Study of a Novel Frequency Locking Technique for Magnetrons

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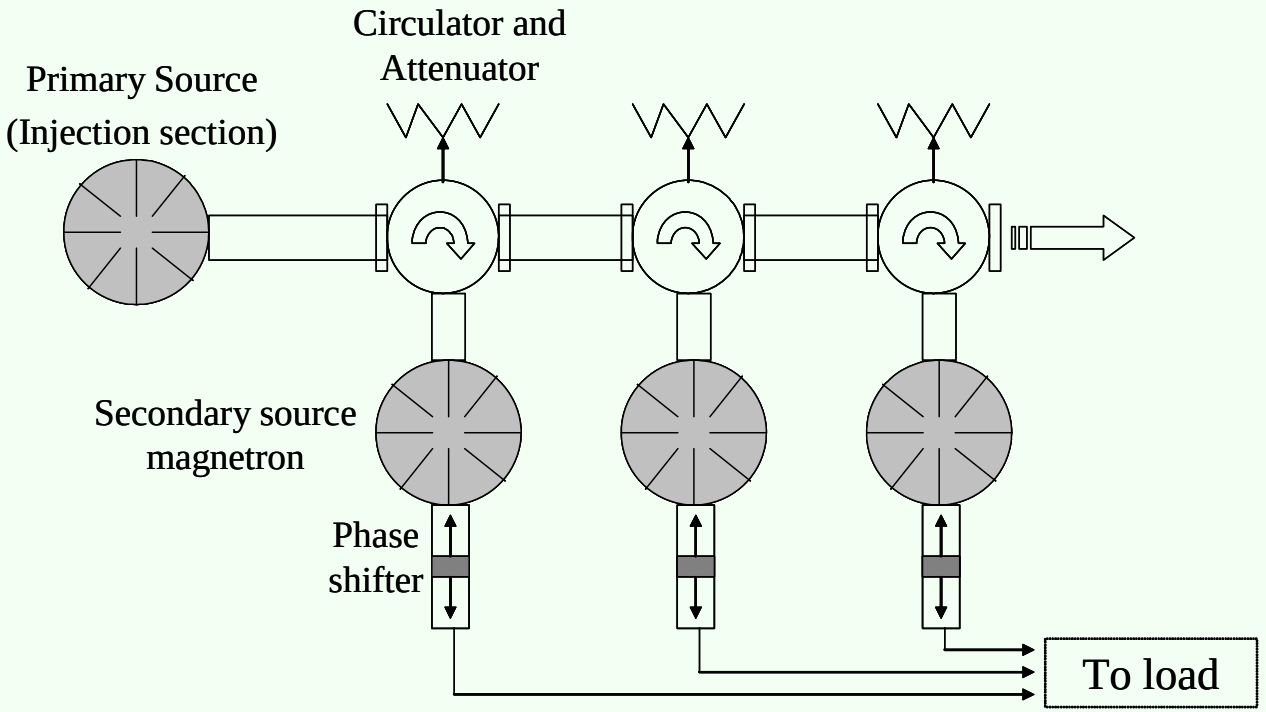
Phase Locking in Magnetrons

