DEFLECTING CAVITY FOT BUNCHLENGTH DIAGNOSTICS AT COMPACT ERL INJECTOR

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Abstract

Energy Recovery Linac (ERL) as synchrotron light source is planned to construct in KEK. Before the construction of full-set of ERL, compact ERL to study the accelerator technologies will be constructed. For the injector, a high voltage photoemission gun with DC operation and measurement systems for the low emittance beam will be developed. In order to observe bunch length and longitudinal beam profile, we have fabricated and designed a single-cell deflecting cavity with 2.6 GHz dipole mode. In addition, power input test, vacuum test and frequency measurements were carried out. We describe the optimization of the cavity, mechanical design and the measurements results with simulation.

INTRODUCTION

ERL for synchrotron light source requires an electron gun with high brightness, short bunch, and high current. In order to satisfy these conditions, a high voltage DC gun with Negative Electron Affinity (NEA) photo cathode is one of the excellent methods. Some of photo cathodes have slower response time, which generate a long tail compared with laser pulse width [1]. The slower cathode response affects the beam parameter generated by the DC gun. For example, the emittance growth is caused by both the longer tail and space charge effect. For that reason, since the beam parameter depends on the property of the photo cathodes, the investigation of the cathode property is required to generate high quality beam. The cathode response can be measured by the measurement of the bunch length. Bunch length diagnostics usually use a deflecting cavity. A bunch what passes a deflecting cavity is inclined by RF field for the transverse direction and the longitudinal beam information is projected along a transverse coordinate. Therefore, the bunch length can be measured through measuring the transverse beam size after the deflecting cavity.

KEK will have two electron guns for ERL. First is the Nagoya Polarized Electron Source 3 (NPES3). The gun was developed by Nagoya University for the purpose of International Linear Collider (ILC) and accelerating voltage is 200 kV. Second is 2nd 500 kV-gun developing by KEK (1st 500-kV gun is JAEA gun). Our deflecting cavity will be used with above two different energy electron guns.

The deflecting cavity was expected operate integral multiples of 1.3 GHz that is ERL operational Frequency. So measurement target of bunch length ranges from several picoseconds to a hundred picoseconds.

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In this paper, we describe the design of a deflecting cavity and the cavity fabrication with the measurement results. In addition we present a particle tracking result.

CAVITY DESIGN

In order to reduce the power of an RF amplifier and the cavity size, we designed the deflecting cavity similar to rectangular cavity what drives 2.6 GHz dipole mode. Figure 1 shows the cavity shape. To split the orthogonal dipole modes, the cavity is slight longer about vertical direction. Considering nearest neighbour beam chambers, the beam pipe diameter of the deflecting cavity is 38 mm.

Figure 2 illustrates TM120 deflecting mode electromagnetic field.

The quality factor is 15300 calculated by Gdfidl [2]. Table.1 shows the resonant frequency about several modes.

The cavity input power is estimated to be 20 W. At that time, the peak magnetic flux density is nearly 4 [Gauss] and the deflecting field gives the kick angle of ±2 mrad for the head and tail of the bunch with the beam energy of 500 kV and 40psec bunch length. A view Screen to measure the transverse beam profile will be installed at downstream of 1.6m from deflector. In order to improve the resolution of measurement, beam is collimated by a slit before deflector. In the case of beam thorough a 100 μm slit, the resolution of approximately 3 picoseconds will be obtained.

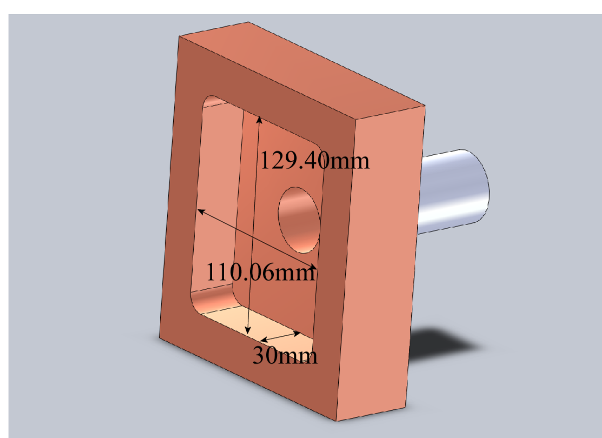

Figure 1: Cavity shape

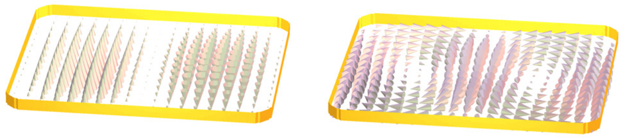

Figure 2: Electric field (left) and magnetic field (right) of TM120 mode

Table.1 Resonant Frequencies Some Modes

Mode	Frequency [GHz]
TM110	1.842
TM120	2.600
TM210	2.856
TM220	3.554
TM130	3.778

CAVITY FABRICATION AND MEASUMENT RESULTS

The cavity was made by two main bodies, beam pipe, coupler, probes, tuners, pipes for water cooling, and flanges. Figure 3 shows the photograph of the cavity.

