Gyrotron Efficiency Reductions Due to After-Cavity Interactions

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***Abstract*—A In several recently tested gyrotrons, interaction efficiencies have been lower than expected based on cavity simulations. More extensive simulations allowing for interaction beyond the cavity indicate that beam-wave interactions in the quasi-optical launcher can reduce overall efficiency. This effect is evaluated for designs at several frequencies and power levels, and possible mitigation techniques are assessed.**

I. Introduction And Background

Modern gyrotrons producing average output power levels above 100 kW typically employ cylindrical interaction cavities to support whispering-gallery transverse electric (TE) excitation modes, which propagate from the cavity through an uptaper to a quasi-optical launcher to convert the mode to a quasi-Gaussian beam. Past cavity designs have typically been developed by optimizing cavity/uptaper efficiency and mode purity in a nominal magnetic field profile. This approach neglects possible interactions in the launcher. As has been suggested elsewhere, however, it is possible that under certain conditions, the electron beam and interaction mode may encounter a second resonance in the launcher region [1,2]. Because several recent gyrotrons have yielded efficiencies lower than predicted by simulations that fail to include possible after-cavity interactions (ACI), a revisiting of these designs has been performed, to determine whether experimental efficiency shortfalls might be consistent with the predicted ACI effects.

II. Results

Several cavity designs were re-evaluated to include after-cavity effects, including a 95 GHz, 100 kW gyrotron employing a $TE_{6,2}$ interaction mode, a 110 GHz, 1.3 MW gyrotron employing a $TE_{22,6}$ interaction mode, a 140 GHz, 900 kW gyrotron employing a $TE_{28,7}$ interaction mode, and a 95 GHz 2 MW gyrotron employing a $TE_{22,6}$ interaction mode. Efficiency simulations were performed using the MAGY code [3] for a range of magnetic field values and beam currents near the nominal design parameters for each case, both with and without the launcher included in the simulated geometry. Results for the 95 GHz 2 MW geometry are described here as an example. Figure 1 shows the cumulative interaction efficiency as a function of axial position; an after-cavity efficiency degradation is clearly visible. In Figure 2, resultant interaction efficiencies for this geometry (with and without the launcher included) are plotted vs. magnetic field and beam current. These plots demonstrate that the predicted efficiency degradation grows more severe as beam current is increased.

Further simulations were performed to assess the effects of modifying the launcher geometry and the magnetic field profile. Results were generally insensitive to details of the launcher geometry (requiring unrealistic increases in launcher radius to avoid interaction), but scenarios resulting in more rapid fall-off of axial magnetic field were found to be effective in reducing susceptibility to ACI.

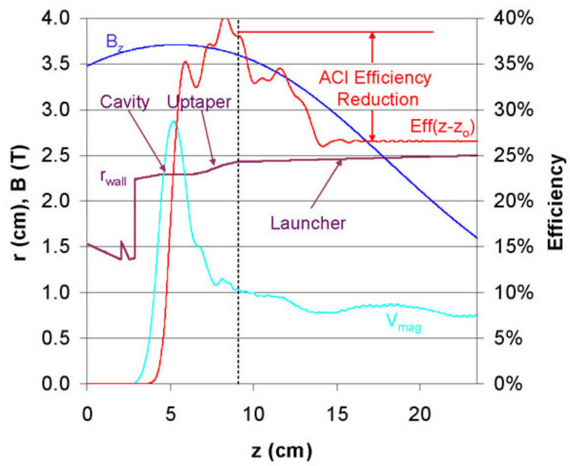

Figure 1. Efficiency vs. axial position. (V=80kV, α=1.4)

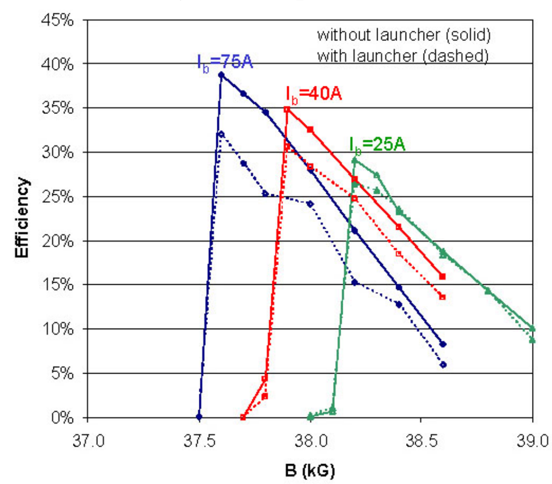

Figure 2. Efficiency vs. B and I_b. (V=90kV, α=1.4)

References

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