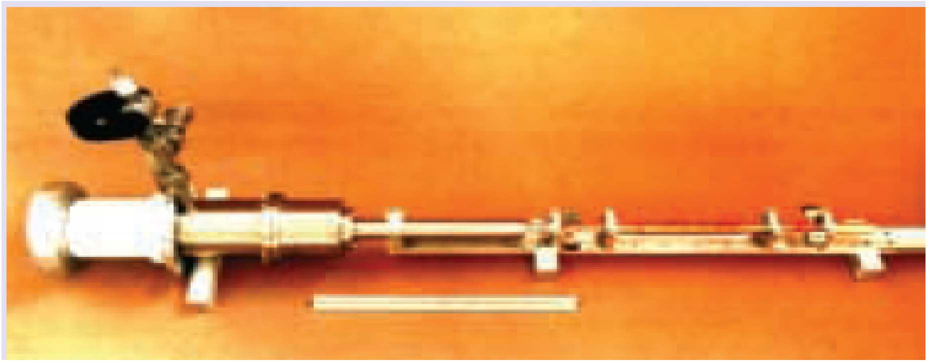
Ka and W Band TE_{01} Gyro-Devices



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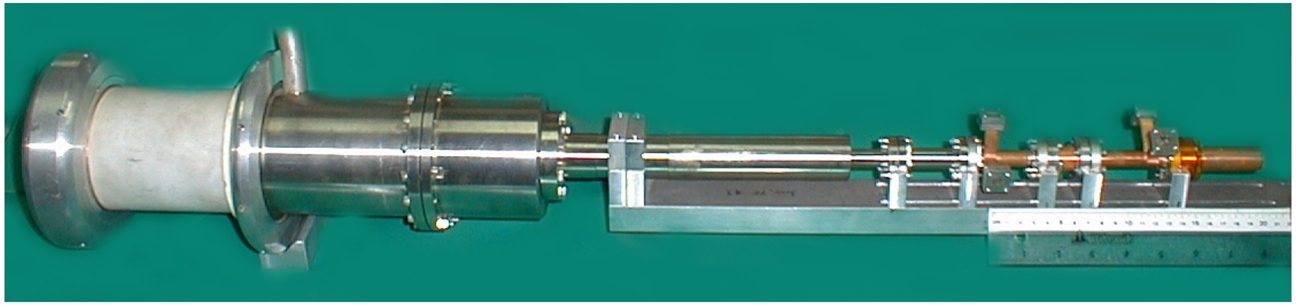
Ka Band TE_{01} Gyro-TWA

- The high power and broad bandwidth capabilities of gyrotron traveling-wave amplifiers (gyro-TWAs) make them attractive sources in the millimeter wave range.
- The property of the TE_{01} mode in the gyro-TWA exhibits the low Ohmic dissipation and lager guiding center radius.



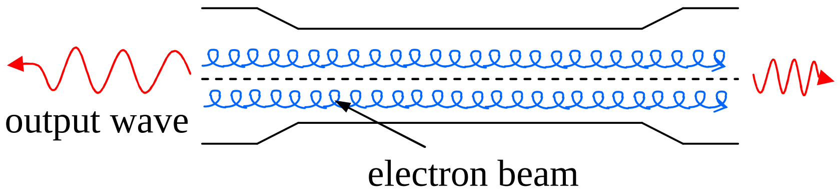
35 GHz TE_{11} Gyro-TWA [NTHU]

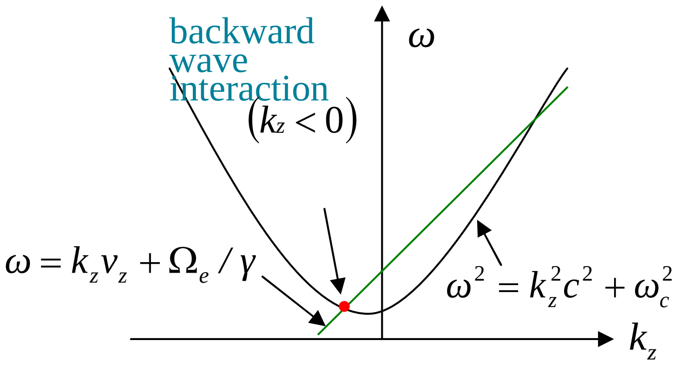
W Band TE_{01} Gyro-BWO

- Development of high-power microwave devices in the W-band for commercial, industrial, and military applications is attracting considerable interest.

