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THz generation by photo-mixing of chirped pulses at 1 μm

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The presentation will focus on THz generation by photo-mixing of chirped optical pulses on a GaBiAs dipole photo-conductive antenna. We demonstrate the emission of long THz pulses with either a narrow or a broad band depending on the relative sign of the chirp.

Keywords: Photo-conductive antennas, Terahertz generation, Photo-mixing.

I. INTRODUCTION

The terahertz (THz) domain, located between microwaves and infrared (from 0.1 to 10 THz), is a frequency band offering multiple applications, particularly in non-destructive imaging and telecommunications. [1]. A common method to generate waves in these frequencies is to use photo-conductive antennas to convert ultra-short pulses in the infrared to the THz range. The spectrum and temporal shape of the THz waves emitted by the antennas are imposed by the characteristics of the emitter as well as by the duration and shape of the exciting optical pulse. Inspired by the THz generation in continuous wave regime [2-4]. An interesting approach is to excite the emitter by photo-mixing chirped long pulses in order to target a frequency spectrum with a narrow-band [5,6]. Here we present additional investigations with 1 μm femtosecond pulses to highlight the possibility to employ the chirped pulse photo-mixing for the generation of a long THz pulse with either a narrow or a broad-band depending on the relative sign of the chirp.

II. PRINCIPLE AND EXPERIMENTAL SETUP

The photo-mixing process usually consists of exciting the antenna with two continuous waves with a beating frequency lying in the THz range. This beat note can also be created from overlapping two optical chirped pulses with a broad optical bandwidth. By chirping the pulse, a quasi-linear distribution of the optical frequency as the function of time is created. Thus, the temporal overlap between two delayed chirped pulses can provide an instantaneous beating frequency in the THz. To generate a narrowband THz pulse, the beating needs to be maintained at a constant frequency over time (inset of Figure 2.a.). This frequency is set within a Michelson interferometer, which divides the stretched pulse in two pulses with a tunable relative delay.

In this work, the chirp is created by reflecting the optical pulse in a Volume Bragg Gratings (VBG) introducing a linear rate of ~ 6.2 ps/nm centered at 1030 nm, which stretches the pulse from a duration of 70 fs to 110 ps. After passing through the Michelson interferometer, the two resultant pulses excite a GaBiAs photo-conductive antenna. By applying a bias voltage to accelerate the excited carriers, a transient current is created, leading to the emission of a THz wave. The detection is achieved by a standard sampling method with a second GaBiAs photo-conductive antenna.

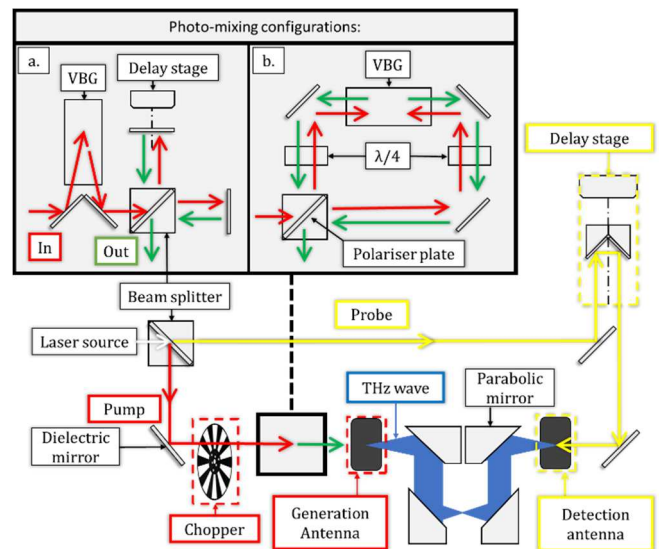


Figure 1: Experimental set-up. Top left configurations are parts of the setup placed in the path of the pump to implement the photo-mixing process with two chirped pulses with either the same (case a) or opposite (case b) rate.

Without these configurations, the setup generates short THz pulses.

III. CONFIGURATIONS AND RESULTS

III.a. THz emission from two identical chirped pulses

In the initial experiment, the optical pulse passes through one side of the VBG before being split within the Michelson interferometer (Figure 1.a.). The photo-mixing is therefore composed of two delayed pulses with the same chirp. It results in a constant beat frequency set by the interferometer's delay. Figure 2.a shows a THz temporal trace emitted when the beating is set at 0.5 THz. The pulse duration is 110 ps and

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is consistent with the duration of the optical chirped pulses. For comparison, the THz pulse excited with the ultra-short pulse has a duration of 0.8 ps between the maximum and the minimum. The corresponding spectrum, depicted in Figure 2.b (blue line) is narrower compared to the spectrum of a THz pulse emitted via the antenna excitation with a single ultra-short pulse (red line). When the relative delay is scanned, the THz spectrum can be tuned up to more than 1.5 THz as seen in Figure. 2.b (dotted lines). The intensity of the main frequency follows the shape of the short-pulse spectrum, meaning that the limitation in frequency tunability is determined by the antenna's response. Complementary works are under progress to confirm clearly the origin of the secondary weaker peaks spaced by approximately 150 GHz around the main frequency peak.

