Multi-Foci Acoustic Field Generation Using Dammann Gratings for Phased Array Transducers

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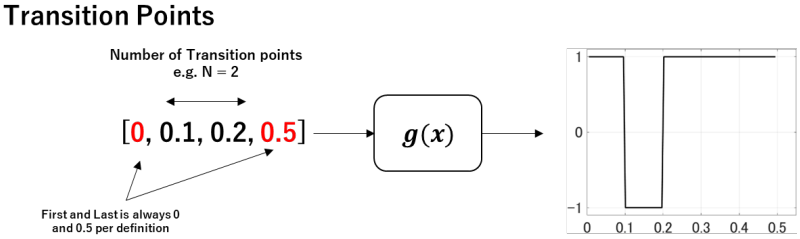
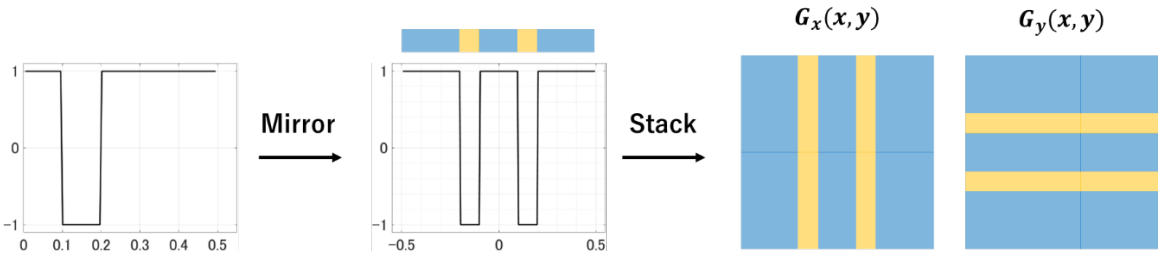
1. Dammann Gratings Generation Steps

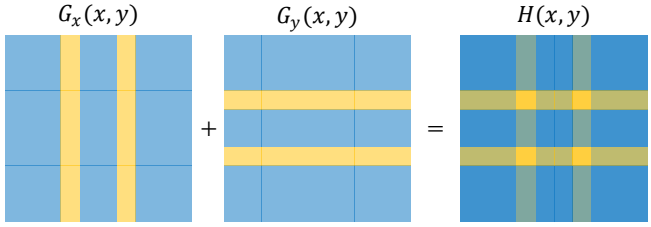
Step 1: Generate 1D Dammann Gratings



Step 2: Create 2D array for by mirroring by the axis and stacking it



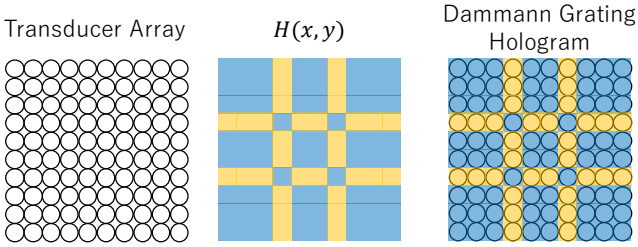
Step 3: Add two gratings together, and process the overlapping parts.



-2/0/+2 Region Forms when added
Replace with -1/+1/-1, respectively

We took method used by SSPIM[1] to process the overlapping part.

Step 4: Take the closest interpolation to create Dammann Grating Hologram



Convert -1 and 1 to 0 and π

In this paper, we only explore axisymmetric gratings in x and y directions, but a Dammann grating with different gratings for x and y axis can also be generated.

