bias
Bremer Institut für
angewandte Strahltechnik GmbH

Spatial Light Modulator Based Propagation of Partially Coherent Speckle Fields in a 4f setup

Bachelor Thesis

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Outline

- Motivation
- Hypotheses
- The Theory of the Propagation of Light
- Experimental and Numerical Methods
- Results from the Experiment and the Simulation
- Conclusion

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Motivation

- Measuring micro parts (size ~ 1mm)

- Requirements:
  - High accuracy
  - High speed
  - Robustness
  - Extended depth of field

- State of the art:

  No current method can fulfill all the requirements at the same time

Motivation

- Measuring micro parts (size ~ 1mm)

	Phase evaluation	SWLI and OCT	SCP
High accuracy	✗	✓	✓
High speed	✓	✗	✓
Robustness	✗	✗	✗
Extended depth of field	✓	✓	✗

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Hypotheses

I. The 4f setup can be simulated on the basis of Fourier optics.

I. The Speckle size can be predicted from parameters of the light source and the 4f setup

I. The spatial light modulator can move the focal plane in the 4f setup

I. The depth of focus can be predicted from parameters of the light source and the 4f setup

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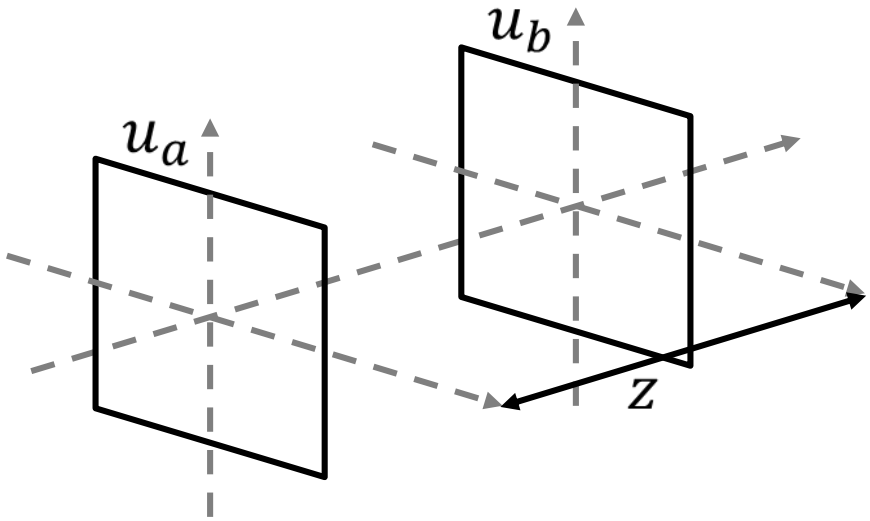
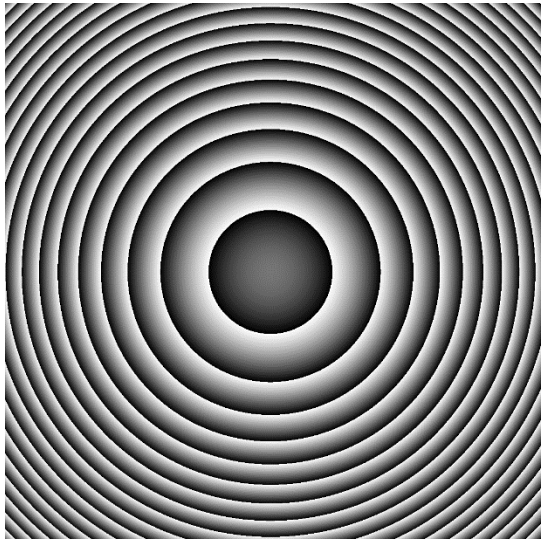
Theory of Propagation of light





