COLD CATHODE ELECTRON TUBE TOWARD PLENTY MULTI BEAM TUBE

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Abstract

The multi beam electron tube with a lot of beam pipes is required for the lower applied voltage and the higher frequency because the efficiency has a limit according to the perveance. However, the total heater power consumption becomes too high if many thermal cathodes are used. Thus the cold cathode such as the carbon nano tube (CNT) is suitable for such a multi beam electron tube. Further the cold cathode has the advantage to work as a switching device since the metal grid close to the cathode can be used. The design and the fundamental test of the partial model will be presented.

ELECTRON TUBE USING COLD CATHODE

If we attempt to design the hundred or thousand multi beam electron tube, the following problems were occurred:

- Huge power consumption of thermal cathodes.
- Complicated gain cavity system using higher mode.
- Huge solenoid magnet.
- Parallel switching device adopting higher current is required for the pulse operation.

To avoid them, the grid triode [1] like the inductive output tube (IOT) using the field emission cathode has a possibility as a solution of such a plenty multi beam electron tube.

The advantages using the field emission cathode compared with the thermal cathode are as followings:

- No power consumption for the cathode.
- Very thin metal wire grid can be used and long life time is expected since the life time described in reference [1] is mostly caused by the high temperature of the thermal cathode.
- No resonant frequency change is occurred.
- Shorter grid gap and higher surface field makes to operate at higher frequency.
- Shorter bunch caused by the E-I curve of the field emitter can operate as the frequency doubler as shown in Fig. 1. Fig. 1 (left) shows the expected emission current according to the E-I curve of the carbon nano tube (CNT). Fig. 1 (right) shows the comparison of the frequency component between the CNT cathode and the thermal cathode

Further the grid tube has many advantages as followings:

- Huge solenoid magnet is not required since the beam trajectory is shorter.
- No switching device is required for the pulse operation.
- Simple cavity system

The disadvantages using the field emission cathode are as followings:

- Much higher surface field is required for the emission.
- Since it causes the lower gain, multi stage tube has to be considered to get higher gain.
- Proper ageing process is required for the field emission cathode.
- Special treatment is required to reduce the ununiformity of the cathode emission. One candidate for this is that the field emitter is arranged on the high resistance plate.

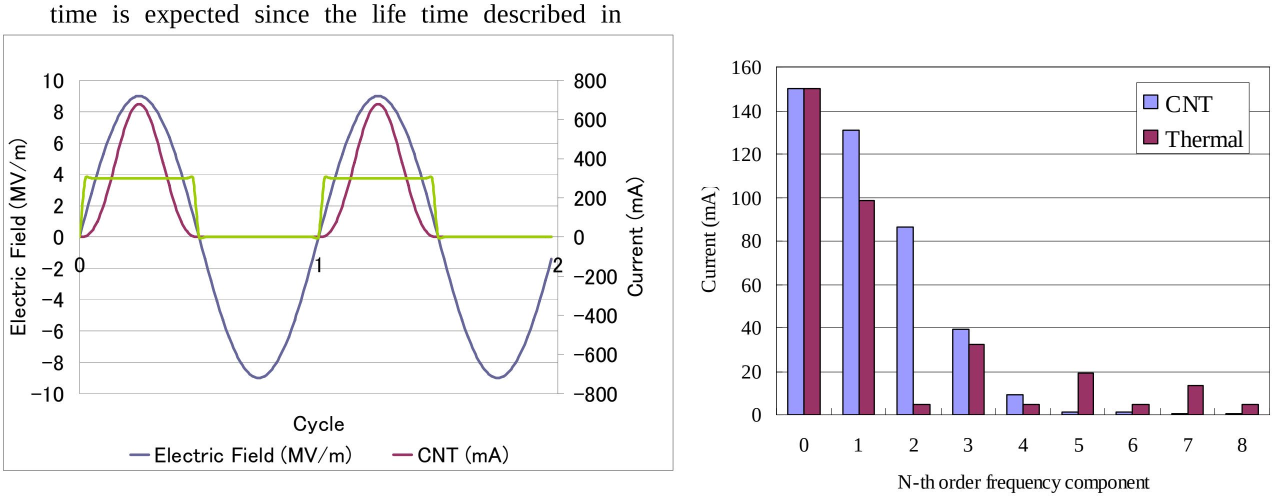

Figure 1: The emission current and its frequency component.

