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Limits to High Power Amplification

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There has been tremendous progress in the power levels of high-power electromagnetic sources, such as klystrons, magnetrons, and TWTs that produce power into the gigawatt (GW) range. The vast majority of these sources are oscillators, where there is not a controlled phase signal associated with the high-power signal. In general, this is not surprising –amplification typically denotes linearity with respect to some input signal, while high power inevitably implies non-linear processes that generate intense relativistic AC electron beams. The vacuum electronics community has performed significant analysis on the sources for oscillation, typically involving undesired electromagnetic feedback from reflections in the device. The limits of high-power amplification in the GW range could be caused by these kinds of reflections, but also from non-linear processes associated with the intense space-charge in high-power microwave devices. One device that has both amplifier and oscillator configuration is the relativistic klystron driven by intense relativistic annular electron beams. In fact, the oscillator configuration explicitly introduces engineered feedback to produce oscillation. Here we report on a new model that captures both amplification and oscillation in the relativistic klystron, building on previous oscillator models(1). We interrogate this model with analytic and numerical methods to develop insight into the limits of high-power amplification. This model is also compared with particle-in-cell simulation and experimental performance. Additional efforts to develop a similar model for a TWT(2) will be detailed.

1. Luginsland, Lau, Hendricks, Coleman "A model of injection-locked relativistic klystron oscillator."IEEE Trans. Plasma. Sci, 24, 935, 1996
2. Hoff, Simon, French, Lau, Wong "Study of a high power sine waveguide traveling wave tube amplifier centered at 8 GHz."Phys. Plasma, 23, 103102, 2016.

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