Gyrokystron Design

A High-Power, High-Gain, Second Harmonic Gyroklystron for K-Band Microwave Amplification

Melanie Veale (Washington University in St. Louis)
Professor Wes Lawson (University of Maryland)
Overview

- Overall Design
  - Gyroklystron Anatomy
  - Design Process
- Simulating the MIG
- Simulating the circuit
  - Zero-Drive Stability
  - Optimization
- Conclusion
Overall Design

Axial Magnetic Field:

Gyrokylystron Schematic:
Simulating the MIG

**Variable Parameters**
- $V_c$
- $B_0$
- Magnetic compression ratio ($f_m$):
  $f_m = B_0 / B_c$

**Beam Properties**
- $P_{beam} = 100$ MW
- Velocity ratio ($\alpha$):
  $\alpha = \text{perpendicular velocity} / \text{axial velocity}$
- Guiding center radius ($r_g$)
- % spread in axial velocity ($\Delta v_z$)
Simulating the MIG

- Choose 3 values of $\alpha$ to study:
  1.2, 1.35, 1.5
- Vary $f_m$ to get smallest possible $\Delta v_z$
  - Adjust $V_c$ for desired $\alpha$
  - Check that the beam doesn’t hit the wall
- Repeat at a range of $B_0$
  - Record $r_g$ for circuit input
Simulating the Circuit

Variable Parameters
- $B_0$
- $P_{in}$, drive frequency
- For each cavity:
  - $Q_{cavity}$
  - Resonant frequency
  - Spacing

Circuit Properties
- Efficiency ($\eta$):
  \[ \eta = \frac{P_{out}}{P_{beam}} = \frac{P_{out}}{100\text{MW}} \]
- Gain = $P_{out} / P_{in}$
- Must be:
  - Self-consistent
  - Zero-drive stable
Simulating the Circuit

- Zero-drive stability
  - Start Q ($Q_{so}$):
    Self-oscillation occurs when $Q_{cavity} > Q_{so}$
  - Cavities 1-3 are generally stable (at the optimal Q), but 4 is unstable
    - Redefine “optimal Q” to be the highest stable Q
      (To be safe, define optimal Q to be $Q_{so} - 10$)
  - Other modes?

![Graph showing Q vs. $B_0$ for different $Q_{so}$ values](image)
Simulating the Circuit

- Optimization
  - $P_{in}$
  - $Q$ (cavities 3 and 4)
  - $B_0$ (with and without stability)
Conclusion

- **Best Design:**
  \[ P_{\text{out}} = 26\text{MW} \ (\eta = 26\%), \ \text{Gain} = 58\text{dB} \]
  - For \( \alpha = 1.35, \ B_0 = .71\text{T}, \ P_{\text{in}} = 38\text{W} \)
  - Operating mode is zero-drive stable

- **Other work**
  - Experimental check
    - Especially stability for other modes
  - Other operating frequencies
    - If necessary, investigate changing cathode shape in the MIG