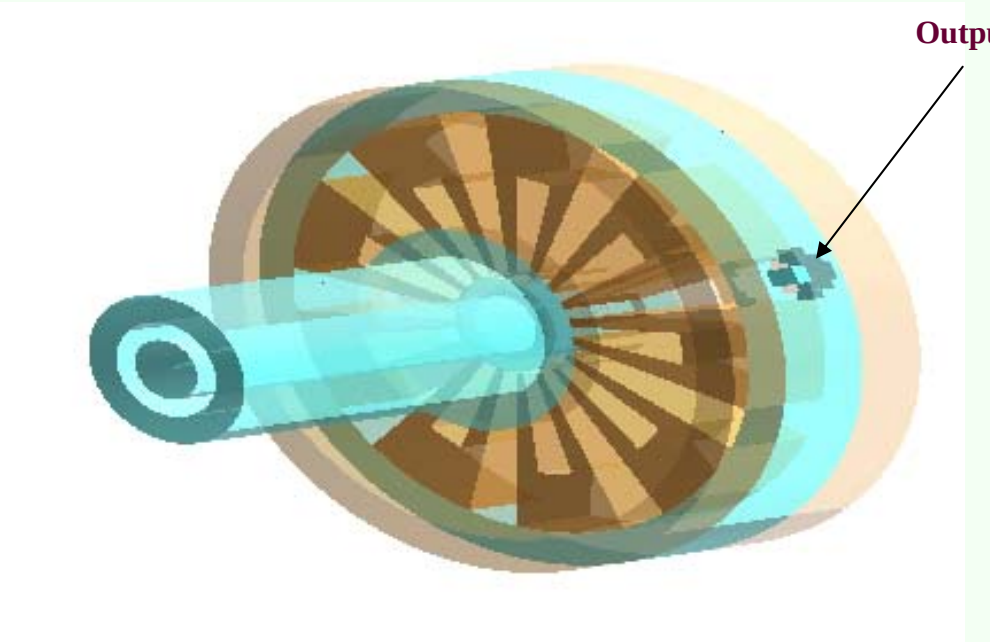


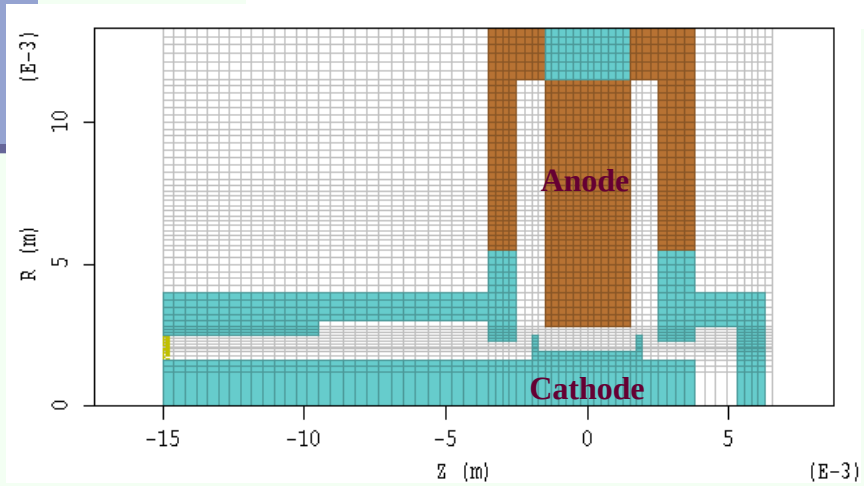
- A phase locking array of magnetrons to achieve high power microwave radiation
- A cheap alternative for high power RF generator in particle accelerator – multi-cavity klystron

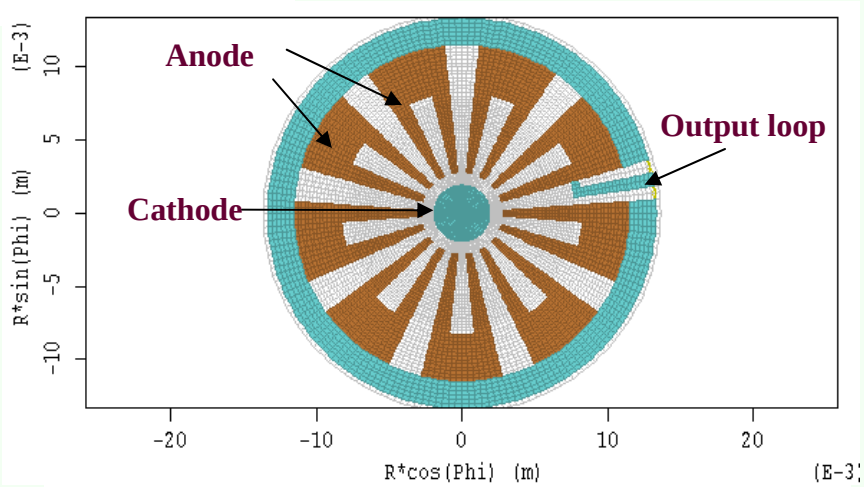
Introduction

- Traditional phase locking through output system:
  (Output injection; Expensive isolation/circulator system; High locking power requirement)
- Novel phase locking through magnetron side arm:
  (Sidearm injection; No isolation/circulator system; Lower locking power requirement; Quick locking time)
- Computer simulations: (3D PIC MAGIC code)
- Experiments: (Magnetron and signal injection system design; Experiment setup)