TEST TUBE

The test tube was designed to obtain the fundamental characteristics of the RF response of the field emitter. The inductive output tube is a good candidate for such a test. Further the test tube was designed to work as the frequency multiplier of the input and the output frequency of C-band and X-band respectively since the higher efficiency for the frequency multiplication shown in Fig.1 is an important feature.

Field Emitter

The multi-wall carbon nano tube (MWCNT) which is strongly bonded on the titanium plated surface is used for the field emission cathode. Its bonding procedure is written in reference [2]. Further some DC pulse experiments show that the CNT emitter can produce higher current than the expected current of the simple field emitter. This seems to be caused by the thermal effect. One purpose of this test tube is the estimation of such an effect since higher current is expected due to the microwave heating.

Input Cavity and Metal Wire Grid

The C-band input cavity is designed to use the TM_{01} like mode extended to the TEM mode and excited by the coaxial line. The TM_{01} like mode has thin gap whose top is the wire grid and bottom is the CNT emitter. Fig. 2 left and right top, right bottom show the mechanical drawing of the input cavity and the simulation model overlapping the electric field, the assembled input cavity respectively. The grey part of the top of the cavity is the dielectric substance to adjust the resonant frequency.

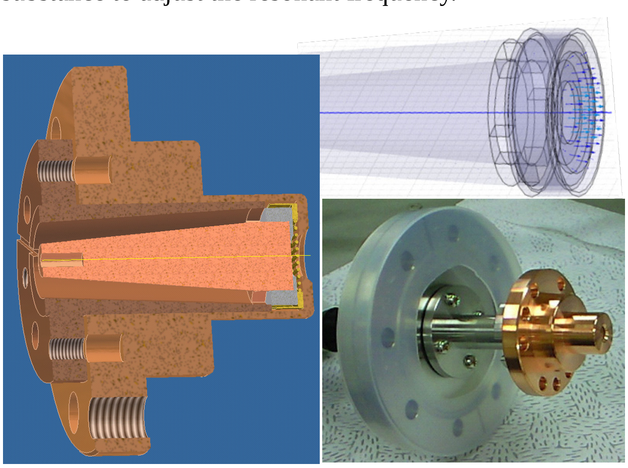

Figure 2: The C-band input cavity of the test tube.

Output Cavity

The output cavity is designed to work at X-band frequency. Fig.3 left and right show the simulation model and the assembled cavity respectively. There is the matching section to connect to the waveguide of WR-90.

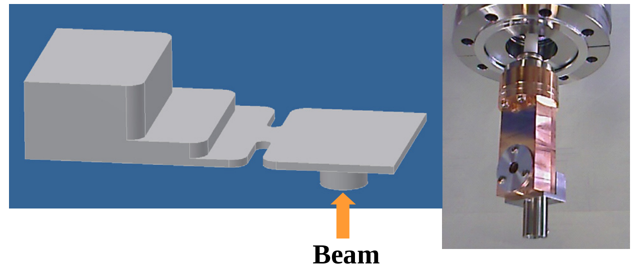

Figure 3: The output cavity of the test tube.

Dielectric Waveguide

It is arbitrary which is selected the anode side or the cathode side for the high voltage. Both have respective advantage. In case of this test tube, the power consumption is enough small not to use the cooling liquid. Thus anode side was selected for high voltage to simplify the cathode side. Further the dielectric waveguide [3] is used to combine the microwave propagation and the high voltage insulation since high frequency cavity including the insulator is difficult. Fig. 4 top and bottom show the simulation model and the mechanical drawing of the X-band dielectric waveguide. The dielectric waveguide is consist of 10 mm diameter alumina rod brazed by Hitachi Haramachi Electronics Co., Ltd and the matching cavity to connect the WR-90 waveguide.

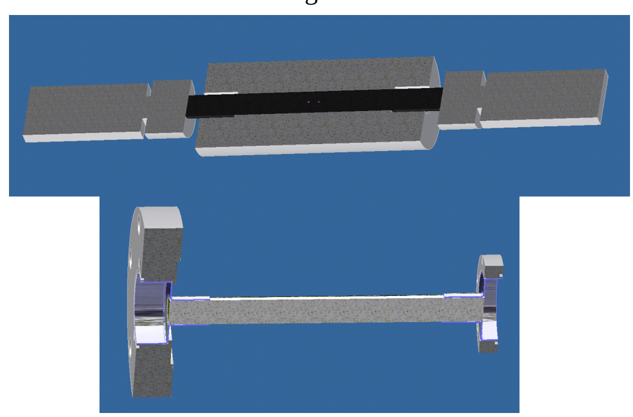

Figure 4: The X-band dielectric waveguide for the insulation.