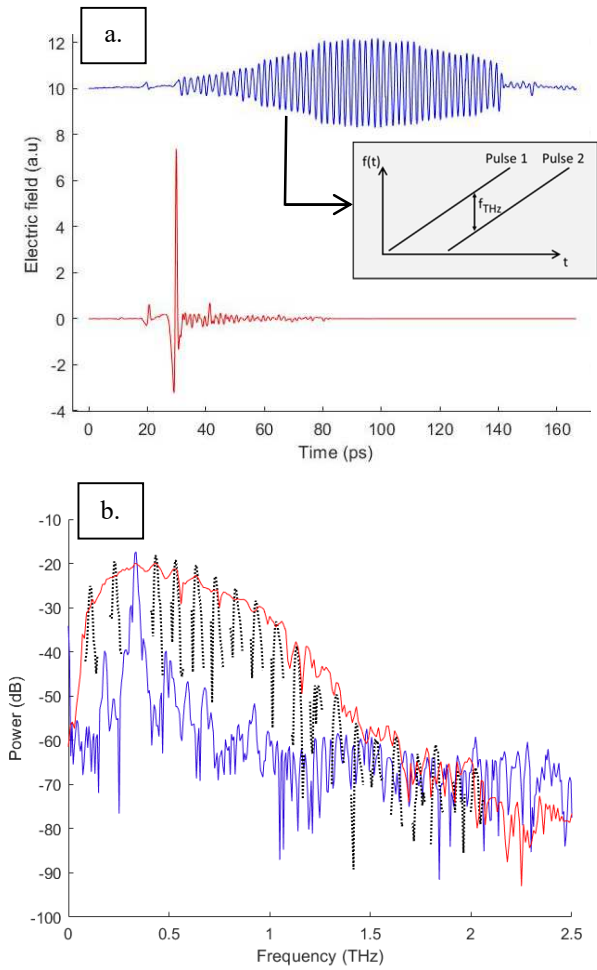


Figure 2: a) THz pulse emitted and detected with GaAsBi antennas excited by: (red) a pulse with a duration of 70 fs. (blue) delayed chirped pulses of 110 ps. The beating frequency is set at 0.5 THz. The inset illustrates the photo-mixing process between two chirped pulses, resulting in a beating f_{THz} b) Corresponding spectra for an excitation with the ultra-short pulse (red line) and the delay chirped pulses (blue line). The black dotted lines show the tunability when the delay between the two pulses is varied.

III.b. THz emission from pulses with opposite chirps

In this configuration (Figure 1.b), the pulse is initially split in two arms and each pulse is reflected from the different side of the VBG. Therefore, the two pulses are chirped to the same duration of 110 ps but owns opposite chirp.

Consequently, the beat frequency evolves linearly over time within the optical bandwidth (inset of Figure 3). From the photo-mixing on the antenna, it leads to the generation of a long THz pulse with a broad bandwidth (Figure 3). Its spectrum goes from a few GHz to 1 THz which limits the duration to approximately 21 ps due to the linear rate introduced by the VBG. Figure 3.b. was computed by sliding a 1.8 ps long temporal gate in the THz pulse. From this spectrogram, the evolution of the THz frequency as function of time is clearly observed as expected from the optical beatnote.

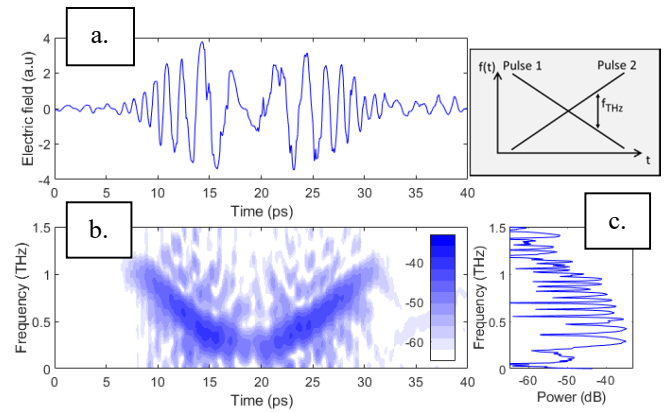


Figure 3: a) Time domain of a broadband long THz pulse. b) Spectrogram of the pulse displaying the distribution in time of the frequencies. c) Spectra of the broadband long THz pulse (blue). The inset illustrates the photo-mixing process between the two optical pulses with an opposite chirp.

IV. CONCLUSION

Emission of long pulses with narrow or broad band spectrum have been demonstrated using the photo-mixing process. Results could be improved using optimised antennas for the photo-mixing process. However, this first experiment presents the possibility of shaping THz pulses by modifying the optical excitation on the antenna. These parametrizable THz pulses could open up better analysis techniques of imagery and spectroscopy experiments.

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