Research report
Harsono C. – PD
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Detection of THz wavefront

We tried to contruct the THz wavefront detection and analysis system (Fig. 2) based on Hartmann sensor/Shack-Hartmann sensor (Fig. 1).

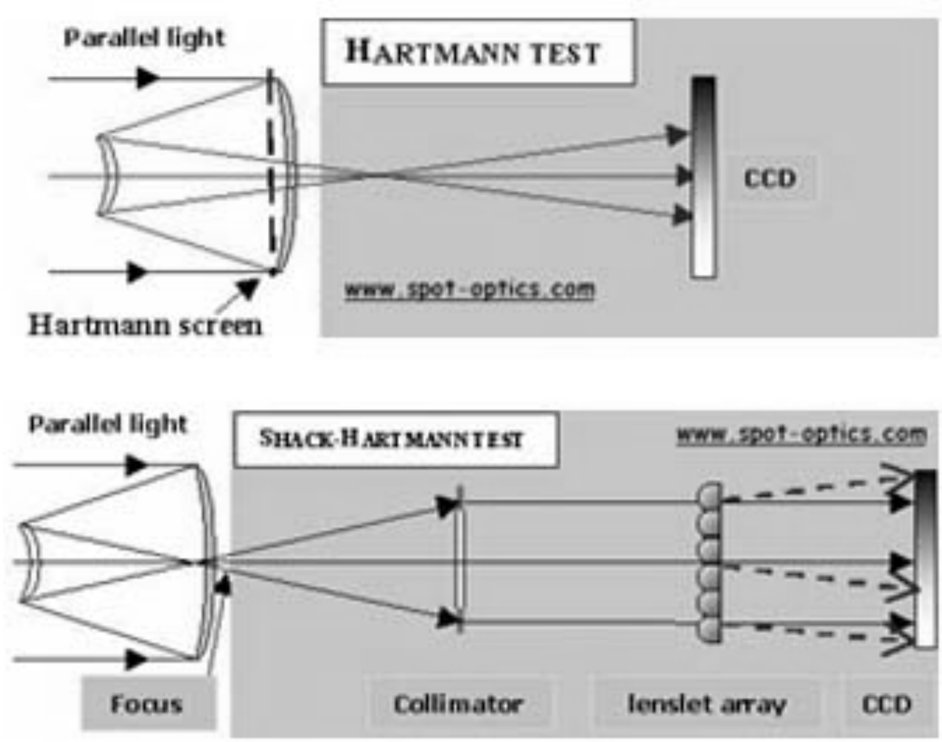


Fig. 1. Principle of Hartmann sensor/Shack-Hartmann sensor

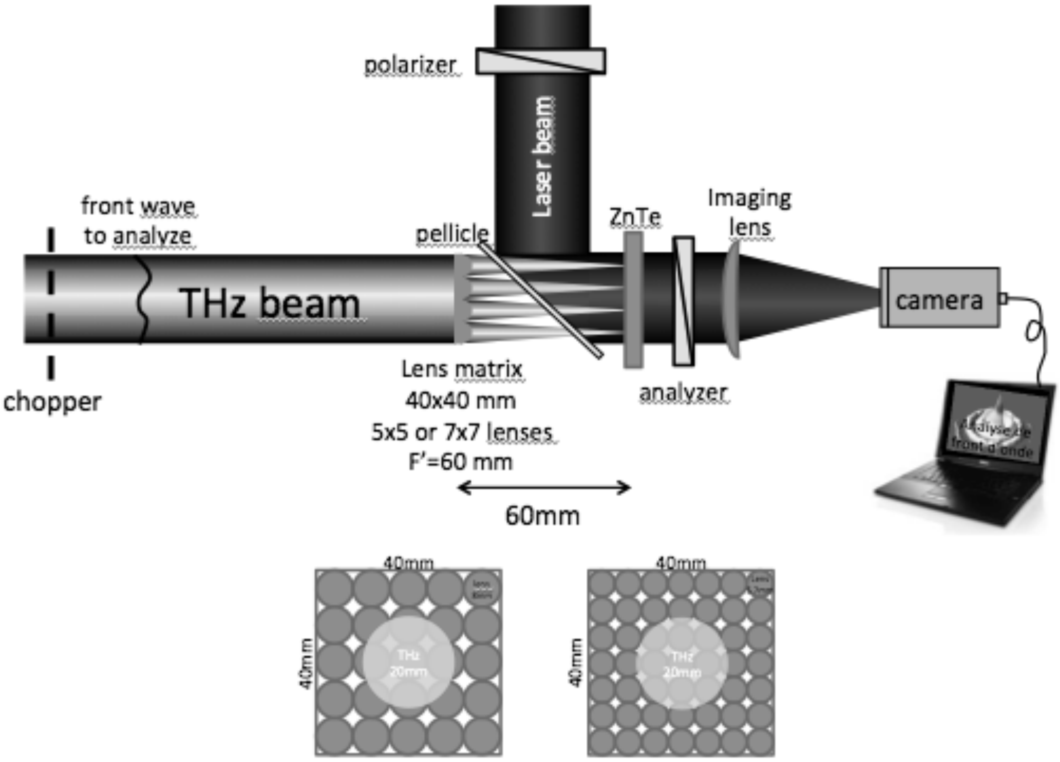
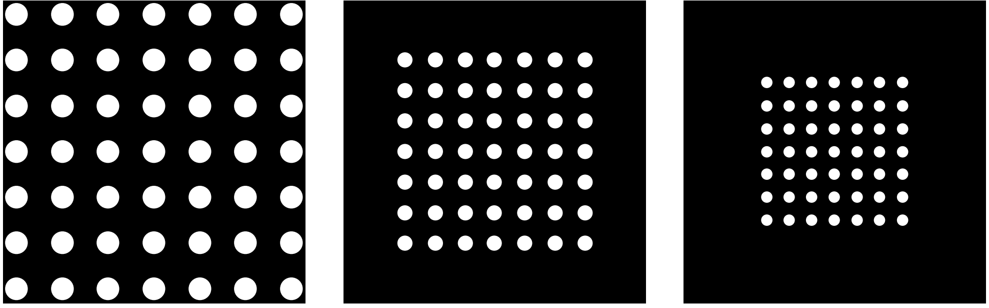


Fig. 2. Setup for THz wavefront analysis

The home-made lens matrix seemed to be unable doing focusing to the ZnTe. The effect of time delay of the lens due to the different thickness of lens material might occur. But, we were not sure that these lens arrays had focusing effect. Therefore, we first tried to observe the diffraction using some methods to understand the diffraction behavior of the THz beam.

1. Using Hartmann mask

We designed some patterns of Hartmann mask for testing (Fig. 3 and Fig. 4)

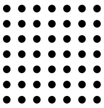


d = 3 mm
p = 6 mm

d = 2 mm
p = 4 mm

d = 1.5 mm
p = 3 mm

Fig. 3. Configuration of Hartmann mask on paper (white = paper, black = gold ink)



d = 1 mm, p = 2 mm

Fig. 4. Configuration of Hartmann mask on metal plate (black = hole on metal plate):

Instead of lens array in Fig. 1, we put a THz lens (f = 50 mm) at 100 mm before the ZnTe and then the Hartmann test at 100 mm in front of the lens (we named this setup as 4F). Fig. 5 show the results of this testing when we change the time delay. Then we change the THz lens with focal length of 100 mm and performed the similar experiment (we named this setup as Fourier). The result was shown in Fig. 6. Next step is remove this setup and with the expanded, collimated THz beam, we observed the effect of Hartmann mask if it was laid very close to the ZnTe (Fig. 7). The results were still confusing and we were still unsure about the conclusion of these experiments.

