
Off-axis self interference incoherent digital holography (SIDH) for single-shot recording

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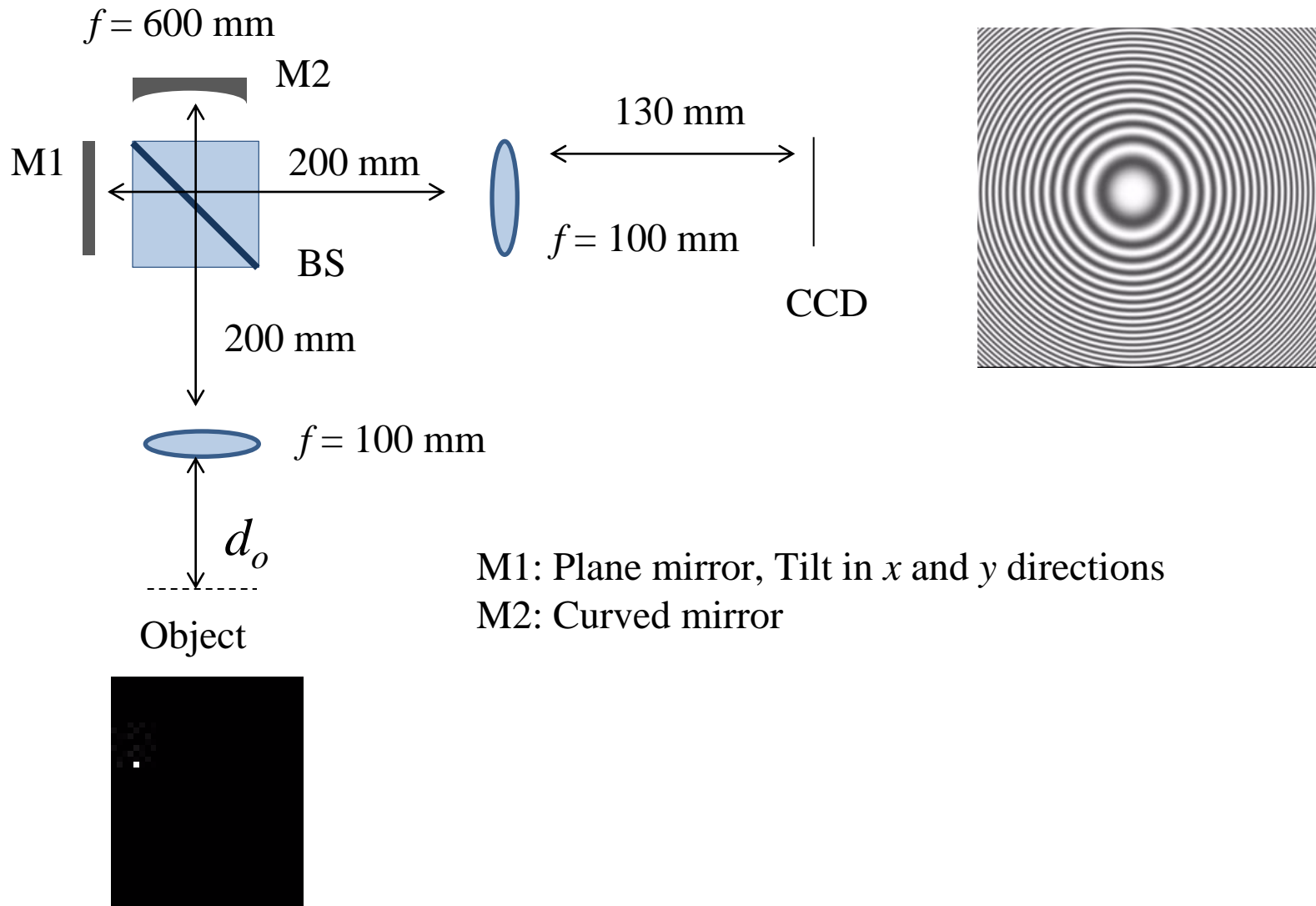
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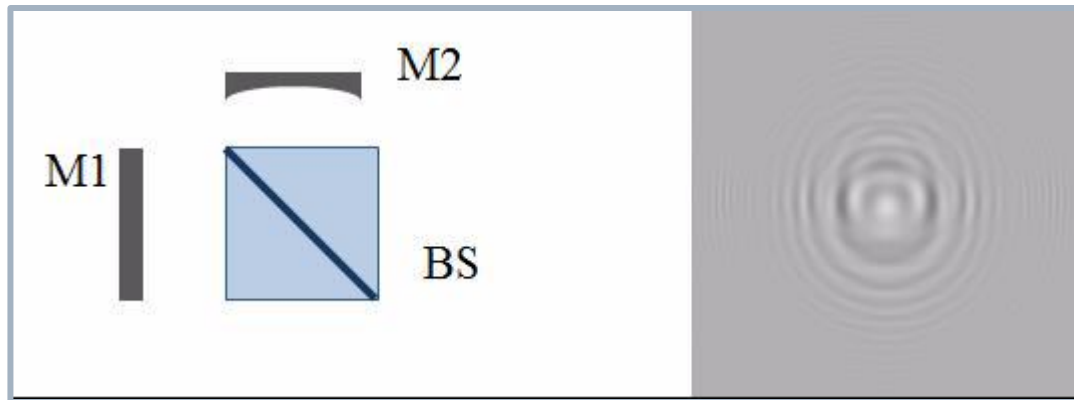
Outline

