A High-Power Schottky Diode Frequency Multiplier Chain at 360 GHz for Gyro-TWA Applications

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***Abstract*—A high-power Schottky diode frequency multiplier chain at 360 GHz, with a 3 dB bandwidth above 20 GHz is presented. The cascaded frequency doublers show peak efficiencies of 35% and 23% at 180 and 354 GHz, respectively. While the 180 GHz doubler generates a maximum power of 69 mW at 300 mW input, the second stage doubler delivers 12 mW output at 360 GHz. Both doublers consist of low parasitic GaAs Schottky diode circuits optimized to handle high input powers, and neither exhibit saturation at the highest applied power.**

***Keywords*—Schottky diode, frequency multiplier, GaAs, frequency doublers.**

I. Introduction

Gyro-travelling wave amplifiers (gyro-TWAs) offer an attractive solution to generate hundreds of watts of CW and pulsed power for future applications in communications, plasma diagnostics and spectroscopy [1, 2]. These devices are currently being developed to generate 40 dB of gain at 360 GHz and thus require RF power of the order of tens of milliwatts to adequately drive their input. Schottky diode frequency multipliers offer an attractive solid-state solution to generate this input power due to their large fractional bandwidth and CW operation. This paper presents results for a x2x2 frequency multiplier chain developed to generate >10 mW at 360 GHz for this gyro-TWA.

II. Overview of the Circuits

The Schottky diode frequency doublers at 180 and 360 GHz were fabricated on gallium arsenide (GaAs) substrates, each with four-anodes in typical anti-series configuration commonly used in frequency doublers [3]. The GaAs circuits were suspended in the metal block via beam-leads that extended from the semiconductor circuit providing mechanical support and RF grounds.

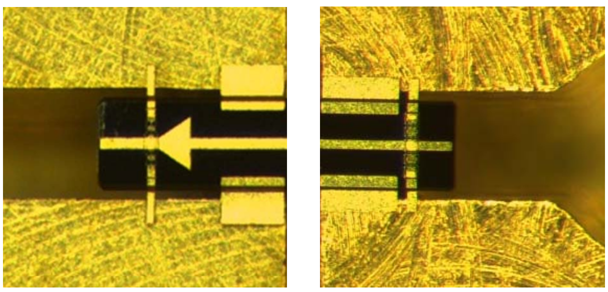

Fig. 1. Internal view of the Schottky frequency doublers at 180 GHz (left) and 360 GHz (right) showing the gold beam-leads.

Photographs taken during assembly of the GaAs circuit placed in the lower block of the frequency doublers are shown in Fig. 1. The circuits were designed to handle high input powers, 200 and 50 mW, respectively for the 180 and 360 GHz doublers, while maintaining good efficiencies. The diode parameters - junction capacitance, series resistance and breakdown voltage for the 180 and 360 GHz doublers were 54 fF, 5 Ω and 9 V, and 15.1 fF, 7 Ω and 9 V, respectively.

III. Performance of the Multiplier Chain

The frequency multiplier chain was tested using a W-band frequency sextupler from Radiometer Physics GmbH (RPG) followed by a high power W-band amplifier from QuinStar Technology. The measurement was performed using a W-band isolator and 10 dB directional coupler to track the input power supplied to the 180 GHz doubler. In testing the 360 GHz doubler, an additional isolator was placed between the two frequency doublers to ensure a good calibration of the respective input and output powers of each device.

For the 180 GHz doubler, the output power was higher than 23 mW from 170 to 190 GHz for 100 mW input, while the 360 GHz doubler generated more than 5 mW of output from 350 to 370 mW for 35 mW input. The peak power conversion efficiencies for the doublers were 35% and 23% at 180 and 354 GHz, respectively. The dependence of output power of the 180 and 360 GHz doublers on frequency at fixed input powers are shown in Fig. 2 and Fig. 3, respectively.

