MECHANICAL AND RF PROPERTIES OF THE DTL FOR THE JAERI/KEK JOINT PROJECT

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Abstract

The Alvarez-type DTL, which accelerates a H^- ion beam from 3 to 50 MeV, is one of the most important components in the injection linac for the JAERI/KEK joint project. It consists of three independent tanks of which the length is about 9 m. The resonance frequency is 324 MHz. The first tank of the DTL has been constructed by assembling the drift tubes precisely. Each drift tube contains the electro-quadrupole magnet that is set in the tube precisely also. The tuning of the post-couplers is being done in order to stabilize the accelerating field. They are also used for the fine adjustment of the accelerating field distribution on the beam axis. The DTL will be installed in the beam line for the beam test.

1 INTRODUCTION

The construction of the main linac has been started for a high-intensity proton accelerator complex of the project proposed by the Japan Atomic Energy Research Institute (JAERI) and the High Energy Accelerator Research Organization (KEK). The accelerator complex consists of a 400-MeV linac, a 3-GeV rapid cycle synchrotron and a 50-GeV synchrotron. The 400-MeV injection linac is comprised of a H^- ion source, a radio-frequency quadrupole (RFQ) linac, a drift-tube linac (DTL), a separated DTL (SDTL), an annular coupled structure (ACS) linac and several beam transport lines [1].

The Alvarez-type DTL accelerates the H^- ion beam from 3 to 50 MeV. It consists of the three independent tanks of which the length is about 9 m. Furthermore each tank is comprised of three short unit tanks of which length is approximately 3 m. The inside diameter of the tank is 560 mm.

The resonant frequency is 324 MHz which is approximately the highest-possible frequency, for the accommodation of the tunable electromagnetic quadrupoles in the drift tube (DT). The higher frequency is more preferable for suppressing the space-charge effect. This frequency is nearly the lowest-possible one for the use with klystrons, practically speaking.

All components for the DTL had been manufactured. The assembling of the tube in the first tank has been completed. The tuning of the post-coupler is being done in order to stabilize the accelerating field.

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2 DT FABRICATION

The drift tube (140 mm in diameter) and the stem (34 mm in diameter) are made of stainless steel. Every stainless steel parts are fabricated by the electron beam welding (EBW) after the installation of the magnet in the DT. (The magnet is bolted in the DT. The DTL-1 has 77 magnets. DTL-2 and -3 have 44 and 28 magnets, respectively.)

After the EBW of all parts, the space around the magnet in the DT is filled with an epoxy resin by a vacuum impregnation method. Finally the surface of the DT is covered by the copper formed by the periodic reverse (PR) electroforming method [2]. The copper surface is lathed for adjusting the size and is finished by the elecro-polishing (EP) method.

The coil of the the quadrupole magnet (Q-mag) installed in the drift tube is also made by the PR copper electroforming technique. The details of the construction process have been reported in the papers of the previous conference [3].

The magnetic field of the Q-mag is measured three times by a rotating coil during the fabrication process. The first measurement is done just after the construction of the magnet. The second one is done after the EBW of the base of the stem on the DT in which the magnet has been accommodated. The last measurement is done just before the electro-polishing of the surface. The purpose of the first measurement is checking the standard properties of the quadrupole field. The measured items are 1) the relation between the current and the magnetic field strength , 2) the position of the quadrupole field center defined as the dipole component minimum, 3) the field strength of the higher order modes, and 4) the temperature rise of the coil with a desired current.

The second measurement is carried out for the check of the position shift of the quadrupole center from the mechanical center. This measurement was added later since we found that the heat of the EBW for the stem base deforms the DT and the deformed part of the DT pushes the magnet. If the shift of the magnet position is lager than a tolerable value, the bore cylinder is lathed again in order to adjust the mechanical center to the quadrupole field center.

The purposes of the last measurement are not only the confirmation of the magnet properties measured before but also the check of the field excited with a pulsed current. The magnet is excited by a DC current for the first and second field measurements since the magnet is not fixed solidly. There are some possibilities that the mechanical oscillation is induced by the pulse excitation of the magnet, resulting some troubles in the magnet. The measured shift of the quadrupole center from the mechanical one by the pulse mode is consistent with that by the DC mode within the measurement error of $\pm 10\mu$m. Figure 1 shows the measured position of the quadrupole field center from the mechanical center defined by the pin inserted into the bore of the DT. The variation of the distribution is approximately ± 30 μm, which s small enough for our requirement, except for the 119th magnet for the DTL-2. The magnetic field center of the 119th DT is shifted about 60 μm from the bore center. The discrepancy of the magnetic center of the 119th DT will be corrected by the position tuning of the DT when DTs are assembled into the DTL-2.

