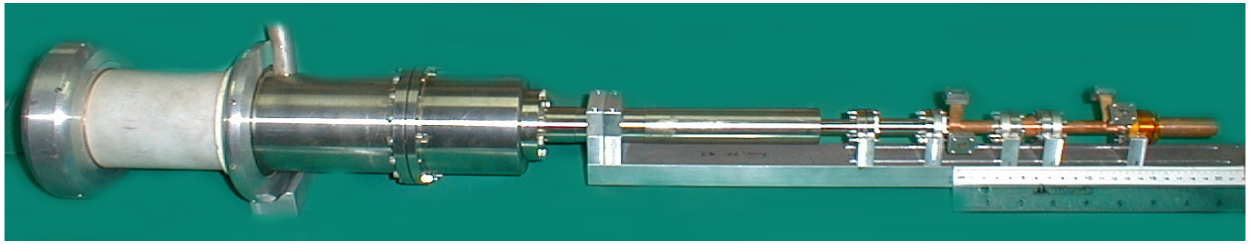
Second Harmonic TE_{21} Gyrotron Backward Wave Oscillator



報　告　人：吳庭旭

指導教授：葉義生 老師

南台科技大學 電機所

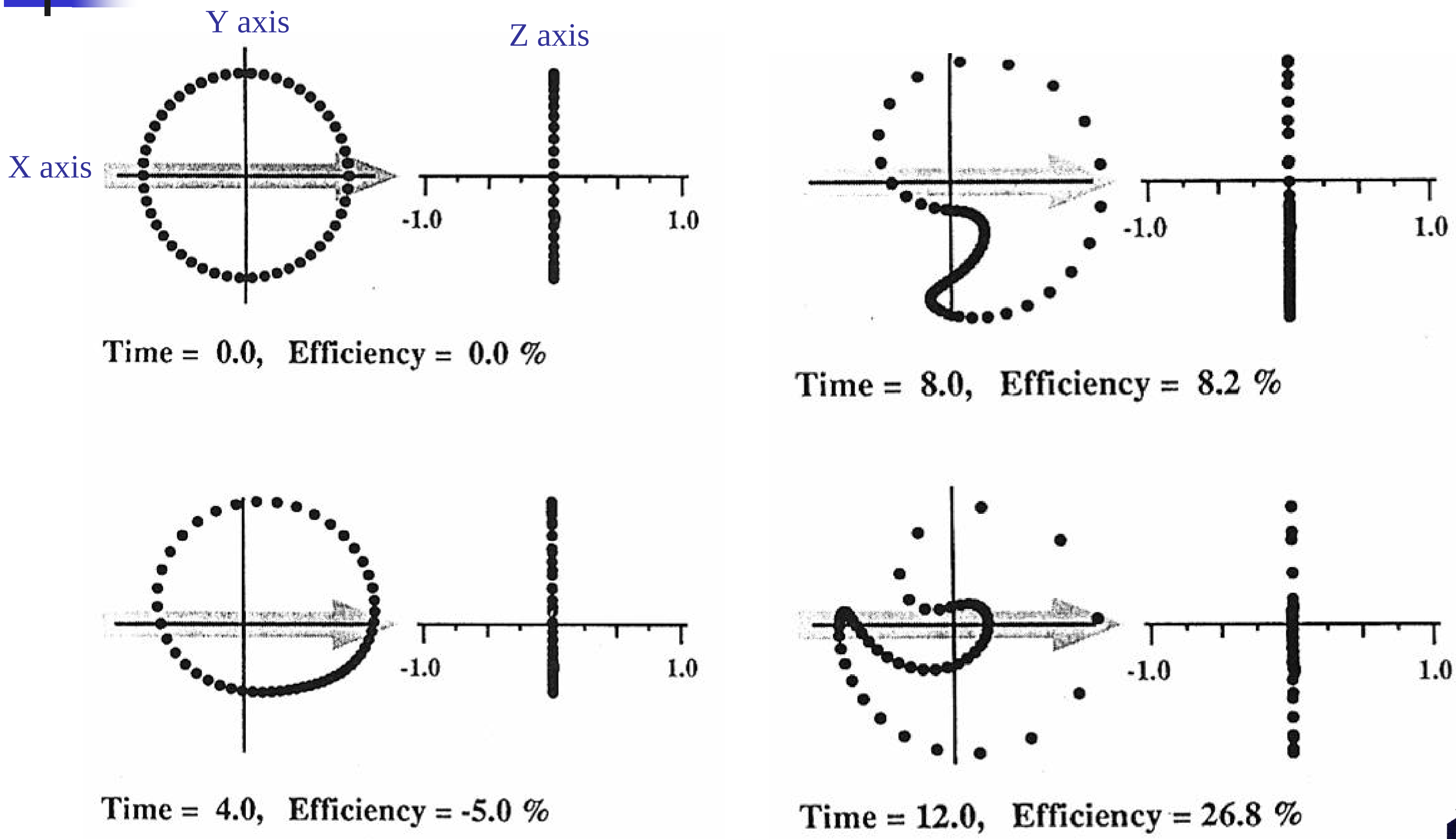
Introduction to Gyro-BWO

- The gyrotron backward-wave oscillator (gyro-BWO) is a promising source of coherent millimeter wave radiation based on the electron cyclotron maser instability on a backward waveguide mode.

- 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.

- The magnetic field is proportional to the relativistic electron cyclotron frequency, so the magnetic field of a gyrotron operating at the cyclotron harmonic is nearly 1/s of that of a gyrotron operating at the fundamental cyclotron.