Magnetron structure

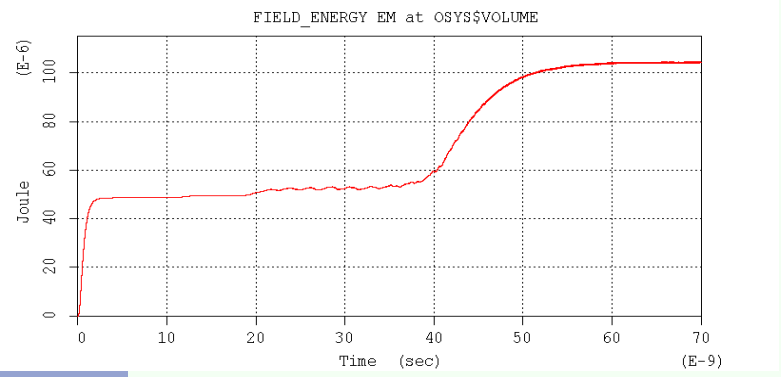




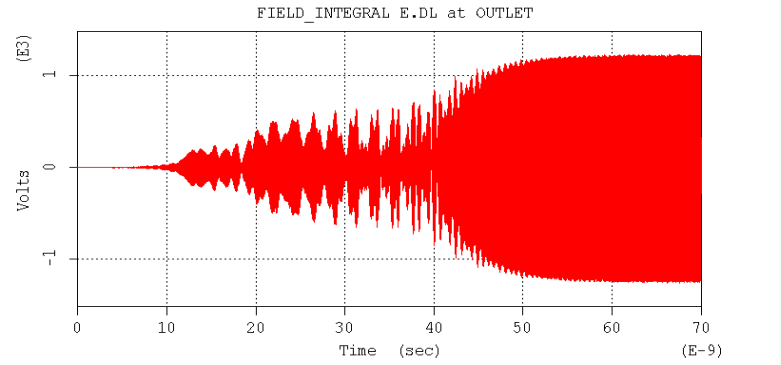


Angular cross section of the magnetron model Axial cross section of the magnetron model

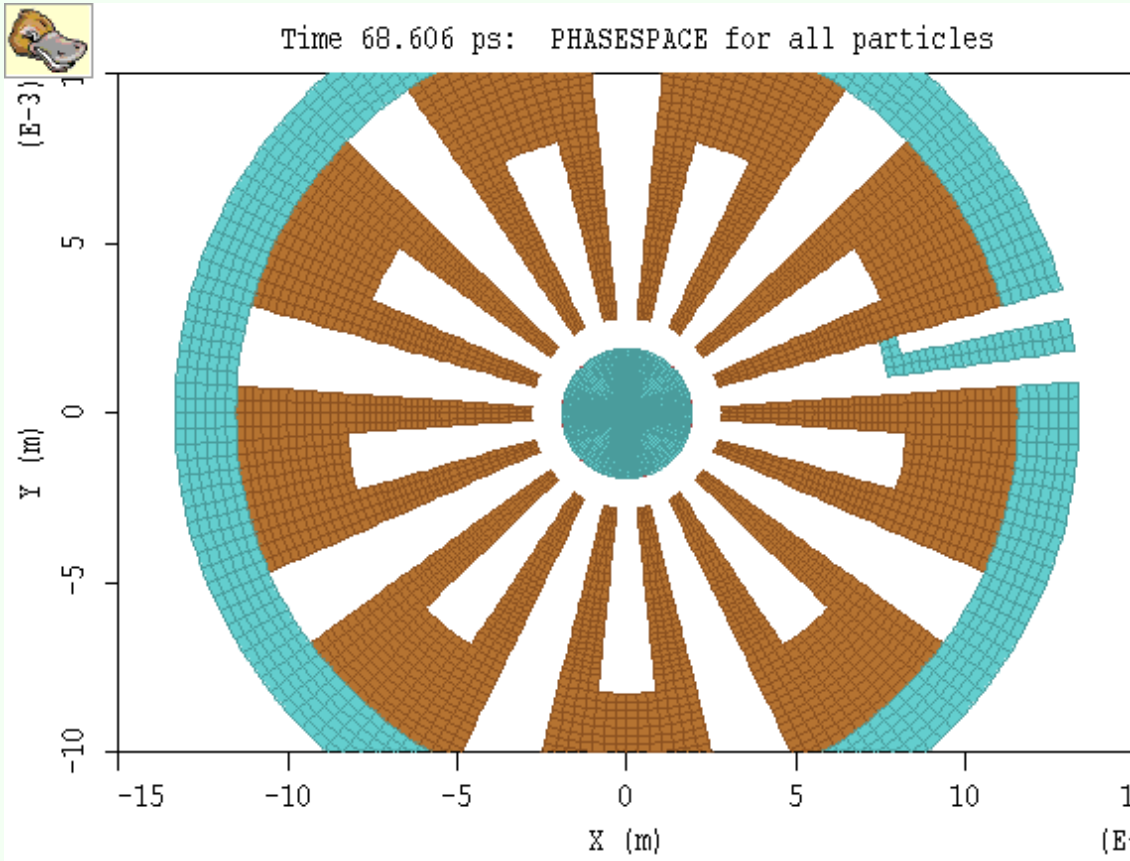
Simulation results without locking signal



