

DEVELOPMENT OF A 324 MHz DRIFT TUBE LINAC FOR CSNS*

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Abstract

The CSNS is a spallation neutron research facility being built at Dongguan in Guangdong Province [1]. The 324MHz Alvarez-type Drift Tube Linac (DTL) will be used to accelerate the H⁻ ion beam from 3 to 80.0 MeV with peak current 15mA. The R&D of a prototype structure at the low energy section of DTL is taking place at IHEP. The first unit tank 2.8m in length for the energy range from 3 to 8.88 MeV and 28 drift tubes containing electromagnetic quadrupoles are developed. This paper introduces the R&D status of the tank and 28 drift tubes. The measurement results of the focusing quadrupoles are also presented.

INTRODUCTION

CSNS linac consists of an H⁻ ion source, an LEBT, a 3MeV RFQ linac, a MEBT and an Alvarez-type Drift Tube Linac (DTL) as shown in the Fig.1. The output beam of the DTL linac is 80.0MeV with peak current of 15mA in the first phase and 132MeV for upgrade. Both the operating frequency of RFQ and DTL are 324MHz. The main parameters of the CSNS DTL are listed in Table 1.

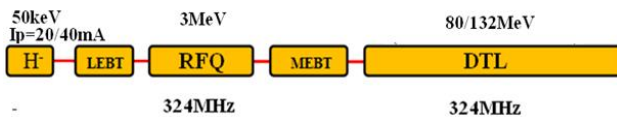


Figure1: CSNS Linac layout.

Due to the higher operating frequency, the size of the tank and the drift tube (DT) become smaller leading many technical difficulties especially in the low-energy part. So the R&D of low energy part of DTL is very important. The following main components of the DTL have been developed in the R&D stage: (1) the first short unit tank, made by copper electroforming technology; (2) 28 pulse-excited quadrupole magnets with a hollow coil made by copper electroforming; (3) 28 drift tubes with electromagnet quadrupoles inside. The Periodic Reverse (PR) copper electroforming method is applied to the tank and the coil manufacture process [2].

Table 1: Design Parameters of CSNS DTL

Tank Number	1	2	3	4
Output Energy (MeV)	21.76	41.65	61.28	80.0
Number of cell	61	36	29	26
Cavity RF power (MW)	1.41	1.41	1.39	1.45
Total RF power (MW)	1.97	2.01	1.98	2.03
Acc. field (MV/m)	2.2-3.1	3.1	3.1	3.1
Syn. phase(deg.)	-30--25	-25	-25	-25
Tank length (m)	8.10	8.56	8.79	9.05

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DTL TANK FABRICATION

The CSNS DTL consists of four independent tanks of which the average length is about 8.6m. Furthermore each tank is divided into three short unit tanks about 2.8m in length for easily manufacture [3].

The tank was made of carbon steel tube with inner diameter 566mm. The inner surface was coated with Oxygen-free Copper (OFC). It has rather complex structure to be electroformed. The first unit tank (2767mm in length) contains 9 large ports for tuners, vacuum, and approximate 60 small ports for drift-tubes, post couplers and pickups. There are twelve straight water cooling channel embedded into tank out-wall.

The Periodic Reverse (PR) copper electroforming technology has been successfully applied in the tank manufacture for both inner surface and all ports/holes. Fig. 2 shows the tank prototype module after electroforming. The inner copper surface has been polished and the ports have been fine machined for high accuracy and high flatness. The measured inner surface flatness are between 0.26~0.29 μm (design 1.6 μm). The average copper thickness is 0.2mm (design 0.15mm).

The vacuum test of the first unit tank was also carried out in last May. The vacuum reached 8.5×10^{-4} Pa only a turbo molecular pump ($0.6 \text{ m}^3 / \text{s}^{-1}$) working. Up to now, the polish of the tank inner surface has been finished and the washing will be carried out in this month.