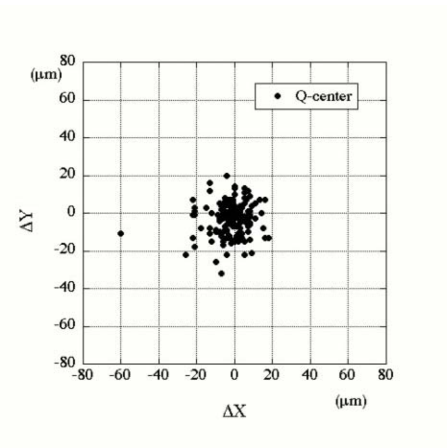

Figure 1: Discrepancy between the mechanical center and the magnetic center.

3 RF PROPERTIES OF TANKS

Each DTL tank, which is approximately 9 m in length, consists of three short unit tanks ($\sim$3 m in length, 560 mm in diameter). The measured results for the resonant frequency and unloaded Q-value for TM_{010} mode for each unit tank of DTL-1 and -2 are summarized in the table-1. The flat copper plates were used as the endplates of each unit tanks for the measurement. Every Q-values are larger than 90% of the calculated one.

Table 1: Q_0 of TM_{010} mode for DTL unit tank.
m/c: (measured Q)/(calculated Q)

Tank No.	meas.(calc.)	m/c(%)	freq. (MHz)
DTL1-1	74960 (79126)	94.7	409.058
1-2	76820 (79005)	97.2	409.049
1-3	75800 (79222)	95.7	409.031
DTL2-2	73200 (79105)	92.6	408.844
2-2	75110 (78227)	96.0	408.883
2-3	76120 (79030)	96.7	408.867

4 DT ALIGHNMENT

It is the most difficult engineering subject to assemble the drift tubes in the tank precisely. Tolerable alignment error of the tube is $\pm 50\mu$m in the vertical (x-y) plane to the beam axis and ± 100 μm from the design position for z-axis along the beam line. The center position of bore of the DT for x-y plane has been measured by an alignment telescope with an optical target and the position along the beam axis has measured by a laser interference meter of which the accuracy is about 1m. The assembled results for 76 DTs of the DTL-1 are summarized in figure 2. The result shows that the required accuracy for the alignment of the DTs has been achieved.

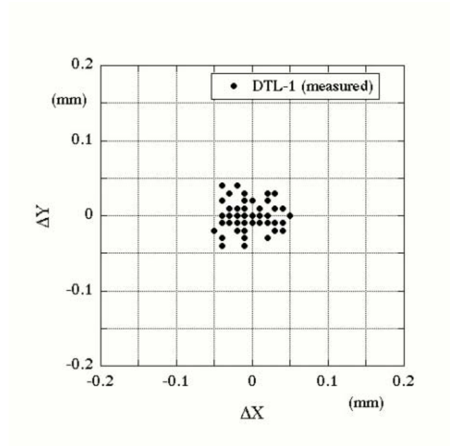

Figure 2: Discrepancy between the DT bore center and the beam axis.

5 ACCELERATING FIELD

5.1 Adjustment of the tuners

Each DTL tank has two auto-tuners and 10 fixed tuners. (There are four fixed tuners in the first and third unit tanks. The second unit tank has two movable tuners and two fixed tuners.) The insertion length of each fixed tuners are adjusted in order to obtain the uniform accelerating field on the beam axis. (For tuning, the ”fixed” tuners are replaced by the ”movable” model tuners.) Figure 3 shows the measured field distribution of the tank along the beam axis by a bead-pull perturbation method after the adjustment of the tuners. Here, no post-couplers are used. The abscissa is z-axis. The ordinate shows the count which is proportional to the square of the electric field. The bore radius is changed from the 58th gap. The bore diameter is 13 mm from the first cell to the 57th cell. The diameter is increased to 20 mm from the 58th cell. Namely the bore radius changes in the 57th full size DT. Therefore the ratio of the gap to the cell length is drastically changed at the 57th DT in order to keep the uniform average accelerating field per cell. Figure 4 shows the average accelerating field distribution corresponds to the data shown in figure 3. The resonant frequency f_0 is 323.812 MHz in this case (Air, temperature 25.4 degree, humidity 50%, 1 atom). It corresponds to the 324 MHz after the corrections as follows; the effect of air (+110±5 kHz), the insertion of the post-couplers (+107±5 kHz), thermal deformation of DTs by rf field (-22±2 kHz) and by the excitation of the Q-magnets (-5±2KHz), temperature correction (the operation temperature is 27 degree. -6±2 kHz)