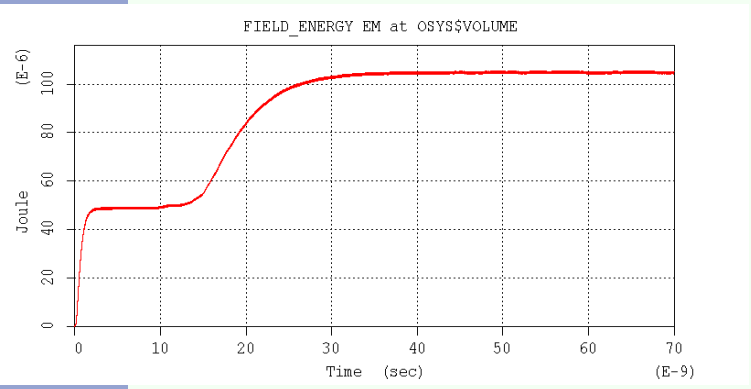
Field Energy



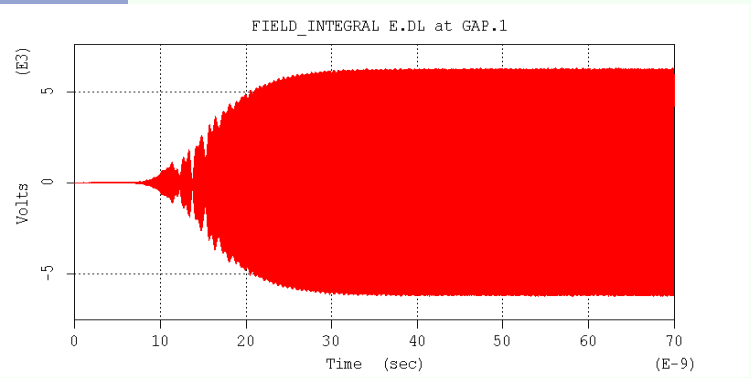
Voltage at the output



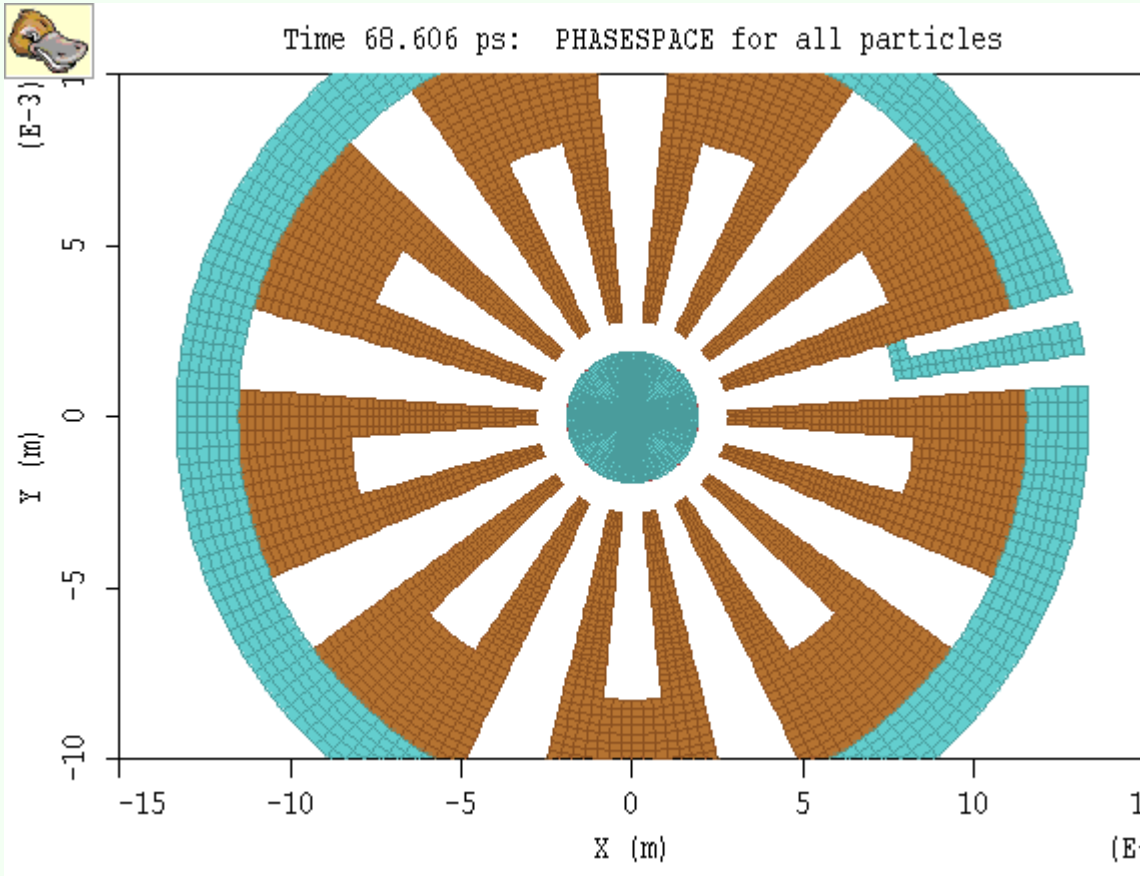
Simulation results with locking signal



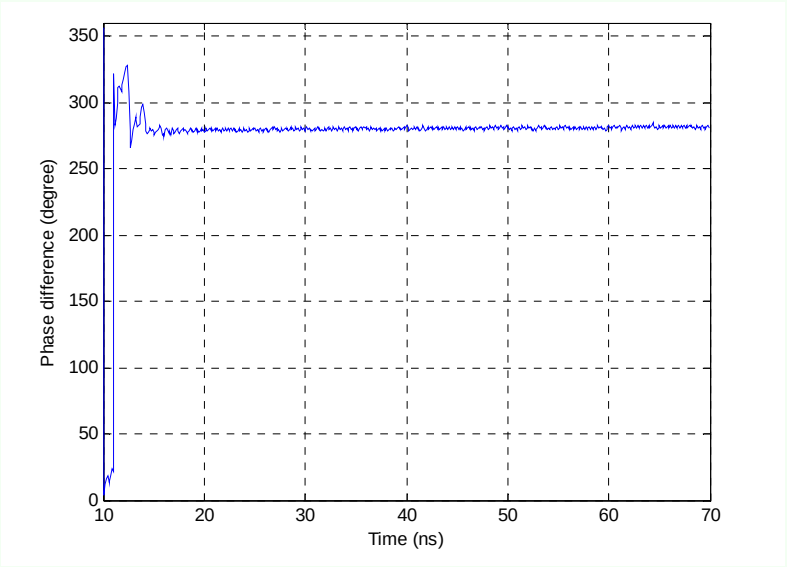
Field Energy

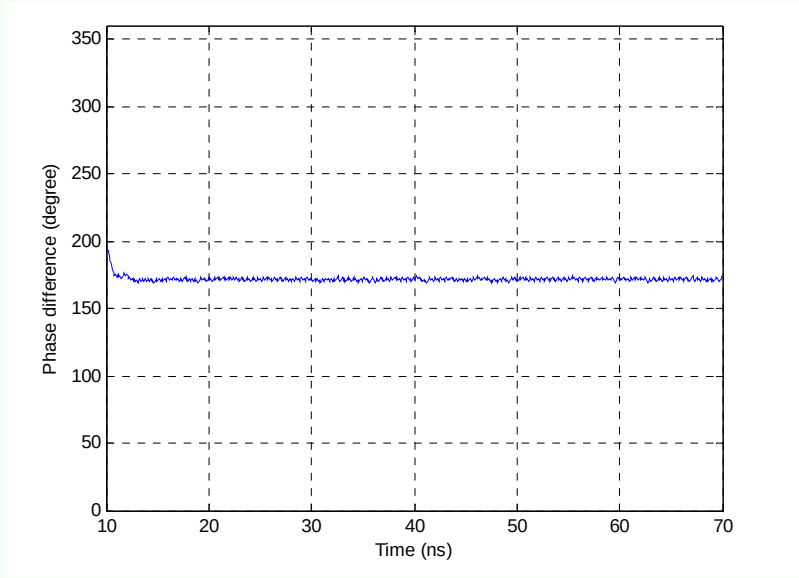


Voltage at the output



