TeraXplore–Single Detector for Multi-color Terahertz (THz) Imaging

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Active multi-color Terahertz (THz) imaging technology has a very large potential for inspection of composite materials. In this project the possibilities of the THz technology were explored on a test setup using off-the-shelf THz source and detectors. Furthermore, a single pixel detector was implemented in 0.18 μm CMOS technology.

THz imaging technology is becoming more and more important in non-destructive material inspection and quality control as it has advantages over other technologies like microwave, infrared, or x-ray. It provides good sensitivity, penetrates electrically non-conductive materials, is safe to use and at the same time can provide spectral information. Multispectral THz imaging can reveal features that are not present in a monochromatic image. This technology has the potential to cover a wide range of applications:

- Analysis of chemicals in powder and tablet form
- Investigation of moisture distributions
- Distinguishing crystalline and amorphous structures
- Determining the layer thicknesses of multi-layer systems
- Detection of food contaminants or foul products
- Medical diagnosis (e.g. detection of skin cancer)
- Identifying flaws and cavities in non-conductive components

Although THz imaging has demonstrated its potential for non-destructive inspection in previous academic work [1], the application is limited due to the lack of multi-color pixel array detector. In the course of the MIP project TeraXplore, a single THz detector was developed based on the “direct detection method”, i.e. the detector consist of an antenna and a (CMOS based) RF receiver (see Figure 1). The antenna and rectifier were integrated in a test chip, the readout was implemented with discrete components.

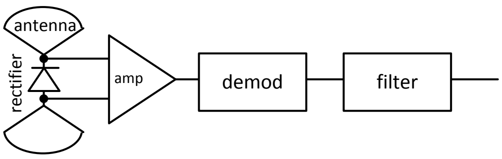

Figure 1: Detector architecture.

Due to the lack of devices for operation up to 500 GHz, dedicated rectifiers have been developed. The following options were considered: Shallow-Trench-Separated (STS) Schottky diode, Poly-Gate-Separated (PGS) Schottky diode and diode-connected MOS transistor of different sizes. The only way to verify the performance is through measurements, thus all these options were implemented on the test chip.

Two different types of antennas were designed (see Figure 2). The patch antenna can be integrated directly using the chip’s metallization layers, which leads to a very short connection to the rectifier. However as the maximum thickness of the dielectric is limited to 6 um, it results in a very narrow band antenna. In order to be able to support multi-spectral imaging a dedicated antenna tuned to each center frequency is needed. In the current implementation, the supported frequencies are 375 GHz, 425 GHz and 475 GHz. The test chip has been implemented in a 0.18 μm CMOS technology. Samples are expected to be evaluated in the fall of 2016.

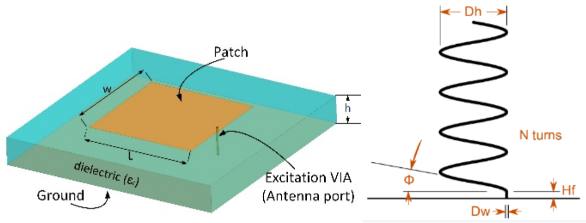

Figure 2: Patch antenna (left) and helix antenna (right).

In addition, an off-chip helix antenna was designed, which can support the entire frequency range from 300 GHz to 500 GHz. Prototyping was done using 3D printing technology. This can be done by either metal printing directly on the outside of a cylinder, or by wrapping a 70 um wire around a 3D-printed cylinder (see Figure 3)

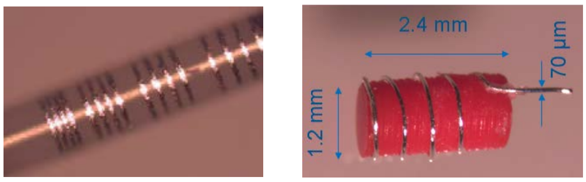

Figure 3: 3D printed antennas.

For the connection of the antenna, the best option found is to deposit gold directly on the chip using aerosol jet, place the helix antenna and then cure it at 200°C. In addition the helix plastic part of the helix antenna is fixed with glue.

In parallel to the detector development, a test setup was built based on off-the-shelf components, which allowed to evaluate the potential of multi-color THz imaging technology for inspection of composite materials and photovoltaic cells. Detailed results are expected this fall.

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[1] C. Stoik, "Non-destructive evaluation or aircraft composites using teraherz time domain spectroscopy", PhD thesis, Air Force Institute of Technology (2008).