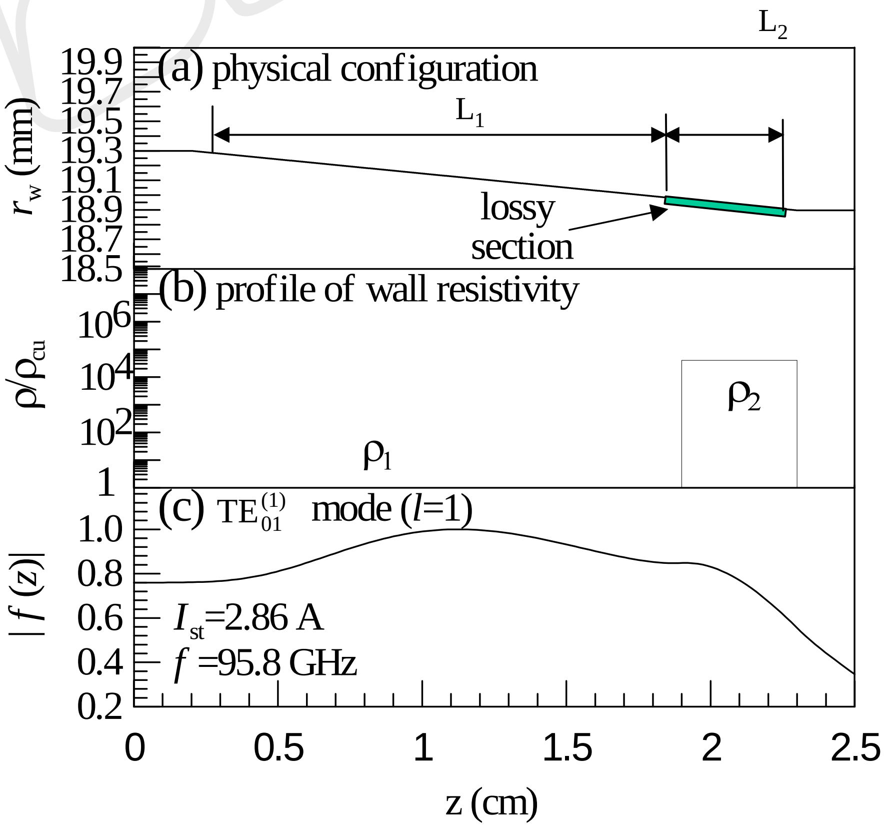
- The gyro-BWO is a nonresonant structure, so that the frequency can be tuned over a wide range by changing the magnetic field or the beam voltage.

