Published in final edited form as:

IEEE Int Vac Electron Conf. 2007 May 15; 2007: 1–2. doi:10.1109/IVELEC.2007.4283314.

Progress of a 140 GHz, 1 kW Confocal Gyro-TWT Amplifier

C. D. Joye¹, M. A. Shapiro, J. R. Sirigiri, R. J. Temkin, and A. C. Torrezan

MIT Plasma Science and Fusion Center, 167 Albany St., Cambridge, MA 02139, USA.

Introduction

The current status of the 140 GHz, 1 kW gyro-traveling wave amplifier is presented. The amplifier operates in the high order HE_{06} mode of a confocal mirror waveguide. The gain of the amplifier is predicted in simulation to be 53 dB, producing pulses up to 2 kW at 30 kV beam voltage and 2A beam current at a beam pitch factor of 0.75 and estimated total velocity spread of 6%. The amplifier [1] will replace a 140 GHz gyrotron oscillator [2] in use for Electron Spin Resonance (ESR) spectroscopy experiments in the Francis Bitter Magnet Laboratory at the Massachusetts Institute of Technology, Cambridge, MA.

Design of 140 GHz gyro-amplifier

The amplifier has a quasioptical interaction structure comprised of two confocal mirrors. The mode selectivity of the confocal waveguide will allow operation at a higher order (HE_{06}) mode which is analogous to a TE_{03} mode of a cylindrical waveguide without mode competition. The overmoded interaction structure improves the power handling capability and is easy to fabricate.

Two mirrors with equal radii of curvature R_c , separated by distance L have mirror aperture width $2a$. Fig. 1 shows this geometry in cross section along with the resulting normalized power contours for the case of a confocal waveguide, $R_c=L=6.9$ mm, with aperture size $2a=6.0$ mm. The resulting field patterns are nearly Gaussian in the x -direction. The electron beam is positioned to interact with the intermediate mode peaks.

The design parameters and simulation results are listed in Table 1. The amplifier consists of three 7cm amplifier sections separated by two quasi-optical separators to limit the gain in each section. Photo 1 shows the completed amplifier structure prior to installation.

Using generalized interaction formalism [3], a code was developed to calculate the gain and bandwidth of the confocal structure. The amplifier section lengths were limited to 7cm to suppress backward wave oscillations.

The interaction circuit was assembled and carefully aligned to within ± 0.03 mm for the mirror separation. Fig. 2 shows the resulting S_{11} as measured on a vector network analyzer. Good coupling of the input power is ensured by keeping S_{11} below -14 dB near 140 GHz.

Confocal Cold Test Verification

We have fabricated and cold-tested confocal waveguide structures supporting the HE_{06} mode as a proof of concept. Fig. 3 shows six main peaks as captured by a Spiricon Pyrocam III [4] pyroelectric camera located 3.7mm from the output of the test structure. Electromagnetic fields

at this position matched well with simulations predicted by HFSS from Ansoft. The EM fields of the overmoded structure have been directly imaged in a single frame capture at a frequency of 140 GHz. In addition, the S_{11} reflectance of the input coupler was measured using a Vector Network Analyzer. The S_{11} value measured -35 dB near 140 GHz, showing good coupler performance as desired.

Conclusion

The design and fabrication of the 140 GHz, 1kW gyro-TWT amplifier has been completed. The hot test of the tube will begin shortly.

References

1. Joye CD, Cerfon A, Shapiro MA, Sirigiri JR, Temkin RJ, Torrezan AC. Design of a wideband 140 GHz, 1 kW Gyro-Amplifier. 2006 IEEE IVEC/IVES, IEEE Catalog No. 06EX1278 2006:465–466.
2. Joye CD, Griffin RG, Hornstein MK, Hu KN, Kreischer KE, Rosay M, Shapiro MA, Sirigiri JR, Temkin RJ, Woskov PP. Operational Characteristics of a 14 Watt, 140 GHz Gyrotron for Dynamic Nuclear Polarization. IEEE Trans. Plasma Science 2006 June; Vol. 34(Iss. 3, Part 1):518–523.
3. Nusinovich GS, Li H. Theory of gyro-travelling wave tubes at cyclotron harmonics. Int. J. Elec 1992;vol. 72:895–907. nos. 5 and 6.
4. Pyrocam III enhanced pyroelectric camera, Model PY-III-C-B. Logan, UT: Spiricon Inc.; <http://www.spiricon.com/>.

Figure 1.

The confocal geometry and normalized power contours for the HE_{06} mode. The annular electron beam position is shown by the dashx-dot circle.

Figure 2.
Measured S_{11} of the completed amplifier structure as shown in Photo 1.

Figure 3.
Pyroelectric camera image showing six main peaks, A–F. Inset: Confocal cold test structure.
Normalized power contours shown.

Photo 1.
Completed three-section confocal interaction circuit. Total circuit length is 25 cm.

Table 1

Parameters & Simulation

Frequency	140 GHz
Operating Mode	HE ₀₆ Confocal
Output Power	2 kW peak
Input Power	10 mW
Saturated Gain	53 dB
Voltage	30 kV
Current	2.0 A
Pitch Factor	0.75
Perp. Vel. Spread	6.0 %
3dB Bandwidth	2.4 GHz (1.7%)