

Mitigating Polarization Effects in On-Die Diffractive Optics for a CMOS Image Sensor

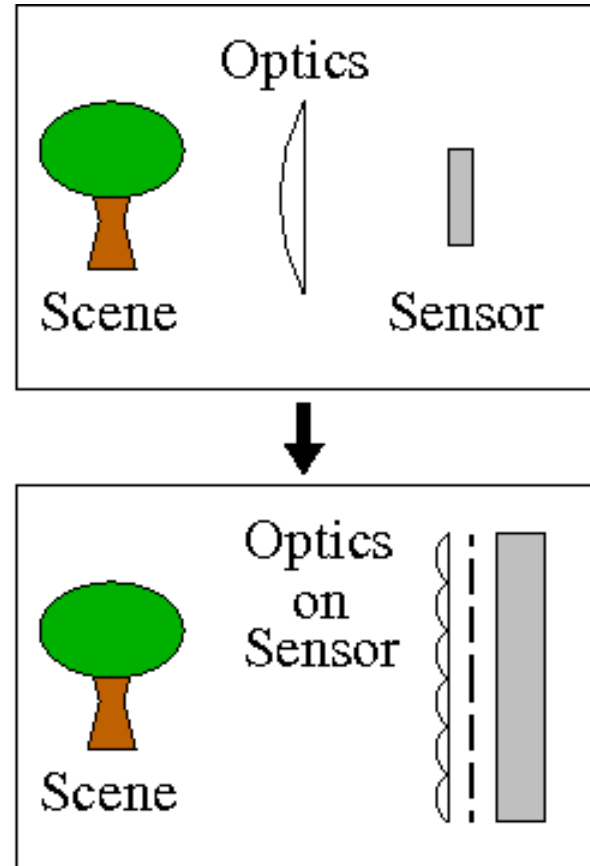
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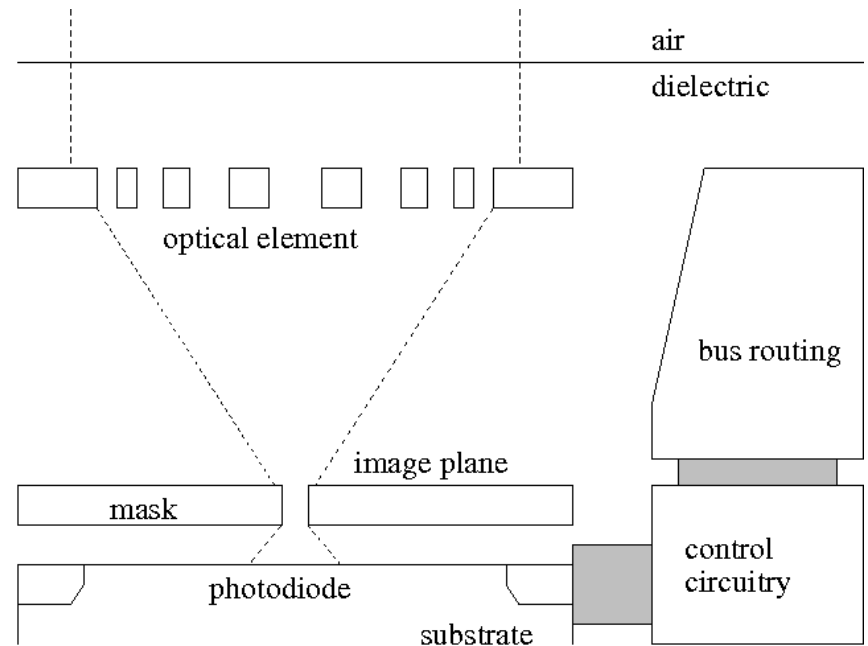
Background: On-Die Optics

- Microlenses are used for many applications (e.g. concentrators)
- Application of interest: Standalone imaging (no external optics needed!)



Background: Diffractive Optics

- Previous works proposed making diffractive optics using CMOS process metal layers.
- Inexpensive! (No extra process steps.)