As an input coupler, a coaxial type antenna, which has an inner conductor of 3mm diameter with outer conductor of 7 mm diameter, is used. Q-external of this coupler shows figure 4. Finally, the head of antenna position was 1.24mm from the cavity wall, and the coupling was 1.02. The quality factor was 14000. This value is about 90% of Gdfidl calculation. Brazing carried out three times with Cu-Au filler material. Before final brazing, coupling was adjusted.

Monitor ports were prepared to measure input power, phase, etc. One sets a symmetrical position with the input port with the Q-external of 2.28×10^{8}. Another sets a rotated by 90 degrees about beam axis. These ports can use similar to cavity BPM.

Four frequency tuners were set. The tuner was developed for KEK-ATF S-band RF gun [3]. A part of cavity wall makes thinly, and the resonant frequency is tuned by pushing or pulling the thin walls. After cavity machining, the resonant frequency of the TM120 mode was 2.5967 GHz in the pressure of the atmosphere. The tuners were able to vary the resonant frequency into 2.5993 GHz.

There are no pumping ports for the reason of cavity size. Following Helium leak test, the cavity was exhausted by an ion pump which was connected to the cavity. The history of vacuum pressure shows Figure 5. About 180 hour later, the pressure arrive at 1.9×10^{-6} Pa.

Cupper pipe for water cooling have internal diameter of 8mm. This pipe was connected with a chiller. The chiller can change the temperature of the cooling liquid between -10~90 Celsius.

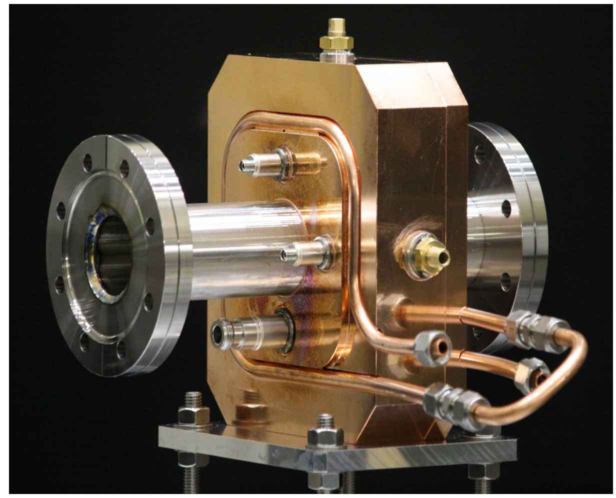

Figure 3: Photo of deflecting cavity

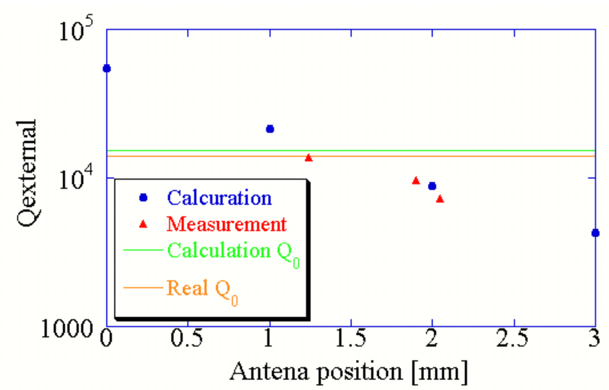

Figure 4: Q-external versus head of antenna position from cavity wall. Positive position is direction of intrusion into cavity

