Real Time THz Imaging Based on Frequency Upconversion

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***Abstract*—We demonstrate video rate-terahertz imaging based on upconversion of THz pulses to the infrared. Mixing of narrow bandwidth THz pulses (centered at 1.5 THz) with strong IR pulses at 1064 nm generates sidebands separated from the IR spectrum by the THz frequency. Removal of the strong IR background enables high speed detection of the upconverted signal with a CMOS camera. Real time imaging of concealed objects is demonstrated with this system.**

I. INTRODUCTION

Imaging with radiation in the THz region of the electromagnetic spectrum (0.1 – 10 THz) is of particular interest for applications in biomedical imaging, security, and non-destructive evaluation of materials. The usefulness is limited by the lack of high power sources and sensitive detectors. The development of THz imaging systems with the capability to rapidly image objects has the potential to greatly expand the commercial and research applications of THz imaging.

II. RESULTS

We have developed an imaging system capable of obtaining video rate THz images with a CMOS camera as a detector. The system uses a novel THz source [1], based on intracavity difference frequency generation in quasi-phase matched gallium arsenide (QPM-GaAs). A fiber laser (1064nm, 8 ps pulses) is used to pump a double resonant optical parametric oscillator. The signal and idler pulses are tuned such that the wavelength separation matches the THz frequency for highest efficiency THz generation. Pulses centered at 1.5 THz with <100 GHz bandwidth and an average power of > 1 mW are produced by the source. The high peak power of the pulses provide high efficiency for the upconversion process, while the narrow bandwidth allows spectral separation of upconverted signal from pump pulses (Fig. 1).

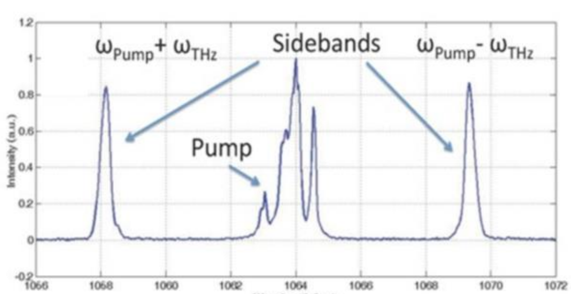

Fig. 1. Spectrum of upconverted THz pulses. The pump beam at 1064 nm mixes with pulses at 1.5 THz to produce sidebands at 1070 nm and 1058 nm. A narrowband notch filter is used to attenuate the pump in this figure. For imaging a long pass filter was used that eliminates nearly all pump light, leaving only the upconverted signal at 1070 nm.

The imaging geometry used is similar to the Fourier imaging geometry used for infrared upconversion experiments [2]. An object is placed in the collimated THz beam one focal length away from a lens. The lens forms the spatial Fourier transform of the object on a QPM-GaAs crystal placed one focal length behind the lens. For the upconversion, a portion of the fiber pump laser is incident on the crystal, where side bands at 1058 nm and 1070 nm are generated. A large diameter pump beam is necessary to upconvert the higher spatial frequencies in the image, which lie further from the beam axis. After using a polarizer and long pass filter to remove the pump beam, an image is formed on a CMOS camera with a second lens.

Figure 2 shows the results of an image taken of a razorblade and washer inside of a closed plastic case (Fig 2a). The images were normalized by dividing by a reference image of the THz beam without any object in place – other than that no image processing was used. Figure 2b is the normalized beam profile with no object. As the plastic case is moved through the THz beam (Fig 2c-e), images were obtained a frame rate of 8 fps. The THz beam passes through the plastic case, clearly showing the razor and washer concealed inside.

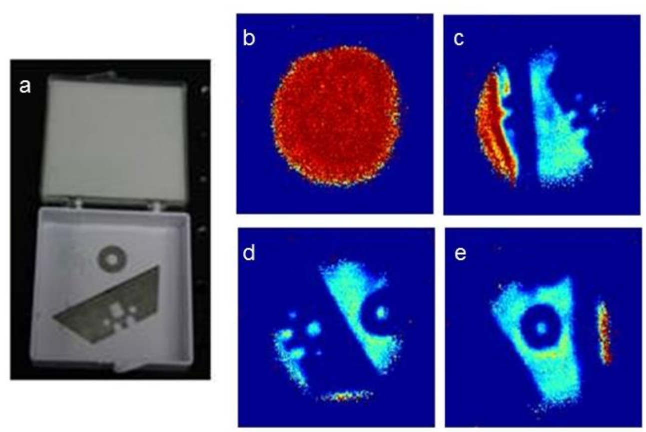

Fig. 2. Digital photograph of the object (a) used for THz imaging. Frames from a video taken at 8 fps as the object is translated through the THz beam (b-e). The normailized beam profile without object is shown in 1b.

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