Phase-retrieval in Single-pixel THz Imaging via Reshaped Wirtinger Flow

Syed An Nazmus Saqueb*(1), Vince Monardo(2), Yuejie Chi(2), and Kubilay Sertel(1)
(1) The Ohio State University, 1330 Kinnear Rd, Columbus, OH 43212
(2) Carnegie Mellon University, 5000 Forbes Ave, Pittsburgh, PA 15213

Phase-retrieval from amplitude-only measurements is considered a classic problem in many scientific areas, such as crystallography, biomedical imaging, speech signal processing and astronomy. The majority of phase-retrieval methods rely on interferometric techniques. For instance, in biomedical imaging, interferometric methods have been successfully used to retrieve the phase information of the scene from intensity measurements in the visible spectrum and using X-rays. Phase recovery not only produces higher contrast in images, but also provides additional information about the scene of interest. However, interferometric phase retrieval strictly requires coherent sources with high illumination and accurate optical alignments. A major challenge in translating such phase-retrieval methods into the terahertz (THz) regime is the scarcity of high power sources and high-sensitivity detectors. Thus, implementing interferometric techniques to acquire phase-sensitive images in THz band is indeed a daunting task and requires very expensive instrumentation.

Recently, a single-pixel imaging system using high-resistivity Si as a spatial light modulator has been demonstrated in THz band to recover phase of the scene from intensity-only measurements (Saqueb, Syed An Nazmus, and Kubilay Sertel. "Phase-Sensitive Single-Pixel THz Imaging Using Intensity-Only Measurements." IEEE Transactions on Terahertz Science and Technology 6.6 (2016): 810-816). A convex optimization based algorithm called PhaseLift was used to recover the phase from oversampled Fourier intensity measurements. Nevertheless, high computation time of PhaseLift algorithm was still a bottleneck to achieve real-time processing. As an alternative to PhaseLift, a non-convex optimization approach, called Wirtinger flow results in much reduced computational time, while producing similar performance as the PhaseLift (Candes, Emmanuel J., Xiaodong Li, and Mahdi Soltanolkotabi. "Phase retrieval via Wirtinger flow: Theory and algorithms." IEEE Transactions on Information Theory 61.4 (2015): 1985-2007). This approach relies on simple gradient descent like scheme and thus, has lower computational complexity than the PhaseLift which is based on a much difficult semi-definite programming (SDP) problem. In this paper, we use a single-pixel THz imaging setup to recover phase-sensitive images from intensity-only measurements by utilizing a variant of the Wirtinger flow algorithm called Reshaped Wirtinger Flow (RWF). The spatial modulation is achieved by optically exciting a high-resistivity Silicon (HRSi) wafer using a commercial LCD projector. Illuminating computer generated pixelated patterns (or “masks”) on the HRSi wafer, we can individually control the complex transmission of object’s THz beam through each pixel. Doing so, we record the Fourier intensity of multiple masked measurements using a single power detector. Subsequently, both the amplitude and the phase of the scene are recovered through either the PhaseLift or the RWF process. Here, we demonstrate that for a 32×32-pixel reconstruction, the RWF algorithm takes 40 times less computation time than the PhaseLift. This simple and cost effective imaging system can enable effective phase recovery of complex scenes in the THz band.