The phase difference curve





$P_{in}=0.01P_{out}$ (20dB below the output power) and fin=9.381GHz

$P_{in}=0.0025P_{out}$ (26dB below the output power) and $f_{in}=9.382GHz$

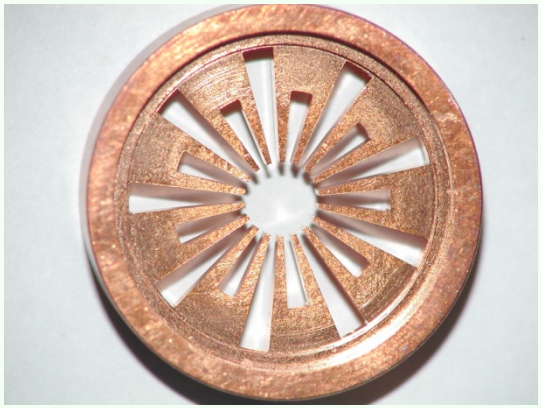
Pi mode: f = 9.383 GHz

Magnetron design

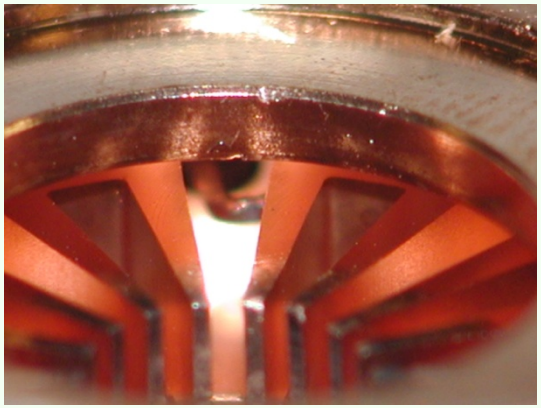
- Design of rising sun magnetron
  - For ease of manufacture and testing, and low cost, selected X-band 10kW design.
- Based on e2v MG5241 strapped-vane-anode marine magnetron.
  - Identical cathode and anode height.
  - Output coupling achieved by loop connection to coaxial line.
  - Improvised magnetic circuit
- Pulsed operation (~1.0us pulse width)

