§2. Preliminary Experiments on an 84GHz Gyrotron with a Single-Stage Depressed Collector

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The energy recovery of the spent electron beam by the depressed collector leads not only to an improvement in total output efficiency, but a reduction of the power loading and X-ray generation at the collector. When considering pure CW high power gyrotrons, these merits are very attractive.

We have been developing an 84GHz CW gyrotron in collaboration with CPI for use as the power source in the ECRH system on LHD (Large Helical Device). Based on the previous success of the 84GHz CW gyrotron, we fabricated a new gyrotron which has the same RF circuits, electron gun, and mode converter, but is equipped with a depressed collector and larger Vacion pumps shown in Fig. 1.

This gyrotron has been improved for high power CW operation: almost all parts of the body and collector sections are water-cooled, and two large 75 liter/second Vacion pumps improve the pumping speed in the tube. The most remarkable difference is the addition of a high voltage insulating section between the body and the collector to be able to apply the retarding potential for the energy recovery of spent electrons. The insulating section is made of a silicon nitride composite which has a low loss-tangent in the millimeter wave range.

Preliminary experiments were performed at the test set at CPI. During the first stage of gyrotron aging (normal operation without the retarding potential) the gyrotron achieved a maximum output power of 639kW and efficiency of 32% at beam voltage of 80kV and beam current of 25A for short pulses. During the normal operation, the insulating section was cooled by pure water so that power from RF leakage could be measured calorimetrically. It was about 0.7-1% of the total output power.

Since the gyrotron test set at CPI is not designed for depressed collector operation, a portable tetrode system was connected between the collector and grounded body to provide the depressed collector potential. By adjusting the screen grid voltage of the tetrode, we were able to set the collector potential relative to the grounded gyrotron body. This system was only capable of operating at 0.5ms pulsewidth.

Figure 2 shows the dependence of the total oscillation efficiency on the depressed voltage for several beam current operations. At each point, the main accelerating voltage (potential difference between cathode and body) was set at 80kV, and the magnetic field and the anode voltage were optimized. For all beam current values, efficiency gradually increased as depression voltage was increased, until anode current was observed. Increasing the depression voltage beyond this point resulted in a drop in efficiency. Increased efficiency was due to energy recovery; the output power actually remained constant or decreased slightly as voltage depression was increased. The highest efficiency achieved was 41.5% at 25kV of depression and 20A of beam current. At this point, output power was 475kW. The highest power of 591kW was obtained with a beam current of 25A and 41% efficiency at a depression voltage of 22.5kV.

Access to the higher efficiency region was inhibited by an increase in anode current .

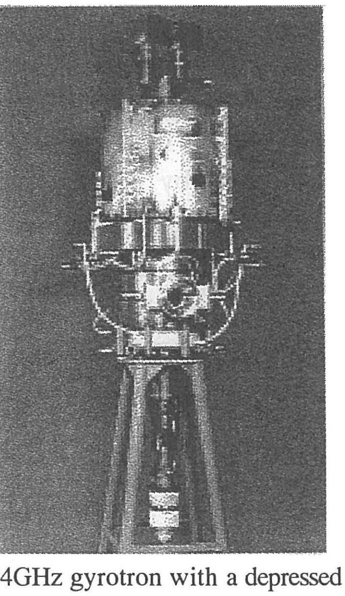

Figure 1 84GHz gyrotron with a depressed collector

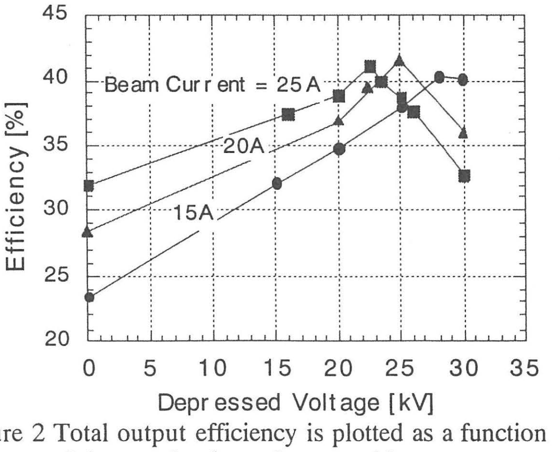

Figure 2 Total output efficiency is plotted as a function of depressed voltage for several beam currents