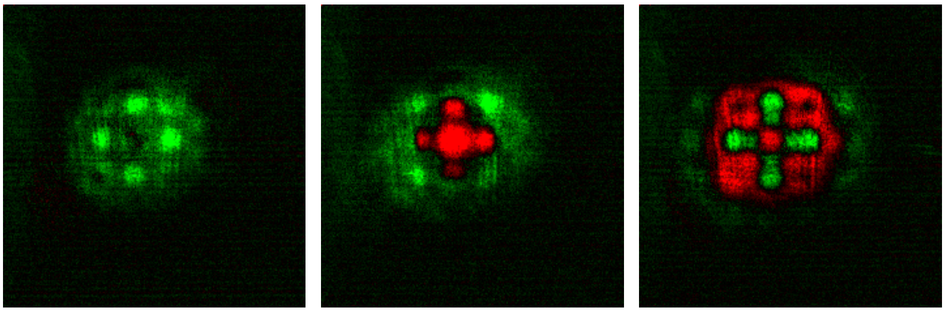


Fig. 5. Images on CMOS camera for Hartmann testing with 4F setup

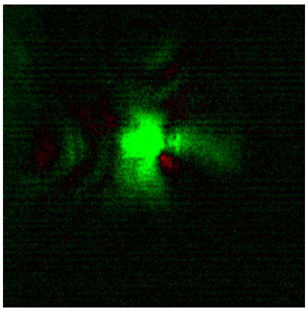


Fig. 6. Image on CMOS camera for Hartmann testing with Fourier setup

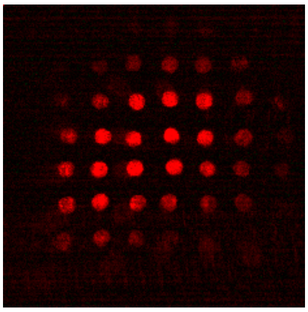


Fig. 7. Image on CMOS camera for Hartmann testing with Hartmann mask on ZnTe

2. Using lens

The wavefront of planar wave should be change after passing through an optical component, such as lens. We tried to detect and compare the wavefront of THz beam with and without THz lens (Fig. 8). The lens (f = 100 mm) was installed at different position (80 mm, 115 mm, 150 mm) in front of ZnTe. We also tried with tilted and shifted lens at 110 mm (Fig. 9). Then, we also tested the Hartmann mask placed at 65 mm in front of the ZnTe, instead of the lens (Fig. 10). The delay stage was moved for 1000 μm within 26 seconds and the image was captured every 100 μs. A significant difference was detected between the planar wave and focused wave, which might strongly indicate the change of THz wavefront due to the presence of lens. Furthermore, the position or orientation change of the lens also induced the wavefront change and it could be well detected by this method. However, we still did not understand well how to use these results to determine the wavefront of the distorted THz wave, in particular to reconstructed the THz wavefront detected by the ZnTe

