A 35GHz, High Power, Wideband, Hybrid Harmonic-Multiplying Gyrotron Amplifier (Gyrotriotron)

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A new triplet gyrotron amplifier, which we call Gyrotriotron, has recently been developed. The device utilizes a 1-2-2 harmonic-multiplying scheme and operates with a short Ku-band gyro-TWT as input stage, a longer Ka-band gyro-TWT as output stage and a multiunit stagger-tuned clustered-cavity as intermediate stage. Electronic coupling of adjacent stages is realized through beam ballistic bunching in the radiation-free drift spaces between the stages. A mode converter/filter
type of interaction circuit is employed for each stage to minimize spurious mode competitions. Theoretical studies show that in addition to the features of lower magnetic field requirement and lower input frequency, high gain, high efficiency and wide bandwidth are expected for this three-stage harmonic multiplying gyro-amplifier.

A proof-of-principle gyrotriotron with predicted 500kW $\text{TE}_{04}$ mode output and 5% bandwidth has been fabricated as a property belonging to University of Maryland. This gyrotriotron tube is
in shipping from Beijing to Washington DC and will be soon tested in the Harmonic Gyrotron Lab at UMCP.

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Schematic of the Gyrotriotron

TE10
Ku Input

Matching load

Matching load

MIG Beam

drift cavity drift

Ka TE04
output

s_1 = 1
Gyro-TWT

s_2 = 2
Clustered Cavity

s_3 = 2
Gyro-TWT
Beam-Wave Interaction in the Gyrotriotron (H. Guo, Y. Miao)

a). Resonant Response of the clustered-cavity;

b). Beam-wave interaction in the buncher and output stage;

c). Beam-wave interaction in the input stage.
Comparing with Harmonic-Doubling Gyro-TWT

<table>
<thead>
<tr>
<th>UMCP Gyro-TWT</th>
<th>frequency</th>
<th>Efficiency</th>
<th>Peak Power</th>
<th>Gain</th>
<th>Bandwidth</th>
<th>Output Mode</th>
<th>Harmonic Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ka output, Ku input</td>
<td>12% (unsaturated)</td>
<td>180KW</td>
<td>27dB</td>
<td>3.2%</td>
<td>TE₀₃</td>
<td>2nd</td>
<td></td>
</tr>
</tbody>
</table>
2 or more short TE$_{0n}$ mode cavities, which are closely adjacent but uncoupled, can be used as beam buncher for gyro-amplifiers.

- Frequency bands of adjacent cavities overlapped.
- No beam bunching occurring between the cavities of the cluster.

(a). $f_1 = f_2 = f_3 = f_4$, $Q = 1/4 \, Q_s$
(b). $f_1 \neq f_2 \neq f_3 \neq f_4$
HFSS Simulation of TE Clustered-Cavity

Fig. Transverse field structure of TE Clustered-cavity subunit, resonating in the TE$_{031}$ Mode

Fig. Axial field structure of Clustered-cavity subunit,

Fig. Relative amplitude of electric field along the cavity axis.
An Example of Clustered-Cavity as Bunching Stage of Gyrotrottron
(3-Stage Harmonic Multiplying Hybrid Gyro-Amplifier)

<table>
<thead>
<tr>
<th>Sub-Cavity No.</th>
<th>Frequency (GHz)</th>
<th>R1 (mm)</th>
<th>R2 (mm)</th>
<th>R3 (mm)</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>33.5911</td>
<td>10.57</td>
<td>10.82</td>
<td>15.33</td>
<td>88</td>
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<tr>
<td>2</td>
<td>34.0368</td>
<td>10.40</td>
<td>10.65</td>
<td>15.08</td>
<td>111</td>
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<tr>
<td>3</td>
<td>34.3979</td>
<td>10.26</td>
<td>10.51</td>
<td>14.88</td>
<td>137</td>
</tr>
<tr>
<td>4</td>
<td>34.8151</td>
<td>10.10</td>
<td>10.35</td>
<td>14.65</td>
<td>195</td>
</tr>
</tbody>
</table>
Input coupler/TE$_{01}$ mode launcher of the gyrotriotron
Lossy Honey-Comb Structure used in drift space of the gyrotriotron
TE0n Mode Converter/Filter Used as Interaction Circuit of the Gyrotriotron

With \( \frac{\mu_{0n}}{a} = \frac{\mu_{0m}}{b} = K_c \)

\( K_c \) is cutoff wavenumber, \( n \) and \( m \) are integers, \( \mu_{0n} \) and \( \mu_{0m} \) are respectively the \( n \)'th and \( m \)'th roots of the equation: \( J_0(\mu) = 0 \)
Wideband TE04 Mode Output Window of the Gyrotriotron
Designed Operation Parameters & Features of the Gyrotriotron

- $V_a = 65KV$
- $I_a = 40A$
- $P_{in} = \text{Ku-band}$
- $P_{out} = 500Kw \text{ in Ka-band TE04 mode}$
- Gain = 50dB
- Bandwidth >5%
- B-Field = 6.5KG

- Harmonic multiplying --> lower B field and input frequency.
- Gyro-TWT combined clustered-cavity GKL --> wide bandwidth, high gain and high efficiency.
- High order TE0n mode selective interaction circuit --> high power capability and high stability.
The Gyrotriotron & the Inventor, Chief Designer H. Guo