MICROWAVE BEATING GENERATED BY A DUAL BEAM ACCELERATOR *

G. Li, T. Shu, J. Zhang, J. Yang, Z. Jin, L. Liu, NUDT, Changsha, 410073, P. R. C.

Abstract

As high power microwave (HPM) technologies gradually matured, the technologies for enhancing the output capacity of HPMs are becoming more and more attractive. However, limited by physics and technology, the approaches for enhancing the output capacity with a single HPM source have encountered difficulties. An alternative method for enhancing the output capacity of HPM sources is the coupling output of dual channel HPM sources. However, if the microwave sources have some coupling with each other, they maybe inter modulate with each other, and the phase-locking of the HPM sources may occur. In order to make sure that the beat waves are generating on the right way, a waveguide diplexer is introduced. Each channel has disjoint pass frequency band, and dual-channel HPM sources are isolated. As the dual-channel electron beams are driven by one accelerator, the HPM sources are expected to have a better match with the accelerator, and even higher microwave power is possible. In the high power experiments, the radiated powers of the beat waves are measured to be about 4.3 GW, 40 ns, the frequencies are about 9.41 GHz and 9.59 GHz.

INTRODUCTION

As high power microwave technologies gradually matured, the technologies for enhancing the output capacity of HPMs are becoming more and more attractive [1-9]. Efforts have been made on increasing the output power, pulse duration, conversion efficiency and the frequency spectrum of the HPM devices. However, limited by physics and technology, the approaches for enhancing the output capacity with a single HPM source have encountered difficulties [10-13]. An alternative method for enhancing the output capacity of HPM sources is taking advantage of coupling output of dual channel HPM sources.

However, if the microwave sources have some coupling with each other, they maybe inter modulate with each other, and the phase-locking of the HPM sources may occur. In order to avoid this phenomenon to make sure that the beat waves are generating on the right way, a waveguide diplexer is introduced.

As each channel has disjoint pass frequency band, the dual-channel HPM sources are isolated. The beat wave generator consists of a diplexer [14-18], two HPM sources and an accelerator capable of producing dual electron beams. As the dual-channel electron beams are driven by one accelerator, the HPM sources are expected to have a better match with the accelerator, and even higher microwave power is possible with this structure.

The enhancement of both the power handling capacity and transmission efficiency and the suppression of the higher order modes in the waveguide-filtering diplexer are studied, and the coupling output of dual-channel Gigawatt level HPMs in the same frequency band and polarization direction is realized.

According to the characteristics of TEm0 mode, an important concept to enhance the power handling capacity of the waveguide components consisting of H-plane discontinuities by enlarging the heights of the main waveguides without any affects on its transmission properties is proposed. A prototype waveguide diplexer is designed and analyzed systematically by the finite element method.

The numerical calculations reveal that, the designed diplexer has its transmission efficiency higher than 98% at 9.38GHz and 9.60GHz, the frequency bands with efficiency higher than 90% are more than 120MHz. The low power experiments show that, the transmission efficiencies are higher than 97% at 9.38GHz and 9.60GHz separately. The frequency band with transmission efficiency higher than 90% is more than 100MHz, which is in agreement with the numerical simulation. In the high power experiments, the radiated powers of the beat waves are measured to be about 4.3GW, 40ns, the frequencies are about 9.41GHz and 9.59GHz. These results demonstrate that, the diplexer is applicable to the generation of GW level beat waves and the power combining of HPMs.

The manuscript is arranged as follows. First, the structure and experimental setup is introduced. Second, discussions and conclusions are presented.

EXPERIMENTS

As the whole microwave beating system consists of several overmoded waveguides, it is of great importance to validate the diplexer with high power condition except the lower power experiments.

The low power and high power experiments are carried out in the anechoic chamber of our laboratory to get rid of the influence of background scattering.

The low power experiments reveal that the dual channel of the diplexer have its power transmission efficiency higher than 97% at the central frequencies. In accordance with the numerical calculations, the designed diplexer has its transmission efficiency higher than 98% at 9.38GHz and 9.60GHz, the frequency bands with efficiency higher than 90% are more than 120MHz. The low power experiments show that, the transmission efficiencies are higher than 97% at 9.38GHz and 9.60GHz separately. The

* This work was supported by National University of Defense Technology.

Email: nudt-liguolin@hotmail.com.

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frequency band with transmission efficiency higher than 90% is more than 100MHz, which is in agreement with the numerical simulation.

The dual high power micrwoave sources have different working frequencies for the both channel high power diplexers. They have similar structures and close in physical dimension.

In this section, the designed diplexer, mode converter, and the antenna are combined into an organic and compact system.