[1] https://github.com/aakhtemostafa/SSPIM

2. Figure 2 - Raw pressure field version

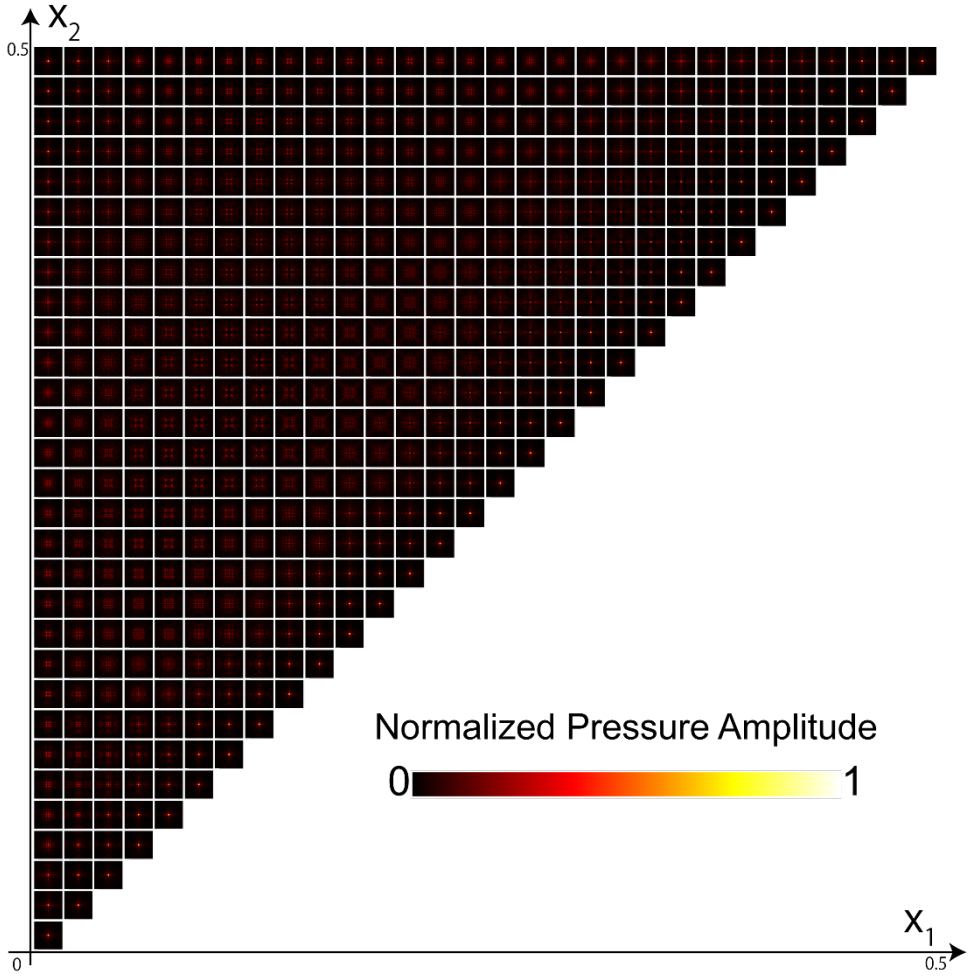
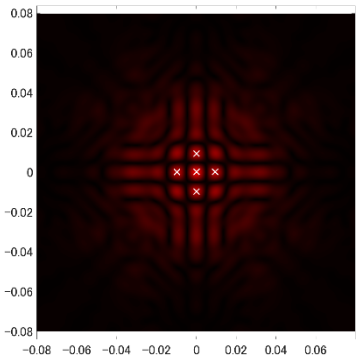
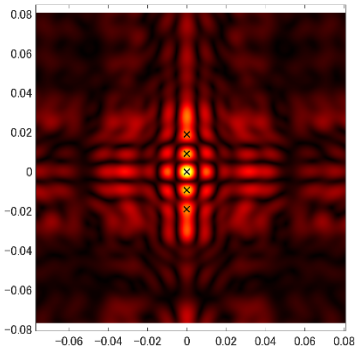


