Theoretical analyses and numerical simulation about photomixing process in InGaAs with antenna structure for CW terahertz generation

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***Abstract*—A new THz photomixer based on InGaAs and integrated with antenna structure is proposed. The photomixing process for terahertz generation has been discussed and simulated. The proposed scheme works at 1550nm wavelength range. Thus many commercial devices for optical fiber communication system can be used to design the experimental scheme. Furthermore, as there is no additional antenna element, it is very helpful to solve the serious impedance mismatch question.**

I. INTRODUCTION

PHOTOMIXING is a promising continuous-wave terahertz source as potentially compact, easy-integration, low power consuming, low-cost, room temperature working, and the frequency of the generated terahertz signal can be easily tuned by tuning the central frequency of the pump laser. So this technology has been extensively studied. The most mature developed photomixer usually applies two linearly polarized laser beams with a central wavelength around 800 nm and a difference in their central frequency falling in the terahertz spectrum to pump the annealed low-temperature-grown (LTG) GaAs film to generate a photocurrent signal modulated at THz frequency. Then, this signal is guided to a certain antenna structure to radiate THz wave. This traditional photomixer works as a current source loaded by the additional antenna configuration under a highly mismatched condition, as a result, the THz output power is quite low[1]. D. Saeedkia recently proposed a novel photomixing structure which is integrated with antenna element. As the additional antenna structure is omitted, this design is very helpful to solve the serious impedance mismatch question[2]. Furthermore, in order to take advantage of the compact and low cost optical amplifiers, of the wavelength-tunable laser diodes and of the superior fiber technology, efforts are currently made to shift the central wavelength of the pump lasers to 1550 nm by using other material instead of LTG-GaAs. Recently, J. Mangeney has proved that the heavy-ion-irradiated InGaAs is a good alternative material[3].

In this paper, a new THz photomixer which can be operated at 1550 nm and integrated with antenna structure is proposed for the first time. As shown in Fig. 1, two linearly polarized laser beams, with a central wavelength around 1550 nm and a small difference in their central frequencies falling in the terahertz spectrum, impinge the undoped 2-μm-thick n-type InGaAs film in the *x*-*z* plane, which is bombarded by heavy ions such as Br+ or Au+ of high initial energy after grown on semi-insulating InP substrates. Upon the two lasers excitation a spatiotemporal photocurrent grating forms inside the InGaAs film. Through reasonable design of the InGaAs film area and the thickness of substrate materials, the photomixing region can be regarded as a microstrip antenna structure, so the THz signal is directly emitted from this area.

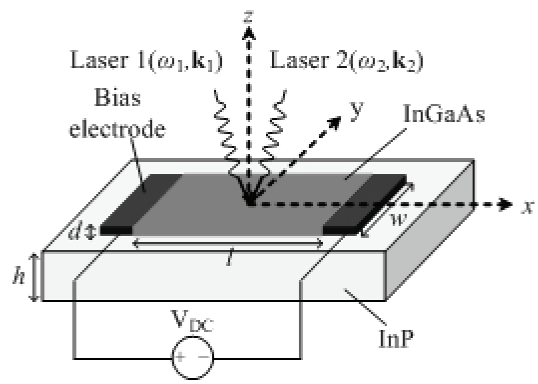

Fig. 1. Schematic of a THz photomixer working at 1550 nm integrated with antenna structure.

This novel THz photomixer proposed in this paper has the following promising characteristics: the operating wavelengths are shifted to 1550 nm, so it is enabled to take the advantage of more mature technology in optical communication system. Furthermore, as there is no additional antenna element, it is very helpful to solve the serious impedance mismatch question in the traditional photomixer, and the structure of the photomixer becomes more simply.

II. ANALYSIS AND DISCUSSION

The photocurrent inside the InGaAs film described above can be found by solving the continuity equations for the electron densities under certain appropriate conditions[4]. The THz radiation power from the photomixing region can be calculated by the CAD models for radiation from microstrip antenna described in Ref. 5.

The power and frequency of the output terahertz wave are the functions of the applied bias, physical parameters of the InGaAs material such as the lifetime and the drift velocity of the carrier, parameter of the pump lasers and the size of the photomixing area and the thickness of substrate. Theoretical analysis and numerical simulation results showed that: for maximum THz power output, the best value for the

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photomixing region length l is

$$l = \frac{\pi}{(k_1 + k_2)\sin(\theta / 2)} \qquad (1)$$

where k_1 and k_2 are the lasers phase constant vectors along the x axis, θ is angel of the two beams. The resonant frequency of the microstrip antenna is related to the thickness of the substrate determines by[4]

$$h = \frac{c}{2f\sqrt{\varepsilon_r - 1}} \qquad (2)$$

where ε_r is the relative permittivity of the substrate materials, for InP, $\varepsilon_r = 12.1$. f is the beat frequency of the two lasers, which is equal to the frequency of the output THz wave. This makes the proposed device to be a very narrow band THz radiator. Using the formula (1) and (2), for $\theta = 3^\circ$ and $f = 1$ THz, we can calculate that the optimum values of the length of the photomixing and the thickness of the substrate are $l = 14.8$ μm and $h = 22.5$ μm, respectively.

For simulation purpose, the THz radiation power versus the beat frequency for three different InGaAs samples introduced by N. Chimot et al. is shown in Fig. 2. The average power of the two lasers is 0.45 mW/μm^2. The applied bias voltage is 1.5 V. The carrier lifetime and drift velocity of the three InGaAs samples from (a) to (c) are 0.9 ps / 1360 cm^{2}V^{-1}S^{-1}, and 1.7 ps / 4300 cm^{2}V^{-1}S^{-1}, and 0.27 ps / 200 cm^{2}V^{-1}S^{-1}, respectively[5-6]. As it can be seen from Fig. 2 the maximum THz radiation power occurs at the designed frequency, and a number of peak power points occur at the odd-multiple of the designed frequency.

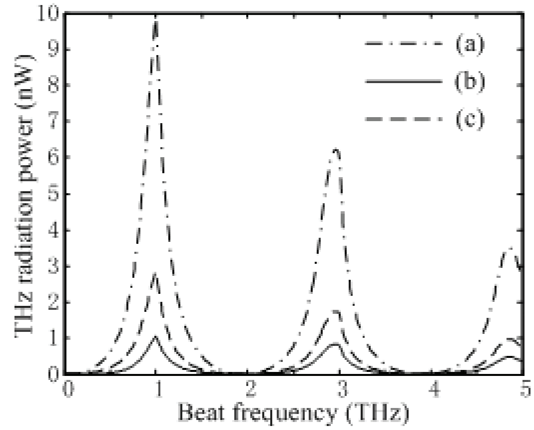

Fig. 2. THz radiation power of heavy-ion-irradiated InGaAs based photomixer designed for 1 THz beat frequency and operated at 1550 nm.

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