Terahertz imaging by THz→IR conversion

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***Abstract*—A low-cost THz→IR converter based on a printed metasurface is fabricated. The converter is a thin membrane which absorbs the terahertz radiation at a single frequency using a grating of antennas, and converts it into thermal IR radiation. Here, we demonstrate THz imaging at 96 GHz using an IR camera equipped with the converter. The membrane can be upgraded to convert simultaneously multiple frequencies thus giving a possible path for terahertz multispectral imaging using an IR camera.**

The relatively high cost of terahertz cameras is an issue that may prevent the wide use of terahertz imaging. In this work, a low-cost THz→IR converter is fabricated by inkjet printing in order to equip a standard IR camera, and its use for terahertz imaging is demonstrated. The conversion component is a thin membrane composed of a terahertz metasurface absorber and a thermal emitter (see Fig.1).

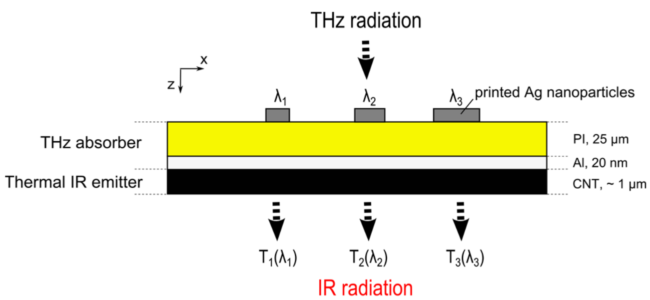

Fig. 1. Principle of the multispectral THz→IR conversion: the THz incident light is absorbed by the grating of MIM antennas at a resonance wavelength, and subsequent black body radiation coming from the emissive layer is captured by a standard IR camera – PI: polyimide, Al: aluminum, CNT:

The metasurface is a grating of metal-insulator-metal (MIM) antennas with sub-wavelength dimensions. Each antenna exhibits a total absorption of the incident radiation at a resonance frequency. The latter can be tuned by adjusting the dimensions of the antenna [1,2], so that an arrangement of antennas can be found to convert multiple THz frequencies for multispectral imaging (Fig.1) The aim of this work is to demonstrate THz detection and imaging using a membrane designed to convert terahertz radiation at 96 GHz.

A grating of MIM antennas was printed (Dimatix, DMP-2800, Fujifilm) using a commercial silver nanoparticles ink on a metallized polyimide film. The dimensions of the antennas were computed using a Fourier modal method [3] to adjust the resonant absorption at 96 GHz. On the metallized rear face, a thin layer of an aqueous carbon nanotubes ink was deposed using a micropipette. The emissivity of the layer was measured by FTIR and equals 0.95 in the range 1.5-5 µm. Figure 2.a-b shows pictures of the front (THz) and rear (IR) sides of the membrane attached to an optical mount. Figure 2.c shows a scanning electron microscope image of the printed antennas. In order to demonstrate terahertz detection using this membrane, an IMPATT diode (Terasense, 96 mW, 96GHz) was chosen to illuminate the membrane while an infrared camera (FLIR SC7600, 1.5-5 µm) equipped with a 50 mm objective was used to collect the IR radiation from the IR side. Figure 2.d shows a typical IR image obtained with the camera when the THz beam is focused on the membrane. Hot spots observed on the image are due to the local THz absorption by the antenna.

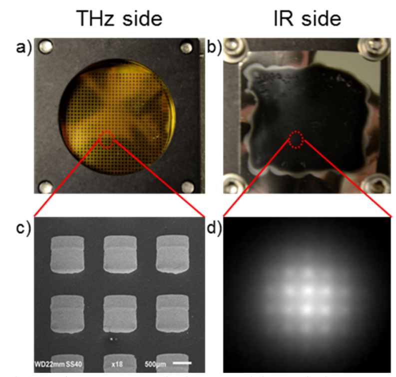

Fig. 2. Images of (a) the THz and (b) IR sides of the THz→IR conversion membrane. (c) Scanning electron microscope image of the printed MIM antenna and (d) IR image of a THz beam focused on the membrane.

Finally, the membrane was integrated in a simple non-destructive testing configuration. The object considered is a drilled ruler placed behind a 5 mm thick card (Fig. 3.a). The IMPATT diode was collimated in order to illuminate the object from behind. A PTFE lens (150 mm focal) was inserted to obtain an image of the object on the membrane. Figure 3.b-c shows that visible and infrared radiations do not penetrate the card, while terahertz imaging system allows to identify the ruler behind the card (Fig. 3.d) with a resolution limited by diffraction. Some progress still needs to be done to optimize the sensitivity of the camera. In particular it will be necessary to ensure that the resonance frequency of the fabricated grating perfectly matches the frequency of the IMPATT diode. Future work will thus be dedicated to the study of the spectral response of the fabricated membrane, and to the design of multispectral THz→IR converters.

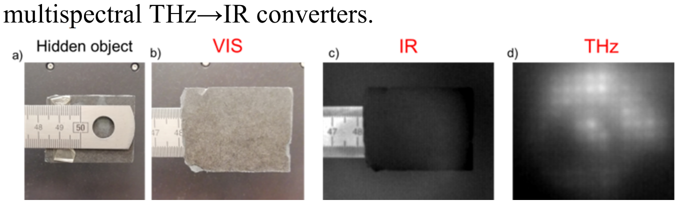

Fig. 3. (a) View from behind of the test object. (b) Visible, (c) IR and (d) THz images of the object from the front. The THz image is obtained by illuminating the object at 96 GHz.

References

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