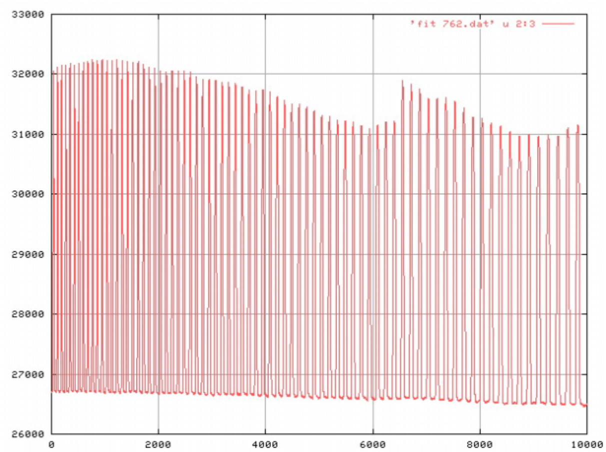

Figure 3: Measured electric field along the beam axis.

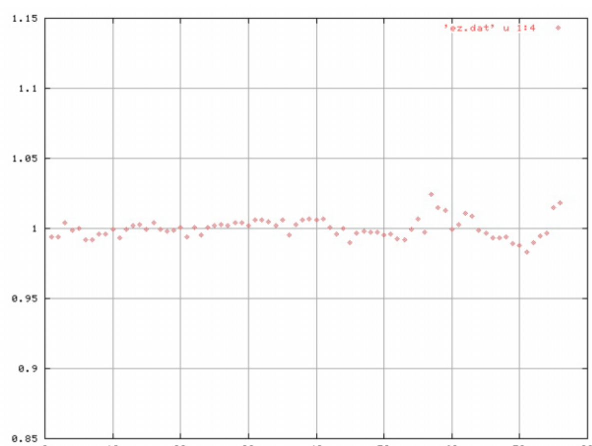

Figure 4: Averaged accelerating field for each cell.
No post-couplers are used.

5.2 *Adjustment of the post-couplers*

The insertion length of the post-coupler is adjusted by the measurement of the field uniformity of the distribution of the average electric field for each gap on the beam axis. The initial field distribution is inclined intentionally by the tuners as shown in figure 5 so as to see the effect of post-coupler clearly.

Each post-coupler has a tab on the top of the bar. The tilt of the each tab is tuned after the adjustment of the insertion length of the post-coupler. Every post-couplers are inserted uniformly but the tilt of each tab is adjusted one by one. Required field flatness is that the maximum field deviation is less than ±1%. The result at the present stage is shown in figure 5, showing that the maximum deviation is approximately 2%, which was not changed when the tuner perturbation was turned off. Therefore the additional tuning of the post-coupler is required.

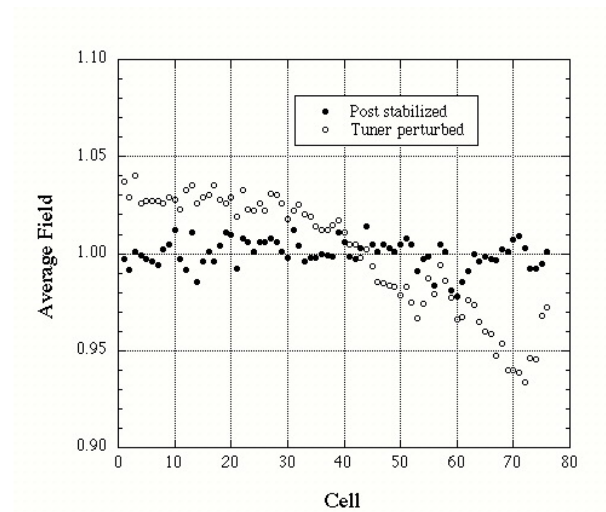

Figure 5: Effect of the post-coupler.
○: the initial distribution without post-couplers.
●: stabilized distribution by post-couplers.

6 SCHEDULE

The post-coupler tuning is being continued in order to achieve more uniform field. Then, the tank will be installed in the tunnel of the test facility in KEK for both the high-power test at the end of this year and beam experiment. All DTL tanks will be moved to JAERI from KEK at the beginning of 2005.

7 REFERENCES

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