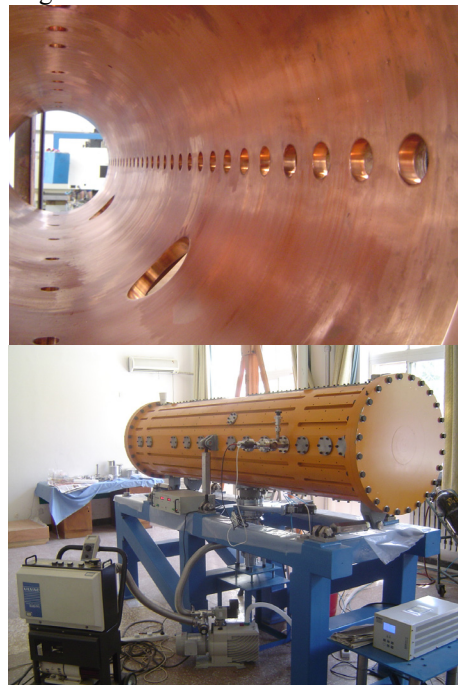


Figure 2: Prototype of the first unit DTL tank.

ELECTROMAGNET QUADRUPOLE

In CSNS DTL, the electromagnetic quadrupoles (EMQ) are used to supply transverse focusing to the beam.

The R&D of the quadrupole for the lower energy section of the DTL is a critical issue for the DTL structure because the size of the drift tube for this section is so small that it is not possible to apply the standard techniques for installation the electromagnetic quadrupole. The SAKAE type coil is applied [4]. For the strong focusing scheme, the EMQs are used with high gradient from 75T/m to 38T/m. The diameter of the magnet is 138 mm and the tube widths are in the range from 49.89mm to 236.1mm.

Fig. 3 shows the main components of the quadrupole. The core material choose the silicon steel which thickness is 0.5mm. The wire cutting and the Periodic Reverse copper electroforming method are applied to the coil manufacture process. After the assembly of the first prototype EMQ, some properties were measured by Hall probe. The results are agreed with the calculated ones [5].

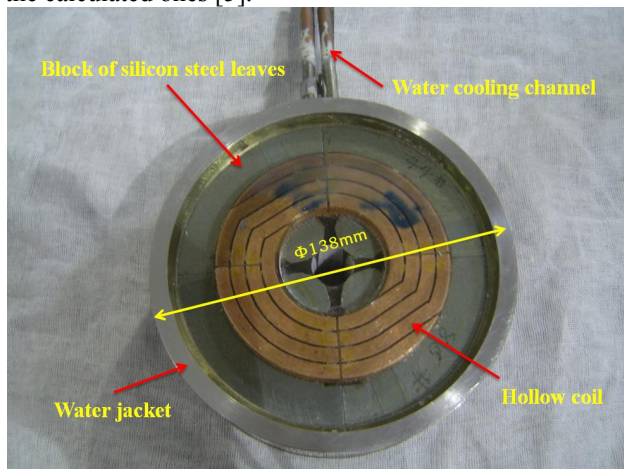


Figure 3: The EMQ assemble.

DT FABRICATION

One of the main features of the CSNS DTL is the use of Oxygen Free Copper (OFC) in all parts of drift tubes. Long-term deformation test has been done which convinced us the material selection and design.

The fabrication process is a little complex accompanied with many kinds test. Every parts of the drift tube and the stem (34mm in diameter) are fabricated by the electron beam welding (EBW) after the installation of the EMQ into the DT. The space around the magnet in the DT is filled with the epoxy resin by a vacuum impregnation method.

The magnetic field of the EMQs is measured some times by a rotating coil measurement system during the DT fabrication process. The first measurement is carried out just after the construction and installation of the magnet into DT without any EBW for checking the deviation between the tube mechanical center and the quadrupole field center which is defined as the position

with a minimum dipole component. In this stage the magnet installed into drift tube requires that the concentric tolerance be less than 0.05mm error. If the deviation of the magnet position is larger than the tolerable value, the bore cylinder is lathed in order to adjust the mechanical centre to the field centre. The second measurement is done after the EBW of the tube shells and the base of the stem on the DT in which the magnet has been accommodated. The purpose of this measurement is to get the discrepancy between the mechanical centre and the quadrupole field centre. Then the beam pipe and the tube cylinder are lathed in accordance with the magnetic centre. The tolerable deviation of the mechanical centre of DT from the magnetic field centre is limited $\pm 0.03\text{mm}$ for the beam dynamics requirement. The last one is done after all the fabrication process of the surface being polished. The purposes of the last measurement are not only the confirmation of the magnet properties measured before but also the get the discrepancy data for alignment work.