- Motivation & introduction
- Off-axis self-interference incoherent digital holography (SIDH) for single-shot recording
- Comparison of reconstructing methods
- Refocusing feature of the off-axis SIDH
- Conclusion

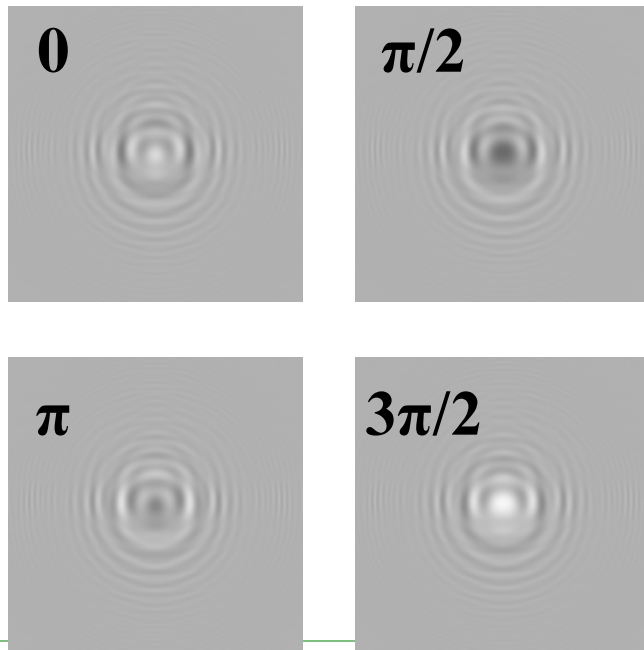
➤ Self-interference incoherent digital holography (SIDH)



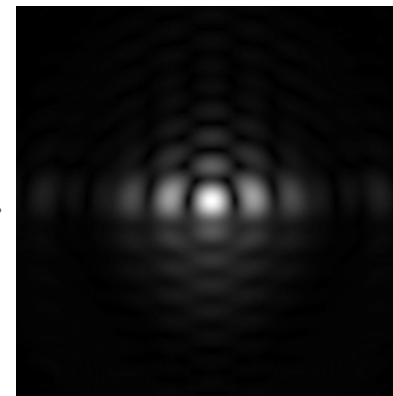
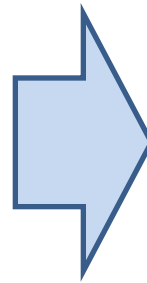
➤ Phase-shift interferometry