Basic Mechanism of Gyrotron



Computer Models of Nonlinear Simulation Code

- Fields of the circularly polarized TE_{mn} mode

$$B_z = k_{mn}^2 f(z) J_m(k_{mn} r) e^{-i(\omega t - m\theta)}$$

- Field equation

$$\left(\frac{d^2}{dz^2} + k_z^{\ 2} \right) f(z) = i \frac{8|I_b|}{x_{mn}^2 K_{mn} \omega} \sum_{j=1}^{N} W_j \frac{\mathbf{v}_j(z) \cdot \mathbf{E}^*(r_j, \theta_j, t_j, z)}{v_{zj}(z) f^*(z)}$$

- The relativistic equation of motion

$$\frac{d}{dt} \vec{P} = -e\vec{E} - \frac{e}{c} \vec{v} \times \left(\vec{B}_0 + \vec{B} \right)$$

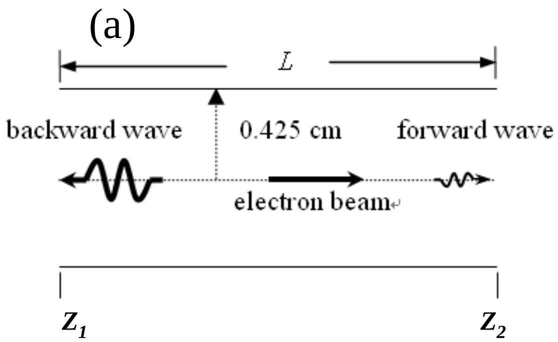
- Boundary conditions (gyro-BWO)

