Aberration Rectified THz Beam Focusing via Diffractive Lens Design Using a Modified Direct Binary Search Algorithm

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A myriad of THz systems rely on focusing incident THz waves onto a single spatial line or a point, to maximize the intensity within a spatial region of interest. Conventional THz lenses are bulky, thick, expensive and suffer from strong wavefront (geometric as well as chromatic) aberrations which hinders the performance of THz systems. Metamaterials and metasurfaces can provide effective solutions; however, such alternatives are usually polarization dependent, hard to fabricate, and difficult to simulate; in contrast to an all-dielectric based approach. In this work we seek to experimentally demonstrate that the basic principles of scalar diffractive optics, under proper design considerations, can be coupled with a computer-aided optimization based search algorithm, i.e. modified direct binary search technique, to design aberration rectified diffractive THz lenses for both narrowband and broadband focusing.

For aberration rectified focusing, we implemented a computer-aided optimization based search algorithm i.e. modified direct binary search technique, to optimize the distribution of pixel heights. Unlike a perturbation-based iterative method like the direct binary search algorithm employed in previous works (e.g. [P. Wang et al, Scientific Reports, 6, 2016]) our modified direct binary search employs a gradient descent to the search for the optimal solution in the design space, thus intuitively reducing the computation time as well as the search-space complexity. Our results evidence that our algorithm can reduce by >10X the number of iterations required so to achieve a desired convergence.

The designed lenses were fabricated and tested. The fabricated narrowband lenses have a demonstrated efficiency of >85% and >90% for both 1D and 2D lenses, respectively. In comparison, the broadband lenses exhibit an efficiency of >75% for 1D lenses, reaching up to >80% in case of 2D lenses within a given frequency bandwidth of 300 GHz i.e. 0.3 THz to 0.6 THz. As expected, the overall efficiency is higher for 2D lenses because of the design-space containing a larger number of pixels thus more degrees of freedom. Our work paves the way for the design and optimization of future efficient THz diffractive optical components that are error tolerant and which could provide any tailored design response.