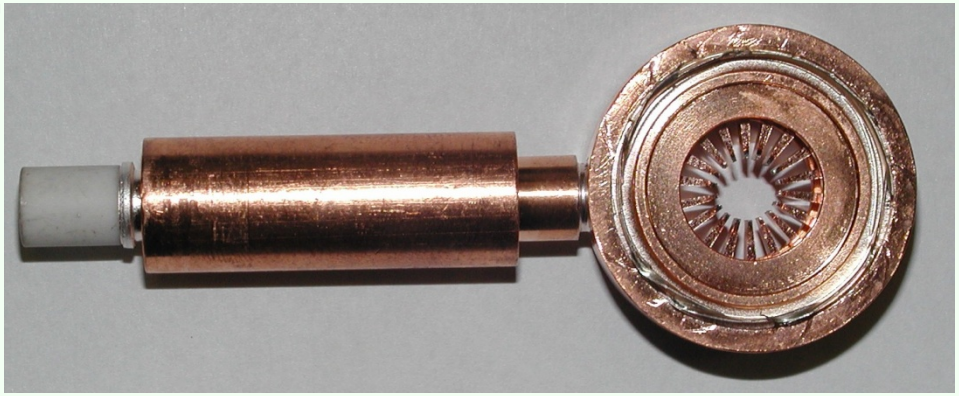
Continued

- Rising sun anode



- Rising sun output coupling loop
- Anode/output assembly



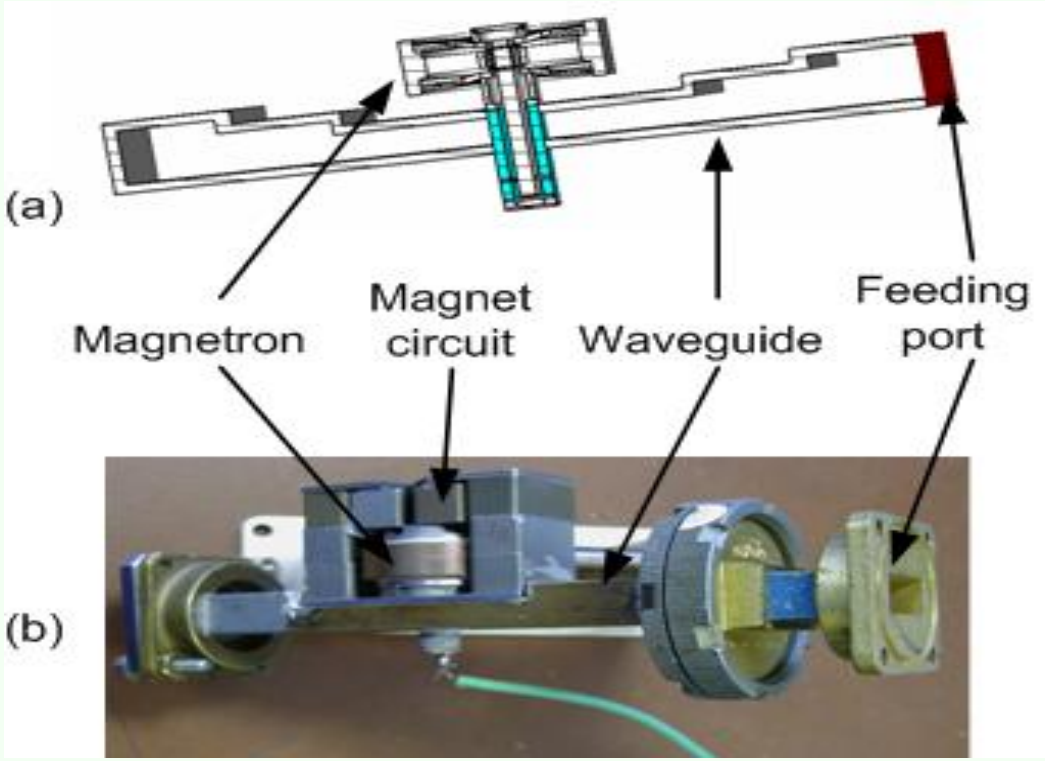


Design of signal injection system

- Coupling to sidearm.
  - Initially attempted using a coaxial loop inserted close to cathode sidearm
  - Proved unsuccessful due to:
    - RF leakage
    - Insufficient RF coupling to cathode
    - HT breakdown in confined space
  - It was decided to proceed using a waveguide system.

