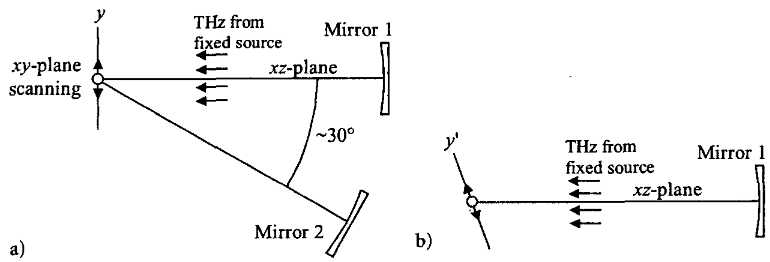
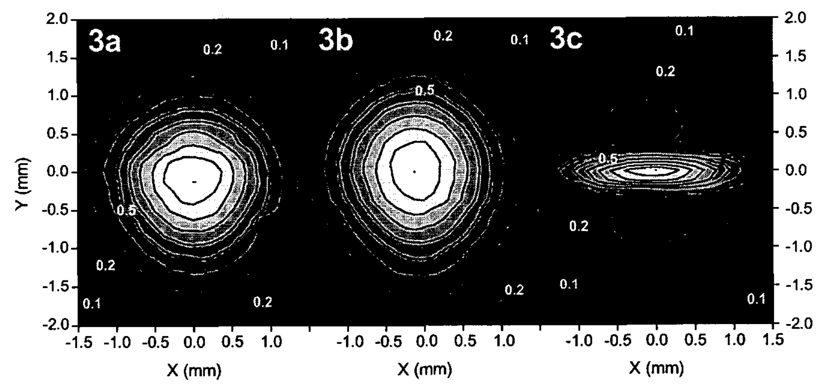


CFD2 Fig. 2. Shown in Fig. 2a is the physical manifestation of a 2-element, optical phased array with mirror separation equal to ~30°. In this 2-mirror system, the object scans in the *xy*-plane which is normal to the optic axis of mirror 1. However, this plane of motion is tilted ~30° off normal to the optic axis of mirror 2. Fig. 2b shows how mirror 1 is used to generate the image that mirror 2 would generate if it were actually implemented.



CFD2 Fig. 3. Single mirror images of the 1 mm ball at 0° and 15° orientations are shown in Fig. 3a and Fig. 3b. Fig. 3c is their direct superposition and shows the enhanced vertical resolution. All plots are normalized to unity and contour lines represent steps of 0.1.

to form the second image, mirror 1 was re-used. This was possible by leaving mirror 1 fixed but giving it the viewpoint of mirror 2. Figure 2b shows how mirror 1 can be given this viewpoint by tilting the scanning plane. Scanning the object in the *xy'*-plane (the tilted configuration) made it possible to obtain the same image mirror 2 would generate without ever physically implementing it. That is, by simply tilting the scanning plane about the *x*-axis, mirror 1 behaved as mirror 2.

One important point for our experiment is that the second mirror appeared to be located ~30° below the first, even though the scanning plane was only rotated 15°. This subtle point is a consequence of both configurations having the same fixed THz illumination source. The tilted configuration introduces phase changes as the object moves closer to and farther from the source (in the +*z* and –*z* directions respectively), when scanned along the *y'*-axis. If the object was self-luminous, this would not be a factor and the second mirror would appear to be located 15° below the first, as one would expect. Fortunately, the 30° apparent separation is actually beneficial because it creates a larger synthetic aperture thus improving resolution over the 15° case. Figure 3c shows the superposition of both images and the ~4× increase in resolution in the vertical dimension, where resolution is defined by the full-width-half-max measurement of the image. The horizontal dimension does not show any increase in resolution. These observations are in good agreement with theory and show the potential of high-resolution, phased-array THz imaging.

Reference

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CFD3 **8:30 am**

Towards an Apertureless Electro-optic T-ray Microscope

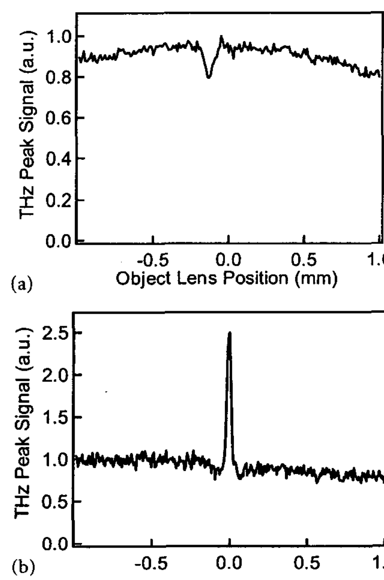
Tao Yuan,[1] Samuel Mickan,[1,2] JinZhou Xu,[1] Derek Abbott,[2] and X.-C Zhang,[1] [1]Department of Physics, Applied Physics and Astronomy, Rensselaer Polytechnic Institute, Troy, NY 12180, USA; [2]Centre for Biomedical Engineering and Department of Electrocal & Elctronic Engineering, Adelaide University, SA 5005, Australia; Email: Zhangxc@rpi.edu

