THE DEVELOPMENT OF L-BAND INDUCTIVE OUTPUT TUBE WITHOUT TROLLEY TOWARD HIGHER APPLIED VOLTAGE

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Abstract

The L-band inductive output tube (IOT) without trolley was developed to operate under higher applied voltage. The operation frequency of conventional IOTs is tuned using its trolley. This mechanism is based on the lower frequency IOT. However it causes less insulation voltage of the ceramics since the electric insulation oil is not available for its trolley and the length of the insulation ceramics is limited because it is a part of the resonant cavity. In case of IOTs, it is important to increase the applied voltage for higher output power since the grid gap is very narrow and its area cannot be increased to keep the gain. Thus we developed an IOT which has a longer insulating ceramic and the input cavity is filled with vacuum to use the electric insulation oil. Further the dielectric waveguide can solve to feed the input microwave to the cathode grid without trolley. These new features of the IOT are very effective for the fixed frequency application such as the accelerator, for example the energy recovery linac. The design and the experimental results will be presented in this report.

SIMULATION OF IOT

The characteristics of an inductive output tube (IOT) [1,2] are mainly determined by its input cavity. However the cathode-grid gap is too thin to calculate the interaction between particles and electromagnetic field using the general simulation code. We use the following cavity model to calculate the input cavity [3].

The beam admittance and the loaded frequency shift are described as followings.

$$\begin{aligned} Y_{beam} &= G_{beam} + jB_{beam} \\ &= \frac{1}{2}\frac{I}{V}\frac{\sin(\theta_e) + j\cos(\theta_e)}{\theta_e}\left\{\frac{\sin(\theta_e)}{\theta_e} - \cos(\theta_e)\right\} \\ &\left(\theta_e = \frac{\beta_e d}{2}\right) \\ \delta_B &= \frac{f_B - f_0}{f_0} = \sqrt{1 + B_{beam}(R/Q)} \end{aligned} \tag{1}$$

The terminal admittance is

$$Y_T = (G_{cav} + G_{beam}) + j\left(\frac{2\delta}{(R/Q)} + B_{beam}\right) \tag{2}$$

Thus the voltage of the input cavity is described using the reflection coefficient ρ as followings.

$$\begin{aligned} \rho &= \frac{G_{ext} - Y_T}{G_{ext} + Y_T} \\ V_{input} &= \sqrt{2(1-\rho^2)P_{in}Q_{uh}(R/Q)} \end{aligned} \tag{3}$$

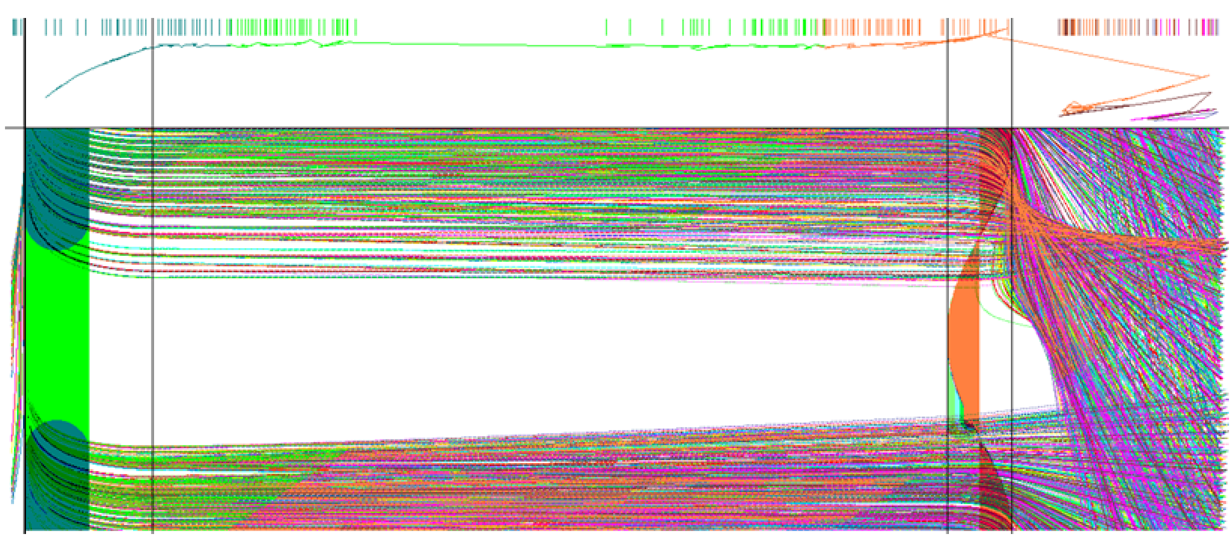

Figure 1: Simulation Result.