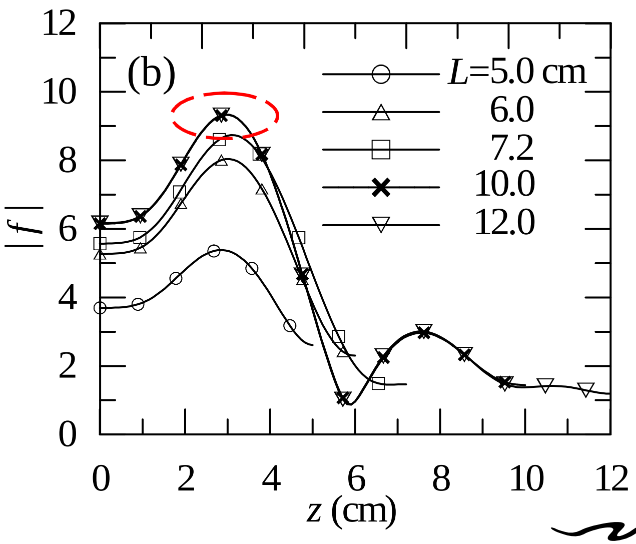
$$f'(z_1) = -ik_z f(z_1)$$

$$f'(z_2) = ik_z f(z_2)$$

Saturated Behavior