Quadrupole magnetic field measurements are carried out accompanying the DT manufacture procedures. For obtaining higher accuracy the rotating coil support has been upgraded. Fig. 4 shows the records which is the comparison of the deviations of the mechanical centre from the magnetic field centre before and after the measurement system upgrade. It can be obtained that all of the deviations (round one) fall into the tolerable area $\pm 0.03\text{mm}$ after the measurement system upgrade comparing those ones (square one) before upgrade. The average deviation much decrease from $28.6\mu\text{m}$ to $12.3\mu\text{m}$, approximately 60%. Furthermore the dipole component becomes less than 0.05% of quadrupole one at the magnetic centre comparing 0.3% before upgrade. Higher-order multipole components are also sufficiently small at the field centre.

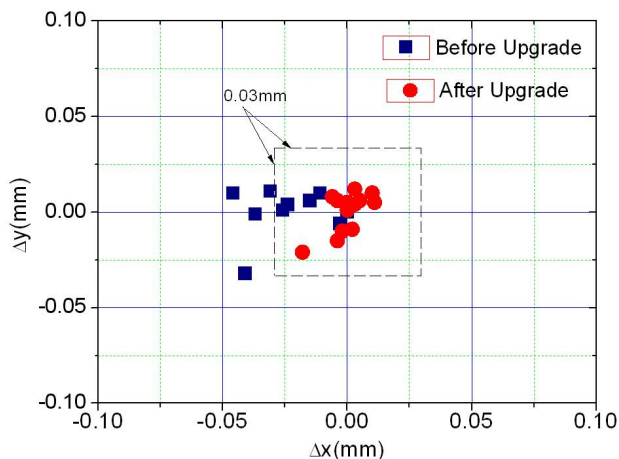


Figure 4: The comparison of the deviation of the mechanical center from the magnetic field center before and after the measurement system upgrade.

After the first prototype of DT has been successfully completed in this January [5], the batch products of DT are under manufacturing (as shown in Fig. 5). Up to now, fifteen DTs have been finished.



Figure 5: The DTs.

OTHER COMPONENTS

Some aluminum cold models, such as post-couplers, slug tuners, vacuum grill and tank end wall containing a DT have been developed (as shown in Fig. 6). They will be used in the cold test in this autumn.



Figure 6: Aluminum cold models: postcoupler (a), slug tuner (b), vacuum grill(c), end wall (d).

PRESENT STATUS AND PERSPECTIVES

The prototypes of the tank and the drift tube containing 28 EMQs for 324MHz DTL have been developed in IHEP for CSNS project. The inner surface process of the tank has been finished and the last treatment is under preparation. The magnetic field of measurement of the quadrupole has been carried out. The filed gradient agreed with the calculated one and the higher-order multipole components were sufficiently small. The discrepancy between the mechanical center and the quadrupole field center is small enough for beam transmission. The mass production of DT is under manufacturing. The other components, such as post-couplers and slug tuners have been also developed for cold test. The alignment and the cold tests of the DTL will be carried out at this autumn.

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REFERENCES

- [1] WEI J, FU S N et al. China Spallation Neutron Source - an overview of application prospects., Chinese Physics C 2009, **33**(11): 1033-1042.
- [2] K. Yoshino, et al, Development of a DTL Quadrupole Magnet with a New Electroformed Hollow Coil For the JAERI/KEK Joint Project , Proceedings of LINAC 2000, California, USA, 569(2002).
- [3] J. Peng, Z.R. Sun, S.N. Fu, Design of 132MeV DTL for CSNS, Proceedings of LINAC 2006, Knoxville, Tennessee, USA.
- [4] E. Takasaki, et al, Results of the Magnetic Field Measurements of the DTL Quadrupole Magnets for the J-PARC, Proceedings of LINAC 2004, Lübeck, Germany.
- [5] X. Yin, K. Gong, J. Peng, Y. Xiao, Q. Peng, B. Yin, S. Fu, Development of a Quadrupole Magnet for CSNS DTL, TUP062, this conference.