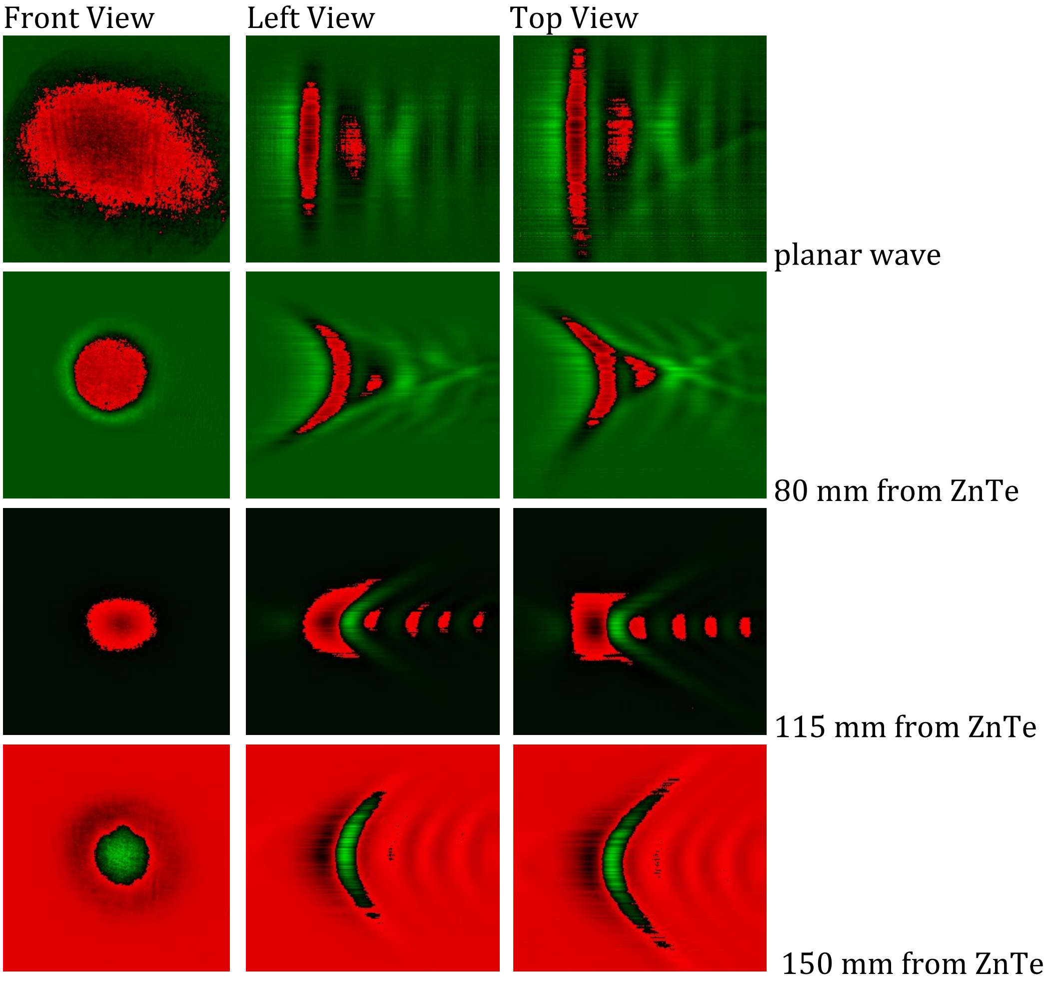


Fig. 8. Image on CMOS camera with different lens distances from ZnTe

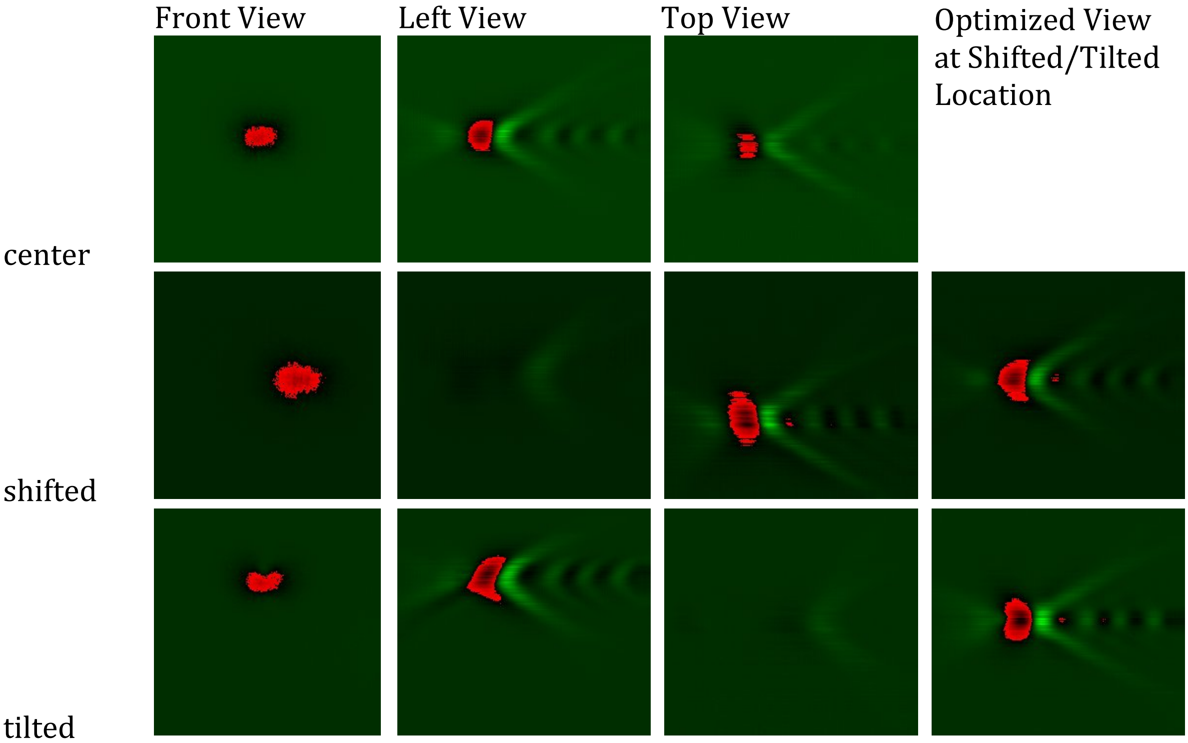


Fig. 9. Image on CMOS camera with different lens orientations at 110 mm from ZnTe