Transfer Function

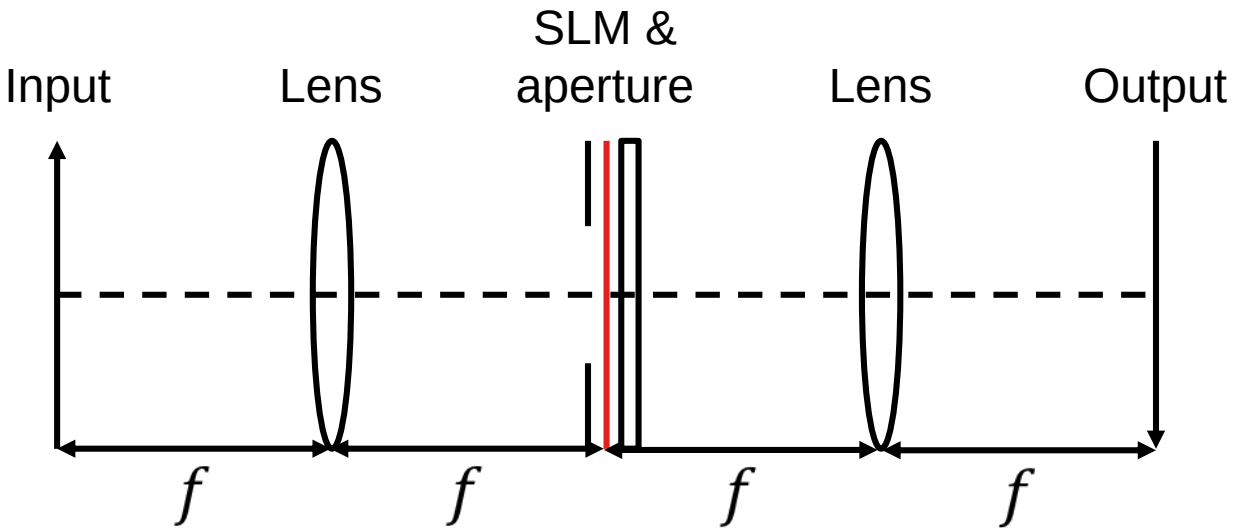
$$H_z = e^{ikz\sqrt{1-\lambda^2\xi^2}}$$

$$u_b = u_a * h_z$$

$$\mathcal{F}^{-1}\{U_b\} = \boxed{u_b = \mathcal{F}^{-1}\{U_a \cdot H_z\}}$$

⇒ The transfer function of propagation H_z is a phase modulating function in the Fourier domain

The 4f setup



- A Fourier representation is created in the center
- The SLM utilizes the transfer function H_z to create a propagated representation in the output plane

