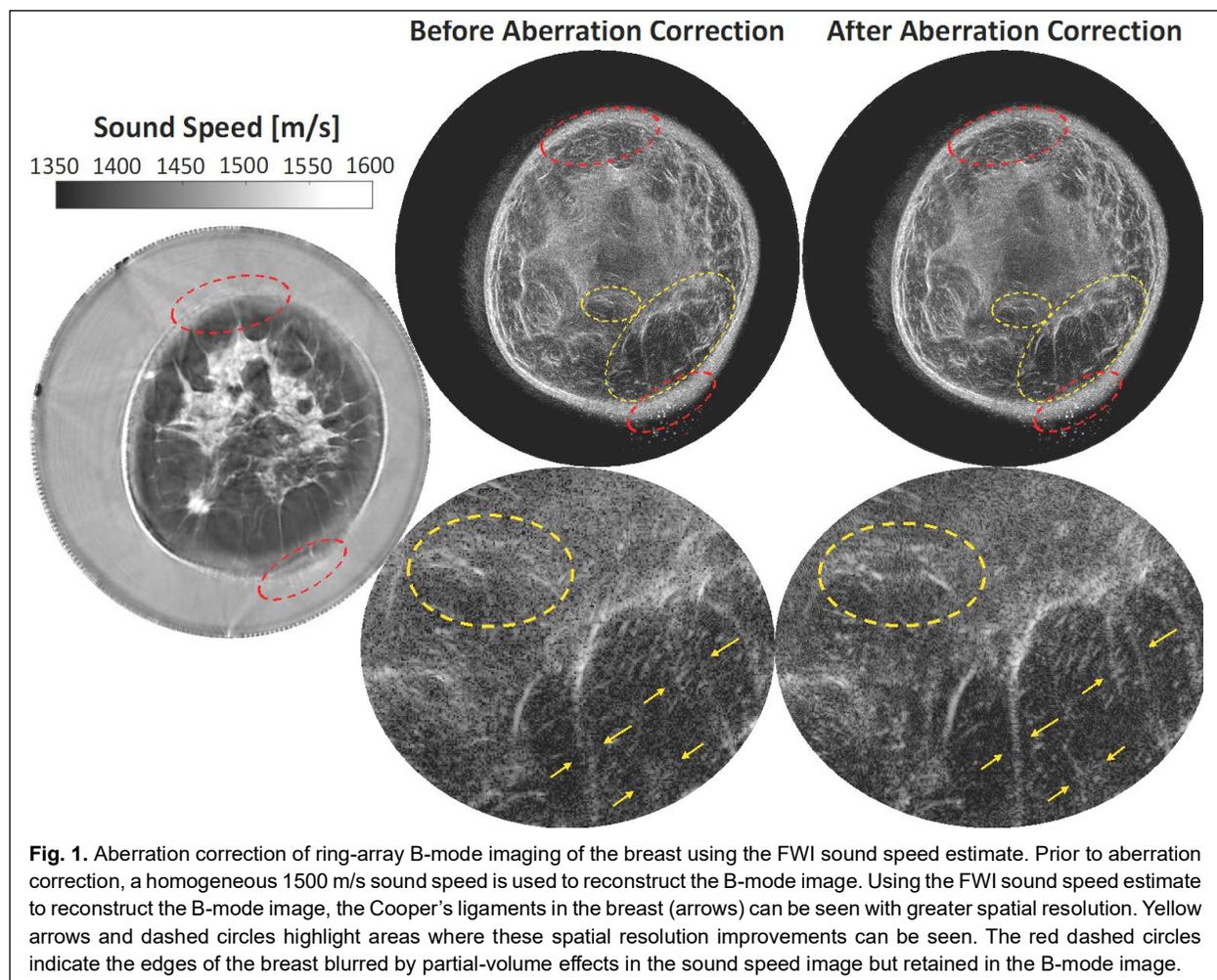Fast and Differentiable Beamforming for Ring-Array Ultrasound

Conventional handheld ultrasound imaging uses backscattered echoes to reconstruct images of tissue reflectivity (also known as B-mode imaging). With the recent advent of differentiable beamforming, enabled by the same GPU-optimized automatic differentiation software used in machine learning, reflectivity imaging can be optimized with respect to imaging parameters. For example, sound speed governs the signal timings used in a delay-and-sum beamformer; therefore, differentiable beamforming can simultaneously reconstruct a sharper B-mode image and the sound speed map used to sharpen it.

Fig. 1. Aberration correction of ring-array B-mode imaging of the breast using the FWI sound speed estimate. Prior to aberration correction, a homogeneous 1500 m/s sound speed is used to reconstruct the B-mode image. Using the FWI sound speed estimate to reconstruct the B-mode image, the Cooper's ligaments in the breast (arrows) can be seen with greater spatial resolution. Yellow arrows and dashed circles highlight areas where these spatial resolution improvements can be seen. The red dashed circles indicate the edges of the breast blurred by partial-volume effects in the sound speed image but retained in the B-mode image.

The goal of this work is to extend differentiable beamforming to imaging with a ring-array transducer. The unique advantage of this imaging geometry is that it enables the use of through-transmission ultrasound data to reconstruct sound speed. In **Fig. 1**, full-waveform inversion (FWI) is applied to the through-transmission to reconstruct sound speed and correct aberrations in the B-mode image. Therefore, this imaging setup enables the essential validation needed to develop differentiable beamforming for ring arrays.

The student responsible for this summer project will convert existing MATLAB beamforming codes to JAX (an automatic differentiation library in Python).