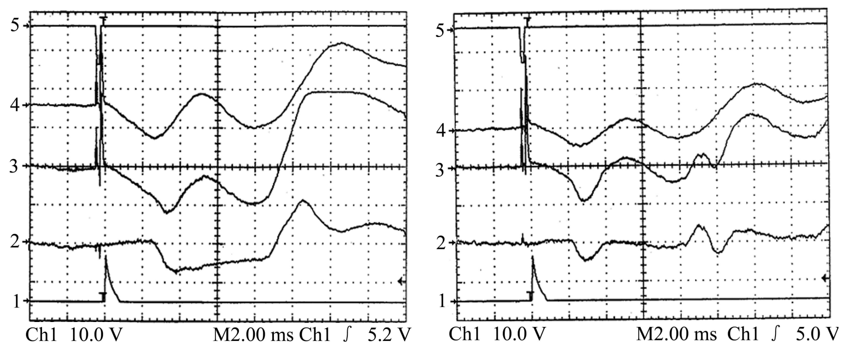

Fig. 2. The typical tilt (left) and offset (right) waveforms. The measured X waveforms (1—triggering signal, 2 on the left—net tilt signal, 2 on the right—net offset signal, 3—compound signal, 4—background signal, 5—pulse current in wire).

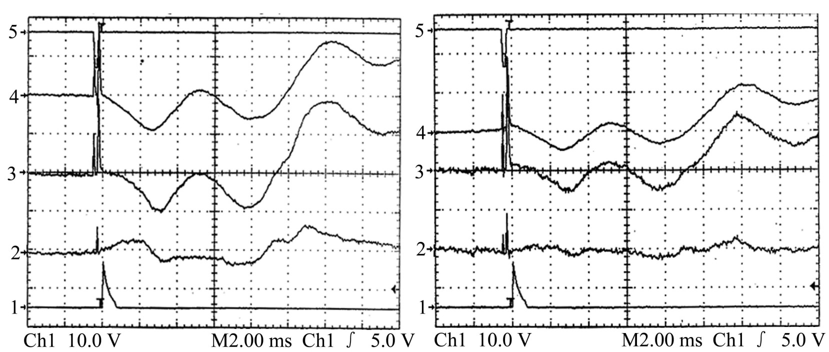

Fig. 3. The typical waveforms before (2 on the left) and after (2 on the right) adjusting the wire's position (1—triggering signal, 3—compound signal, 4—background signal, 5—pulse current in wire).

In general, the magnetic axis with random space direction and position in a cell contains not only tilt but also offset. By adjusting the positions of the two end points in two dimensions, the wire's position is let to approach to the cell's magnetic axis and the cell's magnetic axis and the optical monitors' outputs are observed simultaneously. Eventually, the wire's position can be considered as on the cell's magnetic axis if the tilt and offset signals involved are hardly observable. This effect is shown in Fig. 3.

By comparing the position of the wire before and after being adjusted, the difference between the mechanical and magnetic axes of the cell can be obtained.

A pair of X, Y dipole steering magnets are installed in each cell and they could provide radial direction fields of desired strength to diminish the transverse fields generated by the errors of winding in the course of manufacturing of the solenoid. The effects of the dipole steering magnets can be shown by the stretch wire technique. The waveforms acquired when only dipole steering magnets were adopted, are almost the same as those when only magnetic axis tilt exists (Fig. 2 on the left). So the steering magnets could correct the tilt of the magnetic axis, but not the offset. The left and right charts in Fig. 4 are

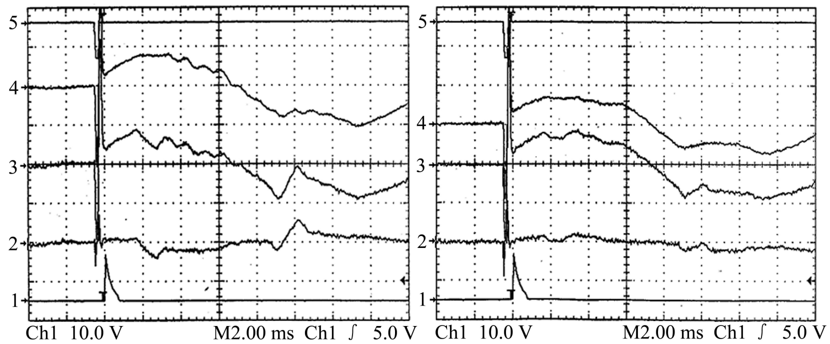

Fig. 4. The measured Y waveforms without (2 on the right) and with (2 on the left) steering magnets correction (1—triggering signal, 3—compound signal, 4—background signal, 5—pulse current in wire).

the initial waveforms and the waveforms corrected by steering magnets, respectively. It can be seen that the tilt signals have been almost diminished. In fact the tilt of each cell can be limited to within 0.11 mrad using this method.

5 Pre-alignment and alignment installation

Each block that consists of 4 induction cells and one multifunctional cavity must be 1) pre-aligned, 2) fixed on adjustable (in 4 dimensions) trestles, 3) installed on the accelerator track. This procedure can be characterized by the following steps:

(1) Setting up four targets on the front and back flanges of a cell;

(2) Determining the front and back centers of the inner tube of the cell by using a laser tracker. The connecting line between the two centers is the mechanical axis of the cell;

(3) Measuring the relative positions of the targets with respect to the centers by using a laser tracker — the mechanical axis of the cell is only defined by the targets;

(4) Setting up a standard line according to the dimensions of the cell, trestle and the accelerator tracks;

(5) Continuously measuring the relative positions of the targets with respect to the standard line by using a laser tracker and adjusting each cell of a block to let its axis coincide with the standard line at the same time;

(6) Repeating the above steps, adjusting continuously the trestles that support the blocks to let the axes of all blocks coincide with the standard line.

According to this alignment procedure described above, the alignment accuracy of one block is that the tilt and offset are less than 1.2 mrad and 0.25 mm, respectively. After using dipole steering coils, the average of tilts is less than 0.12 mrad. The whole accelerator's tilt and offset are estimated to be less than 0.25 mrad and 0.35 mm, respectively.

6 Conclusion

The high quality beam requested for the DRAGON-Ⅰ accelerator leads us to use strict alignment techniques. We have presented that the new design with homogenizer rings, stretched wire techniques with steering corrections and installation with laser tracker are adopted to align the DRAGON-Ⅰ LIA. Dipole steering magnets, besides correcting the magnetic axis tilt, will tune the several kilo-ampere electron beams to reduce further the amplitude of corkscrew motion.

Thanks to Pro. WANG Huacen and the cooperators of IHEP-CAS. We have increased the measured accuracy greatly!

References

1 DING Bo-Nan, DENG Jian-Jun, WANG Hua-Cen et al. HEP & NP, 2005, **29**(6): 604 (in Chinese)

2 DAI Zhi-Yong, LIU Cheng-Jun. Design of Solenoid Magnet with Slender Majority of Transverse Magnetic Field. China Nuclear Science and Technology Report, CNIC-01327. Atomic Energy Press, 1998 (in Chinese)

3 Bonnafond C, Villate D. Alignment Techniques for the High Current AIRIX Accelerator. Proceedings of the 1999 Particle Accelerator Conference. New York: IEEE Service Center, 1999. 1381—1383

4 Caporaso G J, Barletta W A, Birx D L et al. Beam Dynamics in the ATA. In: Briggs Richard J, Toepfer Alan J. Proceedings of the 5th International Conference on High Power Particle Beams. San Francisco: LLNL Press, 1983. 427—432

5 CHEN Y J. Nuclear Instruments and Methods in Physics Research A, 1990, **292**: 455