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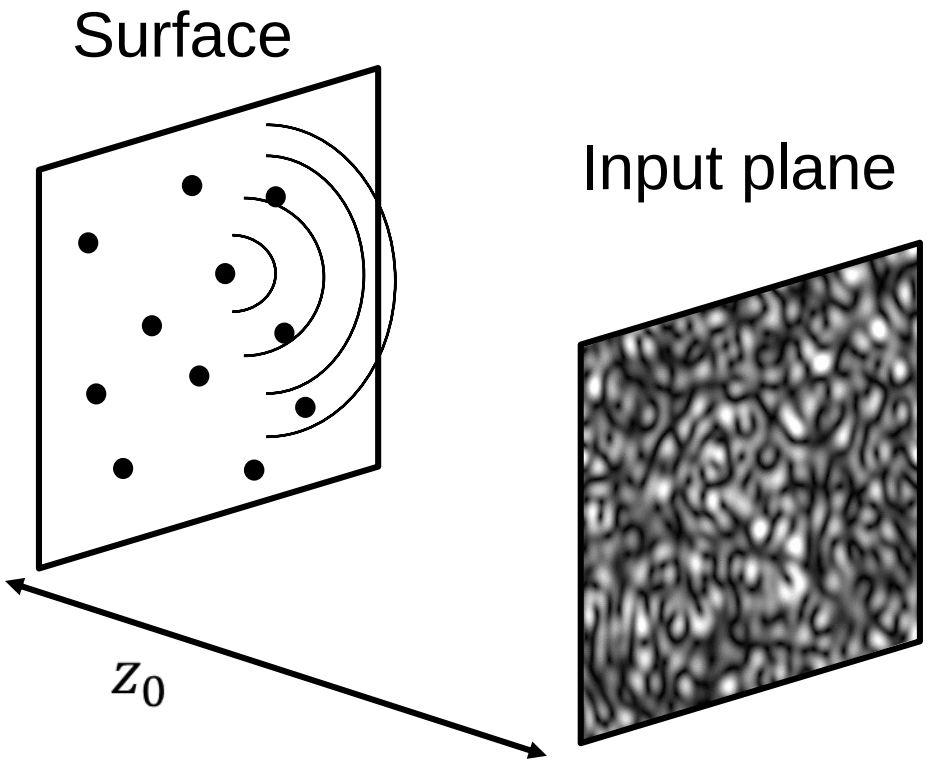
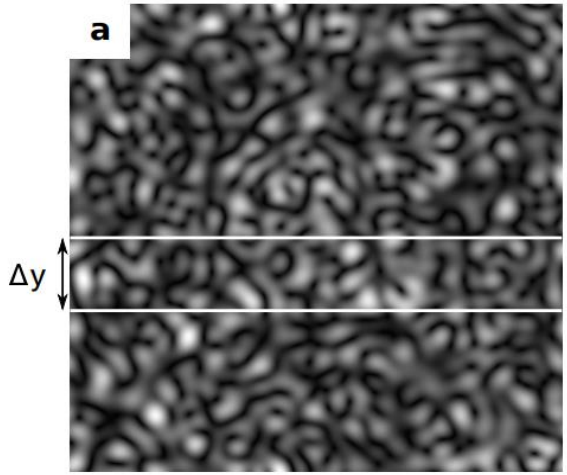
Simulation of the Object



- The rough surface is approximated by a set of points
- The superposition of the spherical waves create the speckle pattern