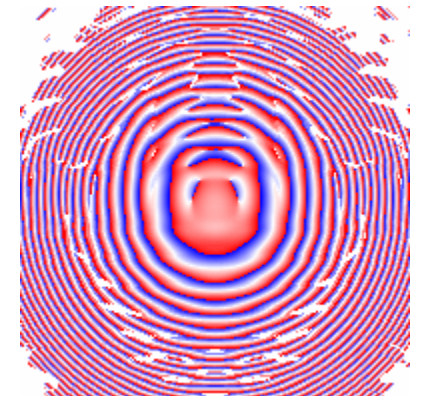
Phase-shifted images



Complex hologram



Amplitude

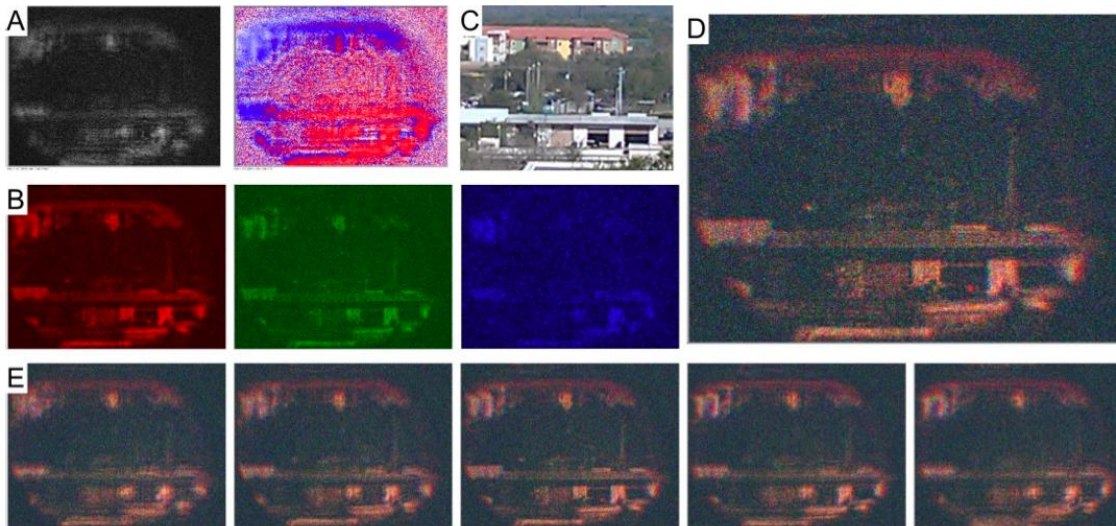


Phase

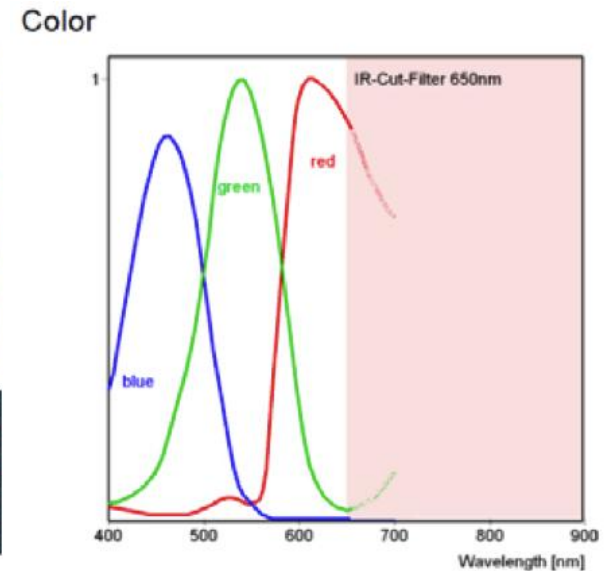
➤ Problems of phase-shift interferometry

1. The object should be stationary during multiple exposures.
2. The amount of phase-shift varies according to the wavelength of illumination.

Natural full-color holographic camera

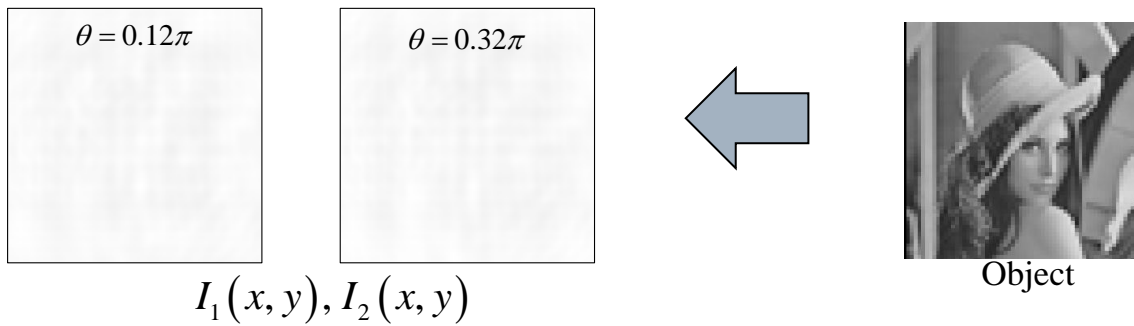


Eight phase-shifted images were used.



620:540:460 ~ 8:7:6

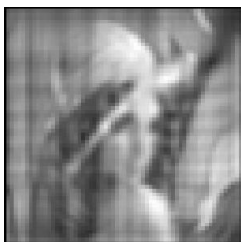
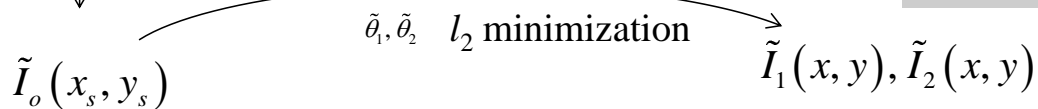
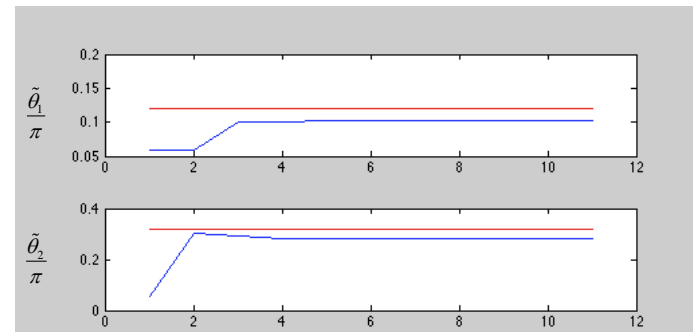
➤ Phase retrieval approach



