Terahertz Planar Varactor Sideband Generator Array

Haiyong Xu[a], Zhiyang Liu[b], Lei Liu[a], Jeffrey L. Hesler[c], and Robert M. Weikle[a], II
[a]University of Virginia, Charlottesville, VA 22904 USA
[b] Tyco Electronics, Lowell, MA 01853 USA
[c] Virginia Diodes Inc., Charlottesville, VA 22902 USA

***Abstract*—The development of a planar 1.6 THz sideband generator (SBG) is described in the paper. The integrated SBG circuit is mounted into a metal waveguide, and with optimized embedding impedances, a sideband conversion loss of better than 20 dB at 1.6 THz can be expected. Because it is difficult to employ multi-diode circuit topologies in waveguide structures designed for operation over 1 THz (due to limited space and fabrication tolerances), a 1.6 THz quasi-optical varactor SBG array that is capable of increasing power handling capacity will also be discussed.**

I. Introduction And Background

IN the submillimeter-wave frequency range, sideband generators play an important role as a tunable sources and are based on mixing a fixed source (e.g., a far-infrared laser) with a tunable microwave source. Such tunable sources have a variety of applications in remote sensing, scaled radar range systems and molecular spectroscopy[1]. To date, state-of-the-art SBG's operating at terahertz frequencies have demonstrated a conversion loss of 14 dB with an output power of 55 µW at 1.6 THz by utilizing a whisker-contacted Schottky varactor[2]. Over the past year, several planar implementations of varactor SBG's have been developed covering different THz frequencies. These implementations improve robustness and repeatability[3]. In this paper, a new planar SBG design is presented that optimizes impedance matching to the device. Furthermore, a quasi-optical varactor diode array designed to handle approximately 100 mW output power from a far-Infrared (FIR) laser source at 191 µm is described.

II. Single Diode Design

The SBG is designed with the aid of Agilent's Advanced Design System (ADS) software. The embedding impedances from the diode junction are calculated for different anode sizes. For 1 µm diameter anode, the zero bias junction capacitance is estimated at 1.6 fF, while the series resistance is 20 Ω. The optimized embedding impedance is found to be, Zopt=46+j100 Ω at 1.6 THz, as shown in Fig. 1. The corresponding conversion loss is less than 9 dB.

Based on the optimized embedding impedance, an integrated circuit using single diode is initially designed using ADS and optimized with Ansoft's High Frequency Structure Simulator (HFSS). This SBG circuit includes a waveguide to microstrip transition, planar diode and microstrip filter. It was fabricated on a quartz substrate. A photograph of the assembled SBG circuit, which was fabricated by Virginia Diodes, Inc. (VDI), is shown in Fig. 2. The integrated circuit width is 50 µm, and the thickness is 10 µm. To achieve the optimized embedding impedance, the finger length is determined to be 14 µm, while the anode diameter is 1 µm.

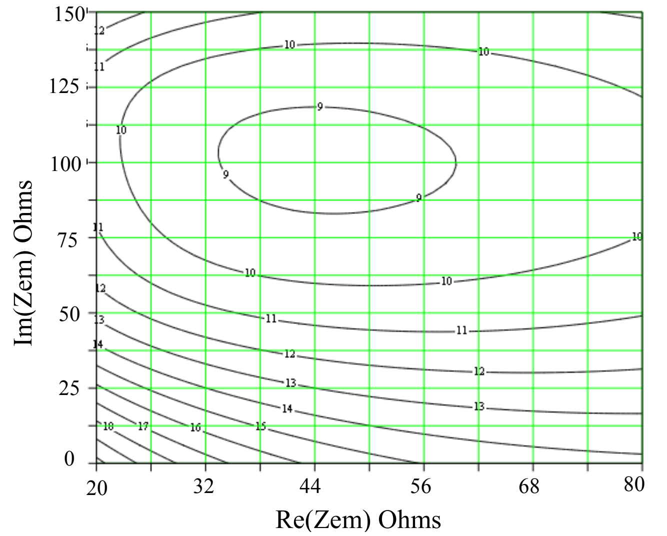

Fig. 1. ADS Simulated conversion loss corresponding to different embedding impedances for 1 µm diameter anode.

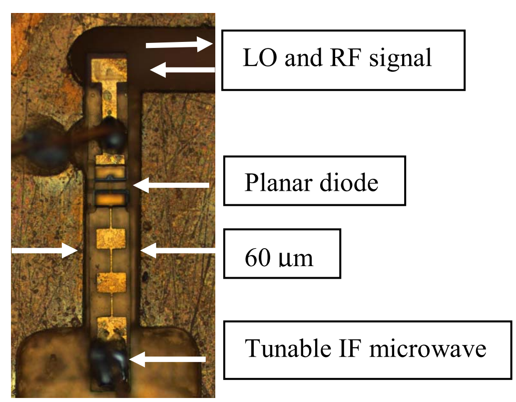

Fig. 2. Photograph of 1.6 THz integrated SBG circuit mounted in an open metal block. The circuit channel width is 60 µm. The varactor is pumped by a tunable IF microwave signal. The output RF signal will be LO +/- IF.