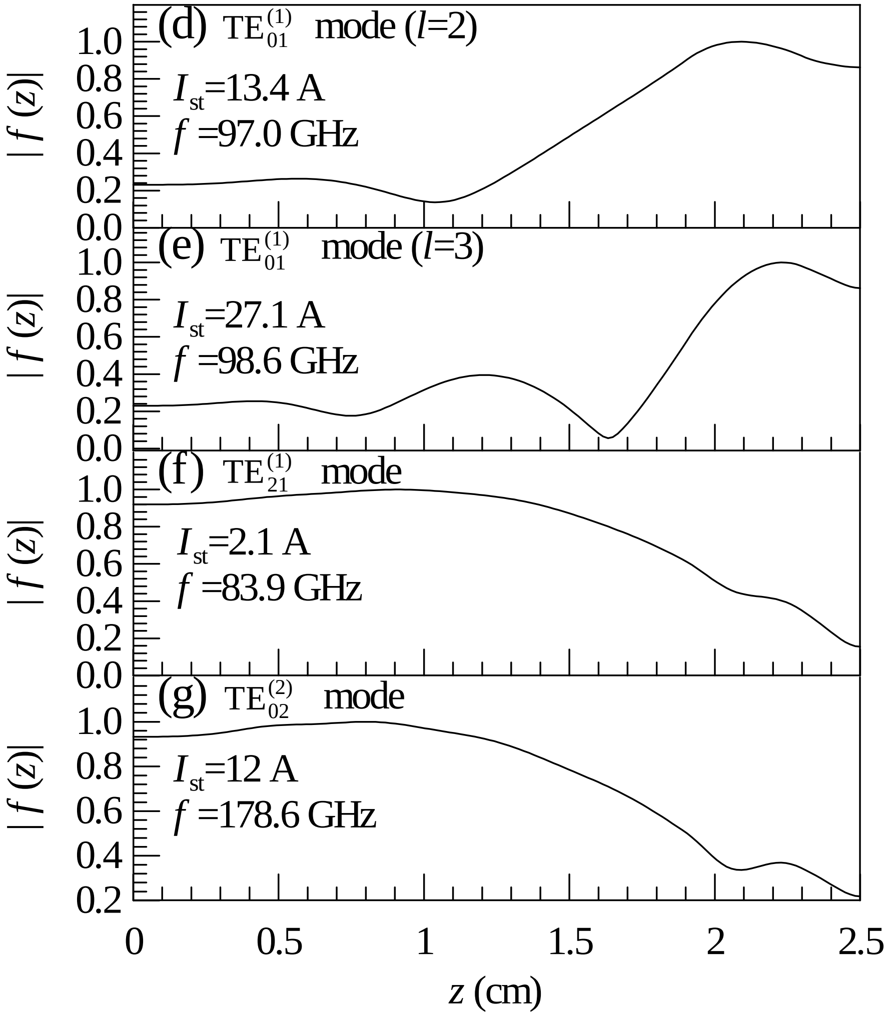
- Theoretical studies of the gyro-BWO first appeared in the mid-1960s in Soviet literature. Linear theory has been developed to analyze the start-oscillation conditions of the gyro-BWO. The efficiency of the gyro-BWO is lower than that of other gyrotron devices for uniform waveguide structure.