Initial guesses

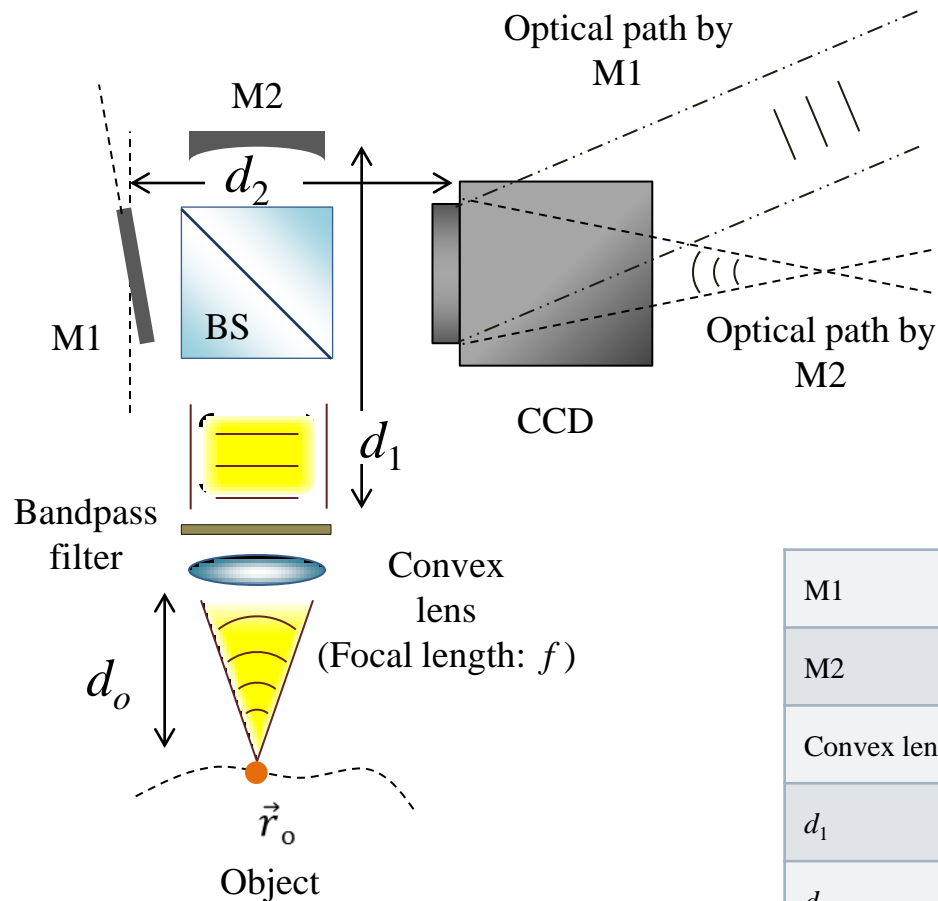
$$\tilde{S} \approx \frac{\sum_{x,y} (I_1(x, y) + I_2(x, y))}{NM}$$

$$\tilde{\alpha} = \tan^{-1} \left[\frac{\max(-I_1 + I_2)}{\max(I_1 + I_2 - \sum 4I_o)} \right]$$



$$\tilde{S}_{n+1} = \tilde{S}_n - \frac{\cos(\alpha)}{4C} \left(\tilde{S} - \frac{\sum_{x,y} (\tilde{I}_1(x, y) + \tilde{I}_2(x, y))}{NM} \right)$$

➤ Single-shot SIDH using off-axis configuration



M1	Plane mirror with tilt
M2	Curved mirror ($f = 600$ mm)
Convex lens	$f = 100$ mm
d_1	200 mm
d_2	330 mm (Additional lens @ 200 mm)

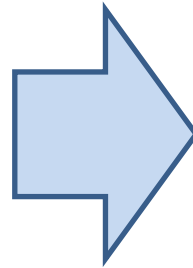
➤ Response to point source object

Off-axis inteferogram

$$u(\vec{r}) = A(\vec{r}_o) |Q(\vec{r}, \vec{r}_o) + L(\vec{r}; \vec{n})|^2$$

Envelope function

$$P(\vec{r}) = \exp\left[-\gamma \cdot \Delta(\vec{r})^2\right]$$



Off-axis inteferogram
(Incoherent)

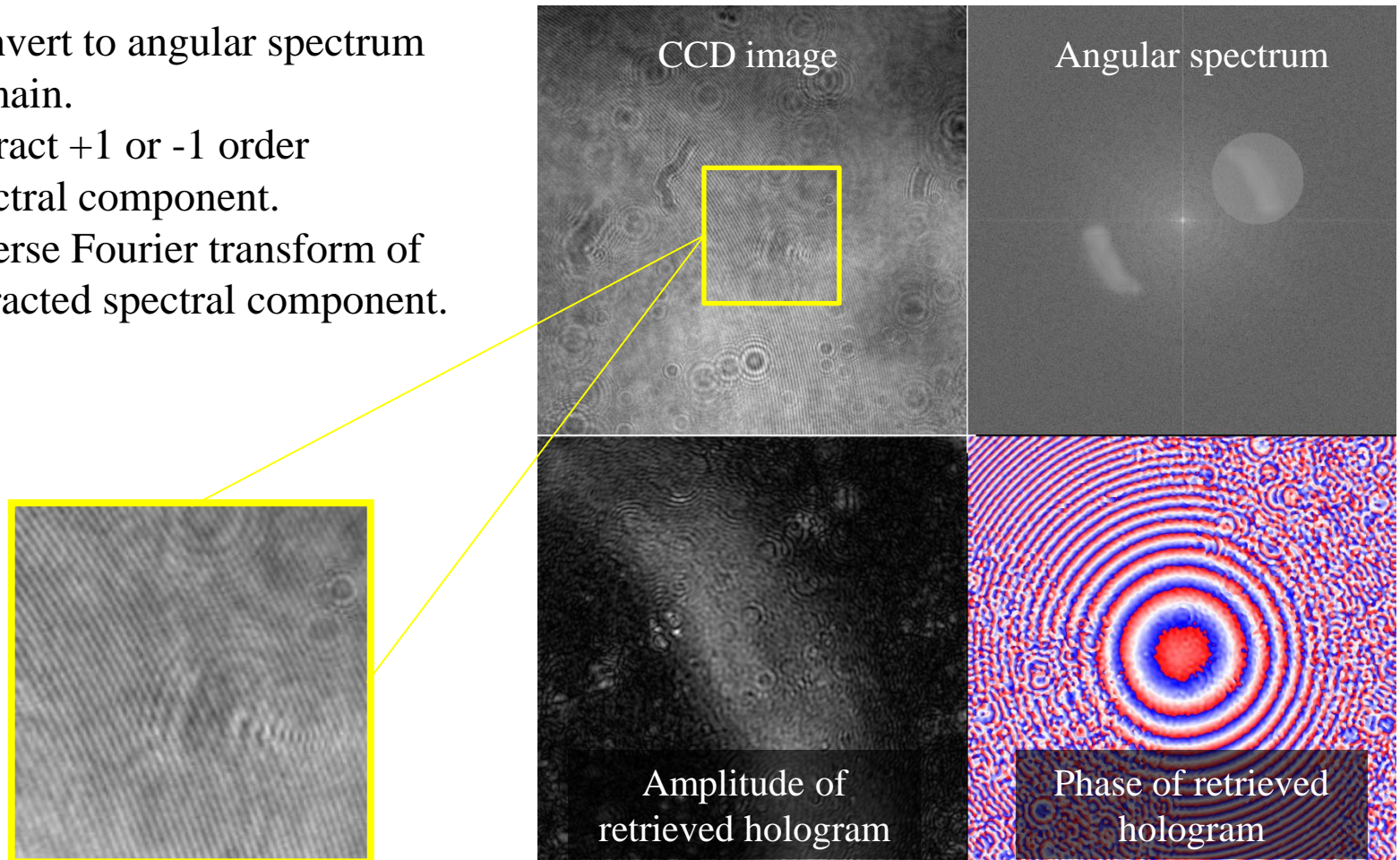
$$u(\vec{r}) = A(\vec{r}_o) \left(2 + P(\vec{r}) [Q \cdot L^* + Q^* \cdot L]\right)$$