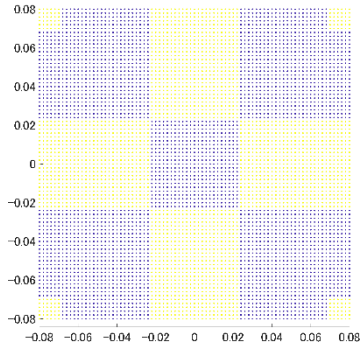
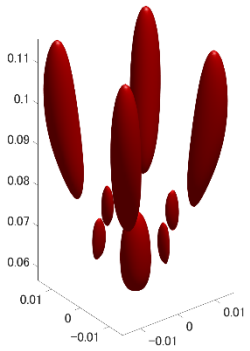
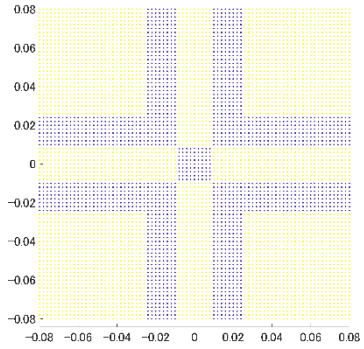
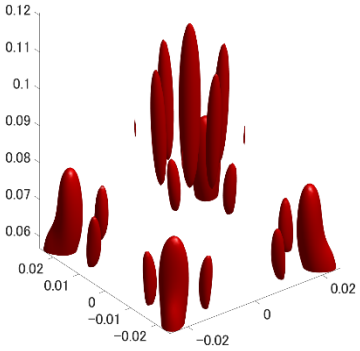
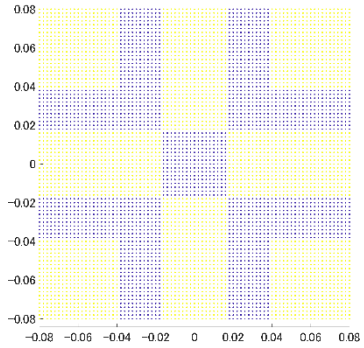
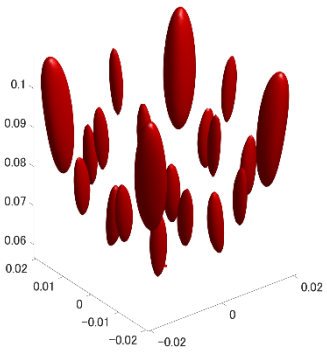
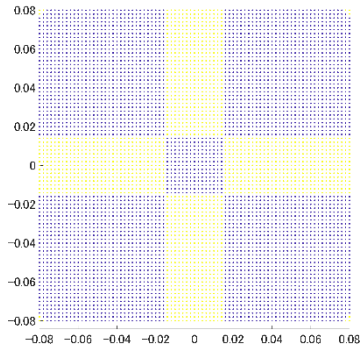
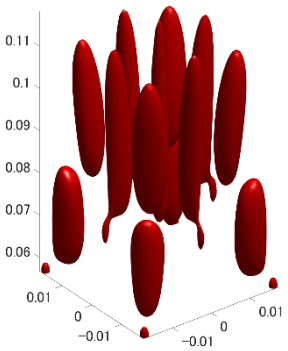
Figure S1: Every combination of Dammann Gratings

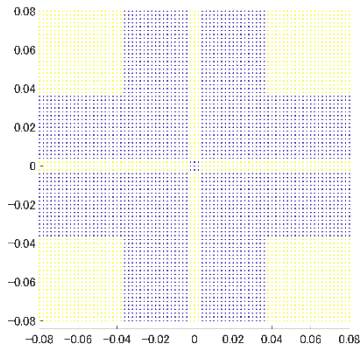
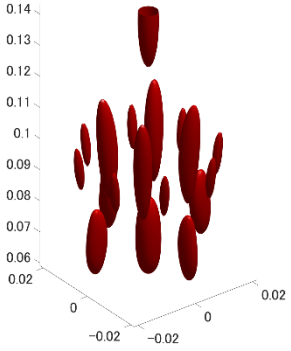
3. Comparison of $n_p = 5$ field (ideal and PAT version)

Ideal	PAT
	

The pressure field is not well reconstructed for peaks of 5 but the acoustic field in principle is well recovered.

4. Hologram and 3D isosurface visualization of selected grating Figure 3

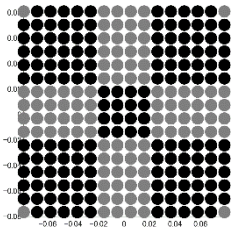
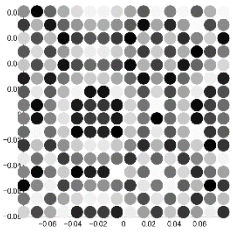
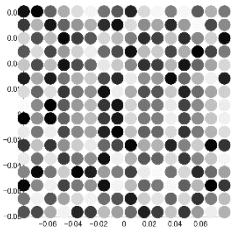
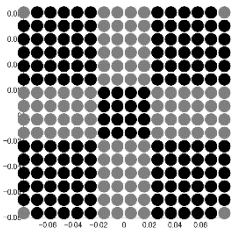
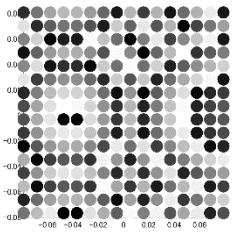
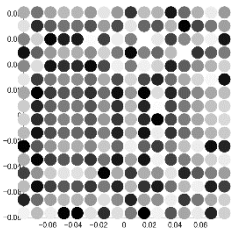
n_p	Hologram 0 π	3D Visualization Isosurface of Normalized Pressure ($p = 0.325 \times 0.707$)
4		
5		
8		
9		