Speckle Size Estimation in the Simulation



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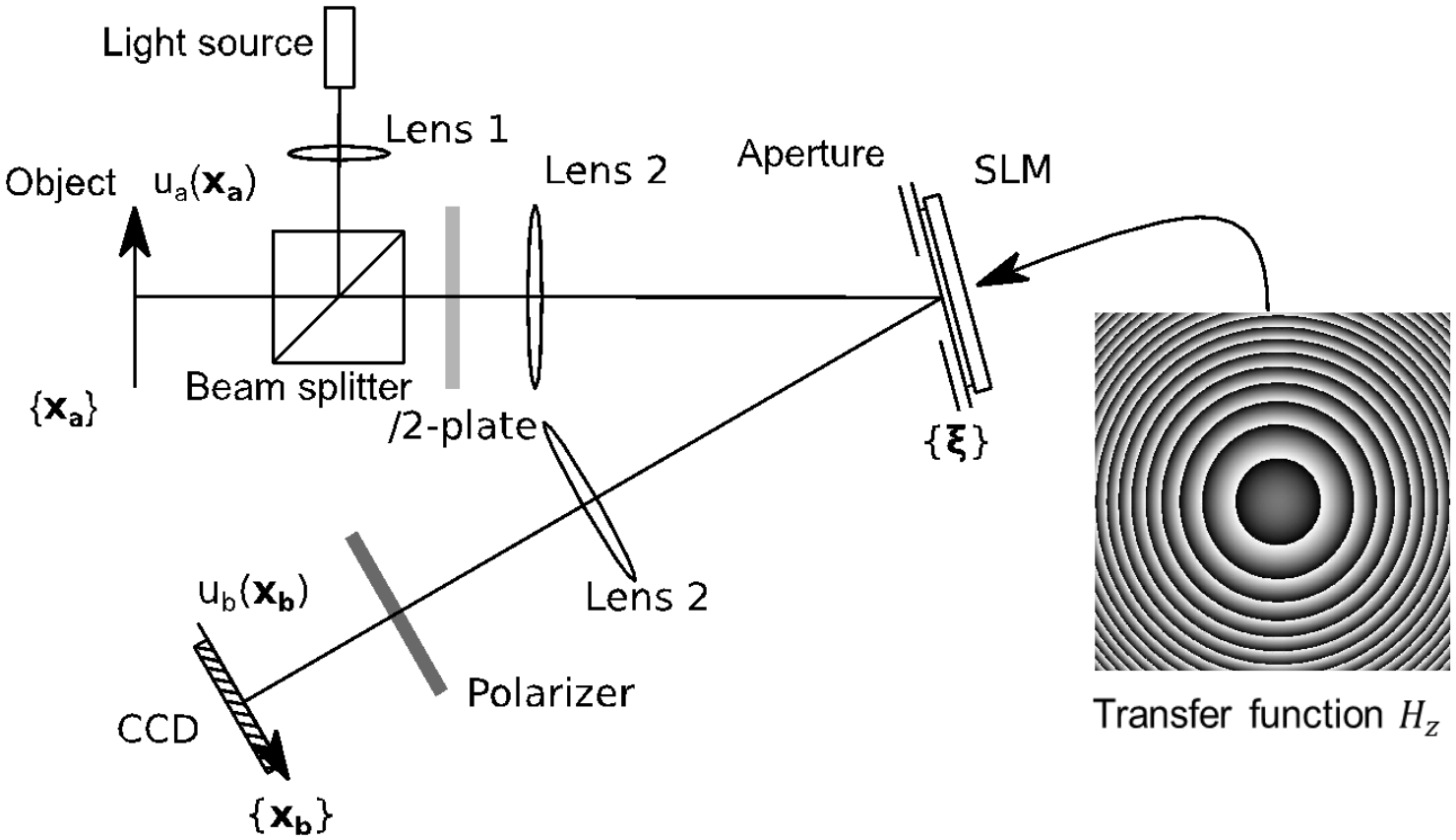
Experimental Setup