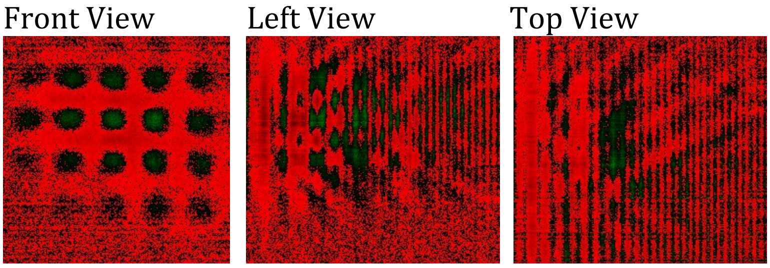


Fig. 10. Image on CMOS camera with Hartmann mask at 65 mm from ZnTe

3. Using apperture

We tried to apply an aperture to observe the effect of diffraction. We put a THz lens (f = 100 mm) at distance of 70 mm in front of ZnTe and an adjustable aperture at 30 mm in front of the lens. The results presented in Fig. 11 suggested that the diffraction by the aperture might influence the wavefront propagation after focusing. In order to understand further the effect of aperture to the planar THz wave, we observed the diffraction using a double slit based on Young interference experiment (Fig. 12) and circular aperture (Fig. 13). If we compare Fig. 11 and Fig. 13, it seemed that the diffractions occurred in the THz wavefront were dominated by the effect of the aperture. We should analyze these results further in frequency domain to get better conclusion about the diffraction pattern at certain frequency due to the slit/aperture.

Future plans

1. Analyze the CMOS images at frequency domain
2. Observe single slit and other simple mask pattern
3. Observe longer time delay
4. Learn the possibility to reconstruct the wavefront
5. Learn more about the principles of Hartmann/Shack-Hartmann sensor for THz measurement

