A 4K Pixel Terahertz Compressive Sensing Camera

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Imaging in THz regime (0.3-10 THz) has great potential in biomedical imaging, security screening and non-destructive evaluation due to its non-ionizing nature and the ability to produce better contrast than X-Rays and Infrared (IR). Nevertheless, so far THz imaging has primarily been demonstrated using single-pixel sensors and employing mechanical raster scans. Such single-pixel imagers are rather bulky and suffer from slow speed and mechanical noise. Coded-aperture single pixel imaging and multi-detector imaging arrays (such as focal-plane cameras) are also being developed as alternative tools to speed-up image acquisition times. Multi-detector arrays can achieve very high speeds; however, such systems can be rather complex and typically exhibit limited sensitivity. As an alternative, fast single pixel coded aperture imaging enabled by compressive sensing techniques can eliminate these issues and realize cost effective, high resolution, real-time THz imaging systems.

Compressive sensing techniques require a spatial light modulator (SLM) to multiplex the THz beam such that a single detector is enough to reconstruct the image scene. A simple and cost effective way to realize such an SLM for the THz band is to use the photoconductivity of high-resistivity silicon to modulate the THz signal using light (L. Cheng and L. Liu, “Optical modulation of continuous THz waves towards reconfigurable quasi-optical THz components,” Optics Express, vol.21, pp. 28657–28667, 2013.). As such, mask patterns can be directly projected onto the substrate to selectively generate photo-carriers over the illuminated areas creating high-resolution pixels opaque to the THz beam. Without compressive sensing, a total of N^2 measurements would be needed to reconstruct a general N×N-pixel image. However, high-resolution imaging can be achieved using much fewer measurements if the scene is sparse in nature. As such, real-time THz imaging of sparse scenes can be realized through compressive sensing.

Here, we present a 64×64 pixel THz compressive sensing camera using a single pixel transceiver system. Virginia Diode’s (VDI) THz frequency extenders (500-750GHz) are used to illuminate the scene. A simple optical system comprised of a pair of lenses and an Indium tin oxide (ITO) glass is used to guide the THz beam to the scene. To realize the SLM, we use a commercial LCD projector. For compressive sensing, $l1$-minimization algorithm is used. We demonstrate the approach using different compression rates and show images with good fidelity using compression as small as 12.5%.