Experiments on the Recirculating Planar Magnetron with Coaxial All-Cavity Extraction

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Abstract: *Calibrated microwave power measurements are presented for the Recirculating Planar Magnetron with Coaxial-All-Cavity Extraction (RPM-CACE). Experimental results are compared with computational predictions using the particle-in-cell code ICEPIC. The RPM-CACE was designed using extensive simulation and optimization to demonstrate the RPM concept, and was simulated to operate at 1.89 GHz and produce peak powers of ~400 MW at 50-70% efficiency. The experiment utilizes a novel coaxial extraction system to minimize the total diameter of the device.*

Keywords: high power microwaves; relativistic magnetron; all-cavity extraction

Introduction

Magnetrons remain one of the most compact and efficient high power microwave sources, with applications in industrial heating and counter-electronics. The Recirculating Planar Magnetron (RPM) extends these advantages by increasing the surface area of the cathode, opening the possibility of higher current and higher peak power than conventional relativistic magnetrons [1,2]. The decoupled planar cavities increase design flexibility, enabling multi-frequency variants [3]. The planar structure, however, does present some challenges for power extraction; the vane-to-vane spacing is too narrow for the radial extraction commonly employed on A6 magnetrons [3]. To address this challenge, the all-cavity extraction system developed by Greenwood [5] was adapted to the RPM geometry [6,7]. This configuration was iteratively designed using the particle-in-cell code ICEPIC, where it generated ~400 MW of simulated power at 50-70% efficiency. Recent experiments at the University of Michigan have tested the CACE prototype, shown in Fig. 1.

Experimental Configuration

RPM-CACE is a recirculating planar magnetron designed to operate in the π–mode at 1.9 GHz. The nominal operating parameters are -330 kV at 2-3 kA for 500 ns with a 0.16 T axial magnetic field. This pulsed power drive is supplied by the Michigan Electron Long Beam Accelerator with Ceramic stack (MELBA-C), which is capable of providing a -1 MV, 10 kA voltage pulse for 1 μs, and a pair of electromagnets in a quasi-Helmholtz configuration. Driver voltage and current are measured by a resistive divider and Rogowski coil, respectively.

Power generated by the 12-cavity slow-wave structure of RPM-CACE is extracted via six coaxial extractors (Fig. 2), and transitions from a TEM coaxial mode to the TE_{10} mode of a rectangular waveguide via the DFA-340e coupler. These couplers were designed to provide minimal bandwidth (1.85-2.15 GHz) but handle high peak power, with a peak electric field of 18 MV/m for an input power of 100 MW [8]. Upon transition to the WR340 waveguide, the power in each arm is sampled by a calibrated (nominally -40 dB) directional coupler. The sampled signal is then split, with half of the power sent to a 6 GHz, 20 GS/s Agilent 58455A oscilloscope for measuring time-resolved RF waveforms and frequency information, and the other half sent to sent to a HP 8472B diode detector for calibrated power measurement. Each waveguide arm is terminated in a matched Ecosorb load.

Figure 1: RPM-CACE installed on the MELBA-C driver. Six waveguide directional couplers sample each adjacent pair of the 12 RF cavities.

Experimental Results

Cold Test: Initial cold test results of the completed RPM-CACE prototype broadly agree with predicted performance. Cold tests were performed by replacing the load and directional couplers of the first and third waveguides with an N-type antenna and driving the first waveguide as port 1. The resulting S11 measurement exhibits a -30 dB resonance at 1.93 GHz, and the corresponding S21 measurement indicates a fairly broad peak of -8 dB, also centered at 1.93 GHz, as shown in Fig. 3.

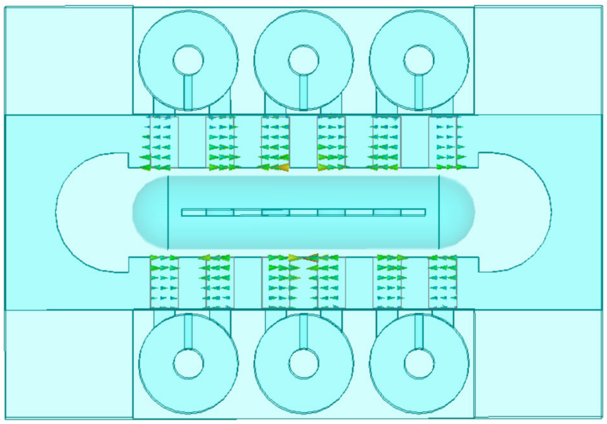

Figure 2: ANSYS model of RPM-CACE showing π-mode electric fields.

Hot Test: Full-power testing of the RPM-CACE has begun, and data analysis is currently underway. Preliminary results with a bare stainless steel cathode (Fig. 4) indicate efficient operation at 1.934 GHz producing 10s of MW per waveguide. Detailed analysis of these results, and their comparison to previous simulations, will be presented. Future work will include high current testing using a carbon fiber coated cathode.

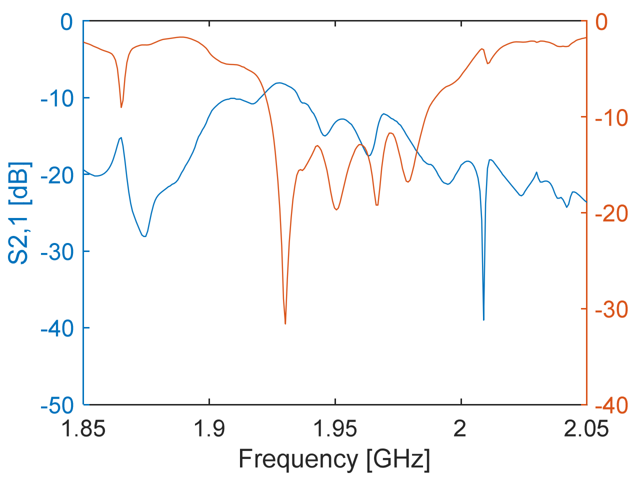

Figure 3: RPM-CACE cold test indicates a resonance at 1.93 GHz.

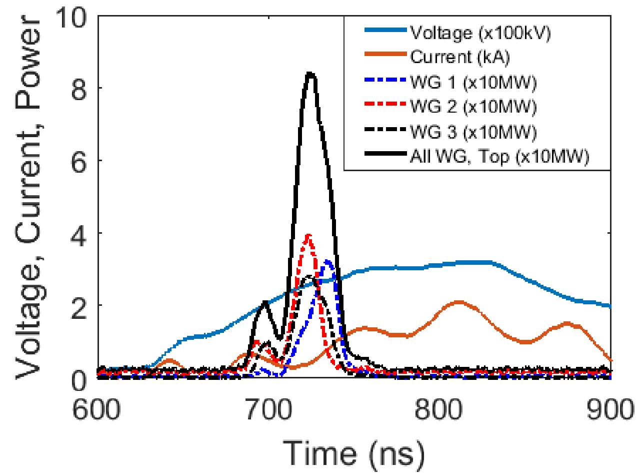

Figure 4: Preliminary tests of RPM-CACE, sampling the top 3 waveguides. Power measurements are only approximations.

Acknowledgements

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