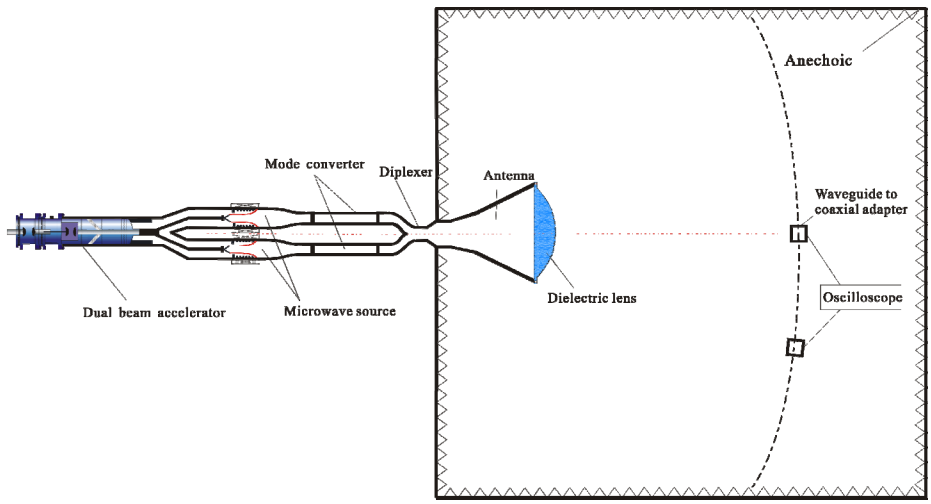

Figure 1: Schematic display of the microwave beating system.

In order to satisfy the simultaneous operation of the individual high power microwave sources, a dual beam accelerator is employed to produce dual beams with desired voltage and current. The total impedance of the accelerator is about 40 ohm. And the structural impedance of the high power microwave sources is about 70 ohm. As a result, the total impedance of the dual high power microwave sources connected parallel is about 35 ohm. Therefore, the high power microwave sources have a good match with the dual beam accelerator, and even higher microwave power is possible with this structure.

The synchronism of the individual high power microwave sources can be judged by the synchronism of the diode current of the individual diode.

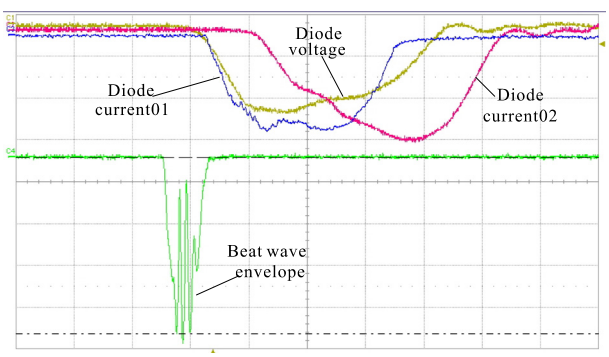

Figure 2: The diode current of the individual diode

As displayed in the Figure 2, the measured time delay of the dual diode is about 54ns. However, the time delay caused by the measuring cable is about -56ns. As a result, the time delay between the diode currents for the generating of the high power microwaves is about -2ns.

Thus, the synchronism operation condition for the individual high power microwave sources can be generally satisfied by employing the dual beam accelerator.

In addition, the radius of the overmoded waveguide for the dual high power microwave sources are 250mm and 260mm separately, and the overmoded ratio is about 14. And he saturation time for the separate oscillations has about 5ns delay.

All in all, the total time delay for the dual microwave beams that meet in the junction is within 8ns, which is very important for the microwave beating procedure.

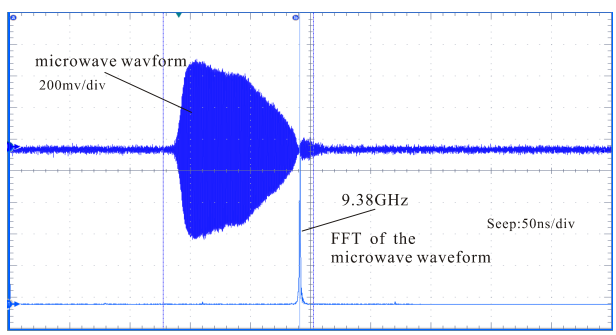

Figure 3: The microwave profile for the 9.38GHz high power microwave source

Figures 3 and Figure 4 give the microwave profiles of the single microwave beams before its entrance to the diplexer. The measured power magnitude of the high power microwave sources can reach to gigawatt level, to make sure that the high power micrwave sources can be employed as the testing device for validating the power handling capacty of the diplexer.

