Phase-sensitive THz Imaging using Intensity-only Measurements

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The state-of-the-art in 2-dimensional spectroscopic imaging in the THz regime (0.3-3 THz) is based on mechanical raster scans using a single, high-performance sensor that collects pixel data serially. More recently, multi-detector arrays have been realized with the goal to achieve high speeds, potentially reaching video frame rates (G.C. Trichopoulos, H.L. Mosbacker, D. Burdette and K. Sertel, “A broadband focal plane array camera for real-time THz imaging applications,” *IEEE Transactions on Antennas and Propagation*, vol.61, no.4, pp.1733-1740, April 2013). However, the noise performance (a.k.a. sensitivity) of such large-format, densely-packed sensors are limited due to complex fabrication requirements of the mixers and intermediate-frequency (IF) electronics for each sensor pixel. To circumvent the slow acquisition rates of raster scanned imaging systems and the poor noise performance of large-format focal plane arrays, compressive sensing (CS) techniques were also employed for THz imaging. The challenge for such compressive approaches has been the realization of a reconfigurable aperture mask that can provide high performance in the THz band.

Notably, CS at 590 THz was demonstrated in (M.I.B. Shams, Z. Jiang, S. Rahman, J. Qayyum, L.-J. Cheng, H.G. Xing, P. Fay and L. Liu, “Approaching Real-time Terahertz Imaging with Photo-induced Coded Apertures and Compressed Sensing,” *Electronics Letters*, vol.50, no.11, pp.801-803, May 22 2014) used amplitude-modulating masks formed by projecting computer generated patterns on a high-resistivity silicon wafer using a commercial DLP projector. Also, Chan *et. al.* achieved CS phase reconstruction using amplitude masks in conjunction with a THz coherent sensor (W.L. Chan, K. Charan, D. Takhar, K.F. Kelly, R.G. Baraniuk and D.M. Mittleman, “A Single-pixel Terahertz Imaging System Based on Compressed Sensing,” Applied Physics Letters, 93, 121105, 2008), however, the technique relies on a costly phase-sensitive detector.

Alternatively, phase reconstruction from intensity-only measurement is possible using “complex” masks and the Phaselift Algorithm (E. J. Candes, T. Strohmer, and V. Voroninski, “Phaselift: Exact and stable signal recovery from magnitude measurements via convex programming,” *Communications on Pure and Applied Mathematics*, 66(8), 1241-1274). Here, we present a phase-sensitive THz imaging system based on the Phaselift process. We use optical excitation of high resistivity silicon to spatially modulate both magnitude and phase of the THz wave to realize a complex reconfigurable CS mask. Recording only the intensity of the modulated signals and applying the Phaselift algorithm, we can reconstruct 16×16 “complex” (i.e. amplitude and phase) images at 690 GHz. We demonstrate the superior contrast that the phase information provides in measuring sample thicknesses down to 190μm.