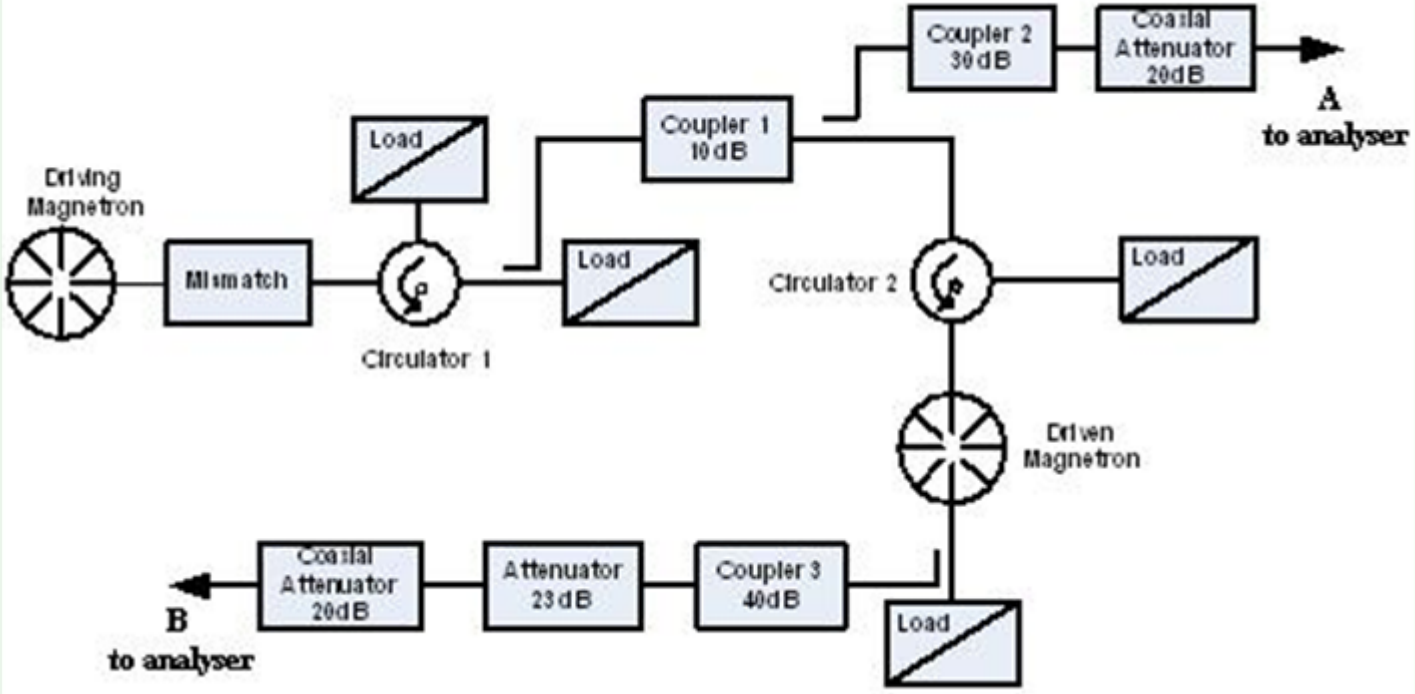
Continued

- Operating around 9GHz: Waveguide WG16
- Half height waveguide could encase existing sidearm.



Experiment setup

- Locking waveguide
  - Sidearm tags insulated
  - Magnets varied to achieve 4000G
  - Driven pulse initiated after locking signal is stabilised
- Phase measurement equipment mixes locking signal and driven signal to convert phase difference into a detected voltage.



Experimental results

- Successful measurements @8.9GHz. Locking signal provided by MG5494 25kW magnetron.
- Locking frequency varied about centre frequency by sliding 1.5:1 VSWR mismatch.
- Experiment repeated using:
  - 10kW strapped vane anode – not locked!
  - & Frequency locking through magnetron output (conventional locking)

Continued

Magnetron	Locking	Input Signal	Frequency Locking Bandwidth	Phase Locking
Rising Sun 8.9GHz	Sidearm	2.5kW (-6dBpp)	3MHz	1-2°
Rising Sun 8.9GHz	Sidearm	0.25kW (-16dBpp)	0.5MHz	1-2°
Rising Sun 8.9GHZ	Output	2.5kW (-6dBpp)	22MHz	1-2°
Strapped Vane MG4010 9.39GHz	Sidearm	2.5kW (-6dBpp)	None	None

Summary and future work

- Novel phase locking through the sidearm of the coaxial port is demonstrated in computer modelling.
- Novel phase locking is also proved in experiments!
- The RF feeding system needs to be improved to reduce the leakage of the locking power and to assess possible applications

Acknowledgement

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Thank you!