Input power sweeps for the 180 and 360 GHz doublers are shown in Fig. 4 and Fig. 5, respectively. The measured peak output power for the 180 GHz doubler was 69 mW at 300 mW input with a power conversion efficiency of 22%. When driven by 60 mW at 180 GHz, the 360 GHz doubler generated 12 mW with a conversion efficiency of 20%. From Table 1, it is noted that although maximum efficiency for both devices is obtained for lower drive powers than the maximum applied, the availability of input power prevented the testing of the multipliers at higher drive power levels.

TABLE I

KEY FREQUENCY MULTIPLIER CHAIN RESULTS

Center frequency (GHz)	**Input power (mW)**	**Output power (mW)**	**Efficiency (%)**
180	300	69	35
360	60	12	20

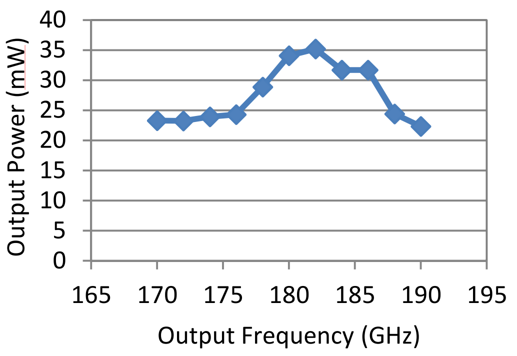

Fig. 2. Measured output power vs output frequency at 100 mW input power for the 180 GHz doubler.

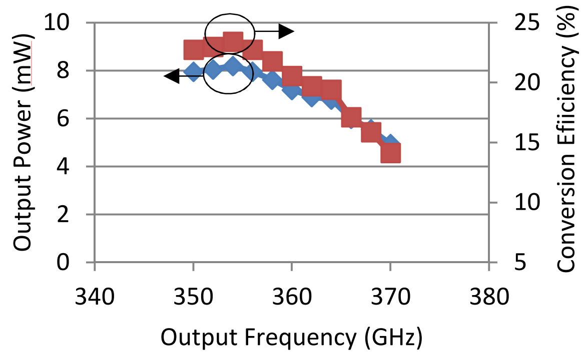

Fig. 3. Measured output power and conversion efficiency vs output frequency for the 360 GHz doubler for 35 mW input power.

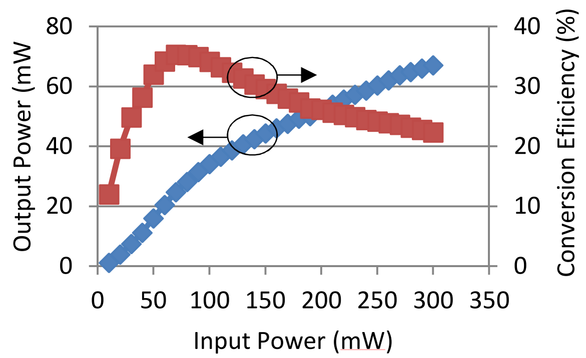

Fig. 4. Measured output power and conversion efficiency vs input power at 180 GHz.

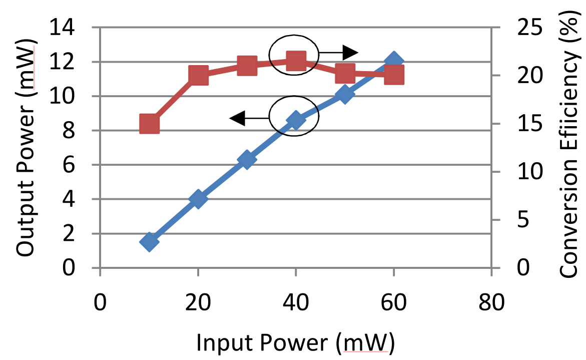

Fig. 5. Measured output power and conversion efficiency vs input power at 360 GHz.

IV. Conclusion

A x2x2 frequency multiplier chain has been developed at 360 GHz to provide the input power for a new generation of Gyro-TWA. The output powers and conversion efficiencies achieved at 180 and 360 GHz are excellent results for frequency doublers at these frequencies. The 180 GHz doubler gave a peak output power of 69 mW and the second stage doubler gave 12 mW at 360 GHz. Whilst both devices are operating beyond their peak efficiency points, neither device broke during testing so are expected to be able to deliver greater output powers than presented here.

References

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