Improved Performance of Hybrid Electronic Terahertz Generators

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***Abstract*— By combining backwards wave oscillators with frequency multipliers the spectral range is extended while taking advantage of improved impedance matching between these components. QS2-180 (OV-86), QS1-260, and QS1-370 have been successfully coupled to Schottky diode frequency multipliers. By empirical means the impedance was tuned significantly improving power conversion efficiency.**

I. Introduction And Background

THE backwards wave oscillator (BWO) is a well established electronic terahertz source in the lower (30GHz to 1.5 THz) portion of the spectrum [1]. A typical BWO provides 1-100 mW of CW power tunable across 100-400 GHz. However, BWO's designed to operate above 180 GHz require bulky magnets, higher cathode voltages, and water cooling. Also, 8 different BWOs are required to provide a quasi-continuous spectral coverage up to 1.5 THz.

One innovative approach to bypassing these problems is to use a high power low frequency BWO, such as QS2-180 (OV-86), in conjunction with solid state frequency multipliers to extend the spectral range of the device [2]. This approach allows one to stay with a lighter magnet, lower cathode voltage power supply, and air cooling. It is also more practical for measurements across wider spectral range, combining one BWO tube with different multipliers

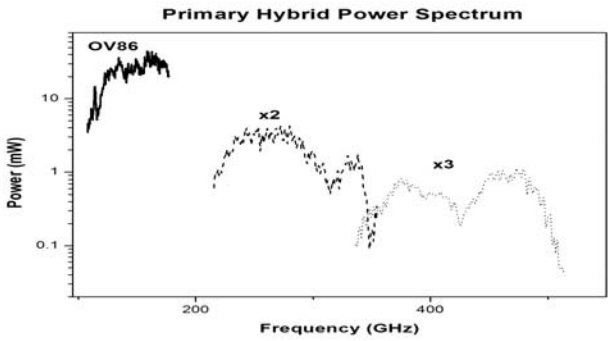
Recent developments in frequency multiplier design [3] presented an opportunity for an improved hybrid electronic terahertz generator. Seeing the opportunity, Microtech Instruments has developed a hybrid electronic system incorporating the high power and broad band tunability of the backwards wave oscillator with the compactness and precision of solid state Schottky diode multipliers producing a hybrid system with a spectral range from 100 to 1500 GHz.

II. Results

Several different designs of Schottky diode multipliers were constructed for testing purposes by Virginia Diodes Inc. as part of research project funded by SBIR grant contract number. W31P4Q-07-C-0140. We tested several different BWO's with different multiplier designs to empirically find optimal impedance matching. Improved impedance matching between the BWO interior and free space resulted in higher output power across 0.2 to 1.5 THz, as illustrated in Figure 1.

With the development of a new frequency doubler for 450-650 GHz the range of the hybrid has been expanded to continuously cover from 100 to 1500 GHz. We expect continued improvement in power output on the new doubler with each generation as we continue refinement of the design.

a.



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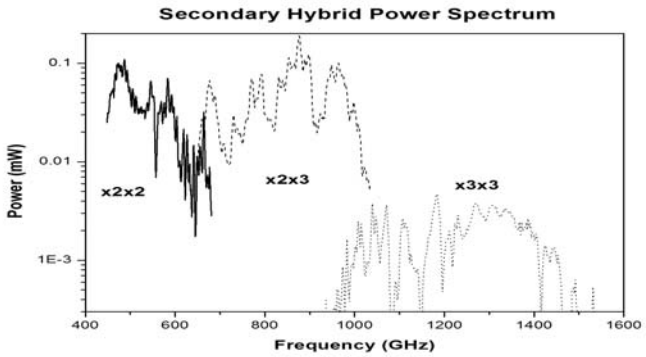

Figure 1: a. shows BWO and single multiplier results. b. shows the results with a second multiplier chained in series.

For the ranges up to 550 GHz a single multiplier is attached to the BWO. To cover the upper portion of the spectrum a secondary multiplier is attached to the output of the primary multiplier. This gives the following combinations as illustrated in Figure 1, x2, x3, x2x2 (x4), x2x3 (x6), and x3x3 (x9). Using this set of 5 combinations is equivalent to 8 different BWO's and spans 100-1500 GHz.

To further demonstrate the improvement is due to increased BWO output caused by an improved match in impedance between free space and the BWO internal cavity a 3-way directional coupler was inserted between the BWO and the multiplier. In Figure 2 the ratio of side channel power without the multiplier to with the multiplier (Extraction efficiency) versus frequency is shown. One can readily note the consistently greater than unity value and see that this empirically demonstrates improved impedance matching. This data is typical of the data collected on QS2-180/hybrid matches that produced higher than theoretically expected efficiencies. Conversely, there was one poor match that

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produced low power output and on the extraction efficiency experiment averaged 96% demonstrating that design was not a good impedance match.