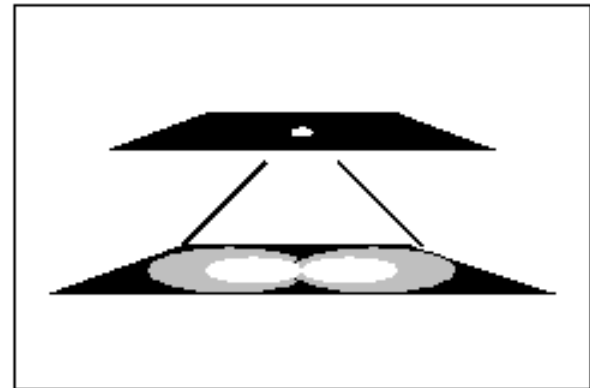
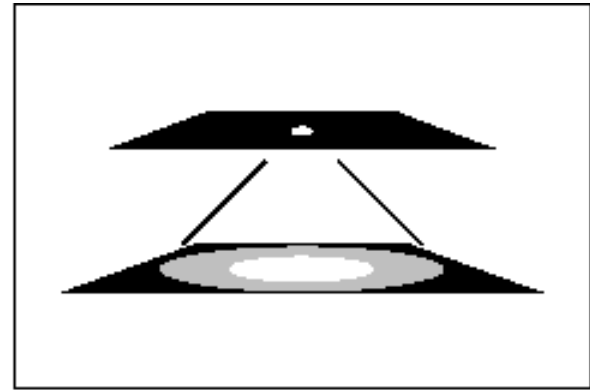


Problem: Polarization

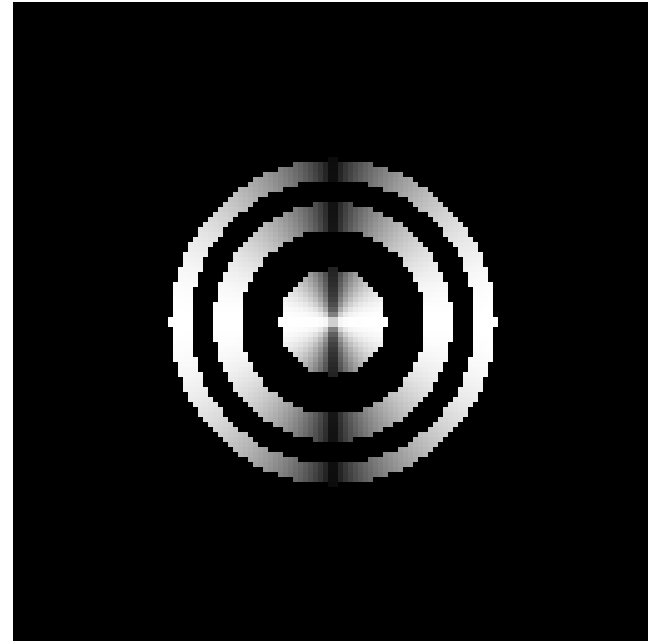
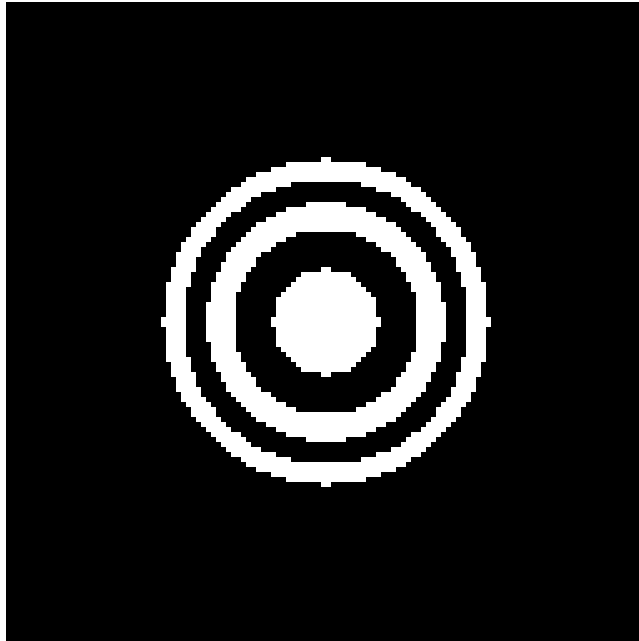
- Blurring ✓ Addressed.
- Wavelength Sensitivity ✓ Addressed.
- Polarization ➤ **Not Addressed.**

Tool: Improved Simulator

- Previous simulator:
Isotropic radiation
from optics.
- Improved simulator:
Dipole radiation from
optics.
 - Models polarization
effects.