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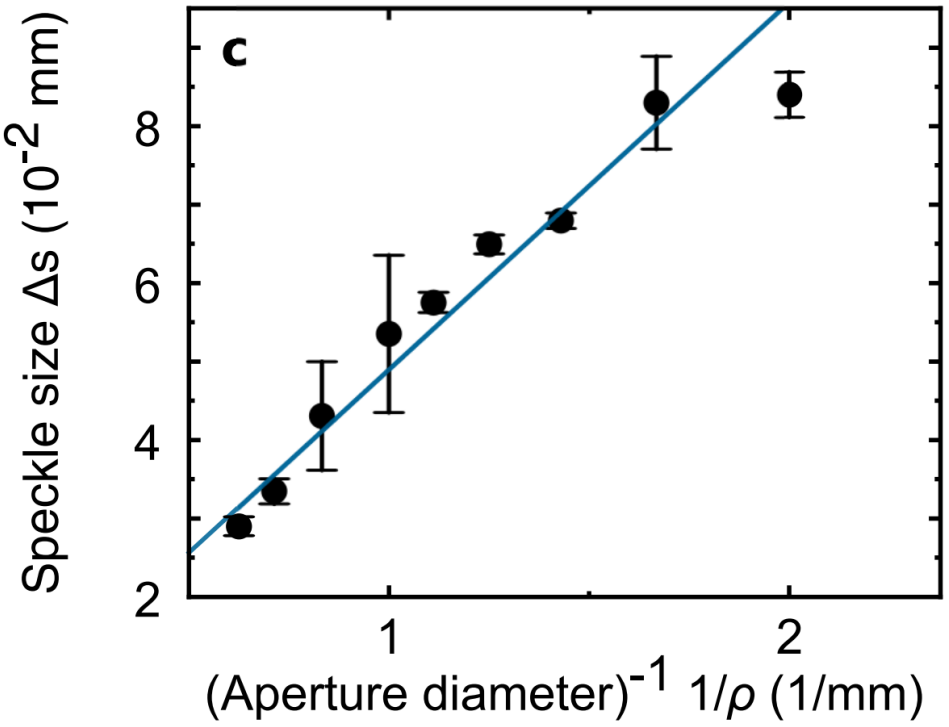
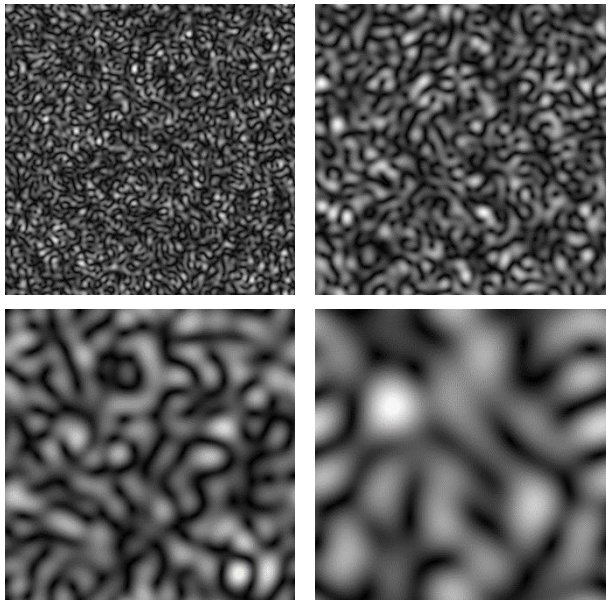
Simulation: Speckle Size

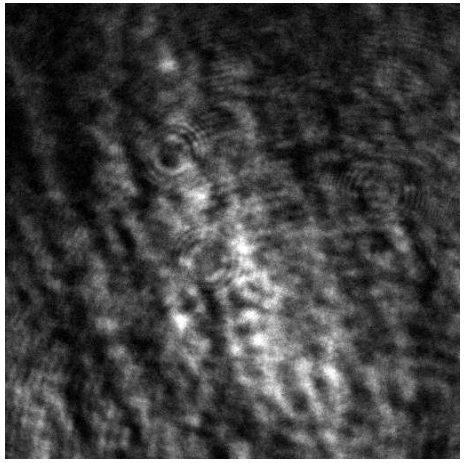




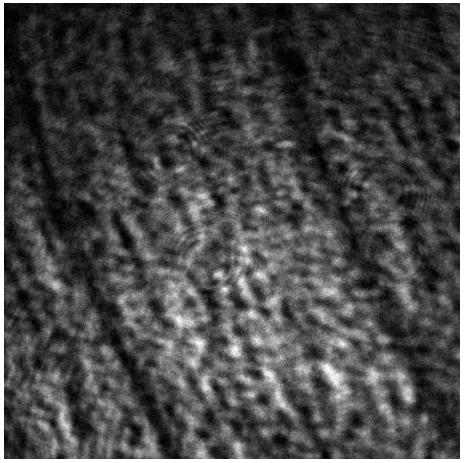
⇒ The Speckle size Δs is inversely proportional to the aperture diameter ρ