For extended object:

$$U(\vec{r}) = \iint_{\vec{r}_o} A(\vec{r}_o) \left(2 + P(\vec{r}) [Q \cdot L^* + Q^* \cdot L]\right) d\vec{r}_o$$

➤ Hologram retrieval from recorded image

1. Convert to angular spectrum domain.
2. Extract +1 or -1 order spectral component.
3. Inverse Fourier transform of extracted spectral component.



➤ Reconstruction methods

Angular spectrum method

$$U(x, y; z) = F^{-1} \left\{ F \{ U_o(x_o, y_o) \} [k_x, k_y] \exp \left[iz \sqrt{k^2 - k_x^2 - k_y^2} \right] \text{circ} \left(\frac{\sqrt{k_x^2 + k_y^2}}{k} \right) \right\} [x, y]$$

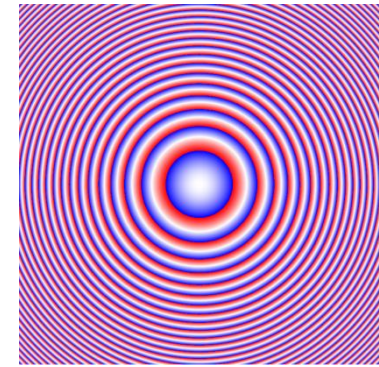
Fresnel propagation

$$U(x, y; z) = 2\pi \exp \left[\frac{ik}{2z} (x^2 + y^2) \right] \times F \left\{ -\frac{ik}{2\pi z} \exp(ikz) \exp \left[\frac{ik}{2z} (x_o^2 + y_o^2) \right] U_o(x_o, y_o) \right\} [k_x, k_y]$$

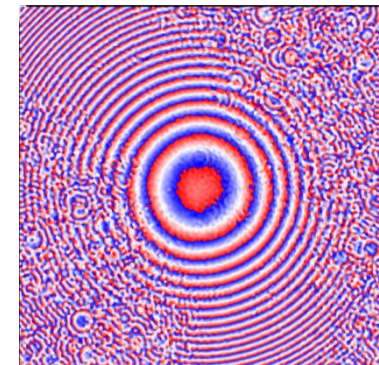
Cross-correlation with guide-star hologram

