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Development Status of Millimeter Wave GaN Schottky Doublers above *W*-band for the Implementation of European Terahertz Sources for Astronomy and Astrophysics

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Abstract

In this report we present the effort to develop high power handling and efficiency GaN-based frequency doublers required to build a 1 THz local oscillator source for instrumentation in astronomy and astrophysics. The design study focuses on identifying the key aspect to reach performances with simplified architecture as compared to existing solutions. Predicted performances of GaN Schottky doublers are presented and discussed. A single section doubler produces an output power of 175 mW at 114 GHz for an input power of 1 W. The reverse bias voltage is tuned to maximize its performance but remains well below the breakdown voltage of the GaN Schottky diodes developed at IEMN (-75 V). Its performance can be enhanced further with thin epilayer and high mobility sample for the diode development and the state-of-the-art performance can be achieved by using power combining technique to reach the 300 mW goals.

1 Introduction

High-power solid-state sources are essential for radio astronomy, atmospheric studies, spectroscopy, high-data-rate communication systems at millimeter-wave and submillimeter-wave frequency. Schottky-diode based sources are a preferred choice because of the advantages such as compactness, low parasites, room temperature operation, etc. Power combined frequency doublers with output power >800 mW over the frequency range 100-200 GHz are reported in [1], by using GaAs diodes [2]. But, the input power of the devices is limited by the breakdown voltage of GaAs diodes. Recently, GaN Schottky diodes with reverse breakdown voltage of -75 V [3] are developed at IEMN, University of Lille. Hence, these diodes could be a superior alternative. In this contribution, the possibility of high-power generation by GaN Schottky doublers is explored.

2 1 THz Source Architecture

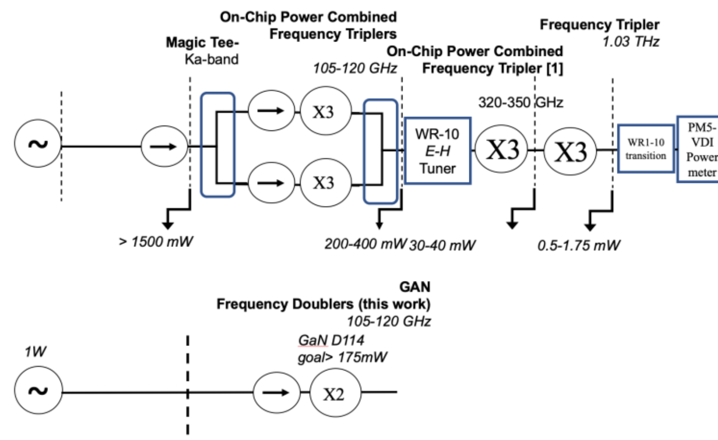


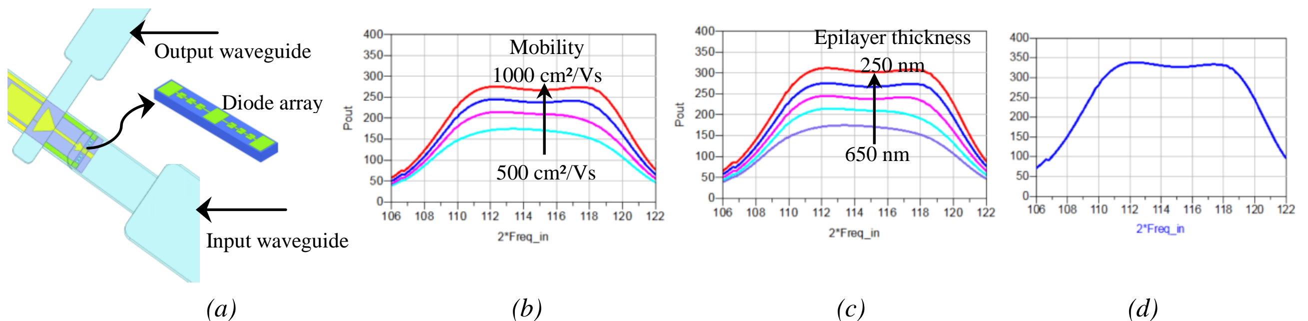
Figure 1 (a) Architecture of record performance at 1 THz in [4] and (b) simplification of the first stage source with 114 GHz GaN doubler

In [4], we previously demonstrated a 1 THz source architecture in order to reach a record of 1.75 mW at 1.02 THz. This source was developed and built at Jet Propulsion Laboratory, USA. The local oscillator (LO) source at 350 GHz consisted in a synthesized signal at 38 GHz amplified up to 1.5 W of power at Ka-band, fed into two separated branches each featuring one dual chip tripler [1] at 114 GHz based recombined to >300 mW at the 350 GHz input to generate a 350 GHz spectrally pure signal of > 35 mW as shown in Figure 1(a). In particular, the LO schematic was consolidated and secured with an *E-H* tuner to allow mismatch correction over frequency, and thermally secured to operate the 110 GHz at their maximum input power on its interfaces. The output power was recorded with an Erickson-VDI PM5 meter. A record power of with 1.75 mW at 1.02 THz was obtained.

In this work, we propose to develop GaN-based frequency doublers that could simplify this 1 THz architecture source by a factor 2 at 114 GHz frequency level, and reach an objective of 200 mW with a single chip feed with 1 W of input signal at 50 GHz or above. In the next paragraph, we demonstrate this development is being possible by novel design of a frequency doubler based on GaN technology.

3 The GaN Schottky Doubler and Its Performance

The proposed GaN Schottky diode array and the doubler configuration operating over 106-122 GHz is shown in Figure 2(a). The diode array consists of six anodes in balanced configuration and it will be mounted in flip-chip technology. An optimum number of anodes can be used based on the desired performance, structural complexity and width of the channel to cutoff the unwanted modes. The input and output waveguides of the present doubler are respectively, standard WR-15 and WR-12. The active epilayer profile having thickness 650 nm and doping concentration $5\times10^{16}/cm^3$ at n^--layer available at IEMN is considered for the design. The R_sC_{j0} product (where R_s is diode series resistance and C_{j0} is diode capacitance at zero bias) is dependent on mobility and epilayer thickness of the active layer design. Precisely, the product is proportional to the epilayer thickness of the active layer design for a given mobility [5]. Again, the diode cutoff frequency and consequently the highest frequency of operation is inversely proportional to the R_sC_{j0} product [6]. For an example, the predicted performances of the doubler are shown in Figure 2(b) and 2(c) with the variation of mobility and epilayer thicknesses, respectively. In each of the cases, the reverse bias voltage is tuned to maximize the output power while the voltage swing across the diode remains well below the diode breakdown voltage. It is to note from Figure 2(d) that an output power > 325 mW for an input power of 1 W is possible to achieve if the mobility of the epitaxial sample is 1000 cm^2/Vs and epilayer thickness is 250 nm.



(a) (b) (c) (d)

Figure 2. (a) Geometry of the GaN Schottky doubler, output power of the doubler in mW with variation in (b) mobility for epilayer thickness = 650 nm, (c) epilayer thickness for mobility = 500 cm²/Vs and (d) mobility = 1000 cm²/Vs, epilayer thickness = 250 nm. Input power = 1 W.

4 Conclusion

The predicted performances show that GaN Schottky doubler has the potential to deliver state-of-the-art output power by proper selection of the active layer thickness and mobility of the epitaxial sample. An output power of about 1W is achievable by combining four sections. This work demonstrates the feasibility of simple architecture sources for the deployment of European Terahertz sources. Moreover, GaN Schottky diodes for the operation over the frequency band of interest are under development at IEMN, University of Lille.

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