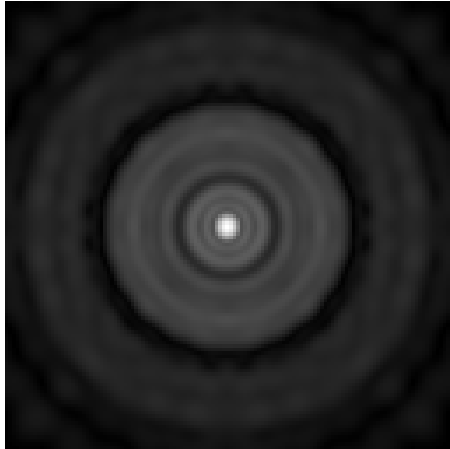


Polarization Effects

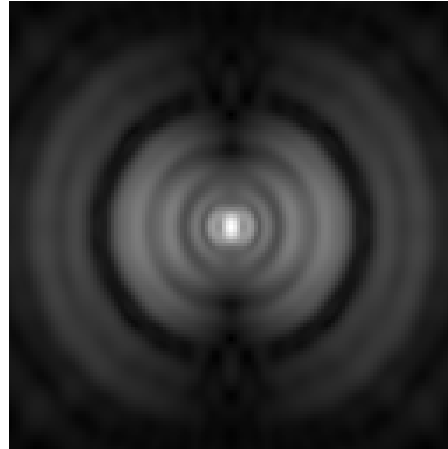


- Zone plate acts as polarizing filter!

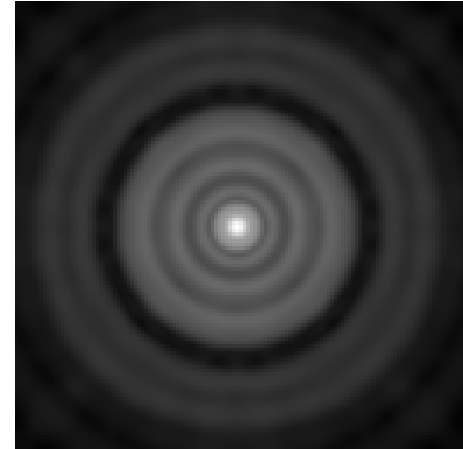
Polarization Effects



Isotropic



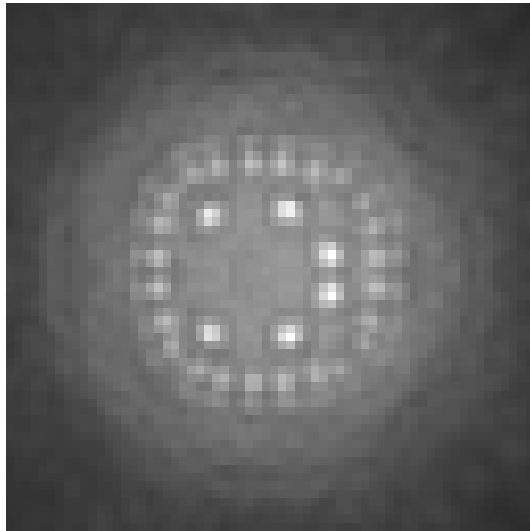
H-Polarized



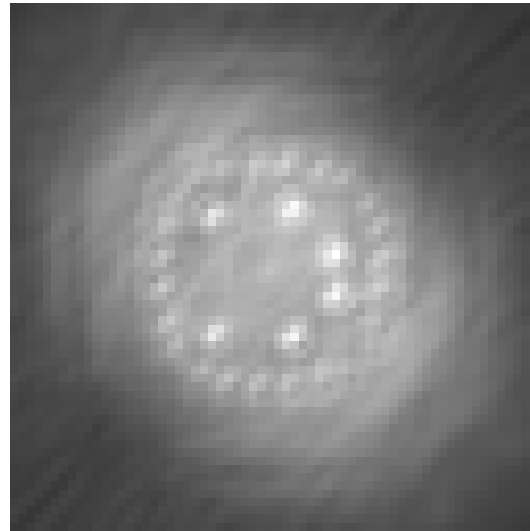
Mixed

- Angular resolution and point spread function depend on polarization.

