ALGAAS HBV PERFORMANCE IN FREQUENCY TRIPLING AT 255 GHZ

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ABSTRACT

This paper presents a novel method to investigate the efficiency of a tripler with a HBV diode based on $Al_{0.7}Ga_{0.3}As$/GaAs. The HBV diodes with different mesa diameters have been fabricated and their DC characteristics have been measured. These characteristics are used by a combined genetic algorithm/harmonic balance simulator to calculate the optimum impedances and output powers at the frequency of 255 GHz. A comparison of the conversion efficiencies are presented for the different structures.

INTRODUCTION

Heterostructure barrier varactor (HBV) diode is a suitable device for direct tripling since the C–V characteristic is evenly symmetric and I–V characteristic is anti–symmetric, so that only odd harmonics are generated. One of the applications where HBV diodes show a great potential is quasi–optical tripler arrays. These varactor devices require less design complexity compared to Schottky diode tripler circuits since no DC bias circuitry and no idler circuit at second harmonic is required [1,2,3].

DESIGN AND FABRICATION OF ALGAAS HBVs

The $Al_{0.7}Ga_{0.3}As$/GaAs HBV structure is grown with Molecular Beam Epitaxy (Fig. 1a) on SI GaAs substrate. The epitaxial growth is carried out at the substrate temperature of 580^{o} C after the thermal removal of the surface oxidized layer at 650^{o} C. A reduced growth rate of 350 nm/hr is used to grow the GaAs thin layers (3.5 nm) for perfect thickness control. The As4 beam equivalent pressure for the GaAs and AlGaAs growth is approximately $4x10^{-6}$ and $2x10^{-5}$ Torr, respectively.

The HBVs are fabricated using standard photolithography techniques for isolation and ohmic contact patterning, and wet chemical etching of mesa isolation. The Ni/AuGe/Ni ohmic contact is evaporated and annealed for 1 *min* at 480° C. The HBVs with diameters of 10, 20 and 40 u*m* are fabricated in the form of two columns with a total of four barriers, as shown in Fig. 1b. The measured I–V and C–V characteristics of the HBVs are shown in Fig. 2a and 2b respectively.

ANALYSIS OF NON-LINEAR CIRCUITS BASED ON THE GENETIC ALGORITHM

The optimal HBV performance in frequency tripling operation requires the determination of the proper embedding impedance and pump power level. These parameters are obtained by an optimisation procedure, based on a non–linear circuit simulator. The effectiveness of an automatic optimisation process highly depends on the reliability of the circuit simulator, which should always reach the solution without any human intervention.

Recently, we presented a new method for the analysis of non–linear circuit, which is based on a combined Genetic Algorithm/Harmonic Balanced technique [4]. This method combines the reliability of the evolutionary approach with the rapidity of the Harmonic Balance technique. At the same time, it avoids the slow convergence of the pure Genetic Algorithm and the device–dependency of many Harmonic Balance techniques.

ANALYSIS OF HBV TRIPLING PERFORMANCE

This section reports the performance analysis of two different HBVs, operated as frequency triplers at 255 *GHz*. The characteristics of the HBVs, fabricated at the University of Darmstadt, are listed in Table I. These two devices differ in the diameter of the pillar, and consequently in the related electrical characteristics.

The analyses of the HBVs are based on the non–linear circuit simulator presented in the previous section. The maximum conversion efficiency of the devices is calculated, with the pump power ranging from 1 to 30 *mW*. For each pump power level, the optimal embedding impedance Z_L is considered (see Fig. 3*a*).
Figs. 3*b*–3*c* report the maximum conversion efficiency and the output power at 255 *GHz* of the two HBVs versus the pump power level P_0 at 85 *GHz.* (Note that the open circuit voltage V_0, shown in Fig. 3*a*, can be easily found once the available pump power P_0 and the impedance Z_L are known).
It is observed that HBV#1 (*i.e.*, the smallest in diameter) exhibits the best conversion performance in the considered pump power range. Conversely, HBV#2 is not suitable for operation in frequency triplers with limited pump power level (P_0<30 mW).

