Symmetric and Asymmetric Mode Interaction in High-Power Traveling Wave Amplifiers: Experiments and Theory

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***Abstract*—High-power microwave amplifier operation has been studied for use in a number of applications. The performance of the amplifiers has been marred, in some cases, by pulse shortening of the microwave signal. A possible source of the shortening is the loss of the beam due to hybrid HEM_{11} mode interaction with the beam. In this paper, we describe experiments which investigate high-power operation and the effects of HEM modes on the amplifier performance. We report the high-output powers (>50 MW) with efficient (>54%) amplification of microwaves in an X-band traveling wave amplifier. In some experiments, peak power levels exceeding 120 MW were measured at an efficiency of 47%. The excitation of the asymmetric hybrid elecromagnetic mode was monitored carefully, but does not seem to have a critical impact on the main interaction process in spite of the fact that its dispersion curve almost overlaps that of the symmetric interacting mode. Theoretical analysis of the interaction in a tapered traveling wave structure indicates that, even if the amount of power in the asymmetric modes at the input of the structure is comparable to that in the symmetric mode, the asymmetric modes cause no power reduction in the symmetric mode. For the case of off-axis beams the TM_{01} output power may drop by about 30% and the power in the hybrid mode reach about one third of that in the symmetric mode. In order to avoid hybrid mode excitation it is necessary to suppress the reflections from both ends of the output structure several decibels below the gain level of the asymmetric mode.**

***Index Terms*—E-Beams, microwaves, TWT.**

example, the high-energy density obtained for a given power translates into large electric fields (100–200 MV/m for ∼100 MW power). This limits the maximum extractable power. The transit time isolation also would make this method very difficult to use in long pulse devices.

In the experiments described in this paper, we make extensive use of slow wave structure tapers to minimize reflections, and use SiC severs and absorbers to further reduce reflected signals. We demonstrate that the use of appropriately distributed severs and absorbers eliminates the sideband formation without limiting the high-beam power to microwave conversion efficiencies. Particle-in-cell (PIC) simulation [2] using the Magic Code [3] has shown that a combination of tapering of the iris aperture with each successive period until the desired aperture is reached together with extensive use of absorbers can lower the reflection level dramatically and is useful in TWT amplifiers with ≤40–50 dB gain over the instantaneous bandwidth of the amplifier.

We further report in this paper a series of experiments designed to examine the importance of hybrid modes in high-output microwave power (∼100 MW) X-band traveling wave tube amplifiers. Two amplifiers were designed and tested such that in one case the passbands of the lowest order TM and HEM modes almost overlapped, while in the other the modes were