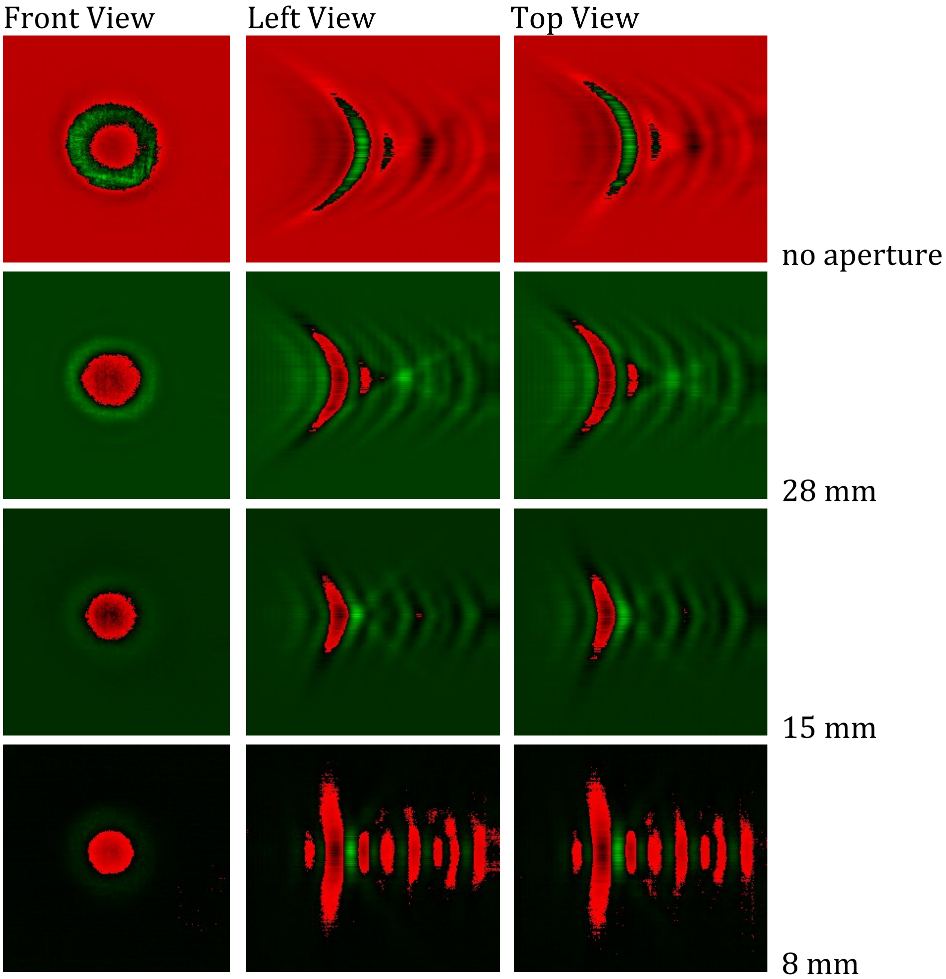


Fig. 11. Image on CMOS camera with a lens and different aperture sizes

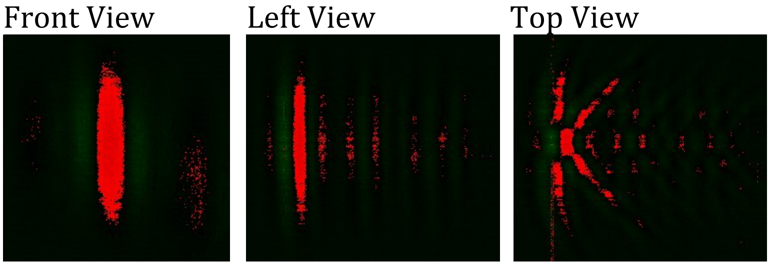


Fig. 12. Image on CMOS camera with double slit (slit width = 1 mm, slit separation = 6 mm)

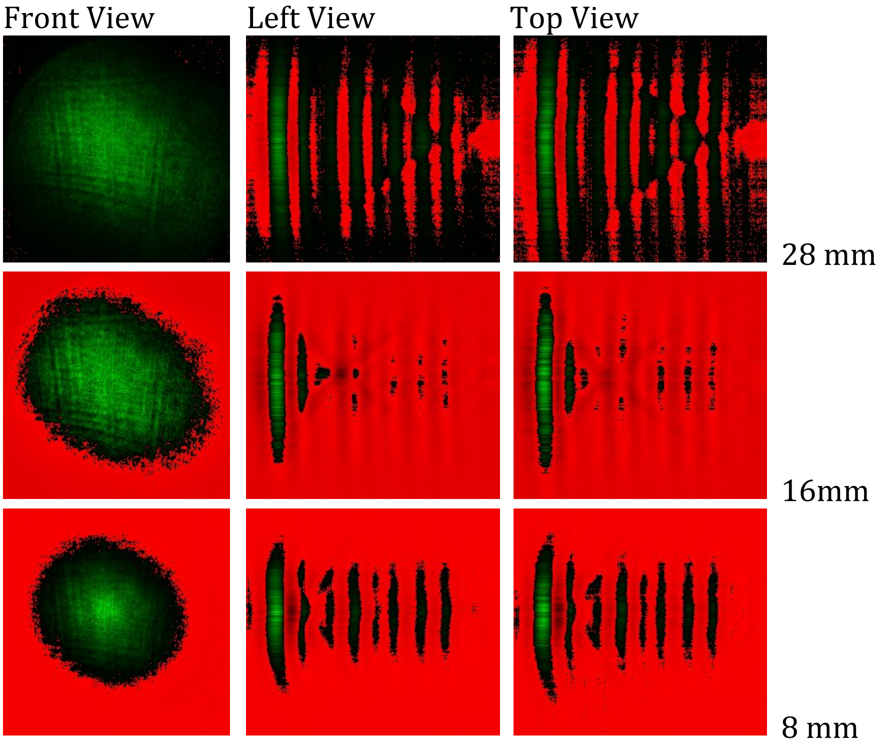


Fig. 13. Image on CMOS camera with different aperture sizes