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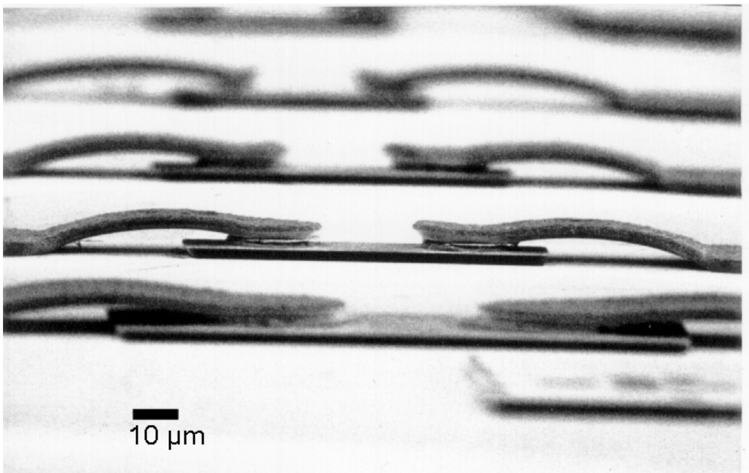
	Diameter [um]	Area [um^2]	Maximum capacitance [fF]
HBV#1	10	78.5	38
HBV#2	20	314.2	154

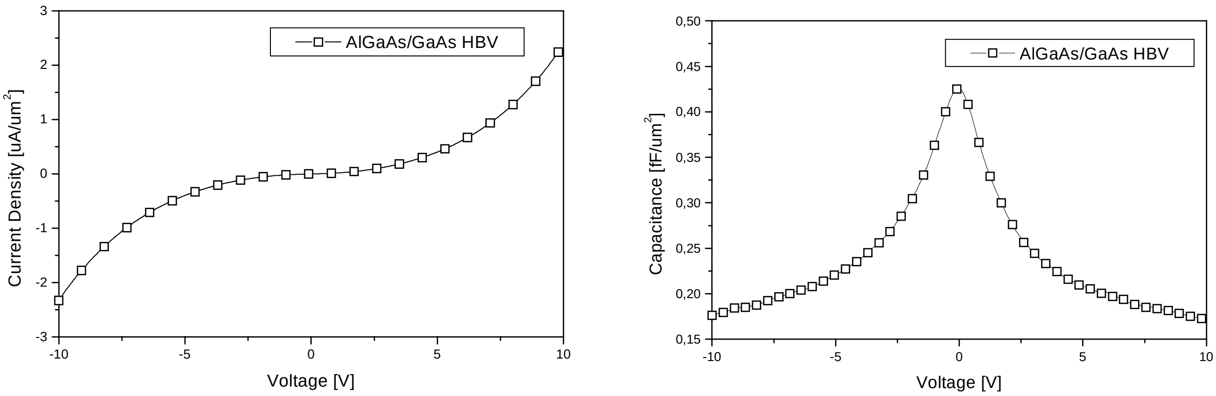
Table I: Geometrical and electrical characteristics of the fabricated HBVs.

Material	Thickness	Doping
GaAs	300 nm	$5x10^{18}$ cm^{-3}
GaAs	250 nm	$8x10^{16}$ cm^{-3}
GaAs	3.5 nm	Undoped
$Al_{0.7}Ga_{0.3}As$	20 nm	Undoped
GaAs	3.5 nm	Undoped
GaAs	500 nm	$8x10^{16}$ cm^{-3}
GaAs	3.5 nm	Undoped
$Al_{0.7}Ga_{0.3}As$	20 nm	Undoped
GaAs	3.5 nm	Undoped
GaAs	250 nm	$8x10^{16}$ cm^{-3}
GaAs	2000 nm	$5x10^{18}$ cm^{-3}
$Al_{0.7}Ga_{0.3}As$	500 nm	Undoped
GaAs	50 nm	Undoped
GaAs S.I Substrate		



