ABSTRACT

Title of Dissertation: A THREE-STAGE, MEGAWATT LEVEL, PHASE-COHERENT HARMONIC-MULTIPLYING INVERTED GYRO-TWYSTRON (PHIGTRON)

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A new type of gyrotron amplifier, the Phase-coherent Harmonic-multiplying Inverted Gyro-twystron (phigtron) is studied theoretically and experimentally. In the two-stage version (version I), the phigtron is composed of an input waveguide and an output cavity separated by a drift section. A theory is developed which demonstrates the axial mode-locking and the parametric instabilities of radiation when a beam of gyrating electrons can resonate simultaneously with several axial modes. Theoretical predictions are compared with the two-stage harmonic-multiplying, inverted gyrotwystron experiment. In this experiment, an open waveguide operating at

frequencies close to cut-off is used as a resonator. In the resonator, modes with the same transverse structure but different axial structures can be excited. The width of the resonance curves of these modes broadens as the number of axial variations grows. This leads to overlapping of the curves. As a result, phase locking of such modes may occur. Such phase-locked operation in a set of modes with overlapping resonance curves can significantly enlarge the bandwidth of gyrodevices. Furthermore, the technique may be broadly applicable to other devices which employ output cavities.

In a three-stage version (version II), the phigtron is composed of an input waveguide, a bunching cavity, and an output cavity separated by drift sections. The experimental results show that the three-stage phigtron has the potential of becoming a high average, high peak power millimeter wave amplifier with good efficiency, high gain, compact driver and medium bandwidth for radar and other advanced applications. At optimized operating statuses, a efficiency of 35%, a gain of 30dB, a peak power of 720kW, and a phase stability of 0.0267^{o} / *Volt* are achieved, which is state-of-the-art for gyrotron amplifier. The generalized theory of the inverted gyrotwystron, is modified and applied to its simulation. Its results predict a highly efficient (38%) operation of the inverted gyrotwystron, which is consistent with the experiment very well. Its phase stability, output power frequency response, drive and gain properties, electron bunching properties, and electron energy modulation along axial distance are also investigated and shown in this dissertation.

To improve the performance of existing phigtron, an upgraded design with efficiency of >30%, gain of 30dB, bandwidth of 2%-3%, and peak output power of 1MW, is presented. In this design, a frequency-independent input coupler is designed as an input section; a $clustered - cavity^{TE}$ cluster-cavity is used as a buncher cavity to expand the operating bandwidth of the phigtron; an Extended Interaction Cavity (EIC) structure is used as the output section to match the wide-band requirement of the input section.