12	 0.08 0.06 0.04 0.02 0 −0.02 −0.04 −0.06 −0.08 −0.08 −0.06 −0.04 −0.02 0 0.02 0.04 0.06 0.08	 0.14 0.13 0.12 0.11 0.1 0.09 0.08 0.07 0.06 0.02 0 −0.02 −0.02 0 0.02

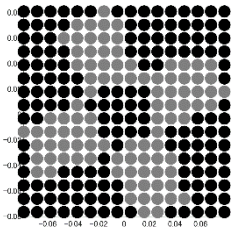
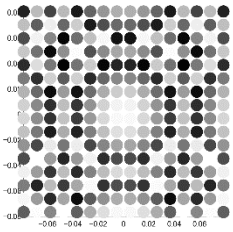
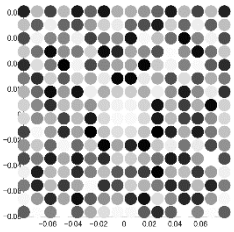
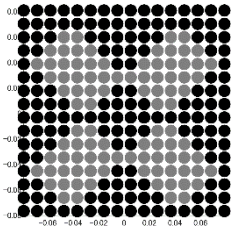
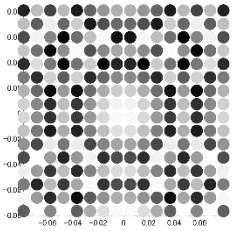
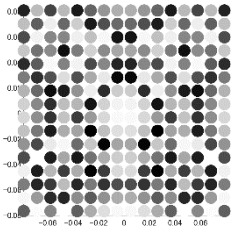
5. Translation and Rotation of Dammann Grating

To demonstrate the translation and rotation of the Damman grating, $n_p = 4$ Damman grating and single focus was combined.

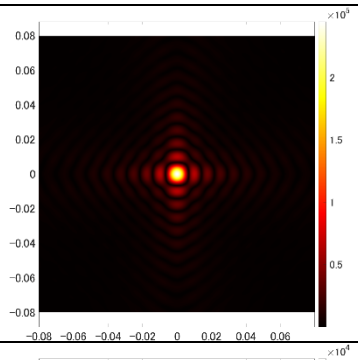
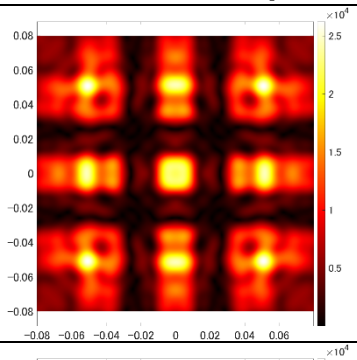
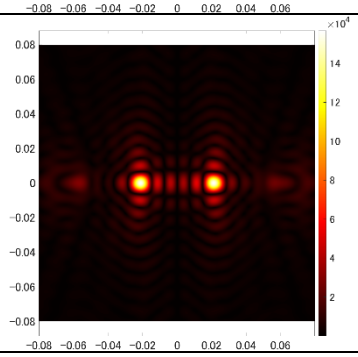
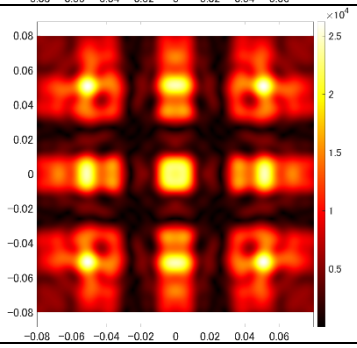
Translation

Shift	Dammann Grating	Single Focus	Total Field
-2.5λ			
-5λ			

Rotation

Rotation	Dammann Grating	Single Focus	Total Field
$\frac{\pi}{8}$			
$\frac{\pi}{4}$			

6. Combining Optimized Lens and Dammann Grating

# of Focus	IBP Focus Field Only	IBP + Dammann ($n_p = 4$)
1		
2		

Here, IBP optimizer based on Marzo & Drinkwater [5] was used to generate single focus and two focus holograms. These were generated for the ideal PAT with 81 by 81 transducers. Although the IBP hologram is calculated correctly, it does not combine well with the Dammann Gratings, even for a single focus case.