The beam admittance is iteratively calculated using the beam current obtained from the voltage of the input cavity.

Except for the special treatment of the input cavity, the disk model is enough to calculate the total IOT since the perveance is not so high compared with a klystron. Figure 1 shows the total IOT simulation.

The design parameters are shown in Table 1.

Table 1: The design parameters

Output Power	> 30 kW
Operating Frequency	1300 MHz
Beam Voltage	40 kV
Beam Current	1.5 A
Power Gain	> 25 dB
Power Efficiency	> 50 %

According to the design parameter, the half inch diameter cathode is used. Further the focusing magnet and the beam collector are designed considering the beam trajectory as shown in Figure 2. The focusing magnet consists of the electromagnet coil of 4000 A turn.

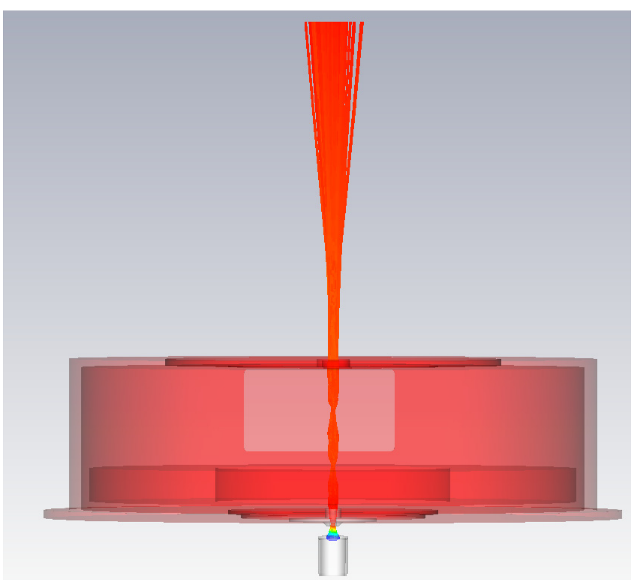

Figure 2: Beam Trajectory.

DIELECTRIC WAVEGUIDE TO ELIMINATE TROLLEY

The withstanding applied voltage of the general IOT is determined by the trolley which cannot be filled with the insulating oil since the trolley consists of a resonant input cavity.

The dielectric waveguide can solve such a problem. The input cavity is placed inside the vacuum tube and the insulating ceramic can be filled with the insulating oil. This method is also convenient for the speedy replacement of the IOT.

Figure 3 shows the dielectric waveguide and its simulation result. The alumina ceramic of 80 mm diameter is used.

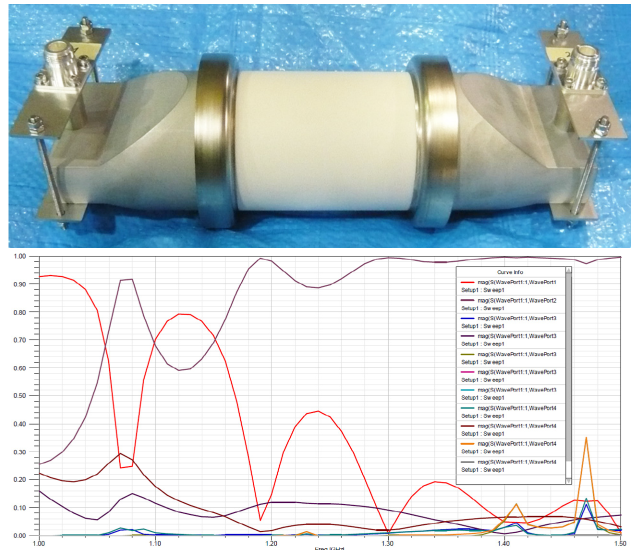

Figure 3: The dielectric waveguide and its simulation result.

EXPERIMENTAL IOT

Figure 4 shows the sectional view of the experimental IOT and it is fabricated as shown in Figure 5.

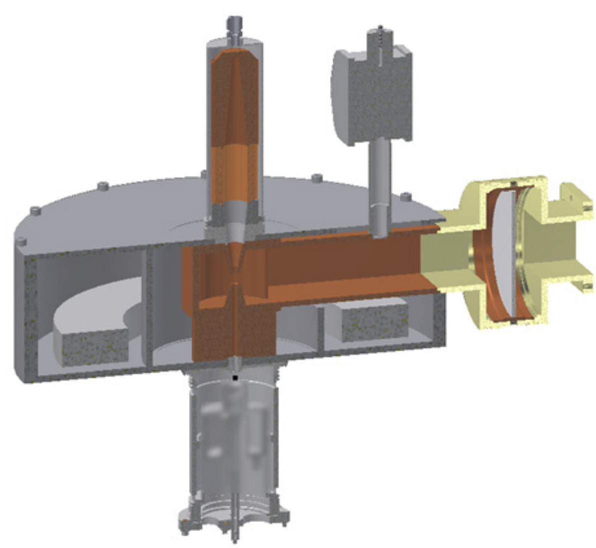

Figure 4: The sectional view of IOT.