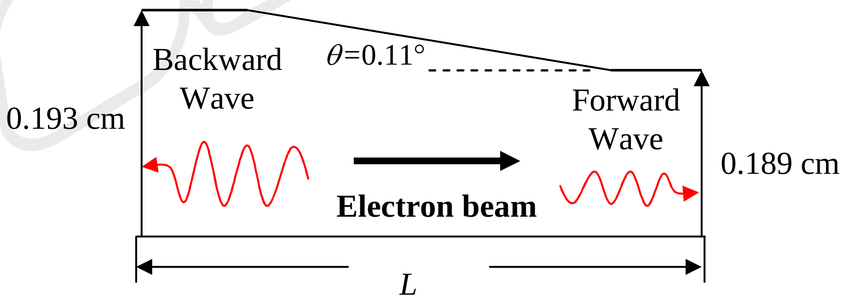
W Band TE_{01} Gyro-BWO

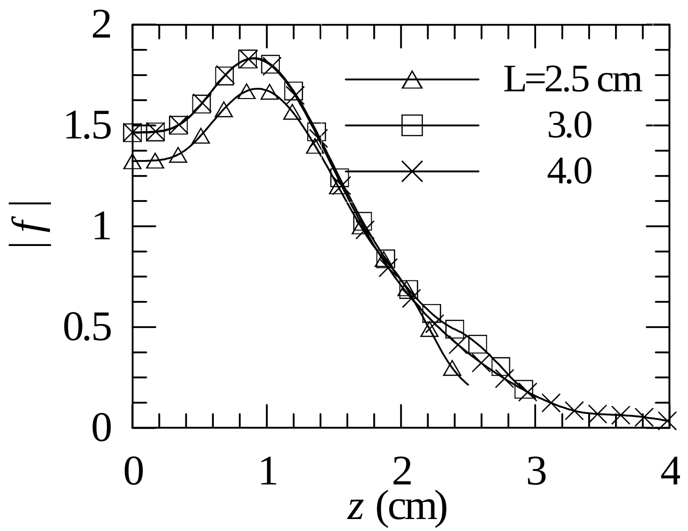




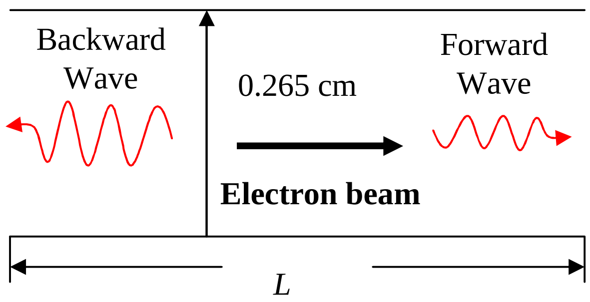
Saturated Behavior of Gyro-BWOs

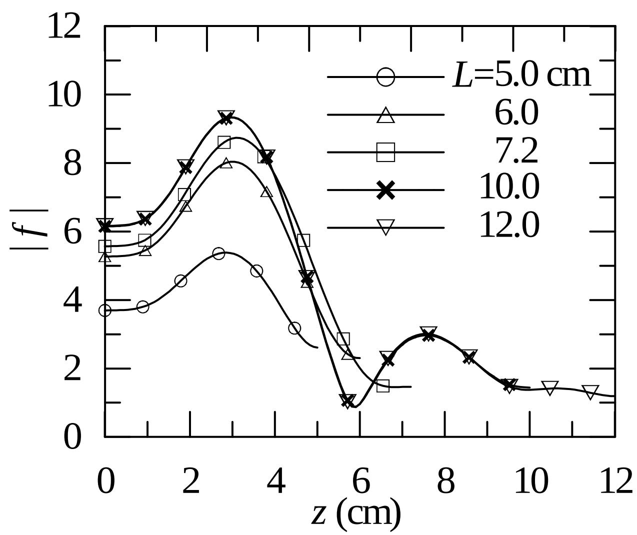