Using the sub-wavelength aperture near field method, the resolution of THz image has been improved to much less than the wavelength or even to 7-μm[1,2] in last several years. However the transmitted power of this method is very low, and the detection antenna has to be very close to the aperture.[3] We demonstrate another kind of near field method: ultrafast laser is focused to a very small spot so that THz waves only generate in this region. The idea spatial resolution is close to the focus spot size.

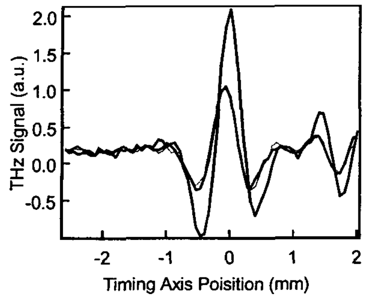
The laser system is the Coherent Mira Laser with Pulse width ~100 fs and repetition rate of 76 MHz. We use objective lens to focus the pump beam on the EO crystal. The THz wave is measured using EO detection and a balanced detector.

First we measure the focus spot size of the laser in a 250 μm thick ZnTe crystal. For laser wavelength of 0.8 μm, the predicted spot diameter for a Gaussian beam is 2.55 μm/NA = 0.4 and 1.57 μm/NA = 0.65, which are very close to our measured values of 2.5 ~ 3 μm/NA = 0.4 and ~1.7 μm/NA = 0.65. The laser can be focused down to a spot size of 1.7 μm even after it in a several hundred μm thick media plate of high refractive index (ZnTe ~2.9). The proceeding data was obtained using a 20×/0.4 objective lens.

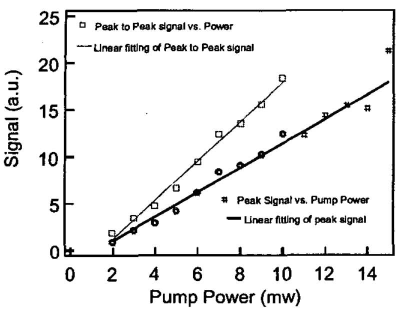
THz wave is generate in the whole beam region in the crystal, the spatial resolution is thereby restricted.[4] This problem is alleviated by using a very thin crystal to generate the THz wave. The generation of THz wave by thin crystal shows very different phenomenon at the focus point compared to a thick crystal. Figure 1 shows the THz peak signal of a 250 μm-thick ZnTe and a 16 μm-thick ZnTe crystal vs. the focus lens position. The pump power is 10 mw (after AO Chopper) for both cases. For the thick crystal the THz signal is reduced when the focus spot is in the crystal while for the thin crystal the opposite effect is seen and we see a strong peak of THz signal in the focus region. Figure 2 shows the THz waveforms of 10 mw-pump power at focus point



CFD3 Fig. 1. Peak THz signal of thick and thin ZnTe crystal pass through the focus region. (a) THz Peak Signal (a.u.) of a 250 μm ZnTe vs. Object Lens (20×/0.4) Position. (b) THz Peak Signal (a.u.) of a 16 μm ZnTe vs. Object Lens (20×/0.4) Position.



CFD3 Fig. 2. THz wave timing of 16 μm ZnTe under Power at focus and ±60 μm from focus.



CFD3 Fig. 3. THz signal at focus point vs. pump.

and ±60 μm from the focus point for the thin ZnTe crystals. A phase shift is visible between the waveforms corresponding to focused and unfocused point.

To investigate the linearity of this unexpected peak we measured the THz signal (peak and peak to peak) for different pump power. Figure 3 shows the THz signal at focus point vs. different pump power. Below the range of 15 mw, the THz signal seems to be linearly dependent to the pump power.

The thin crystal is much more fragile than thick crystal under focused ultrafast laser. We found that a 16-μm crystal can only hold on for less than half a minute before it is destroyed when the pump power is over 10 mw. For the laser that we use this 10 mw threshold power give a threshold intensity of 50 GW/cm^2.