Beam trajectory

The beam trajectory of the test tube is calculated using the code CST Particle Studio (TM) as shown in Fig.5. The beam is focused well only by the electric field.

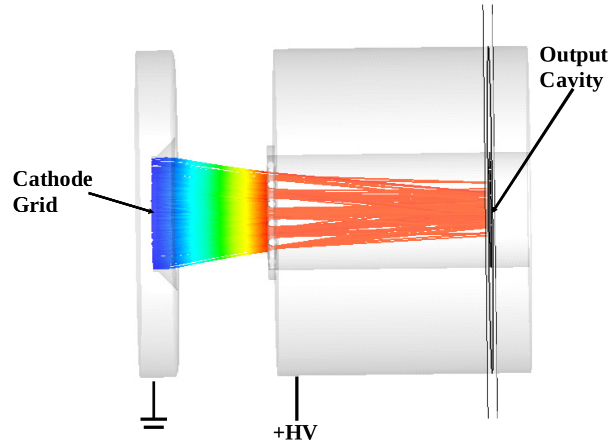

Figure 5: The beam trajectory of the test tube.

Mechanical Design

Fig. 6 shows the overview of the test tube. The C-band input cavity is placed at the left side. And the X-band output is connected to the top of the test tube. The high voltage is applied for the bottom and connected to the output cavity using the central rod. The coaxial feedthrough for the input and the dielectric waveguide using the alumina ceramic for the output are used to avoid the vacuum leak.

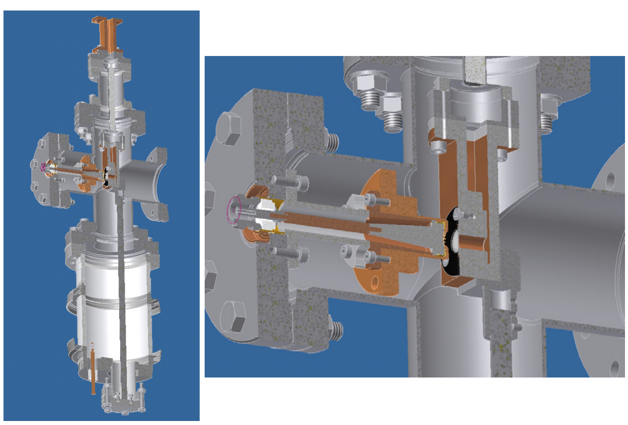

Figure 6: The overview of the test tube.

Experiment

The preliminary experiment was done for the test tube as shown in Fig. 7 (left). The vacuum pressure is approximately 10^{-5} Pa and the applied voltage was +20 kV. Further a capacitor of 3 μF is used to make the pulsed high current. Fig. 7 (right) shows the waveform of the C-band input power and the X-band output power using the crystal detector.

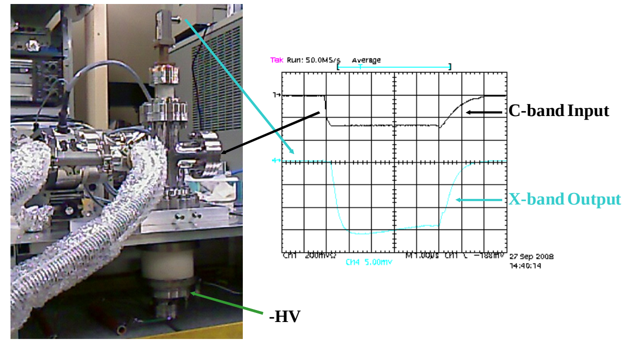

Figure 7: Experiment and result of the test tube.

In this preliminary experiment, the CNT cathode has only 2 mm square size. Further the input power is limited by the output power of preamplifier and the gap between the grid and the CNT cathode of the input cavity becomes longer than the designed value. Thus the output power is much less than the designed power.

SUMMARY AND FUTURE PLAN

The test tube of the grid triode using the CNT emitter was tested. The parameter optimization will be done soon.

After the fundamental characteristics are obtained by this test tube, the multi beam electron tube using such a CNT emitter will be designed.

ACKNOWLEDGEMENT

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