$TE_{01}^{(1)}$ gyro-BWO





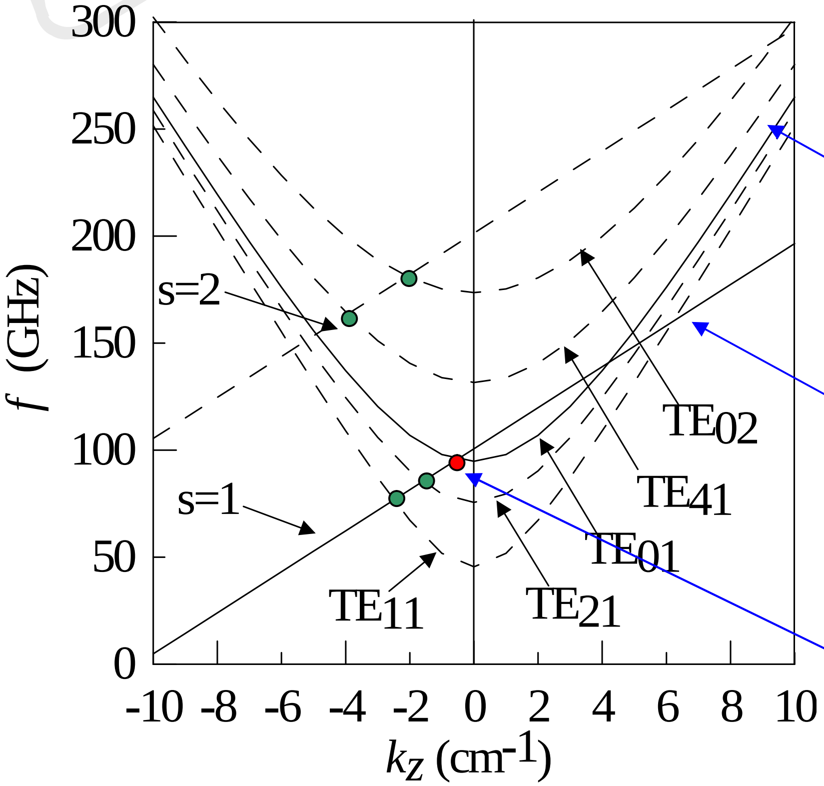
$TE_{11}^{(1)}$ gyro-BWO

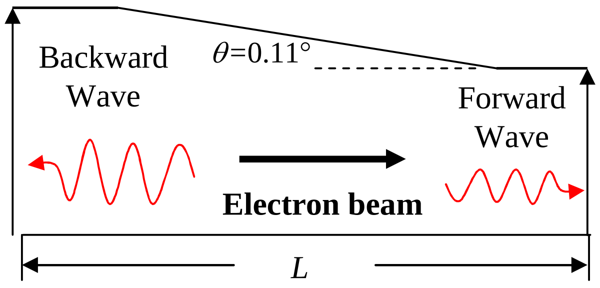




Start-Oscillation Conditions of Transverse Modes

$TE_{01}^{(1)}$ gyro-BWO





