CW generation up to 2 THz by ion-irradiated $In_{0.53}Ga_{0.47}As$ photomixer driven at 1.55 µm wavelengths

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***Abstract*—We report the generation of continuous terahertz waves from microwave frequencies up to 2 THz obtained by photomixing two optical waves at 1.55-µm wavelengths in an optimized ion-irradiated $In_{0.53}Ga_{0.47}As$ interdigitated photomixers. Output powers greater than 40 nW at 0.5 THz and 10 nW at 1 THz have been achieved. The optimum excitation conditions regarding optical power and bias voltage are discussed.**

I. Introduction

Photomixing in ultrafast photoconductive material is a useful technique for the generation of continuous high spectral purity terahertz (THz) radiation. The best performances are obtained with annealed low-temperature grown (LTG) GaAs[1] or ErAs:GaAs[2] materials excited by laser beams with short wavelengths ($\lambda \sim 0.8$ µm). The shift of the operating wavelengths toward the domain of telecommunication wavelengths would enable to take advantage of the compact and low cost optical amplifiers, of the wavelength-tunable laser diodes and of the superior fiber technology available at 1.55 µm wavelength. However, GaAs materials show an extremely weak absorption at fiber-optic wavelengths (1.06 µm, 1.3 µm, and 1.55 µm)[3] and thus, suitable ultrafast photoconductive materials are required for 1.55 µm wavelength[4].

II. Results

We have fabricated an ion-irradiated $In_{0.53}Ga_{0.47}As$ interdigitated photomixers[5]. The electron lifetime in the ion-irradiated $In_{0.53}Ga_{0.47}As$ layer is equal to 0.86 ps. A mesa etching process was used to define an $In_{0.53}Ga_{0.47}As$ absorbing area of 7×7 μm^2 on the InP substrate. The photomixer has a 200 nm thick silicon nitride coating, which operates as an antireflection and passivation layer, and simultaneously improves the reliability and heat tolerance of the device. The current-voltage characteristic is linear up to $V_a = 1.5$ V as expected for an Ohmic behavior of the photoconductive material. Above V_a, a quadratic voltage-dependence of the dc current is observed. This nonlinear behaviour can not be described by an increase of the carrier lifetime at high bias voltage since the electron lifetime deduced from time resolved differential transmission measurements remains constant from 0 V to 2.2 V. We attributed the deviation from Ohmic behavior by the mechanism of recombination-limited transport [6].

The terahertz measurements use two laser diodes operating near 1.55 µm, single-mode fiber-optic combiner, polarization controller and an erbium-doped amplifier. Two detection schemes were used according to the considered frequency range. For power measurements from 150 GHz to 2 THz, the continuous waves were focused with an f/50 paraboloidal mirror onto a liquid-He cooled 3 mm diameter Si bolometer. Absolute power measurements at lower frequency were obtained between 50 and 75 GHz with an electrical spectrum analyzer, using a horn antenna coupled harmonic mixer located just in front of the photomixer antenna and Si lens.

Figure 1 shows the bolometer output voltage (right) and the estimated power (left) as a function of the frequency difference between the two lasers. The spectrum was acquired by pumping the photomixer with 40 mW total optical power and with a bias voltage of 1.5 V. The output power reached a maximum of 45 nW at 0.43 THz. At 1 THz, the estimated power is 10 nW. At 2.5 THz, the power levels approach the sensitivity of the experimental set up.The absolute output power, detected by the harmonic mixer reaches 0.14 µW at 67 GHz, without any correction to account for the 100 GHz low-frequency cut-off of the spiral broadband antenna.

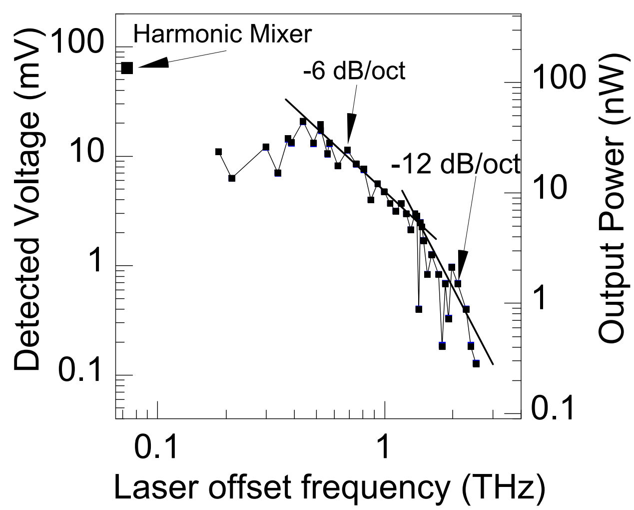

Figure 1 Output power of ion-irradiated-$In_{0.53}Ga_{0.47}As$ photomixers measured versus the frequency difference between the two lasers.

The roll-off of the detected power with a slope around 6 dB/octave is attributed to a limitation by the electron lifetime of 0.86 ps. At frequencies above 1.4 THz, the power drops monotonically at a rate close to 12 dB/ octave, which is consistent with a limitation by electron lifetime constant and by R_AC time constant, evaluated to 0.124 ps from antenna geometry.

As the dc component of the generated photocurrent limits

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the photomixer in ultimate performances, we have reported in Fig. 2, the detected power versus the dc photocurrent at 0.5 THz. Two distinct excitation conditions were applied: 1/ the applied bias voltage is 1.5 V in order to ensure an Ohmic behavior while the incident optical power is varied, 2/ the incident power remains constant at 20 mW while the applied voltage is changed.

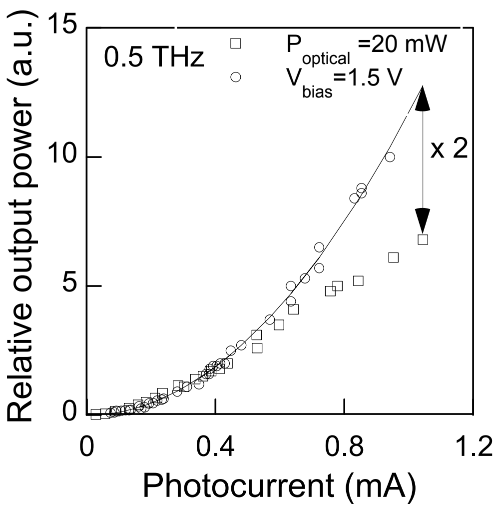

Figure 2 Terahertz powers as a function of dc photocurrent at 0.5 THz.

At low dc photocurrent, the two curves are identical and increase quadratically with the photocurrent. However, at I_{ph}~0.52 mA the output detected power start to saturate when the applied voltage is increased as a results of the transition to a recombination-limited transport regime, whereas the detected power continues to increase when the incident optical power is increased. The optimum operation condition is a bias voltage just before the onset of the recombination-limited transport regime associated with a high incident optical power.

In conclusion, a room temperature THz source has been produced using the 1.55 µm technology with heavy ion-irradiated In0.53Ga0.47As photomixers. With an output power of 10 nW at 1 THz, these photomixers have significant practical and scientific applications.

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