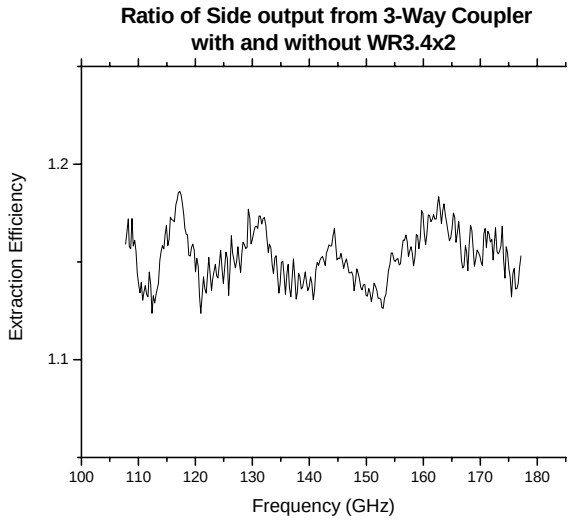

Figure 2. Increased side channel output of the QS2-180 BWO with the WR3.4x2 multiplier in place compared to without as extraction efficiency.

Additionally, the QS1-260 and QS1-370 low frequency BWO's have been coupled with frequency tripling multipliers with good results. The QS1-260-T is the tripled hybrid designation for QS1-260 coupled to a WR1.5x3 tripling frequency multiplier. The QS1-370-T is the hybrid with the QS1-370 coupled to a WR1.0x3. Both new hybrids cover the important H_2O window at 650 GHz.

The QS1-260-T has the extended range from 480-780 GHz. Delivering more than 100 μW of CW THz radiation across the most of the broad spectral range (as can be seen in Figure 3), the QS1-260-T makes an efficient, economical, and more readily available alternative to higher frequency BWO's such as the QS1-710.

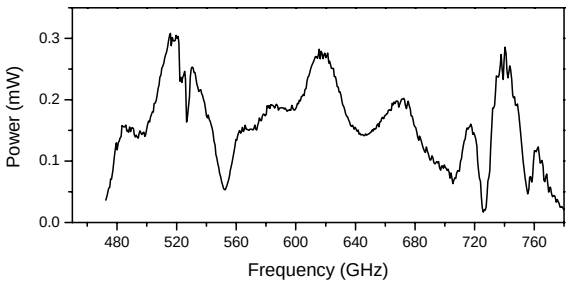

Figure 3: QS1-260-T power spectrum.

The QS1-370-T covers the additional spectral range of 630-1100 GHz. The broad and flat spectral range seen in Figure 4a. demonstrates the advantage of the hybrid technology by spanning a spectral range typically requiring 3 BWO's. The efficiency (seen in 3b.) shows the expected ~5% across most of the spectral range with a peak between 250 and 275 GHz once again demonstrating improved impedance matching between the BWO internal cavity and free space as the greater than 25% efficiency value is beyond theoretical expectations for this tripler.

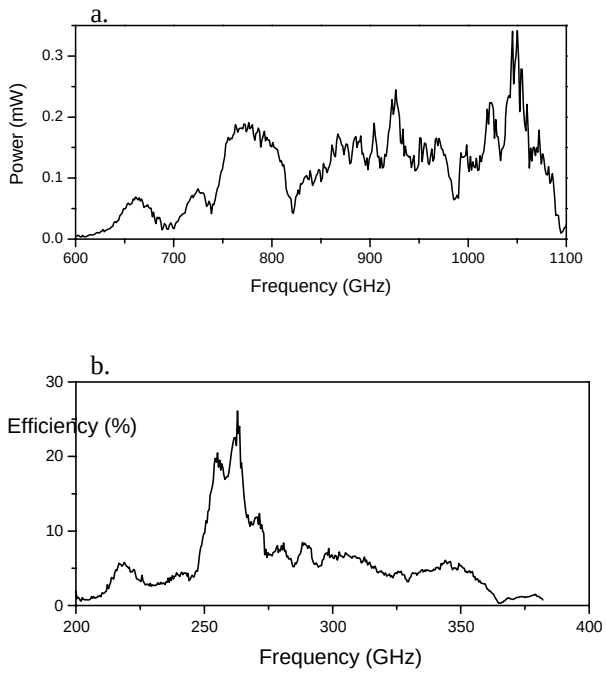

Figure 4: a. The broad power spectrum of the QS1-370-T. b. Efficiency

We demonstrated on 3 different types of BWO's that the impedance matching can be improved on BWO's using a multiplier. We showed that the available baseline power increases with properly matched components. By matching different internal designs (proprietary information on those specifics withheld by VDI) that BWO performance can be extended and simultaneously improved.

This hybrid improvement provides broader spectral coverage using a single BWO with improved power Additionally, one can expect the hybrid systems to have longer cathode life expectancy compared to higher frequency BWO's as the power dissipation on the cathode is significantly lower providing a more useful and economical device.

REFERENCES

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