waveguide mode

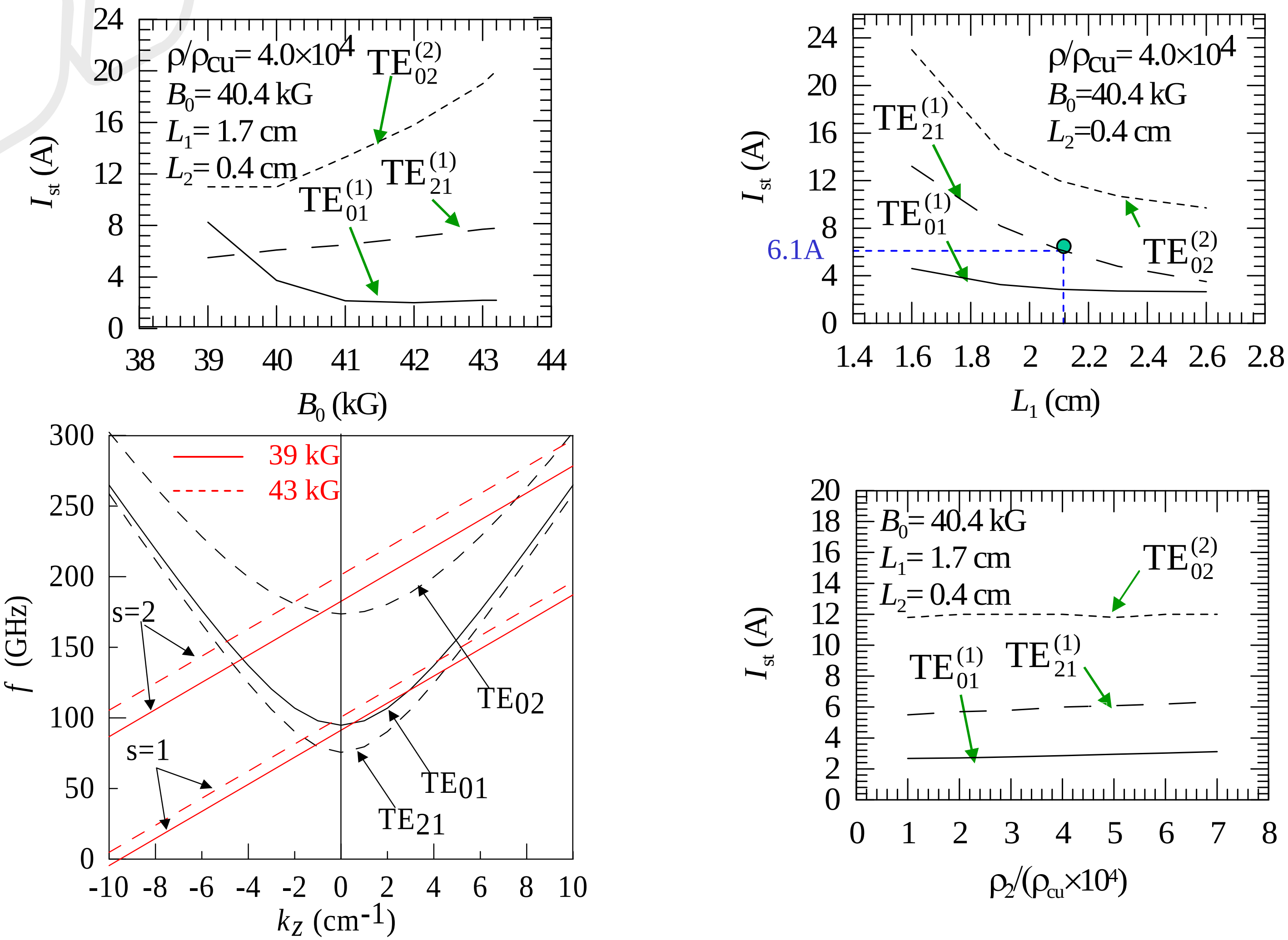
$$\omega^2 = k_z^2 c^2 + \omega_c^2$$

cyclotron harmonic beam-wave resonance line

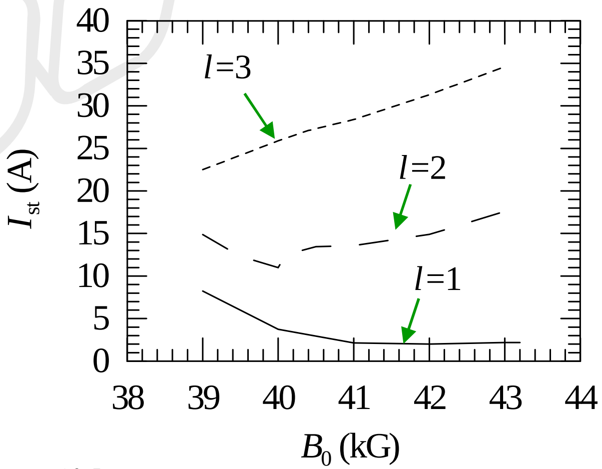
$$\omega = k_z v_z + \Omega_e / \gamma$$