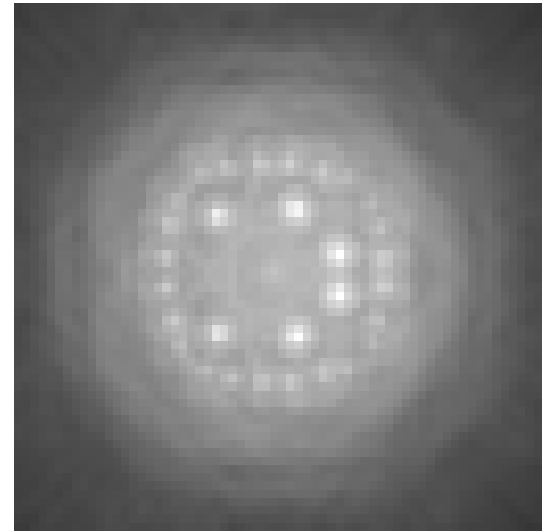
Polarization Effects



Isotropic



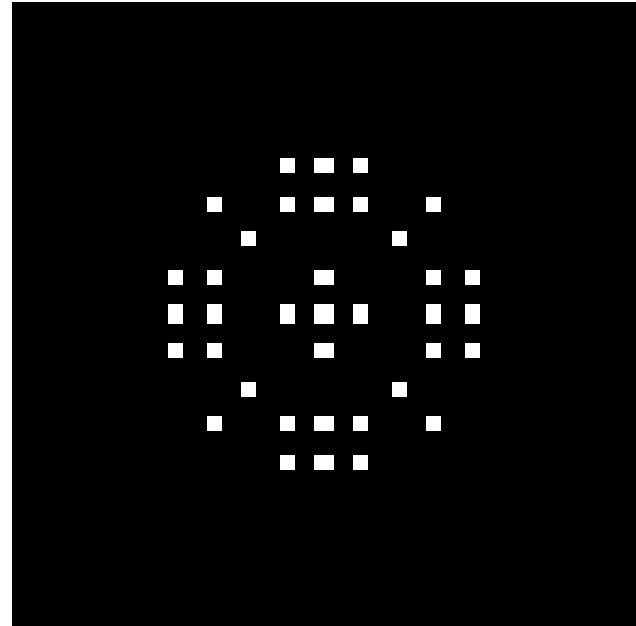
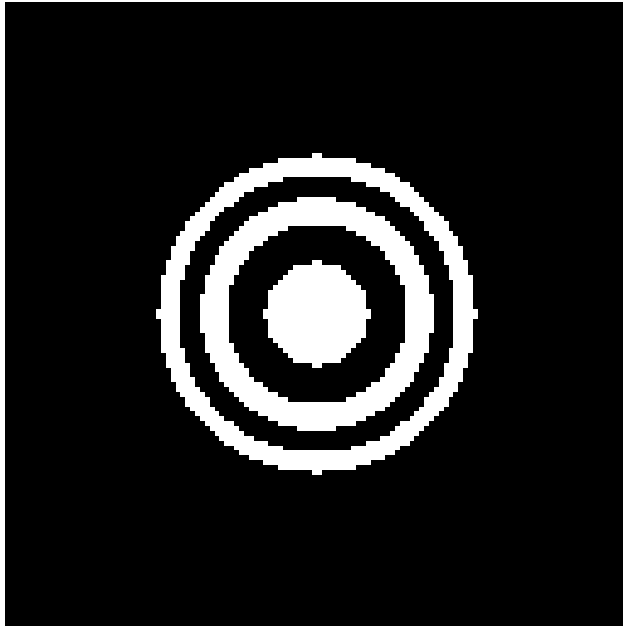
Polarized



