

# Experimental Testing of an Electron Gun and Beam Transport System for a 670 GHz Extended Interaction Klystron

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**Abstract:** *Experimental testing of electron beam formation, transport, and depressed collection is performed in a beamstick for a 670 GHz extended interaction klystron with a 25 kV, 100 mA nominal operating point. Beam transmissions of 77-86% are achieved through a 125 micron diameter by 1.7 cm long beam tunnel.*

**Keywords:** EIK; beamstick; terahertz; electron beam; depressed collector.

## Introduction

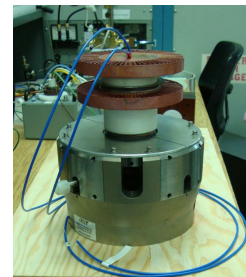
High power amplifiers operating in the upper millimeter-wave to terahertz frequency range are an important technology for new types of communication, radar, and spectroscopy applications. A key technology for these amplifiers is the ability to generate and propagate intense, well collimated, extremely small diameter electron beams through the amplifier structure.

A 670 GHz extended interaction klystron (EIK) amplifier that is presently under development [1] will utilize a 25 kV, 100 mA electron beam with a nominal diameter of 120 microns, passing through an interaction structure having a beam tunnel diameter of 125 microns. These parameters necessitated the development of a new electron gun, as well as a robust beamstick experiment to experimentally test the gun performance and beam transport efficiency over a wide operating parameter space. Demonstrating an efficient depressed collector is an additional goal for the beamstick.

## Experimental Setup

The beamstick (Figure 1) incorporates an electron gun [2] with an adjustable focus electrode voltage with respect to cathode, and a mod anode with an adjustable potential that is located between the cathode and the grounded anode/beam tunnel assembly. The beam tunnel is made

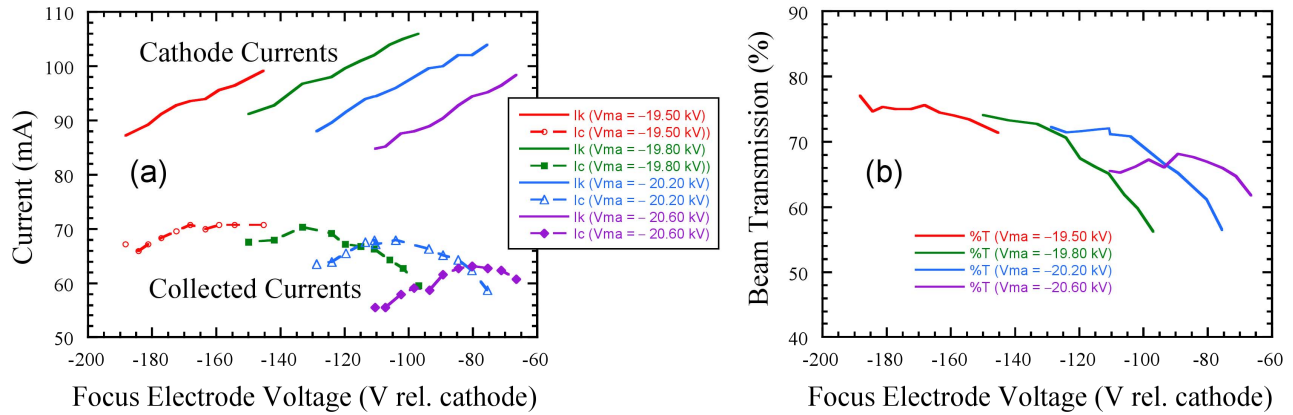
from copper and is 1.7 cm long and 125 microns in diameter. A pair of depressed collectors is employed, with the first being a grading electrode to prevent secondary reflection, and the 2<sup>nd</sup> being the actual collection electrode. The beamstick was energized by cathode pulsing with a 3  $\mu$ s flat-top on the voltage pulse and approximately 1  $\mu$ s rise and fall times, at repetition rates of 1-3 Hz. A compensated resistive divider was used to power the mod anode, along with a floating deck adjustable battery supply for the focus electrode (range -190 to 0 V relative to cathode). The collectors were operated in a true depressed collector topology, with isolation-transformer-fed floating supplies providing voltages relative to the cathode.



**Figure 1.** Photograph of the beamstick

## Results

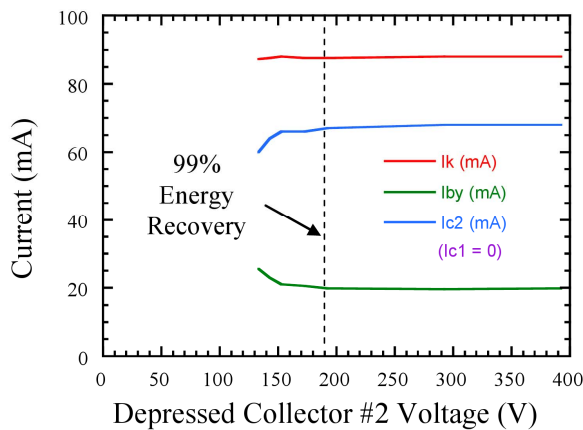
Experimental measurements of cathode current ( $I_k$ ) and collected (i.e., transmitted) current ( $I_c$ ) at -25 kV cathode voltage are shown in Figure 2(a). These are plotted versus the focus electrode voltage (relative to cathode). The different pairs of curves correspond to different mod anode voltages. For a given mod anode voltage ( $V_{ma}$ ), as one makes the focus electrode voltage less negative relative to cathode, the cathode current increases as expected. Initially, the collected current also increases, but eventually



**Figure 2.** Measurements of (a) cathode and collected currents, and (b) percentage beam transmission, for the case with  $-25$  kV cathode voltage.

it reaches a peak, and subsequently rolls over. Thus, there is a value of focus electrode voltage that optimizes the transmitted current. Corresponding percentage beam transmission curves are shown in Figure 2(b). The maximum beam transmission found at this cathode voltage was 77%. A slightly different combination of mod anode and focus electrode voltages was used to find the maximum in transmitted current, which was 74 mA when the cathode current was 97 mA (corresponding to a transmission of 76%).

Extensive studies of cathode emission and beam transmission were performed at over a range of cathode voltages. In general, transmission improved at smaller magnitudes of cathode voltage. At a cathode voltage of  $-20$  kV, a peak transmission of 80% was found (cathode current of 69 mA and collected current of 55 mA). When the cathode voltage was only  $-14.7$  kV, a peak transmission of 86% was measured (cathode current of 44 mA and collected current of 38 mA). At all cathode voltages, magnetic shunting and cathode mechanical movement did not improve the transmission significantly.



**Figure 3.** Measured depressed collector behavior, for the case with  $-25$  kV cathode voltage.

The depressed collector performance was evaluated by studying the collected and body (intercepted) currents as a function of how close the collector potentials could be brought towards the cathode potential. Results for the  $-25$  kV cathode voltage operating point are shown in Figure 3. In this study the 1<sup>st</sup> collector voltage was set at  $+1500$  V relative to cathode, while the 2<sup>nd</sup> collector voltage varied between  $+130$  to  $+400$  V relative to cathode. Body current ( $I_{by}$ ) did not increase until the 2<sup>nd</sup> collector voltage was reduced to  $+190$  V relative to cathode, indicating 99% collector efficiency with respect to the transmitted beam (the first collector was non-intercepting).

In summary, the demonstrated beamstick performance meets the challenging requirements for new classes of high power, high efficiency terahertz amplifiers.

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### References

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