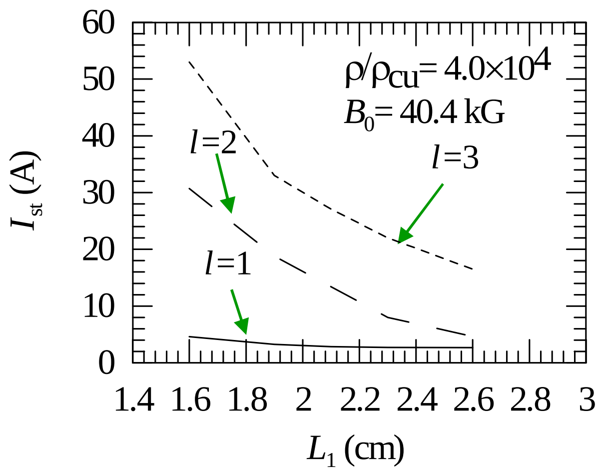
operating point

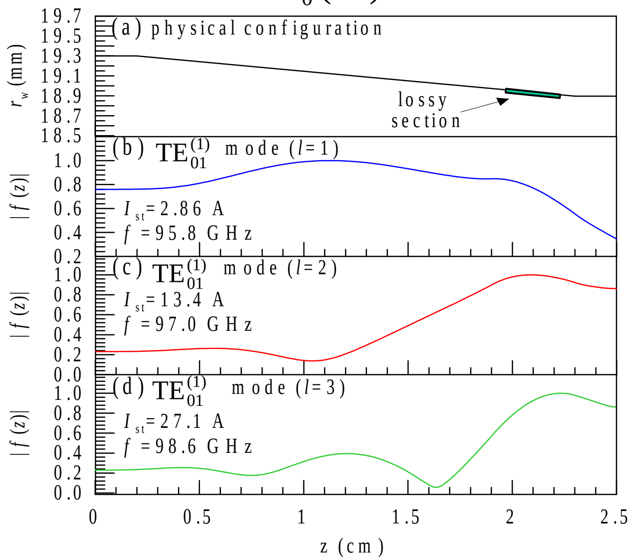
Start-Oscillation Conditions of Transverse Modes

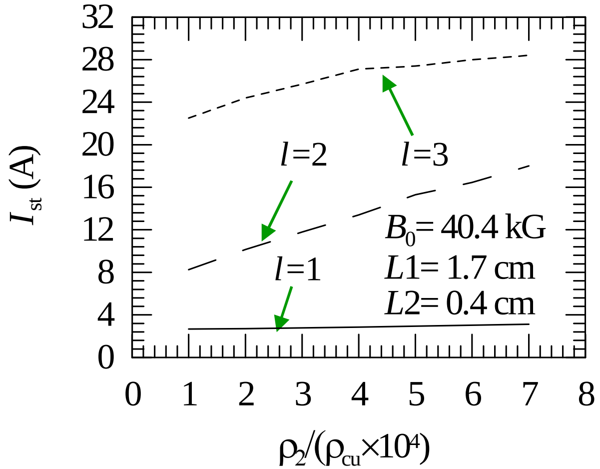


Start-Oscillation Conditions of Axial Modes









Performance of the W Band Gyro-BWOs

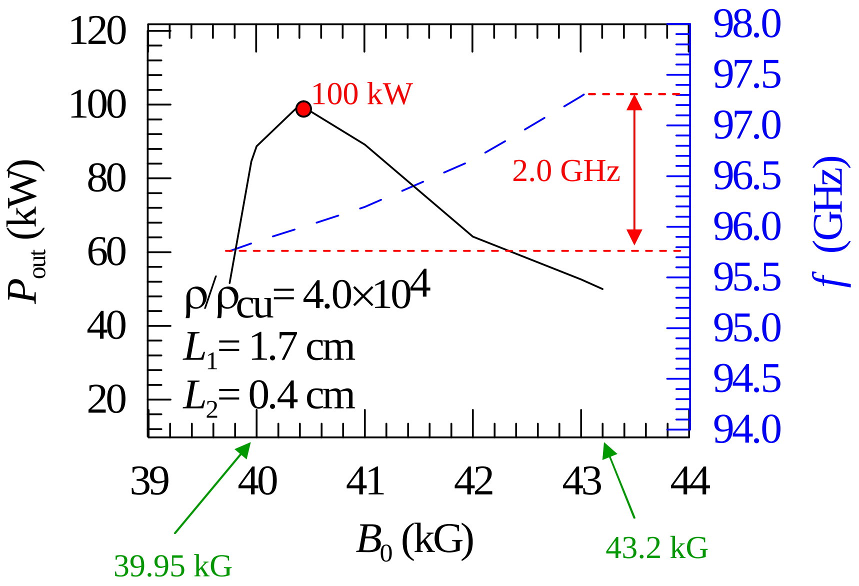
Operating current : 5 A

Peak power : 100 kW at 96 GHz

Efficiency : 20 %

3dB frequency tuning ranges : 1.6 GHz

Velocity spread : 5 %



Summary

- The simulated results show that the field amplitude increases with the interaction length until the length reaches the relaxation length in the gyro-BWO.

- The high order axial mode are effectively suppressed by distributed wall losses or reduce the effective interaction lengths , but transverse mode are only suppressed by reduce the effective interaction lengths .

