Recent Experimental Results of Magnetron Injection Gun (MIG) for 42 GHz 200 kW Gyrotron

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Abstract: *A sealed off magnetron injection gun (MIG) collector module for 42 GHz 200 kW gyrotron has been developed. The paper reports the high voltage and beam-emission test result. In addition, the current-voltage characteristics at different heater wattage are also discussed from recent tests.*

Keywords: Gyrotron; MIG-collector module; current-voltage characteristics; heater wattage.

Introduction

Magnetron injection gun (MIG) is a critical component in the gyrotron [1-2]. In MIG, the cathode operates in the regime of temperature limitation for emission current at set electric field. The high voltage applied between the anode and the cathode of the MIG with magnetic field to obtain desire electron beam properties for high efficiency gyrotron. Due to a variety of reasons, such as a switching operation or by faults, high voltage surges may induce in the MIG. The shape of the transition characteristics of voltage and current can excite different modes in the interaction structure and also spurious oscillations may appear. Further, the non-uniformity of electron emission from the cathode surface can affect the performance of the electron beam. Therefore, the detailed analysis processes in the electron optical system (EOS) of a gyrotron is required to optimize the gun parameters and the RF performance of the device.

In India, the design and development of gyrotron for fusion reactor has been started through multi-institutional project titled, "Design and development of a 42 GHz, 200 kW CW/long pulse gyrotron", and sponsored by Department of Science and Technology (DST). The in-house designed of the whole gyrotron with peripheral systems has been completed [3-4]. Table 1 shows the specifications of the triode type MIG for 42 GHz 200 kW gyrotron [3]. Figure 1 shows the in-house fabricated sealed off MIG with dummy collector. The paper presents the experimental results of the breakdown and beam emission testing of the MIG. Further, uniformity of the beam emission is also determined by the uniformity of temperature on the cathode surface.

Breakdown Test

The high voltage breakdown testing of MIG collector module is carried out at atmospheric environment using 200kV/5mA breakdown test set up. From the electron beam trajectory design analysis, the potential at the modulating anode and the control anode with respect to cathode are 29 kV and 65 kV, respectively. And for the safe operation of the device, voltage breakdown criteria should be taken as 5kV/mm for vacuum and 1 kV/mm for atmosphere [5]. At atmospheric condition, the experimental values of the safe limit of voltage breakdown are presented in table 2. The most critical region is between cathode and modulating anode. At atmospheric condition, breakdown voltage between cathode and modulating anode is 32.4 kV.

Emission Test

The temperature limited dispenser cathode is tested upto 1200°C which follows Richardson-Dushman equation. The temperature measurement across the azimuthal direction is also carried out to check the beam emission uniformity. Azimuthally the maximum temperature difference is 25°C. The triode type MIG collector module has been tested using negative high voltage (50 kV/40 A) pulsed DC power supply. Figure 1 shows the typical voltage and current pulses at pulse repetition frequency, 100 Hz and pulse width, 20 μs. At filament voltage, 7.8 V and filament current, 32.2 A, the desire beam current 10 A has been achieved. The beam current versus beam voltage characteristic is shown in figure 2. The characteristic resembles the operating condition of the temperature limited cathode. The difference in the current-voltage characteristics at different heater wattage are caused by the temperature and field intensity at the cathode.

Conclusion

The different complex measurement including analysis of the voltage breakdown, current-voltage characteristics and monitoring of cathode surface temperature are carried out for complete characterization of emission capability of the cathode as well as allow fast analysis MIG.

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Table 1. Designed MIG parameters for 42 GHz 200 kW gyrotron

Beam current	10.3 A±0.01A
Accelerating voltage	65 kV±1kV
Modulating anode	29 kV±0.5kV
Compression ratio	16
Emitter radius	22.55 mm±0.05mm
Emitter current density	1 A/cm^2
Velocity ratio	1.26±5%
Magnetic field at interaction structure	1.61 T±1%

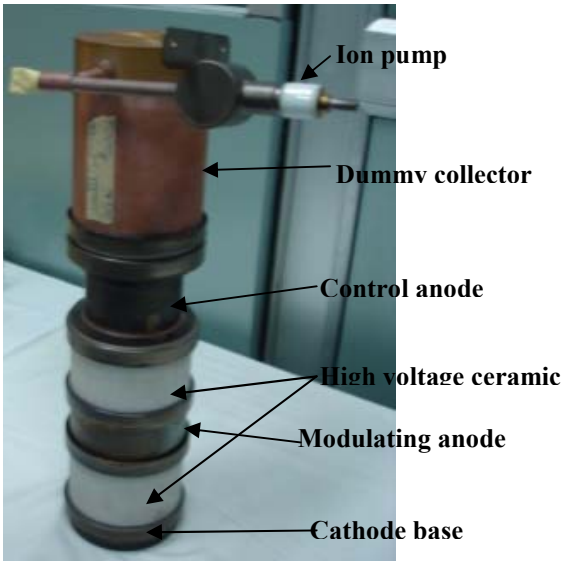

Figure 1. Developed MIG collector module for 42 GHz 200 kW Gyrotron.

Table 2: Breakdown potential value at different region of the MIG-collector module.

Region	Breakdown Potential (kV)
Between cathode and modulating anode	32.4
Between cathode and control anode	48
Between modulating anode and control anode	36

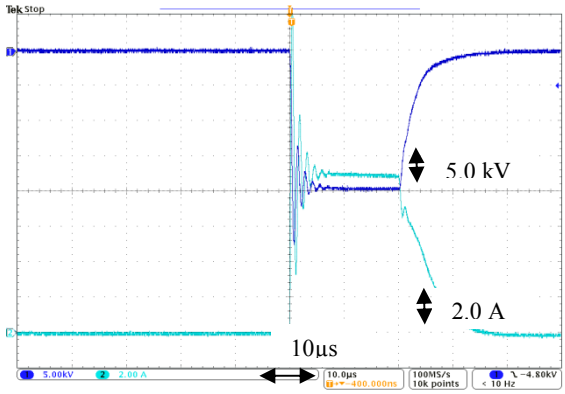

Figure 2. Beam voltage (Indigo trace) and emission current (Cyan trace).

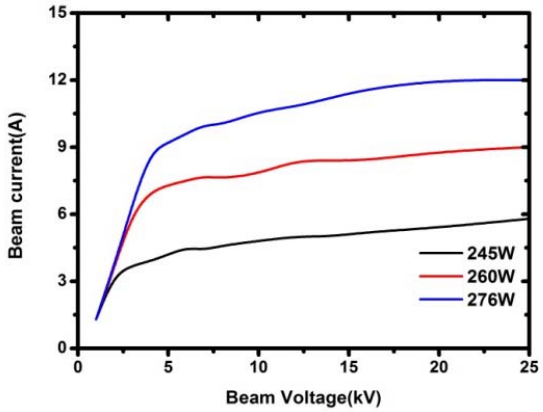

Figure 3. Current-voltage characteristics of the cathode at different heater wattage.

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