The waveguide-to-microstrip transition is used to couple the LO into the diode channel and sidebands (RF) back into the waveguide. The microwave IF signal is applied to pump the diode, while a low-pass microstrip filter integrated with the diode is used to resonate with the varactor and block the RF signal. This SBG was initially tested as fundamental mixer using the Y-factor method. A Far Infrared laser provides approximately 3 mW power as the LO source. A Martin Puplett diplexer is used to combine LO and RF beam. The SBG is biased with a constant current of 0.8 mA. The

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measured conversion loss and noise temperature are 12 dB and 5860 K.

III. ARRAY DESIGN

To improve the power handling capacity of SBG's, multi-diode designs are attractive. However, it is difficult to employ multi-diode circuit topologies in waveguide structures at THz due to limited space and fabrication tolerances. A quasi-optical SBG array addresses these problems[4]. An equivalent unit cell of an SBG array is simulated with HFSS as shown in Fig. 3. Electric wall (E-wall) and magnetic wall (H-wall) planes are defined based on the array symmetry[5]. To avoid the higher order waveguide modes, the unit cell dimension must be less than a certain value. With a quartz substrate, the unit cell dimensions are set to be 70 µm × 70 µm, while the unit cell dimensions for Si substrate will drop to approximately 30 µm × 30 µm. Considering that the planar diode mesa size, is usually larger than 20 µm x 20 µm, a quartz substrate is chosen for this design, which also improves impedance matching. The quartz thickness is determined to be 15 µm to eliminate the substrate modes.

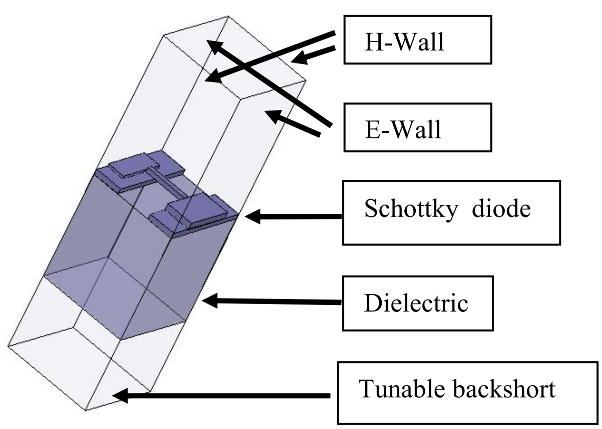

Fig. 3. An equivalent unit cell of SBG array using quartz substrate. A mirror is used as a tunable backshort. E-walls are defined at waveguide walls at the end of the diode, while H-walls are the 2 side waveguide walls along diode finger.

The varactor geometry is adjusted to present the optimized SBG embedding impedance as shown in Fig. 1. The anode size is determined to 1 µm, while the finger length is set to be 14 µm. The simulated embedding impedance versus frequency is shown in Fig. 4. The embedding impedance is 50+j88 Ohms at 1.56 THz, which is expected to give a conversion loss less than 9 dB. This conversion loss doesn't account for circuit conductive and dielectric losses. Furthermore, the Gaussian beam coupling is calculated. The Gaussian laser beam is coupled into the array by an off-axis parabolic mirror with focus length 60 mm. To optimize coupling to the beam, the array is populated with 6 × 6 elements. The array size will be 0.42 mm × 0.42 mm, comparable to the beam waist of the Gaussian mode. A coplanar waveguide transmission (CPW) filter will be designed for the microwave pump signal.

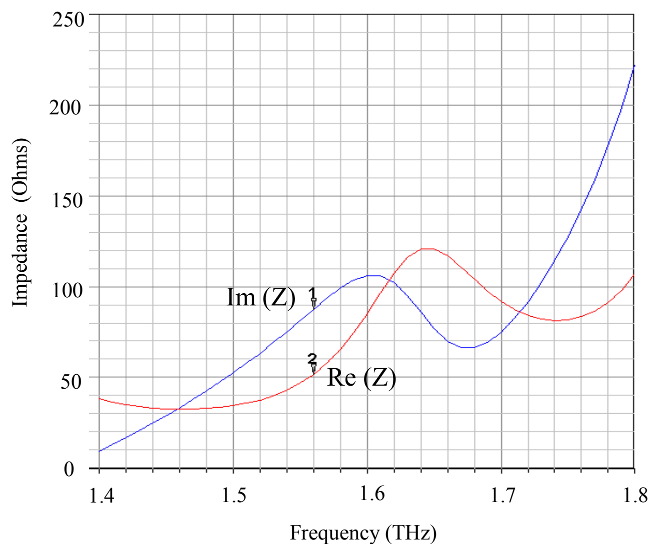

Fig. 4. Simulated embedding impedance of a unit cell. The diode anode size is 1 um, and the finger length is 14 µm. The array unit cell dimension is 70 µm × 70 µm.

IV. CONCLUSION

A 1.6 THz SBG is investigated and a conversion loss contour map is given. Initial results employing a single diode integrated circuit are presented. Moreover, a planar SBG array with 36 elements is designed to handle high laser power, 100 mW. Diode parameters have been designed to match the impedance.

ACKNOWLEDGMENT

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