VI. Conclusions

- The property of the TE_{01} mode in the gyro-TWA and gyro-BWO exhibits the low Ohmic dissipation and lager guiding center radius.
- The stable multi-section gyro-TWT is predicted to yield the peak power of 405 kW at 33GHz corresponds to a saturated gain of 77 dB at interaction efficiency of 20 %.
- The gyro-BWO is predicted to yield a peak output power of 100 kW with an efficiency of 20 % at a beam voltage of 100 kV, beam current is 5 A, α =1.0 and electron beam with an axial velocity spread 5 %.

References(1)

1. V. L. Granatstein, and I. Alexeff, *High-power Microwave Source*, Artech House, 1985.
2. J. L. Seftor, V. L. Granatstein, K. R. Chu, P. Sprangle, and M. E. Real, “The electron cyclotron maser as a high power traveling-wave amplifier of millimeter waves,” *IEEE J. Quantum Electron*, vol. 15, pp. 848-853, 1979.
3. K. R. Chu, A. T. Drobot, H. H. Szu, and P. Sprangle, “Theory and simulation of the Gyrotron Traveling Wave Amplifier Operating at Cyclotron Harmonics,” *IEEE Trans. Microwave Theory Tech.*, vol. 28, no. 4, pp. 313-317, 1980.
4. Y. Y. Lau, K. R. Chu, L. R. Barnett, and V. L. Granatstein, “Gyrotron Travleing Wave Amplifier : I. Analysis of Oscillation,” *Int. J. Infrared Millimeter Waves*, vol. 2, pp. 373-393, 1981.
5. K. R. Chu, and A. T. Lin, “Gain and Bandwidth of the Gyro — TWT and CARM Amplifiers,” *IEEE Trans. Plasma Sci.*, vol.16, no. 6, pp. 90-104, 1988.
6. L. R. Barnett, L. H. Chang, H. Y. Chen, K. R. Chu, Y. K. Lau, and C. C. Tu, ”Absolute instability compentition and suppression in a millimeter-wave gyrotron traveling-wave tube,” *Phys. Rev. Lett.*,vol. 63, pp. 1062-1065, 1989.
7. K. C. Leou, D. B. McDermott, A. J. Balkcum, and N. C. Luhmann, “Stable high power TE01 gyro-TWT amplifiers,” *IEEE Trans. Plasma Sci.*, vol. 22, pp. 585-592, 1994.

References(2)

8. K. R. Chu, L. R. Barnett, H. Y. Chen, Ch. Wang, Y. S. Yeh, Y. C. Tsai, T. T. Yang, and T. Y. Dawn, "Stabilizing of absolute instabilities in gyrotron traveling-wave amplifier," *Phys. Rev. Lett.*, vol. 74, pp. 1103-1106, 1995.
9. K. R. Chu, H. Y. Chen, C. L. Hung, T. H. Chang, L. R. Barnett, S. H. Chen, T. T. Yang, and D. J. Dialetis, "Theory and experiment of ultrahigh-gain gyrotron traveling wave amplifier," *IEEE Trans. Microwave Theory Tech.*, vol. 27, no. 2, pp. 391-404, 1999.
10. Y. S. Yeh, T. S. Wu, Y. T. Lo, C. W. Su, and S. C. Wu, "Stability analysis of gyrotron travelling wave amplifiers," *Int. J. Electron.*, vol. 90, no. 8, pp.517-532, 2003.
11. Y. S. Yeh, Y. T. Lo T. S. Wu, and C. W. Su, "Nonlinear analysis of absolute instability in gyrotron traveling wave amplifiers, " *in Proc. Fourth IEEE International Vacuum Electronics Conference*, 2003.
12. H. H. Song, D. B. McDermott, Y. Hirata, L.R. Barnett, C. W. Domier, H. L. Hsu, T. H. Chang, W. C. Tsai, K. R. Chu, and N. C. Luhmann, "Theory and experiment of a 94 GHz gyrotron travling-wave amplifier," *Phys. Plasmas*, vol. 11, no. 5, pp2935-2941, 2004.