Mixed

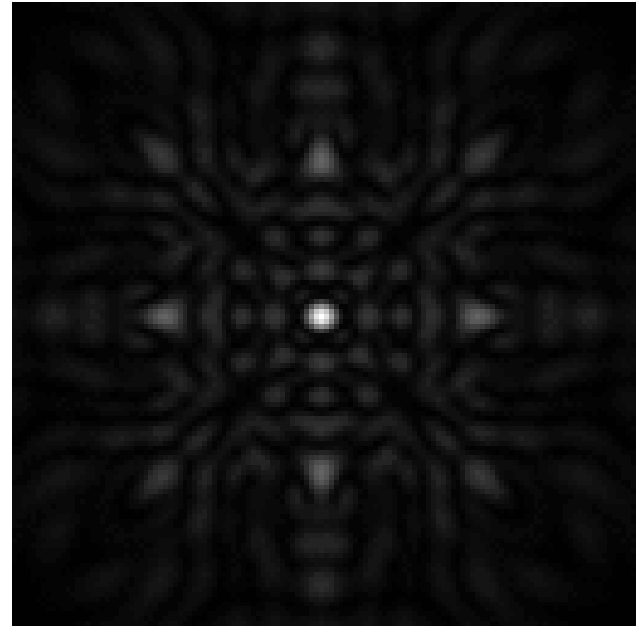
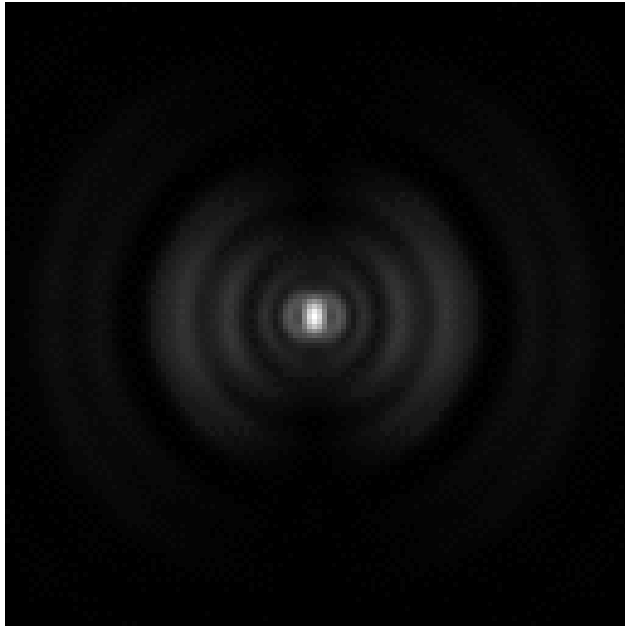
- Images need correction.
- Correction depends on polarization!
 - Polarization not known ahead of time.

Solution: Insensitive Optics



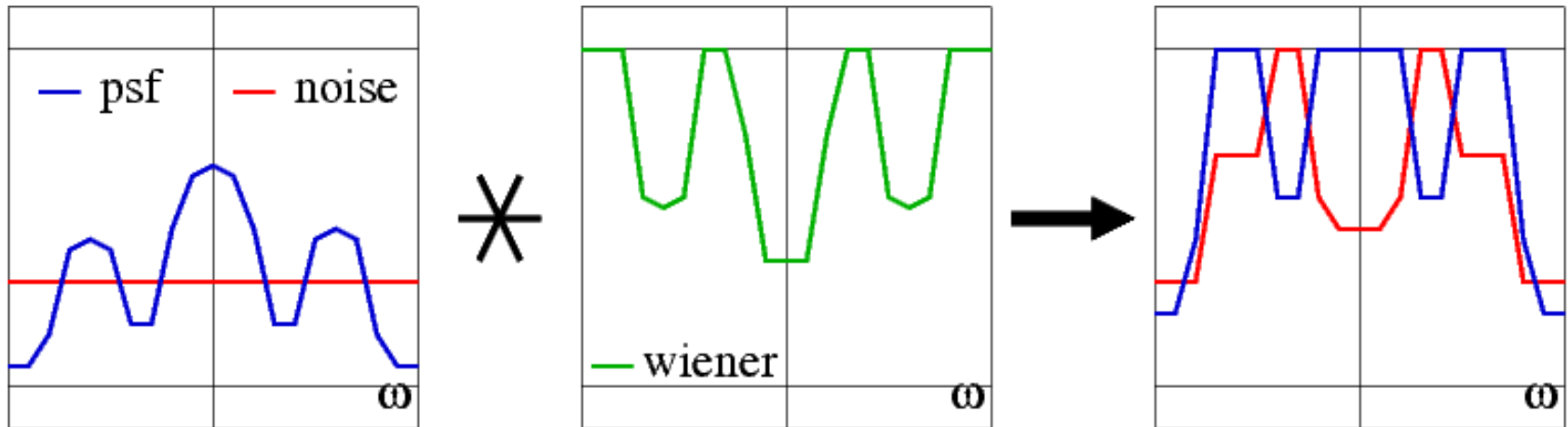
- Zone plate acts as polarizer.
- Hole plate does not!
- Tradeoff: Less light transmitted, more artifacts.