$TE_{21}^{(2)}$ gyro-BWO





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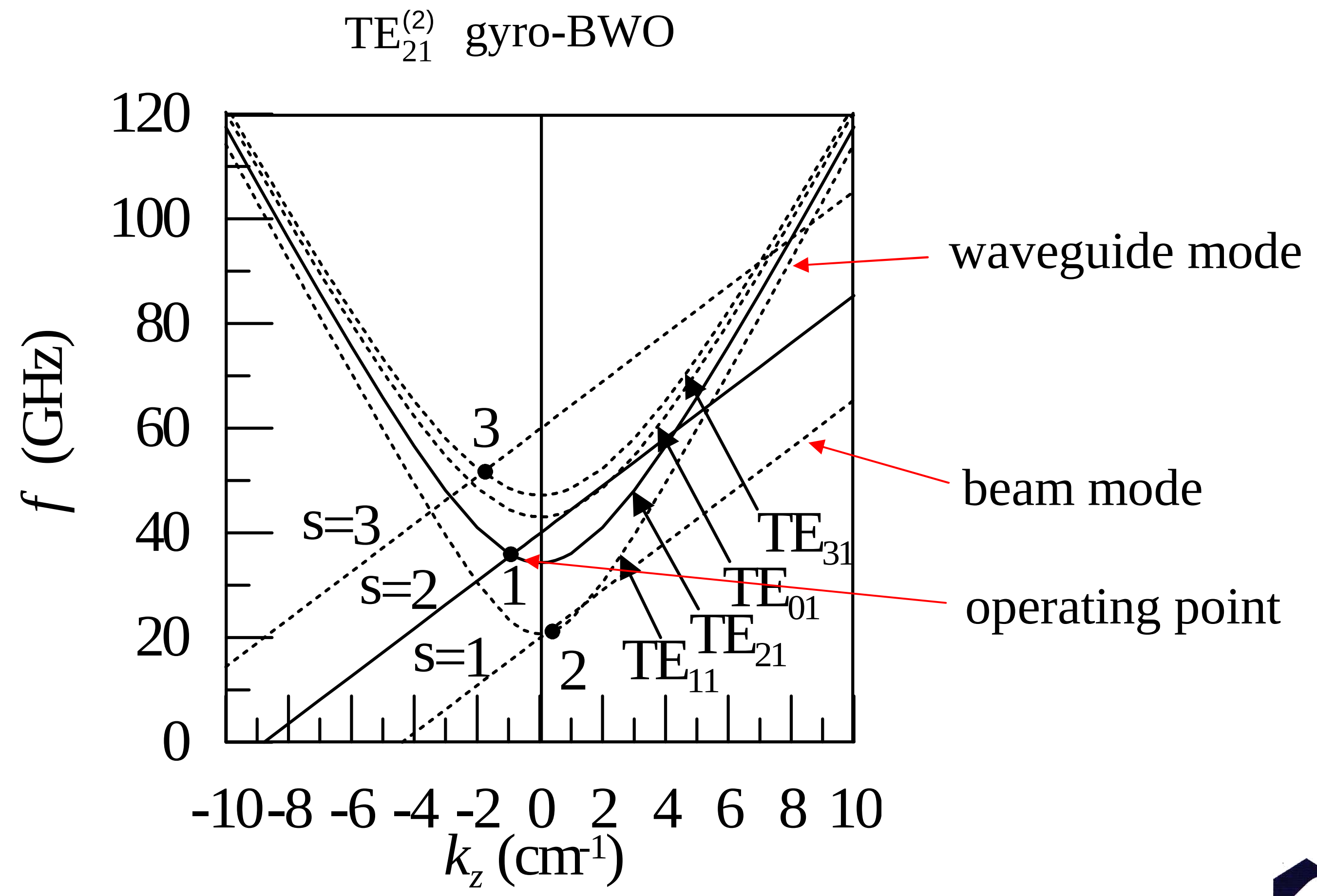
