Design of a 140 GHz, 100 W Gyroklystron Amplifier

C. D. Joye*, M. A. Shapiro, J. R. Sirigiri, R. J. Temkin
MIT Plasma Science and Fusion Center, 167 Albany St.,
Cambridge, MA 02139, USA
**email: cjoye@mit.edu   Tel: 1-617-253-0571*

Abstract
We present the preliminary design and the simulation results for a 140 GHz, 100 watt CW gyroklystron amplifier for use in Dynamic Nuclear Polarization (DNP) experiments. The amplifier operates with a 10 kV, 100 mA electron beam and simulations show a saturated gain of 32 dB at $\alpha = 1.4$ for the TE_{02} mode with an efficiency of 9% and output power of 86 watts. The use of Photonic Band Gap (PBG) cavities to suppress mode competition is also under evaluation.

Introduction
The Francis Bitter Magnet Lab (FBML) at the Massachusetts Institute of Technology (MIT) is currently using a 140 GHz gyrotron oscillator in their Dynamic Nuclear Polarization (DNP) experiments. The availability of a high gain amplifier at 140 GHz capable of CW operation up to 100 W will significantly improve the experimental capabilities by providing a phase stable signal. The amplifier can be used to generate nanosecond wide pulse streams by merely switching the low power input driver, a feature difficult to provide in an oscillator configuration due to the unavailability of high power CW switches with nanosecond rise and fall times at 140 GHz. Two different configurations of fast wave gyroamplifiers are being considered, namely, a gyroklystron and a gyro-TWT. While the gyroklystron can operate at low voltage and provide high gain, the gyro-TWT can give a wider bandwidth and by using a distributed lossy circuit one can also obtain a higher gain [1]. In this paper, we present a preliminary design of a low voltage gyroklystron amplifier to generate 100 W of CW power at 140 GHz. The specifications of the device are shown in Table 1.

Novel Design Features
The amplifier will operate at 10 kV, which is a very low voltage compared to other gyroamplifiers. The use of photonic band gap cavities to suppress mode competition in the overmoded interaction structure [2] is also being investigated.

Frequency	140 GHz
Output Power	100 W
Saturated Gain	35 dB
Bandwidth	1 GHz (min)
Efficiency	10 %
Mode	TE_{02}
Beam voltage	10 kV
Beam current	0.1 A
Pitch-ratio, α	1.4
Magnetic field	51 kG
Number of cavities	5

Table 1. Preliminary design parameters of gyroklystron.

Results and Discussion
A nonlinear, nonstationary gyroklystron modeling code, written at MIT and based on the theory developed by Nusinovich, et al. [3] was developed to solve and track the

temporal evolution of the fields in the cavities. This simulation was based on the operation parameters in Table 1. The time evolution of the normalized fields in each cavity is shown in Figure 1. The final output power in the simulation was 86 watts with a saturated gain around 32 dB and corresponding efficiency of 9%. The simulation used a velocity spread of 4%. The electron beam radius was 0.64 mm, the first radial maximum of the TE_{02} mode.

The gyroklystron will require the design of a new electron gun, which is currently being carried out. The experiment will use a new superconducting magnet system, and the source will be an injection-locked solid state source at 140 GHz capable of 50 mW.

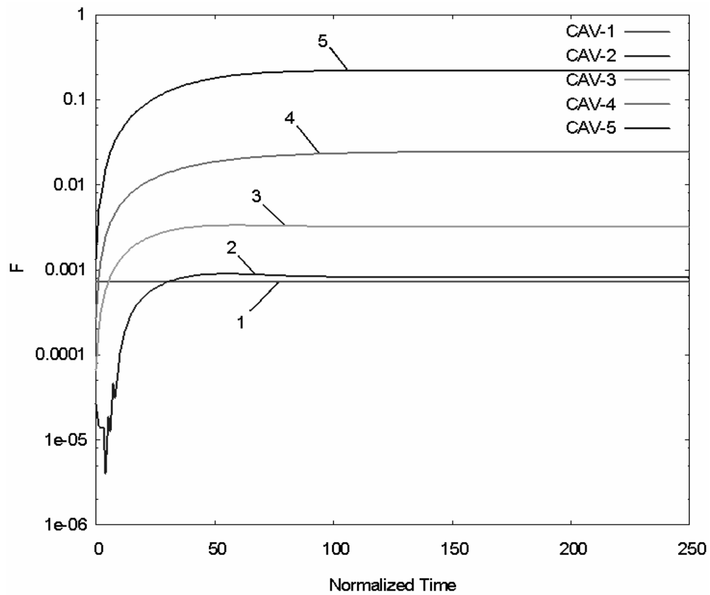

Figure 1. Evolution of normalized fields.

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References

[1] K. R. Chu, et al., "Ultra High Gain Traveling Wave Amplifier," Physical Reveiw Letters, **81**, pp. 4760-4763 (1998).

[2] J. R. Sirigiri, K. E. Kreischer, J. Machusak, I. Mastovsky, M. A. Shapiro, and R. J. Temkin, "Photonic-Band-Gap Resonator Gyrotron," Physical Reveiw Letters, **86(24)**, pp. 5628-5631 (2001).

[3] G. S. Nusinovich, B. G. Danly, B. Levush, "Gain and Bandwidth in Stagger-Tuned Gyroklystrons," Physics of Plasmas, **4(2)**, pp. 469-478 (1997).