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Is it possible to employ TM modes for gyrotron

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This work examines the transverse magnetic (TM) waveguide modes, which have long been considered as the unsuitable ones for the operation of the electron cyclotron maser (ECM). Gyrotrons are vacuum electronic devices based on ECM. We will show that some TM modes might be feasible for the operation of gyrotrons. Linear theory shows that the interaction of TM-mode gyrotrons depends on the sign of the wave number (k_z), unlike that of TE modes. Interestingly, the TM_{11} gyrotron as well as the TE_{01} gyrotron exhibit a similar starting behavior. By optimizing the interaction structure of the proposed gyrotron backward-wave oscillator (gyro-BWO), a maximum efficiency of 35% can be achieved with a frequency tuning range of more than 6 GHz at the pitch factor of 1.5. The peak efficiency can remain high of 32% at low beam voltage (10 kV), low magnetic field (32.8 kG), indicating additional operating conditions, which may facilitate the development of low-cost and tabletop gyrotron systems.

The transverse magnetic (TM) modes, possessing the nonzero, longitudinal component of the electric field (E_z), are traditionally considered as unsuitable and excluded from the operating modes of gyrotrons. Professor Tsun-Hsu Chang's group study the TM-mode gyrotrons for years. They first found that the TM modes are suitable for the backward-wave oscillation (gyro-BWO).[1] Then, they developed an approach to calculate the starting oscillation current of the TM-mode gyrotrons and discovered that it is possible to excite TM-mode gyrotron backward oscillators.[2] Recent study on nonlinear simulations further reveals that the TM modes might be suitable for the gyrotron backward-wave oscillator.[3-4]

Figure 1(a) schematically sketches the optimized structure of the proposed TM-mode gyro-BWO. Figure 1(b) displays the nonlinear efficiencies and the operating frequency with α=1.5 and zero-spread ideal case.

These groundbreaking studies alter the understanding of TM-mode gyrotrons and open up a new direction for gyrotron community. This work is supported by Ministry of Science and Technology Council (NSTC) under grant No. 110-2112-M-007-013-MY3 and 111-2112-M-007 -017-MY3.

References

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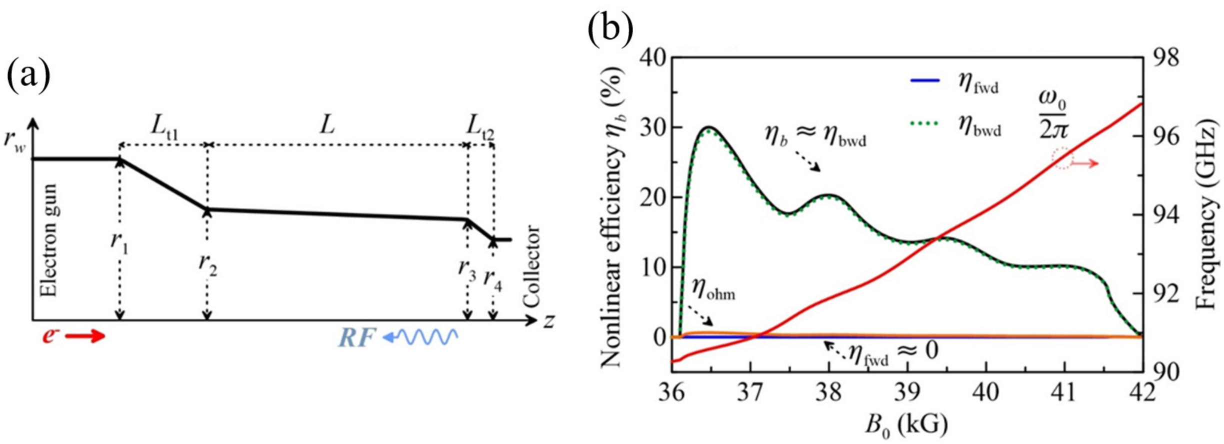

Figure 1 (a) Geometry of the interaction structure. (b) Nonlinear efficiencies and oscillating frequency vs. magnetic field. I_b, V_b, and α are 5A, 70 kV, and 1.5, respectively. Color codes: black (electron beam efficiency, η_b), blue (forward-wave efficiency, η_{fwd}), green (backward-wave efficiency, η_{bwd}), orange (Ohmic dissipation efficiency, η_{ohm}), and red (oscillating frequency, $\omega_0 / 2\pi$).