$$U(x, y; z) = U_o(x, y) * H^*(x, y; z)$$

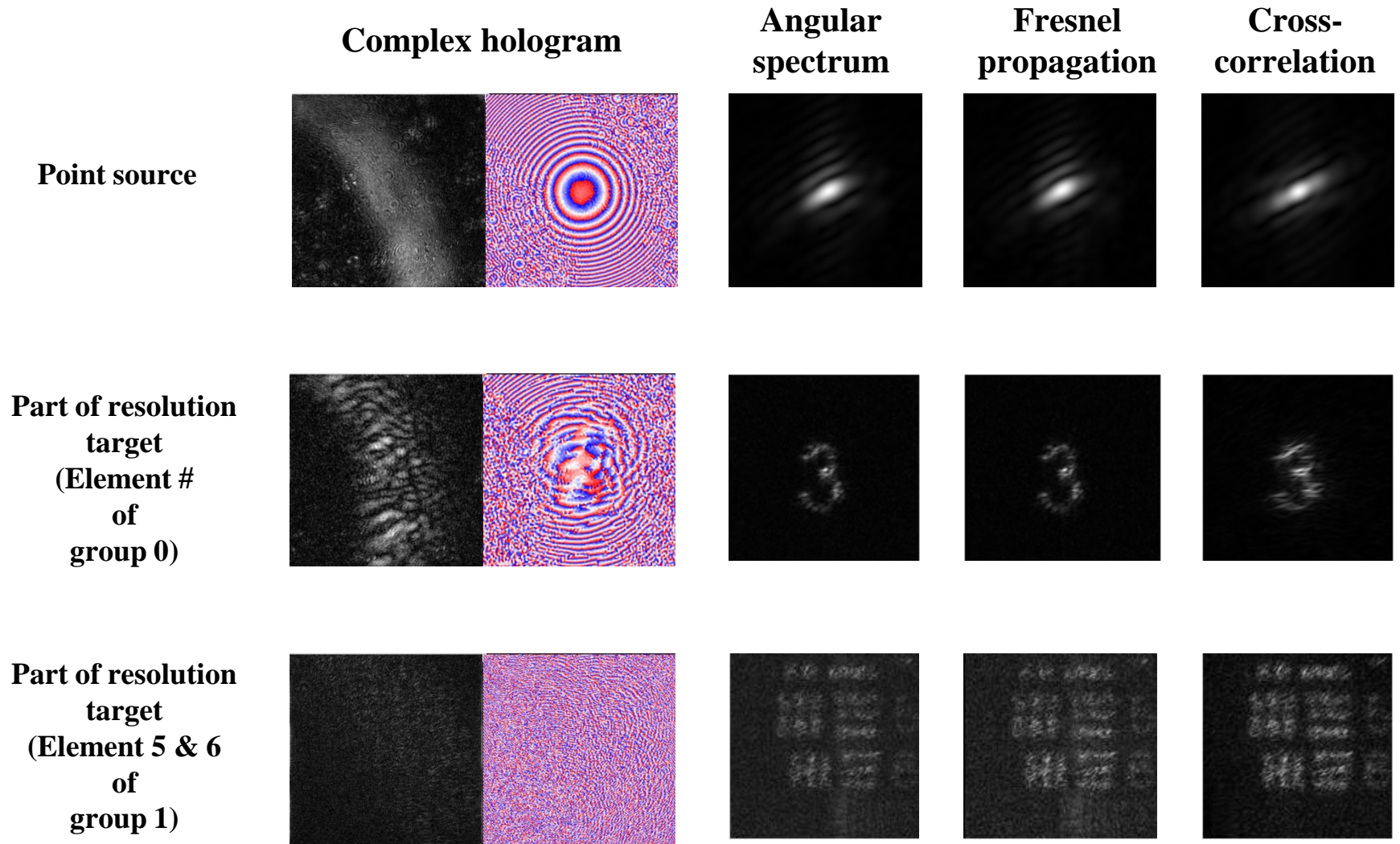
Propagation kernel



Phase of guide-star hologram



➤ Comparison of reconstruction results



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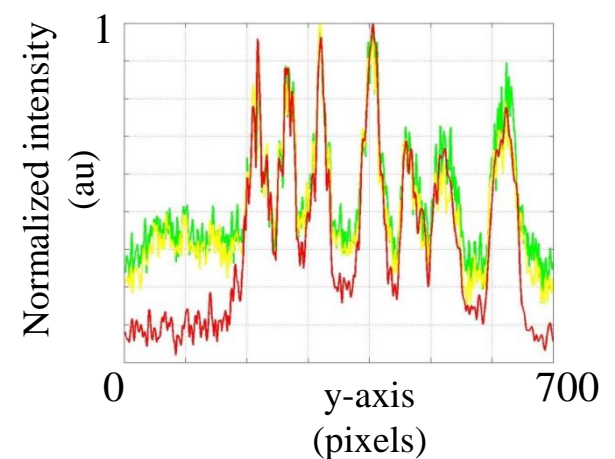
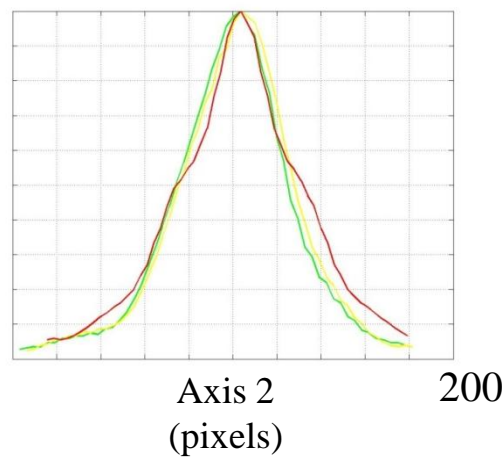
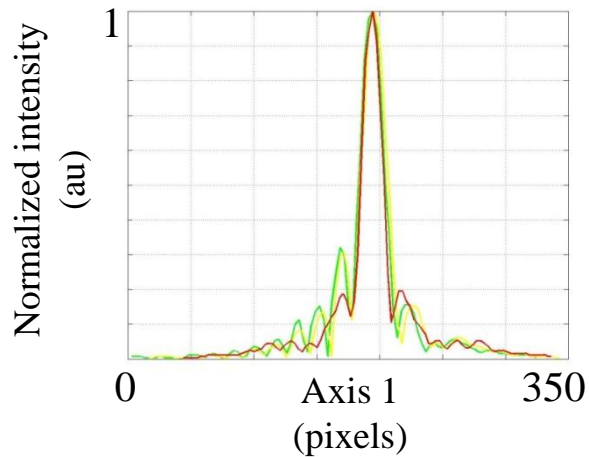
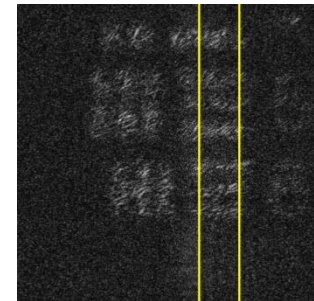
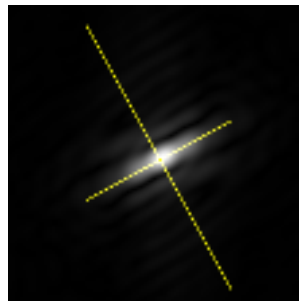
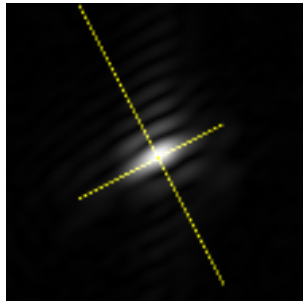
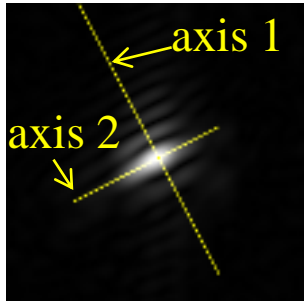
Point spread function