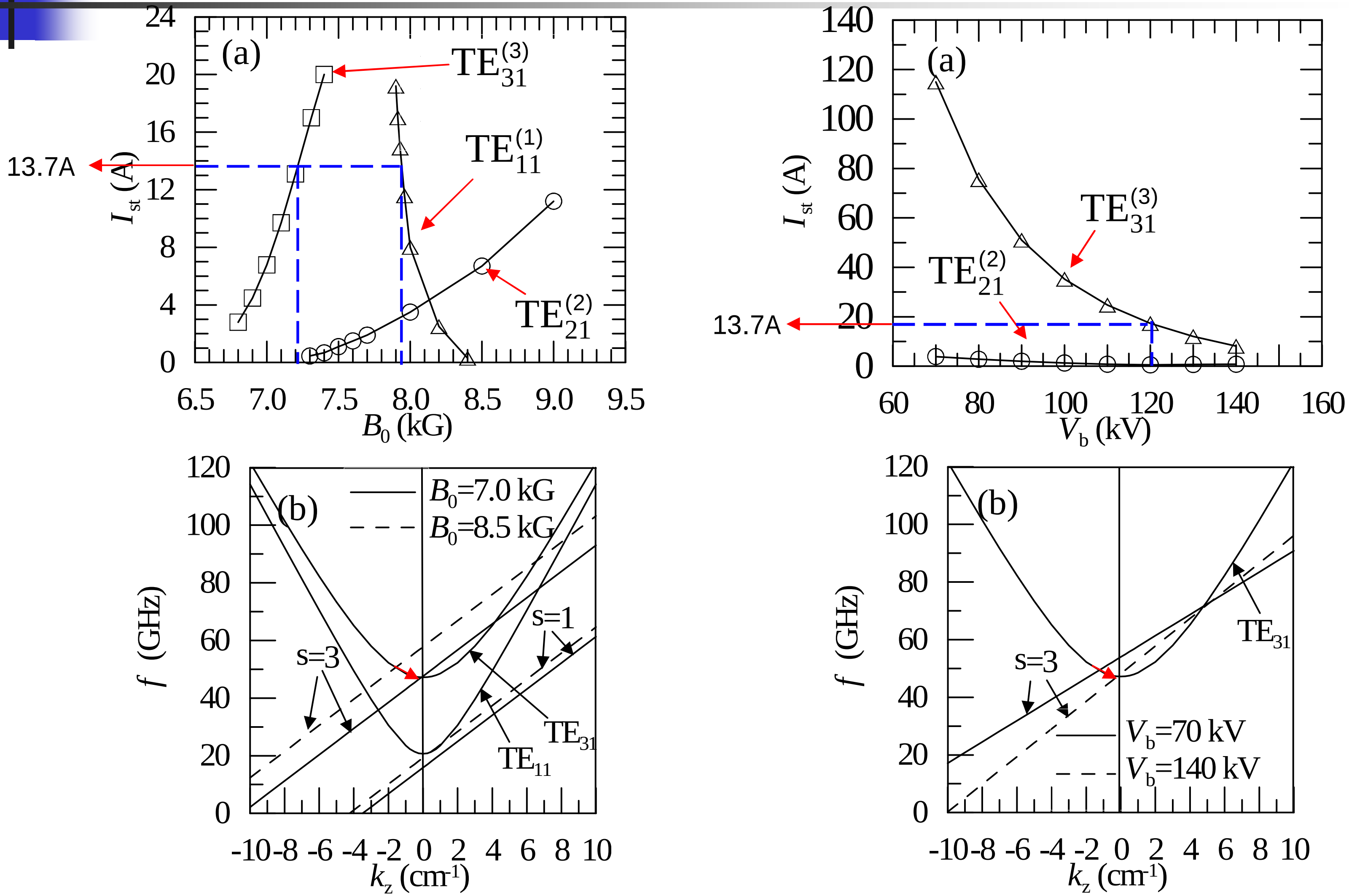
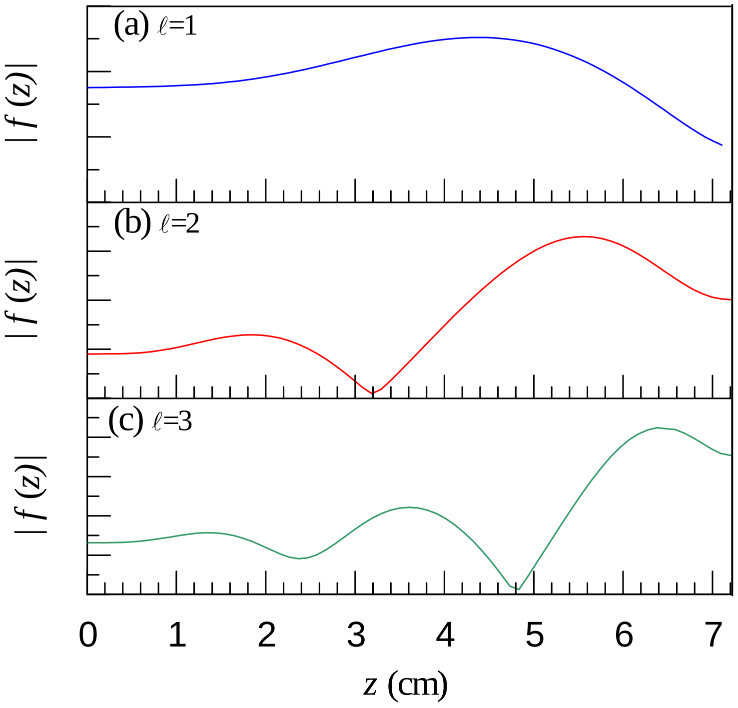
Start-Oscillation Conditions of Various Transverse Modes

