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THz emission from Be-doped GaAs

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Abstract

Directing ultrashort near-infrared laser pulses between two electrodes on the surface of GaAs:Be may produce THz radiation. We have measured the generated THz signal as a function of the applied bias voltage, the optical excitation energy, and the beam size, for a series of samples of differing doping levels. The variation in THz signal with bias is approximately quadratic, as expected. In contrast, the variation of THz signal with optical excitation power is subquadratic. As determined by apertureless z-scans, the THz emission depends strongly on the excitation beam diameter. As the Be concentration is varied, the THz emission varies slightly until the Mott limit is exceeded and the material becomes metallic and THz production ceases.

Keywords

be-doped, thz, emission, gaas

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THz emission from Be-doped GaAs

S. Hargreaves and R. A. Lewis

***Abstract*—Directing ultrashort near-infrared laser pulses between two electrodes on the surface of GaAs:Be may produce THz radiation. We have measured the generated THz signal as a function of the applied bias voltage, the optical excitation energy, and the beam size, for a series of samples of differing doping levels. The variation in THz signal with bias is approximately quadratic, as expected. In contrast, the variation of THz signal with optical excitation power is sub-quadratic. As determined by apertureless z-scans, the THz emission depends strongly on the excitation beam diameter. As the Be concentration is varied, the THz emission varies slightly until the Mott limit is exceeded and the material becomes metallic and THz production ceases.**

***Index Terms*—GaAs, GaAs:Be, p-GaAs, THz**

I. INTRODUCTION

Generating coherent THz radiation by directing ultrashort laser pulses onto a suitable target has gained much attention in recent years. One important class of targets is photoconductors, furnished with various electrode structures; other classes include electro-optic materials and surface emitters. A commonly-used photoconductive emitter material is low-temperature-grown GaAs (LTG-GaAs). To understand more fully THz generation in GaAs, we have conducted experiments using Be (acceptor) doped GaAs, GaAs:Be, as the photoconductive emitter material.

Beryllium is the common p-type dopant in GaAs and GaAs:Be has been the subject of many optical studies. THz absorption spectroscopy has been used to determine the energy levels of the impurity states [1]. Further information on the impurity states has been gained by using the techniques of visible photoluminescence (PL) and THz photo-thermal ionization spectroscopy (PTIS) [2]. Magnetospectroscopy of the Be impurity in GaAs [3] has been reported to intermediate [4] and to high magnetic fields [5, 6], and the *g* factors determined and compared with theoretical estimations. The effect of intense THz radiation, provided by a free-electron laser, on the GaAs:Be impurity spectrum has been investigated [7]. The properties of LTG-GaAs:Be have been studied using photoconductive sampling and the electron and hole mobilities so determined [8].

GaAs:Be has also been investigated as a candidate THz emitter. The carrier dynamics of LT-GaAs:Be have been investigated. The contribution of free holes is seen to extend the lifetime to hundreds of picoseconds [9, 10]. The application of a LTG-GaAs:Be layer has been found to enhance THz emission relative to emitters without a layer or with only an undoped LTG-GaAs layer [11]. Very recently, the THz emission from strained GaAsN:Be layers has been reported; low temperatures and intense electric fields are employed [12].

II. EXPERIMENTAL DETAILS

The samples used in this investigation were grown by molecular beam epitaxy. Sample details are provided in Table I.

Optical excitation was via 12-fs pulses of 790 nm centre frequency and 80 MHz repetition rate from a FemtoSource Ti-sapphire laser. Electrical contacts were furnished by (a) evaporation of Au alloy, (b) sputtering of Au, and (c) painting with Ag paste. The sputtered Au contacts have not proved effective in generating THz radiation; this approach is under further investigation. The painted Ag contacts are very simple to produce and prove very successful. The excitation beam was chopped at 11.3 Hz for detection with a lock-in amplifier. Sufficient THz was generated to be detected by a Golay room-temperature detector, without recourse to helium-cooled Si or Ge bolometers.

III. RESULTS AND DISCUSSION

In addition to the coherent THz signal, two incoherent sources may be observed at the 11.3 Hz chopping frequency. These are (a) modulated joule heating by the photocurrent and (b) laser heating by the excitation beam.