Extended object

Angular spectrum

Fresnel propagation

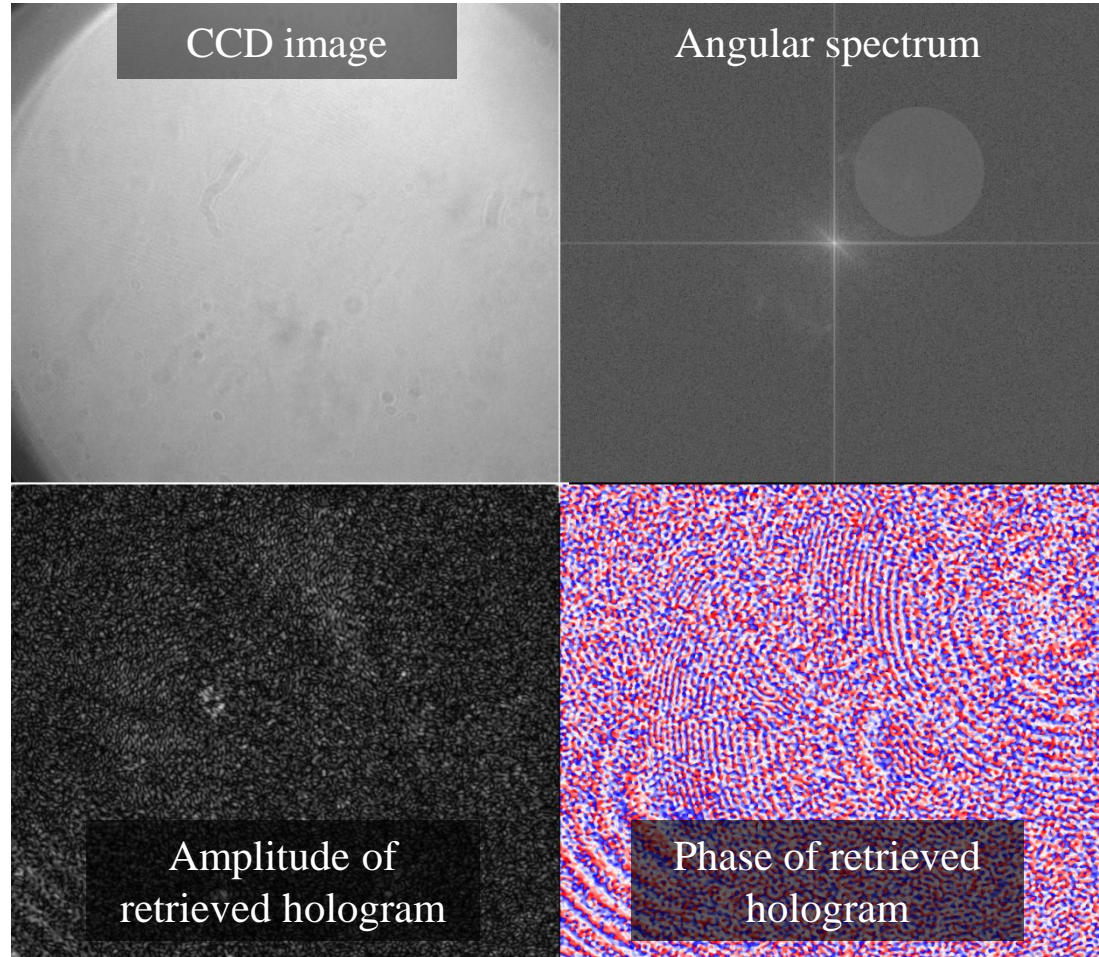
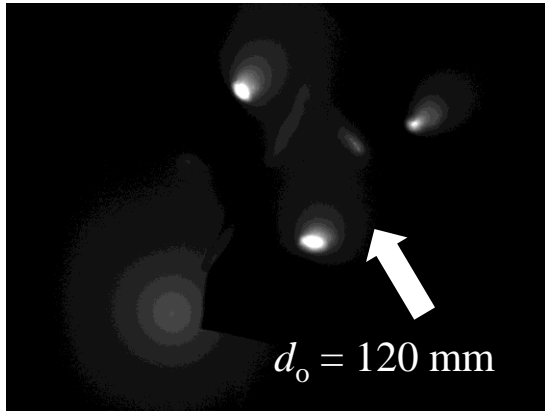
Cross-correlation with
guide-star hologram