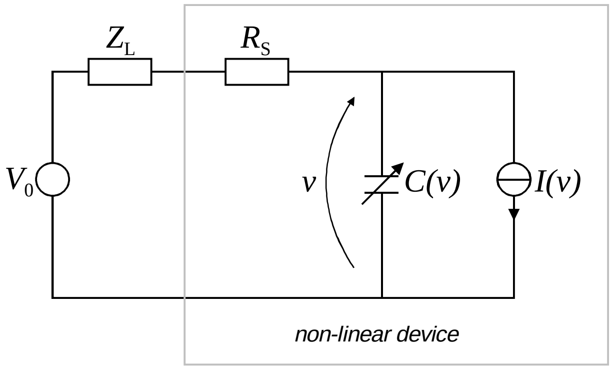
(*a*) (*b*)

Figure 1: (*a*) Epitaxial design of the MBE grown $Al_{0.7}Ga_{0.3}As$/GaAs HBV structure. (*b*) SEM picture of the two–column four–barrier $Al_{0.7}Ga_{0.3}As$/GaAs HBVs.

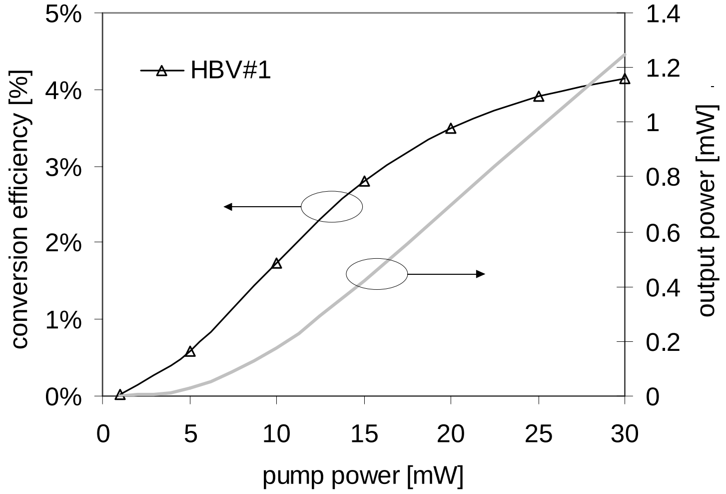


(*a*) (*b*)

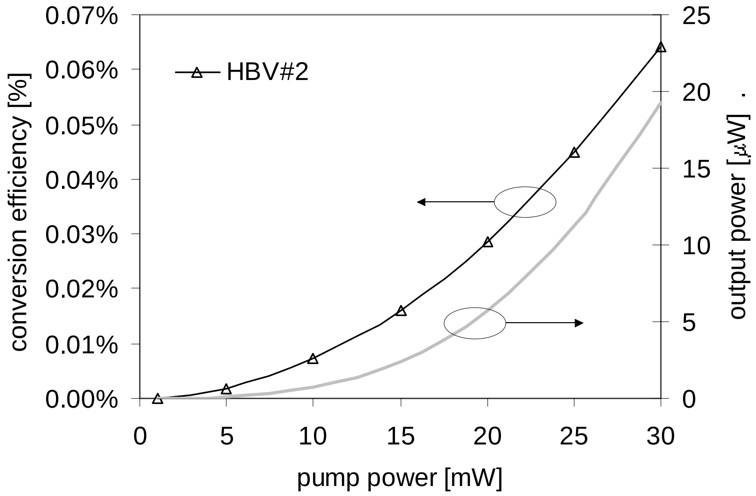
Figure 2: (*a*) Measured I–V characteristics of the $Al_{0.7}Ga_{0.3}As$/GaAs HBVs. (*b*) Measured C–V characteristics of the $Al_{0.7}Ga_{0.3}As$/GaAs HBVs.



(a)



(b)



(c)

Figure 3: (a) Equivalent circuit model of the frequency tripler. (b)–(c) Maximum conversion efficiency and output power at 255 *GHz* of the two HBVs versus the pump power level at the fundamental frequency 85 *GHz*.