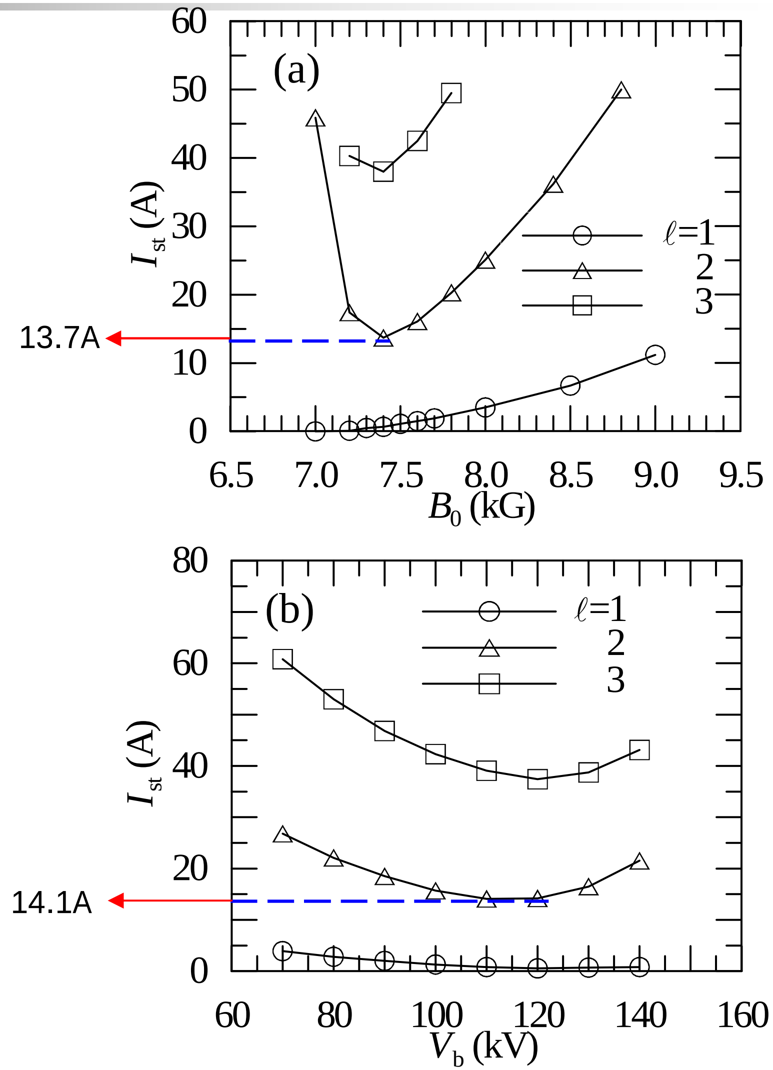


Start-Oscillation Conditions of Various Transverse Modes



Start-Oscillation Conditions of Various Axial Modes

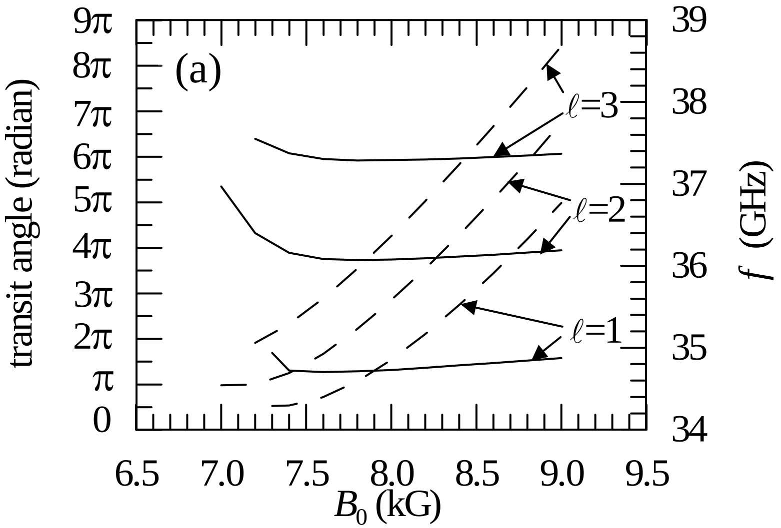


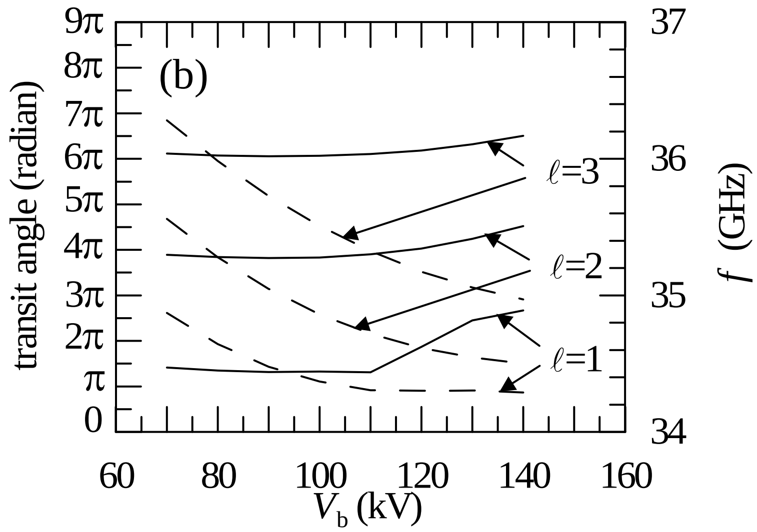


Start-Oscillation Conditions of Various Axial Modes

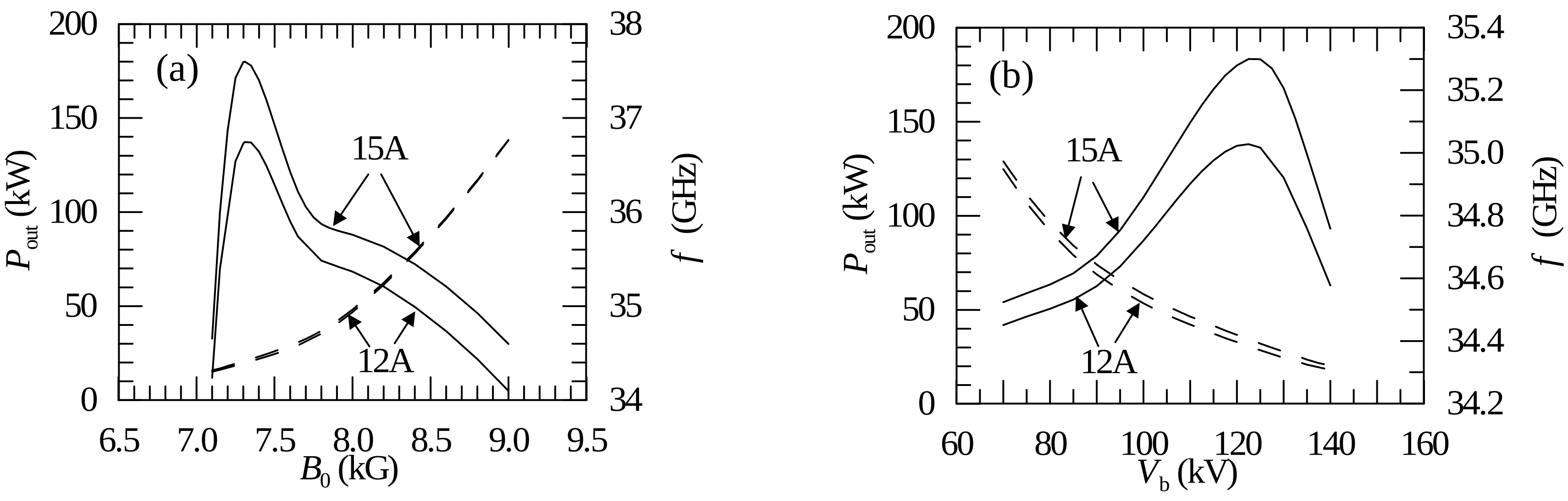
- The electron transit angle provides the total phase variation of the backward wave as experienced by the electrons in the interaction space. The electron transit angle is defined as

$$\Theta = (\omega - k_z v_{z0} - s\Omega_c)(L / v_{z0})$$





Performance of the Gyro-BWOs



Conclusions

- 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 electron transit angle of each axial mode has unique value, almost independent of the magnetic field and beam voltage, unless the oscillation frequency closes to the waveguide cutoff.

- The $TE_{21}^{(2)}$ gyro-BWO is predicted to yield a peak output power of 137 kW with an efficiency of 9.5 % at a beam voltage of 120 kV, beam current is 12 A and electron beam with an axial velocity spread $\Delta v_z / v_z = 8\%$.

References

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