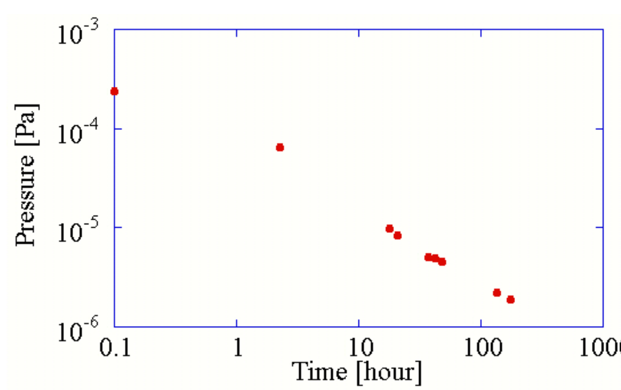

Figure 5: History of vacuum pressure

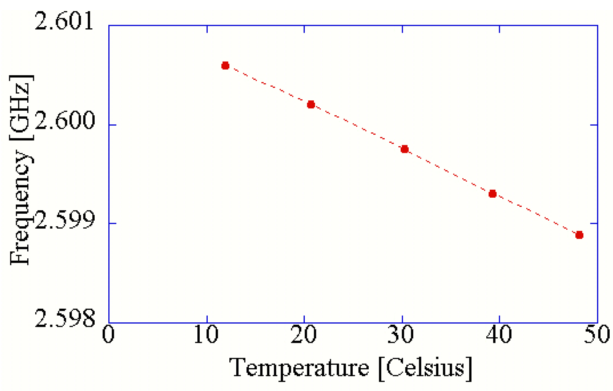

Figure 6: Frequency versus cavity temperature

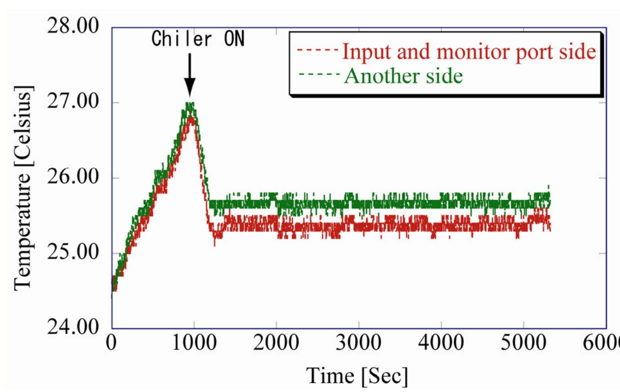

Figure 7: Temperature stability when input power is 20W

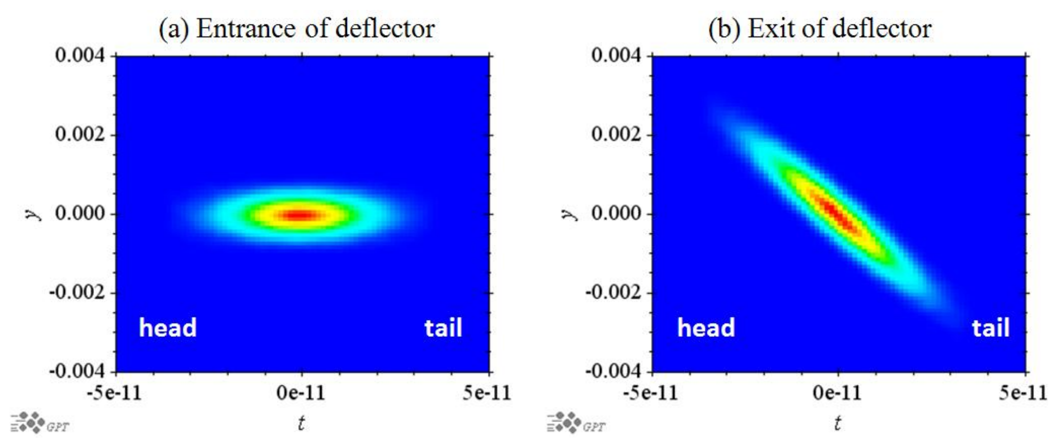

Figure 8: Simulation result. (a) is initial distribution, (b) is after deflector. This figure is plotted with vertical position as the vertical axis in meter and time as the horizontal axis in second.

Frequency measurement in vacuum was carried out. That depends on cavity temperature. Figure 6 shows cavity temperature versus resonant frequency. From the measurement, $\delta f/\delta t = -48$ [kHz], and 2.600 GHz was correspond to 24 Celsius. Figure 7 shows temperature stability when input power is 20W. Temperature is stable accuracy of ±0.1 Celsius.

BEAM SIMULATION

Beam simulation for deflecting cavity still in progress. Simulation was executed by particle tracking code of General Particle Tracer (GPT) [4]. Deflecting field was given by simple form which exist horizontal magnetic field. Both initial horizontal and vertical rms beam sizes are 0.3mm, and initial bunch length is 10 psec. An electron bunch with 500 keV passed through the deflector, which is located at 0.5 m from the initial position, and transferred to one meter downstream. Figure 8 shows simulation results. After the cavity, longitudinal position was projected along the vertical direction. So, we measure a transverse beam size, we can obtain bunch length.

SUMMARY

We have designed and fabricated a 2.6 GHz dipole mode deflecting cavity. Since power input test and vacuum test, frequency stability and vacuum pressure are competent for beam diagnostics in KEK DC guns.

In future, we advance simulation more suitable for real diagnostics.

REFERENCES

[1] Sergey Belomestnykh et al, [Deflecting cavity for beam diagnostics at Cornell ERL injector] Nuclear Instruments and Methods in Physics Research A 614 179-183
[2] http://www.gdfidl.de/
[3] KEK GIJUTUKENKYUUKAI [PHOTO CATHODE RFGUN CAVITY NO SEISAKU] TAKATOMI TOSHIKAZU in Japanese
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