Those experiments are crucial to the future studies of THz microscope.

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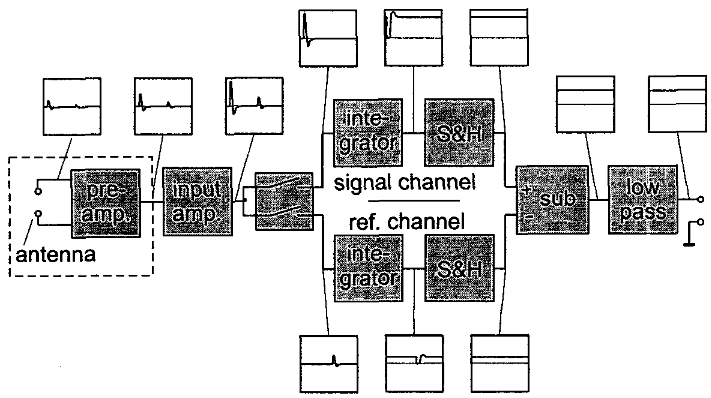
CFD4 **8:45 am**

Alternate Pulse Locked Gated Integrator (APOGI) Amplifier for Reading out THz Signals from Arrays of Photoconductive Antennas

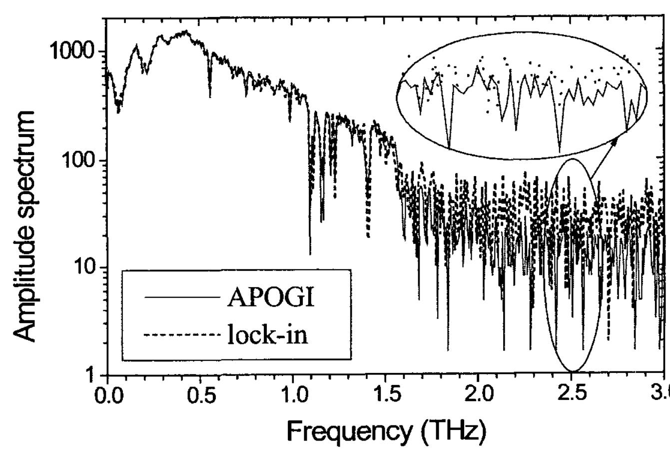
M. Herrmann, M. Tani, M. Watanabe, K. Sakai, Communications Research Laboratory, Kansai Advanced Research Center, Ozawa 588-2, Nishi-ku, Kobe 651-2492, Japan, Email: herrmann@crl.go.jp

Photoconductive antennas[1] have been standard devices for detecting pulsed electromagnetic radiation in the terahertz (THz) frequency range. When it comes to imaging with THz waves,[2–4] however, the competing method of free-space electro-optic sampling[5] has a very significant speed advantage because it can use commercial CCD cameras for recording many data points at virtually the same time, while recording THz images with photoconductive antennas relies on time-consuming mechanical lateral scanning. In order to speed up this scanning process, we aim at THz imaging with one- and two- dimensional arrays of photoconductive antennas. As with a CCD camera, many data points could then be taken at the same time (as many as antennas in the array), but a data storage would also be needed for every antenna. Conventional antenna read-out electronics are usually based on lock-in amplifiers and are bulky and relatively expensive equipment, not suitable for detection in arrays. In this paper we present a simple, small and inexpensive read-out circuit that can be used in large numbers and is convenient for reading out signals from arrays of photoconductive antennas.

Our THz system is based on an amplified femtosecond laser with 1 kHz repetition rate. THz radiation is generated from the laser pulses with a ZnTe(110) crystal. The THz pulses are recorded with a photoconductive antenna. The pump laser beam is chopped at a frequency of 500 Hz locked to the laser trigger sync output, so that the antenna signal consists of a series of alternating signal and reference pulses with an electric charge of approximately 0.1 pC. These pulses are amplified with a pre-amplifier situated close to the antenna (5 cm) in order to avoid picking up noise in sensitive input lines. Signal and reference pulses are then fed into two separate integrating channels (Fig. 1) which are connected to the input only



CFD4 Fig. 1. Block diagram of the APOGI circuit. Signal and reference pulses are fed into separate channels and integrated, a sample-and-hold amplifier makes sure that a constant output signal is available at all times.



CFD4 Fig. 2. THz spectrum recorded both with conventional lock-in detection and with APOGI. There is no significant difference between the spectra. Noise (see inset) is on a comparative level.