Planar GHz Ultrasonic Lens for Fourier Ultrasonics

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Background, Motivation, and Objective

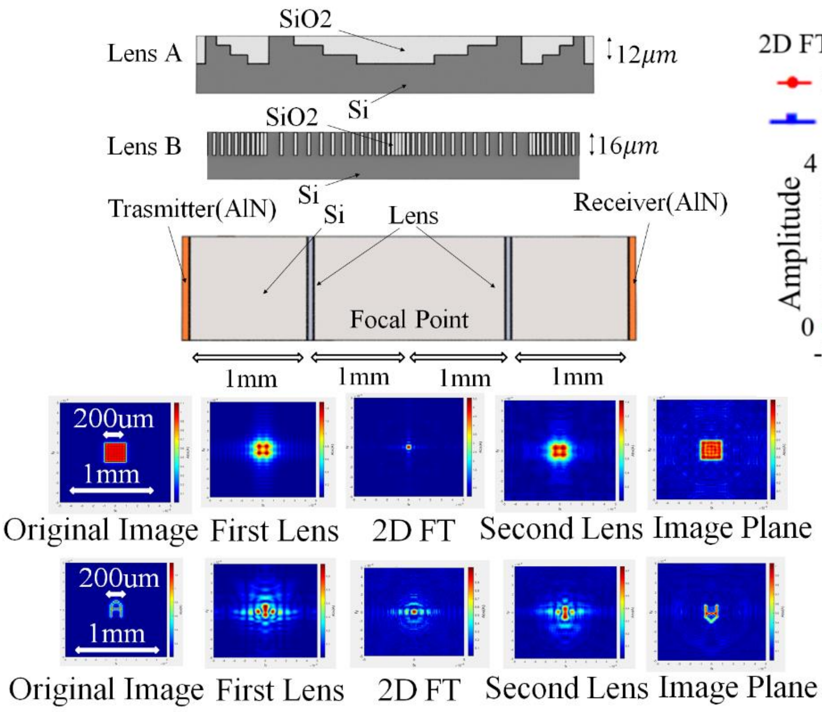
Recently we have developed an architecture to compute Fast Fourier Transforms using the wave propagation properties of ultrasonic waves [Liu 2018]. Improving the speed and reducing the power of Fast Fourier Transforms can accelerate computation for large scale data compression, computer vision in Fourier convolution neural networks, and differential equation solving in plasma physics. A key component of the system is an ultrasonic lens for the Fourier ultrasonic transform [Goodmam 2005]. The role of the ultrasonic lens is to focus the incoming wavefront and maximize transmittance with minimal dispersion and local diffraction effects. While conventional acoustic lens are 3 dimensional [Briggs 2009], a compact <1cc system is made possible by using planar ultrasonic lenses.

Statement of Contribution/Methods

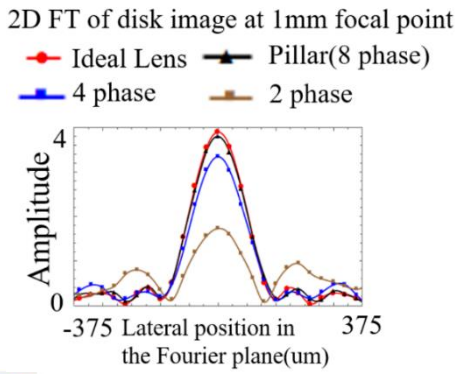
This paper presents numerical framework to compute ultrasonic Fourier transforms using analytical models of wave propagation and 2D planar lenses. These lenses are compatible with typical microfabrication processes. Two planar lenses are simulated. The first planar lens design (Fig. 1A) consists of 3 circular layers of silicon dioxide of heights corresponding to three phase shifts. This lens is harder to process than a planar lens. The second planar lens design consists of silicon and 1-um radius silicon-dioxide pillars with a height of 16um (Fig. 1A). The pillars can be formed in a silicon wafer and CMP polishing can be used to form a lens, a process underway in our group. The focal length of the planar lens is 1mm with a wavelength of 7um and a driving frequency of 1.2GHz.

Results/Discussion

In order to characterize the lens design, we simulated an inverse Fourier transform, using a Green's function based wave propagation model, in addition to a Fourier transform so as to receive the original image at a second image plane. The difference in intensity between these two images is an indication of the error of the system. For a square shape, lens A gives an error of 13.8% and lens B gives an error of 8.2%. The error is not only a function of the aberration of the lens, but also a result of the high frequency cut-off due to the finite aperture size, and can be minimized by pre-adjusting the images. By varying the pillar diameter vs. the pillar height, the focal length can be varied from 1 mm to 7 mm. While this paper presents numerical results, lenses are under fabrication to verify these results experimentally.



(A)



(B)