Solution: Insensitive Optics



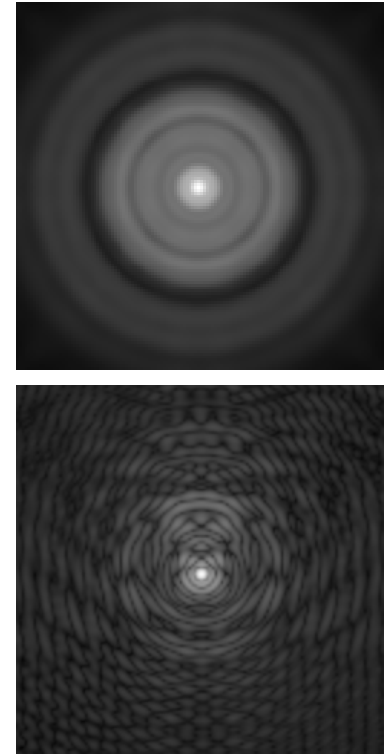
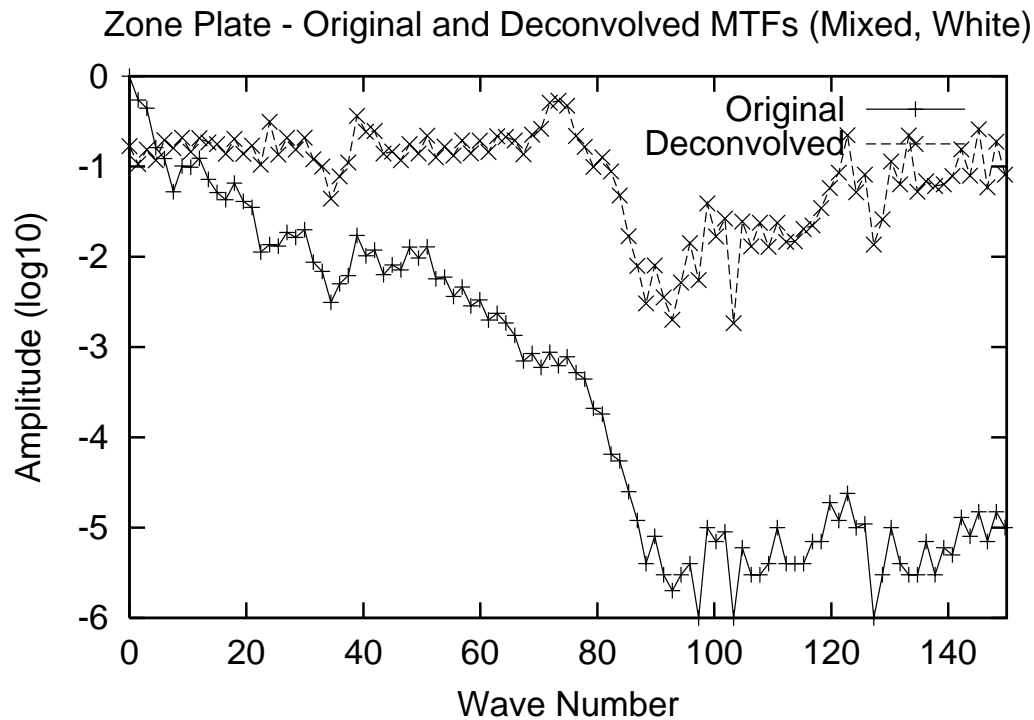
- Hole plate has point spread function artifacts.
- Artifacts aren't polarization-sensitive!
 - Known, unchanging artifacts can be deconvolved.