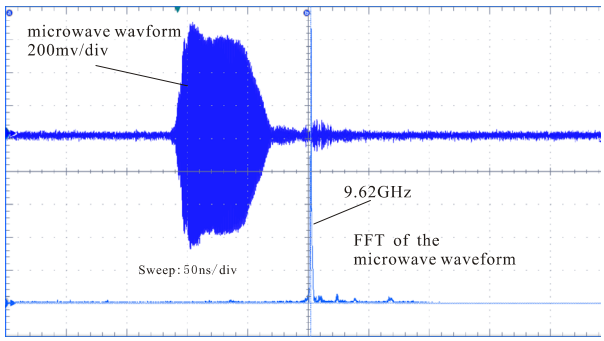

Figure 4: The microwave profile for the 9.38GHz high power microwave source

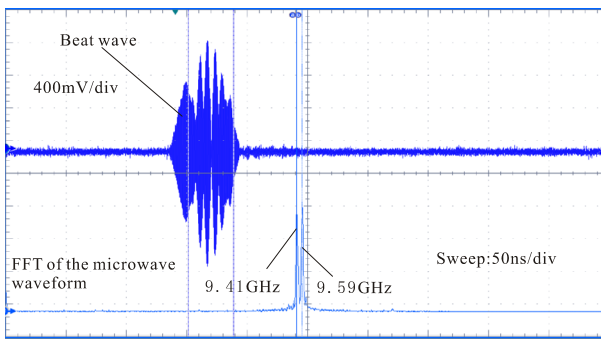

Figure 5 The microwave beating profile

As displayed in Figures 3-5, the Gigawatt level high power microwave beams meeting at the diplexer junctions have induced microwave beating, which is designed by delicate structure.

CONCLUSIONS

This paper discusses the microwave beating generated by a dual beam accelerator. As the dual-channel electron beams are driven by one accelerator, the HPM sources are expected to have a better match with the accelerator, and even higher microwave power is possible. In order to avoid the phase-locking of the individual microwave beams generated by different high power microwave sources, a diplexer is designed and fabricated for high power microwave experiments. In the high power experiments, the radiated powers of the beat waves are measured to be about 4.3 GW, 40 ns, the frequencies are about 9.41 GHz and 9.59 GHz.

REFERENCES

[1] E. Schamiloglu, IEEE MTT-S Int. Microwave Symp. Dig. 2, 1001(2004).
[2] Z. Li, Appl. Phys. Lett., 92, 054102 (2008).
[3] D. H. Kim, H. C. Jung, S. H. Min, S. H. Shin, and G. S. Park, Appl. Phys.Lett. 90, 124103 (2007).
[4] Y. W. Fan, H. H. Zhong, Z. Q. Li, T. Shu, H. W. Yang, H. Zhou, C. W. Yuan, W. H. Zhou, and L. Luo, Phys. Plasmas 15, 083102 (2008).
[5] Z. Li and Y. Qi, Phys. Plasmas 15, 093104 (2008).
[6] L. Liu, Limin Li, X. Zhang, J. Wen, H. Wan, and H. Zhong. Appl. Phys. Lett., 91, 161504 (2007)
[7] Y. W. Fan, H. H. Zhong, Z. Q. Li, T. Shu, H. W. Yang, J. H. Yang, Y.Wang, L. Luo, and Y. S. Zhao, Chin. Phys. B 17, 1804 (2008).
[8] Y. W. Fan, H. H. Zhong, H. W. Yang, Z. Q. Li, T. Shu, J. Zhang, Y. Wang, and L. Luo, J. Appl. Phys. 103, 123301 (2008).
[9] J. Ju, Y. Fan, H. Zhong, and T. Shu, Phys. Plasmas 16, 073103 (2009).
[10] C. Chang, G. Liu, C. X. Tang, C. H. Chen, H. Shao, and W. H. Huang, Appl. Phys.Lett. 96, 111502(2010).
[11] C. Chang, G. Liu, J. Fang, C. Tang, H. Huang, C. Chen, Q. Zhang, T. Liang, X. Zhu, J. Li, Laser and Particle Beams, 28, 185(2008).
[12] C. Chang, G. Liu, H. Huang, C. Chen, J. Fang, Phys. Plasmas, 16, 083501 (2009)
[13] S. K. Nam, C. Lim, and J. P. Verboncoeur, Phys. Plasmas, 16, 023501 (2009)
[14] G. Li, T. Shu, C.Yuan, J. Zhang, Z. Jin, and J. Yang, Physics of Plasmas, 17, 033301 (2010)
[15] G. Li, T. Shu, C. Yuan, J. Zhu, J. Liu, B. Wang, and J. Zhang, Laser and Particle Beams, 28, 35 (2010).
[16] J. Zhang, H. Zhong, and L. Luo, IEEE Trans. Plasma Sci., 32, 2236(2004).
[17] J. Benford, H. Sze, W. Woo, R.R. Smith, B. Harteneck. Phys. Rev. Lett., 62, 969(1989).
[18] H. Sze, D. Price, B. Harteneck. J. Appl. Phys., 67, 2278(1990).