

# **Application of Field Emitter Arrays to Microwave Power Amplifiers**

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Field emitter arrays (FEAs) have potential for use as an electron source in a wide variety of applications including microwave power amplifiers, flat panel displays, electron microscopy, electron beam lithography, and space propulsion systems. Use of an FEA as a cold cathode source for a microwave power amplifier such as the traveling wave tube (TWT), presents significant technical challenges when one considers the high current and high current density requirements coupled with the necessity for excellent beam control. With the recent advances in FEA technology, FEA current densities as well as total array currents have reached values meeting or exceeding many moderate power TWT beam requirements and thus have become an attractive alternative to the thermionic emitters currently used almost exclusively in such devices. One of the most attractive characteristics of FEA emitters is that, by the nature of their emission process, modulation of the electron beam at rf frequencies becomes possible. Interesting and previously unattainable performance appears within reach with the advent of emission gating. Not only does modulated operation offer exciting performance enhancements, many advantages exist for unmodulated operation as well, an aspect of FEA cathodes sometimes overlooked.

This work describes the operation of a field emitter array as the electron source of a traveling wave tube amplifier. Issues of beam control and focus at high current density and low magnetic field are addressed as well as issues relating to the inherent high emittance of the FEA beam and cathode protection from ion bombardment. Large signal, non-linear RF-modulated FEA-TWT interaction simulations show circuit efficiencies that approach 50% even for minimal bunching of average-to-peak current ratios of 0.7 or greater. RF modulation is predicted to significantly improve linearity in the high efficiency regime as well as reduce harmonic power levels. An unmodulated C-Band FEA-TWT was built to test the focusing approach as well as the robustness of these emitters in an operating vacuum amplifier. The device uses a 1 mm diameter Spindt emitter with a custom-designed electron gun and helix circuit. The FEA-TWT has operated to-date with a maximum current of 91.4 mA and shows 99.5% transmission under both drive and no-drive conditions. Output power of the device is 55.0 W at 4.5 GHz with a saturated gain of 23.4 dB and efficiency of 17%. During all operation, the FEA emission appears extremely stable, with no temporal variations observed at any time.

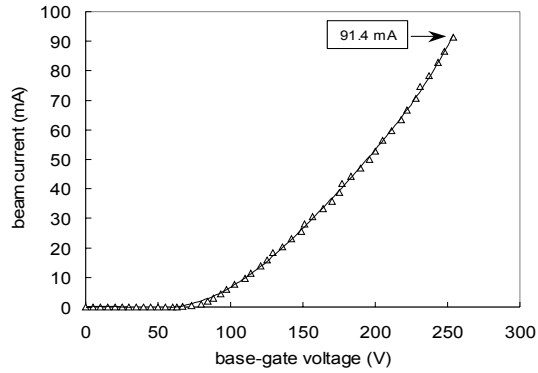


Figure 1. Measured FEA-TWT beam current as a function of applied base-gate voltage.

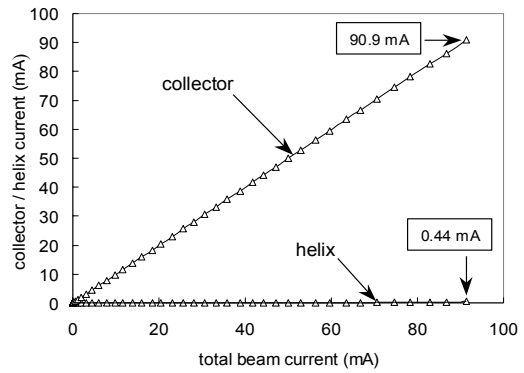


Figure 2. Measured FEA-TWT helix and collector current showing 99.5% transmission at highest current level.

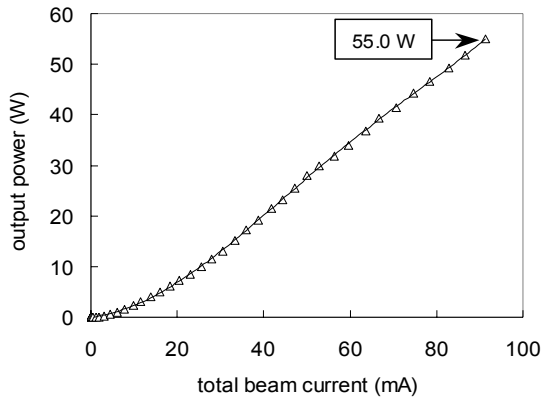


Figure 3. Measured FEA-TWT output power variation with beam current.

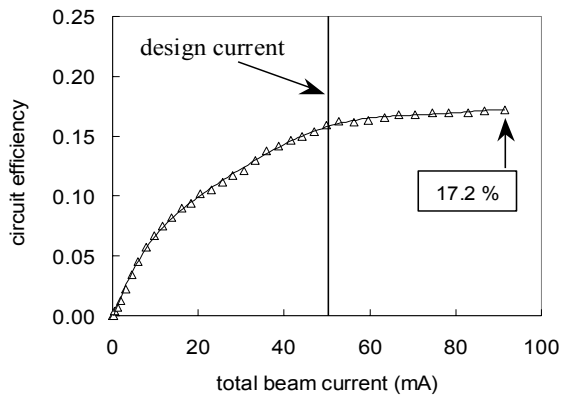


Figure 4. Measured FEA-TWT efficiency variation with beam current.

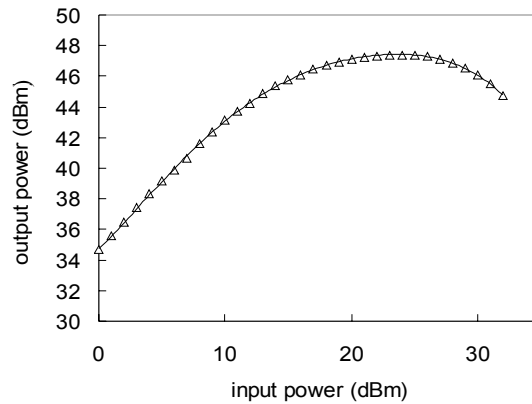


Figure 5. Measured FEA-TWT output power variation with input drive power at  $I_{\text{beam}} = 91.4$  mA and 4.5 GHz.