Tool: Deconvolution Filter



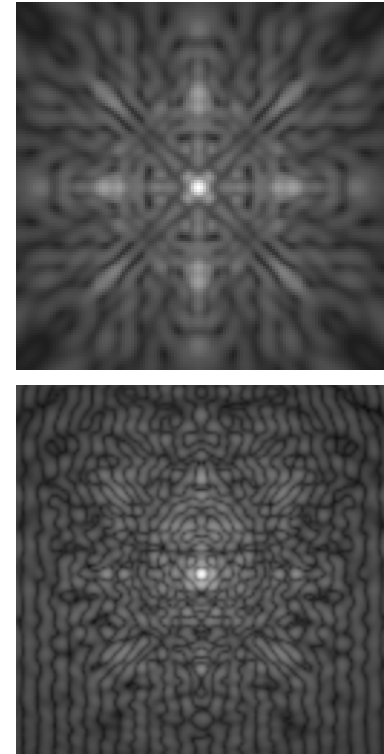
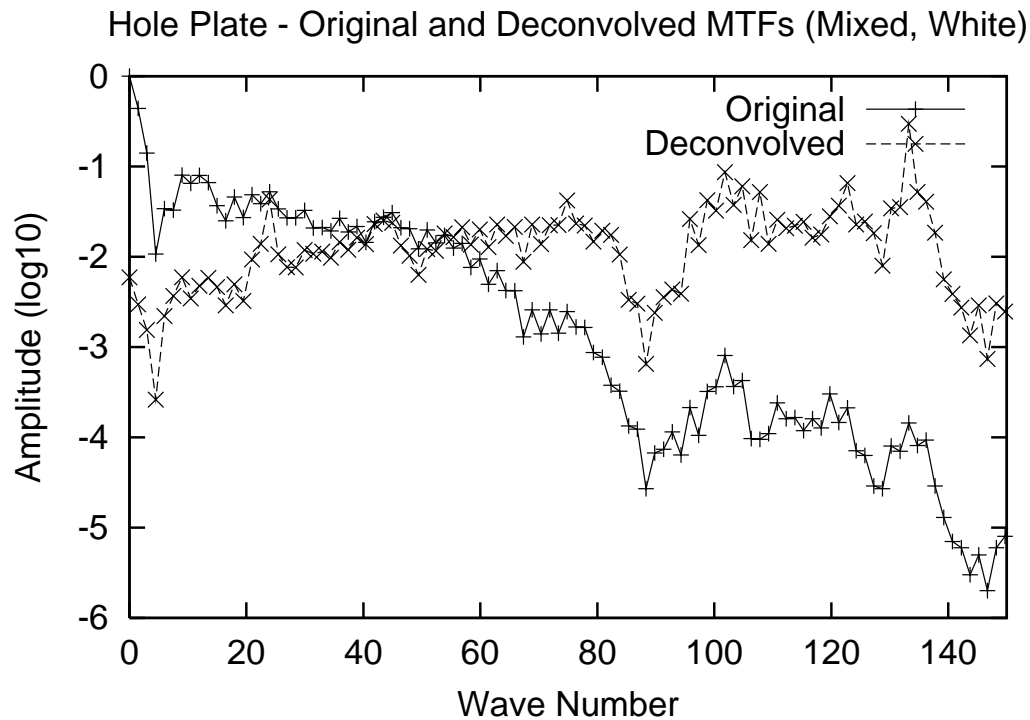
- Wiener filter takes known point spread function and noise, and gives a least-squared-error reconstruction.
- Noise and PSF must be known!
 - Changes in PSF vs. wavelength and angle of incidence modeled as noise.

