Room Temperature Terahertz SubHarmonic Mixer Based on GaNNanodiodes

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Abstract—**GaN Unipolar Nanochannels is fabricated by etching in the AIGaN/GaNheterojunction. Adjusting the GaNnanochannel width results in a nonlinear, quadrantal symmetry, current voltage (I/V) characteristic. It means GaNNanochannel is quite suitable for subharmoicemixing(fIF=|fRF-2fLO|). Here, we will present the DC and RF performance prediction of a novel terahertz sub-harmonically pumped mixer that uses the GaN Unipolar Nanochannels.**

INTRODUCTION

Two dimensional Electron Gas (2-DEG) unipolar nanodiodesknown as self-switching diode(SSD) is fabricated by etching two symmetrical L-shaped trenches in the semiconductor heterojunction[1]. Asymmetric nanodiodebased on different semiconductor heterojunctions has been proposed to obtain planar devices with non-linearcurrent voltage (I-V) characteristic [2]. Devices using InGaAs/GaAs or AlSb/AlGaSbheterojunction have been demonstrated as room temperature direct detectors at millimeter[3]and terahertz frequencies already[2][4]. GaNNanodiodes is fabricated by etching in the AIGaN/GaNheterojunction. Firstly, the possibility of GaNnanodiodes as direct and heterodyne detectors in terahertz frequency range has been foundin the numerical Monte Carlo (MC) simulations[5]. Then, GaNnanodiodesutilized as the direct detector and the fundamental mixer have been realized in the laboratory [6][7].

A rigorous device's model which describes the physical mechanism or the electronic characteristic is very important for the circuit nonlinear simulation. Åberg et al. later modelledthe I/V characteristic of silicon-based SSDs based on FET-equations, and their model is brieflyreviewed in [9]. Schottky diode equation has also been used to describe theI/V characteristic of SSDs, however it is a challenge still to deal with the GaNNanodiodesquadrantal symmetryI/V characteristic. Here we introduced the phenomenologicalunified diode equation for GaNnanodiodes and the mixing conductivity g of the device and the expression is as the following,

$$g = \frac{di_d}{dv_d} = \left[\frac{1}{2}\left(e^{v_d} + e^{-v_d}\right)\right]^{-2} \quad (1)$$

Then, Taylor series expansion to the diode's mixing conductivity g around its operating point v_0。Following the taylor expansion,$v_d$in the Eqn(1) was substituted bythe local signal $v_{LO}e^{j\omega_{LO}t}$and then the curves of each series expansion parameters depend of the operating point v_0 wereplotted in @Mathematica and were shown in Fig1. If the operating point $v_0$was set to zero, which means the device was zero biased, the linear, cubic and quantic terms are all zero atthis case. And the constant and even order terms (quadratic and quartic) are at their peak position. With the RF signal $v_{RF}e^{j\omega_{RF}t}$ exciting, only the even order terms can be obtained, final result contains the $|2n\omega_{LO} - \omega_{RF}|$ termsafter the low pass filtering ($n = 1,2,3\cdots$).

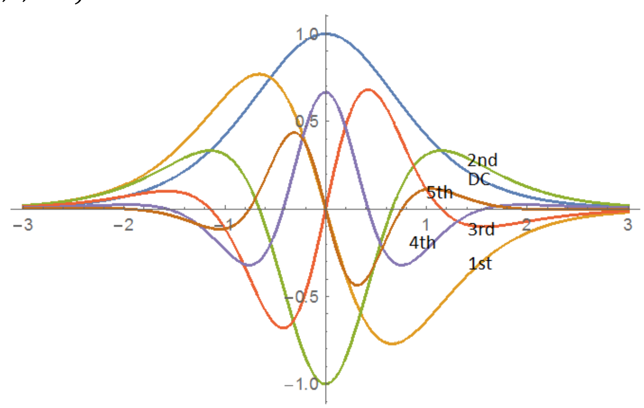

Figure 1.Curves of each series expansion parameters depend of the operating pointv_0.

DESIGN METHODOLOGY

Fig.2 depicts the basic mixer circuit,consisting of a mixer chip placed in a channel across the inputwaveguide. The mixer are using the silicon-on-insulator (SOI) substrate comprisedof the antenna, filter and the SSDs, issuspended at the channel, plus a waveguidebackshort which is the critical part for the optimization of a better LO/RF coupling.

SSDs model is implemented together with the ideal input and output matching networks to optimize the electrical parameters of the anode for certain input power using the Harmonic-balance simulator in ADS.

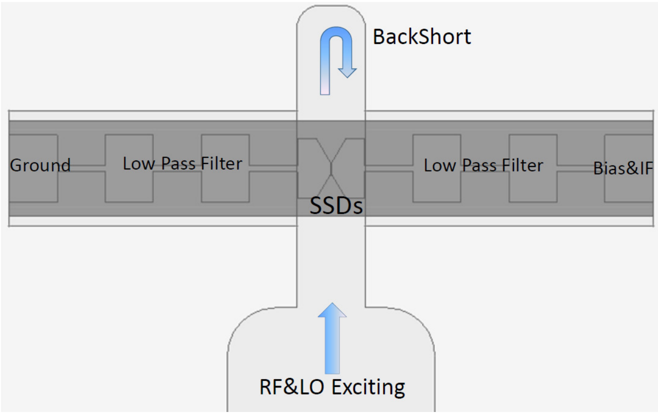

Figure 2.Configuration of mixertopology.

Passive networks around the diodes are simulated in HFSS to get the S-parameter matrices. These matrices were then utilized to determinate initialdimensions of each section using the linear simulator and nonlinear simulator in ADS step by step. Iteration is required to run between the linear and the nonlinear steps until the emergence of the acceptable performance. Finally, the values of each part from the nonlinear step are feedback to reconstruct the mixer in HFSS, then the SSDs models and the S-parameter matrices of the whole mixer circuit are combined to check the performance using the nonlinear harmonic balance simulator in ADS.

SIMULATION RESULTS

The design is designed with the procedure mentioned in the last section and is optimized for available input pump power in practice. lowerconversion lossis obtained as a consequenceof the wider bandwidth, for the mixer working at 300 GHz the relative bandwidth is higher than 12%. It is important toremark that the design owns the character with high port performance, as shown in Fig.3.

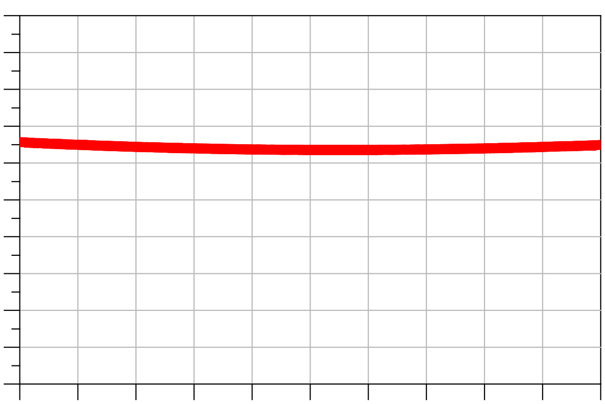

Figure3.Predicted conversion loss as a sub-harmonical mixer.

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