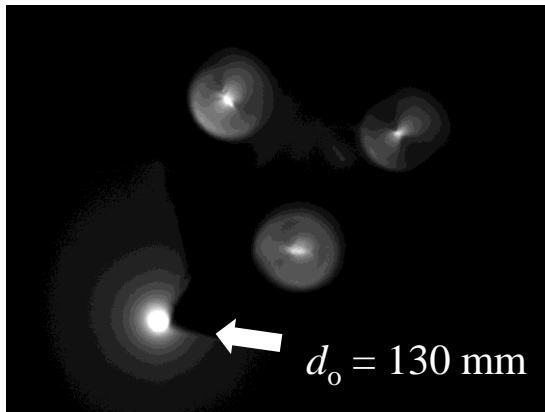
- Yellow: Angular spectrum
- Green: Fresnel propagation
- Red: Cross-correlation

➤ Test of refocusing feature (1)

Focus at three LEDs

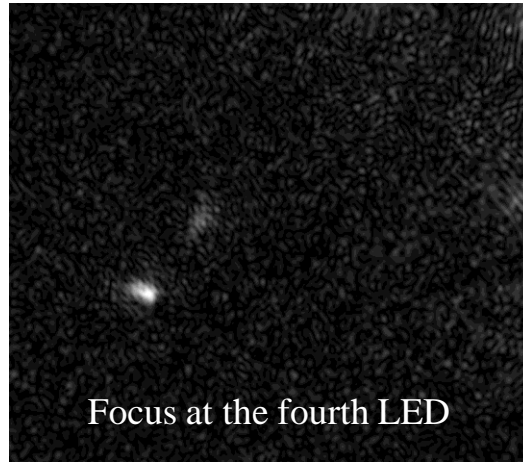
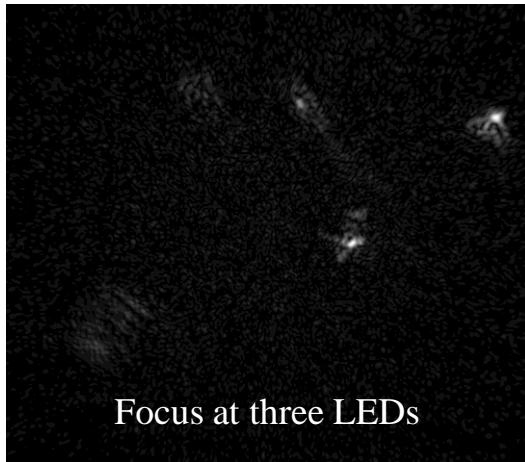


Focus at the fourth LED

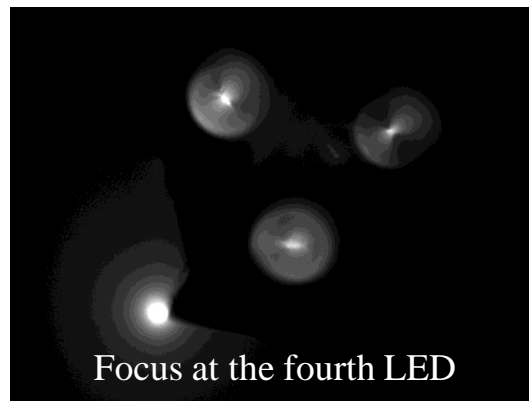
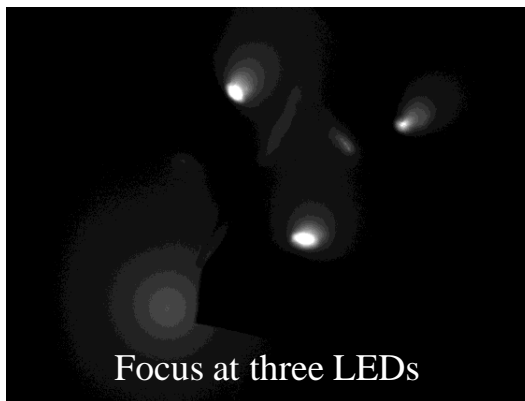


➤ Test of refocusing feature (2)

Numerical reconstruction



Direct image



➤ Conclusions

- Single-shot SIDH can be implemented with an off-axis configuration.
- Complex hologram can be retrieved by extracting +1 or -1 order in the angular spectrum domain.
- For the extended object, the cross-correlation with the guide-star hologram shows better reconstruction results.
- The feature of digital refocusing also works for the proposed scheme.

Thank you!