Results: Zone Plate



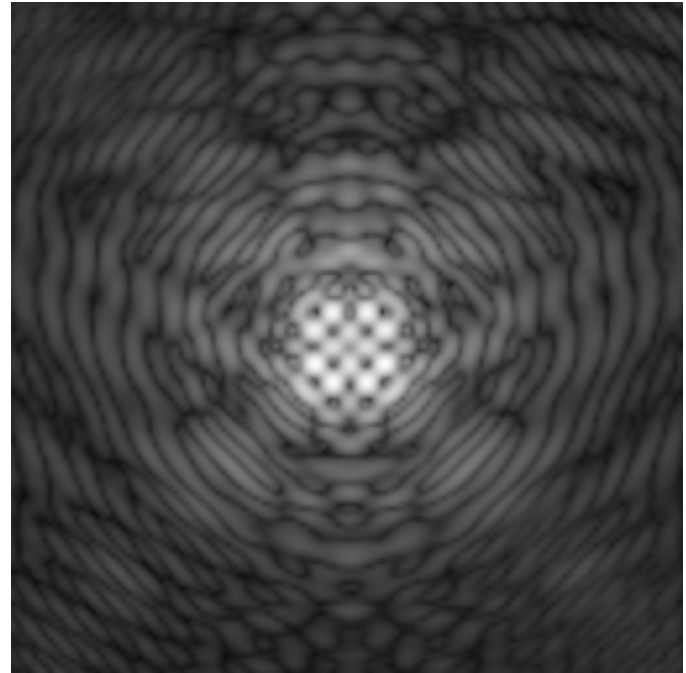
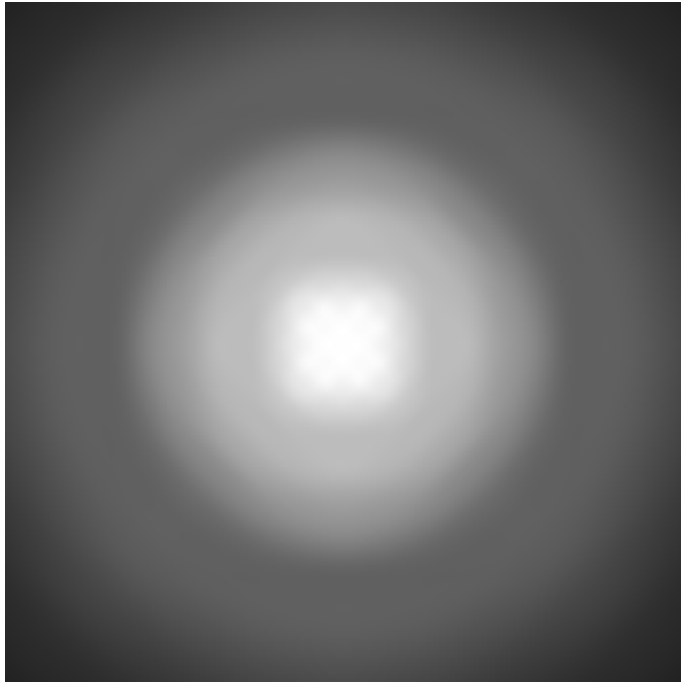
- White light, mixed polarization angles.
- Blurred: 0.16 rad
- Fixed: < 0.1 rad

Results: Hole Plate

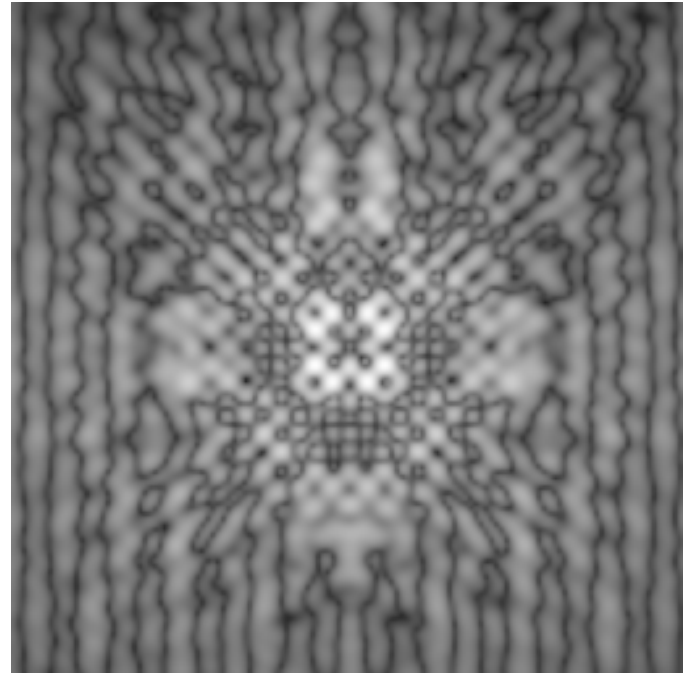


- White light, mixed polarization angles.
- Blurred: 0.16 rad
- Fixed: < 0.1 rad

Images: Zone Plate



Images: Hole Plate



Conclusions

- Polarization artifacts confirmed.
- Zone plate optics still useful, despite artifacts.
- Hole plate is insensitive to polarization, but harder to deconvolve.
- Both achieve < 0.1 rad angular resolution after deconvolution.

Acknowledgements

- Centre for Photonics Fabrication Research, Ottawa
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