TABLE I
GAAS(BE) SAMPLES

Sample	Thickness [μm]	Concentration [atoms cm^{-3}]	Areal Density [atoms cm^{-2}]	THz?
NU651	4	1.50×10^{15}	6.00×10^{11}	yes
NU1444	2	1.00×10^{16}	2.00×10^{12}	yes
NU652	3	2.30×10^{16}	6.90×10^{12}	yes
NU1442	1.5	1.00×10^{17}	1.50×10^{13}	yes
NU1445	1	2.00×10^{18}	2.00×10^{14}	no
NU650	1.5	3.60×10^{18}	5.40×10^{14}	no

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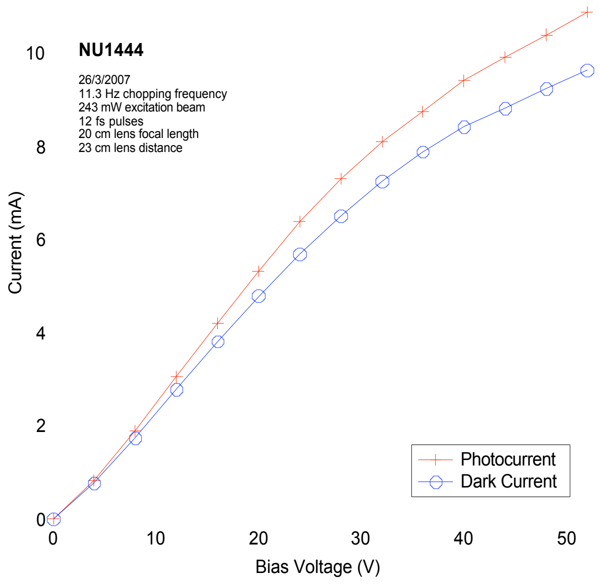

Fig. 1. Photocurrent and dark current for the NU1444 sample. At a bias voltage of 52 V, the average joule heating is approximately 0.5 W.

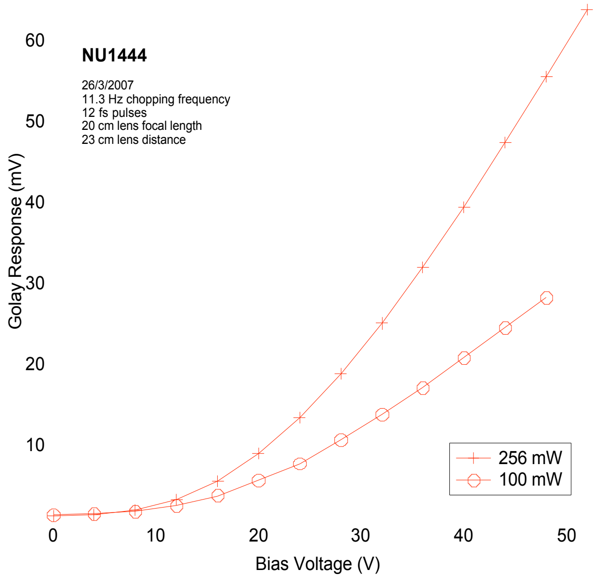

Fig. 2. Golay response for the NU1444 sample. The incoherent THz signal detected is below 1 mV.

To isolate the incoherent sources, the excitation beam was operated in continuous-wave (CW) mode; the resulting Golay signal was insignificant compared to the signal detected in the mode-locked (ML) configuration. We conclude that the proportion of THz emission observed due to these two sources is insignificant, as is the noise contribution from joule heating by the DC bias current.

Due to excessive joule heating, the more heavily-doped samples (NU650 and NU1445) did not allow high bias voltages and did not yield a usable THz signal, whereas a coherent THz signal was easily observed for all the other samples.

IV. CONCLUSION

The importance of the work is that it illustrates that the generation of THz from GaAs:Be depends, among other factors, on the doping level, and that tuning of this may lead to more efficient emitters of THz radiation. The work reported here has not distinguished the different frequencies produced. An immediate extension is to determine the spectrum, for example, by time-domain spectroscopy (TDS).

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