An Improved Ku-band Magnetically Insulated Transmission Line Oscillator with Fast Start-up and High Power Capacity

Tao Jiang, Jiande Zhang, Juntao He, Zhiqiang Li

National University of Defense Technology, Changsha, P.R.China
Outline

- Background
- Design and simulation of the improved Ku-band MILO
- Experimental results
- Conclusions
Background

- Due to the potential application of the Ku-band high power microwave (HPM) in high power radar, communication, and other fields, scaling the sources to Ku-band is one of the major research hotspots.

- Jie Wen from China Academy of Engineering Physics firstly conducted the research of Ku-band MILO. But the device only produced microwave with the power of 89 MW and the pulse width of 16 ns experimentally.

Background

- There are two main reasons that limit the power output level and pulse width of Ku-band MILO:
  - High frequency MILOs with smaller size just can support lower power.
  - The reported Ku-band MILOs following the design of low frequency ones will result in the slow-down of the microwave start-up.

- In order to further enhance the power capacity, and speed up the microwave start-up, an improved Ku-band MILO is proposed and investigated numerically and experimentally.
Outline

- Background
- Design and simulation of the improved Ku-band MILO
- Experimental results
- Conclusions
Model of the improved Ku-band MILO

Seven parts:

- SWS
- Tapered choke
- Enlarged first interaction cavity
- Triple-cavity extractor
- Ladder cathode
- Limited load
- Coaxial output waveguide
Model of the improved Ku-band MILO

Three innovative designs:

- The launch point of the cathode are relatively forward shifted
- A tapered choke cavity is used to replace the traditional uniform choke cavity
- An enlarged first interaction cavity is adopted to replace the normal one
Design of the launch point of cathode

The electrons emitted from the launch point are close to the surface of first two interaction cavities.

The output microwave power is increased to 1.65 GW from 1.4GW and the microwave start-up time is reduced from 9ns to 5.5ns.

Electrons distributions of these two models

Comparison of the output power

Simulated by CHIPIC
Tapered choke cavity

- The electrons emitted from the launch point of the cathode are much closer to the SWS.
- The start-up time of Ku-band MILO with tapered choke cavity is reduced from 5.5 ns to 4.5 ns.
Enlarged first interaction cavity

- The start-up time is further reduced from 4.5 ns to 3.5 ns
- The maximal axial electrical field is reduced from 1.3 MV/cm to 1 MV/cm
Typical simulation results

- **Instantaneous and average output power**
- **Frequency spectrum of the microwave**

- Under the diode voltage of 474 kV and beam current of 42 kA, the improved Ku-band MILO can generates a microwave with a power of 1.65 GW and a frequency of 12.3 GHz, corresponding to a power conversion efficiency of 8%.

- The microwave starts to grow at 3.5 ns and achieves saturation at 7.5 ns.
Typical simulation results

<table>
<thead>
<tr>
<th></th>
<th>start-up time (ns)</th>
<th>Saturation time (ns)</th>
<th>Output power (GW)</th>
<th>Current density (kA/cm²)</th>
<th>Maximum axial field (MV/cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional</td>
<td>9</td>
<td>19</td>
<td>1.65</td>
<td>0.3</td>
<td>1.3</td>
</tr>
<tr>
<td>Improved</td>
<td>3.5</td>
<td>7.5</td>
<td>1.65</td>
<td>0.26</td>
<td>1</td>
</tr>
</tbody>
</table>

- The start-up time and saturation time are decreased greatly.
- The maximal axial electrical field of the SWS is decreased from 1.3 MV/cm to 1.0 MV/cm, which means that the power capacity of the device is enhanced by a large increment.
- The average current density of the cathode is reduced by 10%. It means less erosion of the SWS and longer life of the cathode.
Outline

- Background
- Design and simulation of the improved Ku-band MILO
- **Experimental results**
- Conclusions
Experimental results

- The low impedance accelerator: $9\Omega$, $>600\text{kV}$, $\sim100\text{ns}$
- The far-field measurement is used to measure the microwave power and frequency. Two BJ-140 waveguides placed 5 m away from the radiation antenna are used to receive the HPM
- A digital oscilloscope (Aglient-92504A, 33GHz) is used to measure the microwave waveform and frequency directly
Experimental results

- Experimental results of the improved Ku-band MILO

- In the experiment, the Ku-band MILO device generates an HPM with power of 1 GW, frequency of 12.34 GHz and pulse width of 38 ns.
Experimental results

- Experimental results comparison of the improved Ku-band MILO with the traditional one

- The microwave start-up of the improved Ku-band MILO device is 10ns faster than that of the traditional one.

- The output microwave power of the improved Ku-band MILO is enhanced to 1GW from 600MW.

- The pulse width of the improved Ku-band MILO is broadened to 38ns from 30ns.

Detection waveforms of the improved Ku-band MILO and the traditional one.
Experimental results

- **Comparison of the experimental results with the simulation ones**

Temporal relationship between the detected HPM waveform and the diode voltage introduced voltage waveform of the accelerator

- The experimental start-up is about 10ns slower than the simulation result and the device stop operation at the sharp peak of the voltage

- The imperfect concentricity of the device and the nonuniform cathode emission are the main reasons for the lower power output in experiment than that in simulation
Outline

- Background
- Design and simulation of the improved Ku-band MILO
- Experimental results
- Conclusions
Conclusions

- By introducing an optimized cathode, a tapered choke cavity and an enlarged first interaction cavity to the Ku-band MILO, the start-up time is decreased from 9 ns to 3.5 ns and the maximal axial electrical field of the SWS is decreased from 1.3 MV/cm to 1.0 MV/cm.

- The typical simulation results show that under the diode voltage of 474 kV and beam current of 42 kA, the improved Ku-band MILO can generates a microwave with a power of 1.65 GW and a frequency of 12.3 GHz, corresponding to a power conversion efficiency of 8%.

- The experimental results show that the microwave start-up of the improved Ku-band MILO device is 10 ns faster than that of the traditional one, the output microwave power is enhanced from 600 MW to 1 GW, and the pulse width is broadened from 30 ns to 38 ns.
Thank you for your attention!