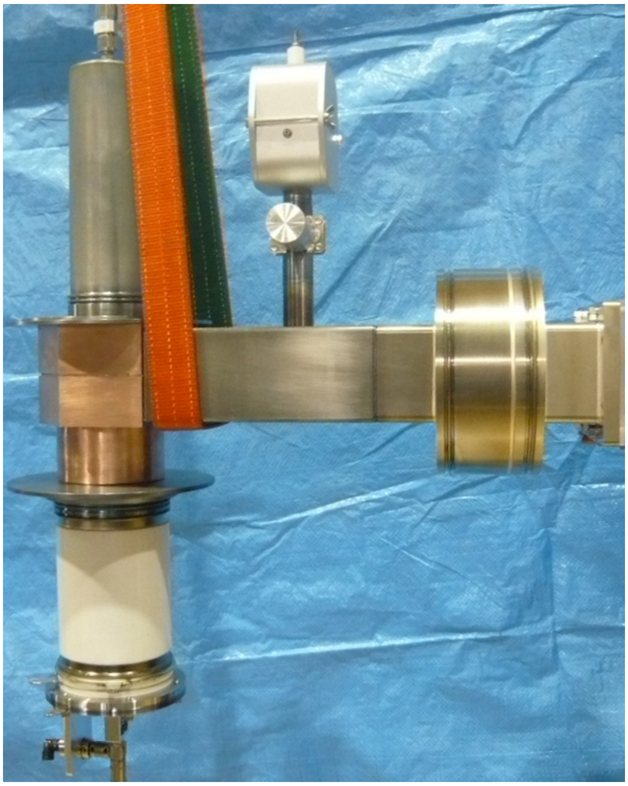

Figure 5: The experimental IOT.

In this experimental IOT, a pillbox window for the RF output is used to be able to operate at higher output power. Thus the coaxial window is reasonable only for the output power of 30 kW.

This IOT is tested using pulsed high voltage of 30 kV only to test the fundamental characteristics. The figure 5 shows waveforms of the applied high voltage, the beam current, the RF input and the RF output.

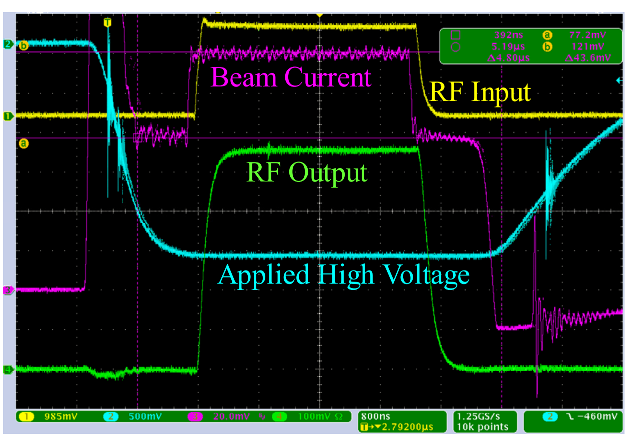

Figure 6: An experimental result.

In this experiment, the unloaded quality factor of the input cavity becomes lower than the designed value. Thus the beam current of around 0.5 A and the output power of 4 kW was obtained in this experiment. This will be solved by the improvement of the grid structure and the cavity conductivity.

TOTAL SYSTEM

We have to consider about the total size of an RF unit and the total fabrication cost for the big project including the ERL project, which requires around 250 IOT units.

The total system including the low-level RF, the semiconductor amplifier, the interlock controls and the power supply is proposed cooperating with The Mitsubishi Electric TOKKI System Corporation as shown in Figure 7.

Figure 7: The proposed total IOT system.

CONCLUSION

We are developing the L-band IOT using a new conceptual design to eliminate the trolley, which causes of the limitation of the applied high voltage. This development will be completed in the near future.

REFERENCES

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[3] 1939J. R. M. Vaughan, "The Input Gap Voltage of a Klystron", IEEE Transactions of Electron Devices, Vol ED-32, No. 11, Nov 1985, p.2510-2511.