$$\Delta s \propto \frac{1}{\rho}$$

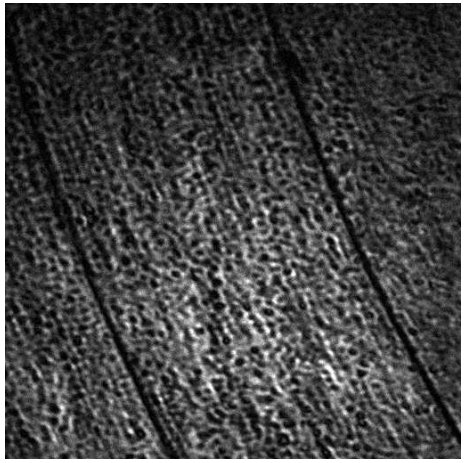
Experiment: Speckle Size



$\rho = 3$ mm



$\rho = 4.5$ mm



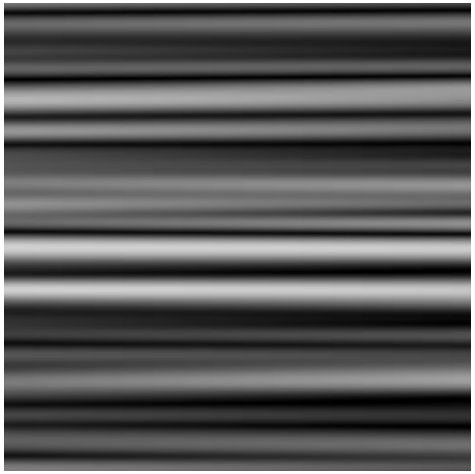
$\rho = 6$ mm

ρ: Aperture diameter

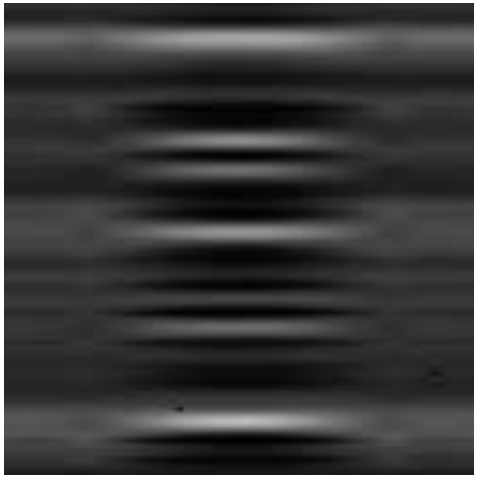
⇒ Experimental validation of $\Delta s \propto \frac{1}{\rho}$

Simulation: Partial Coherence

Amplitude cross sections of



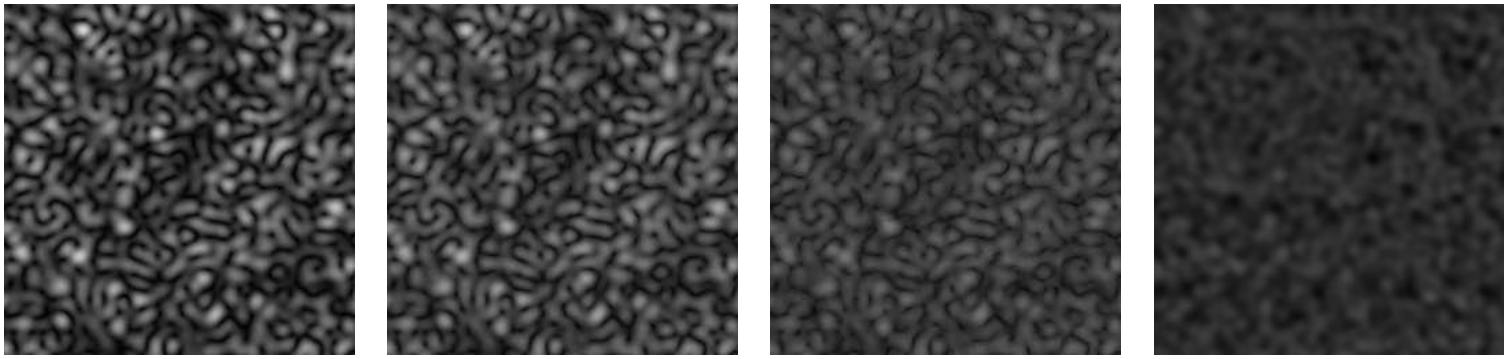
- a fully coherent wavefield



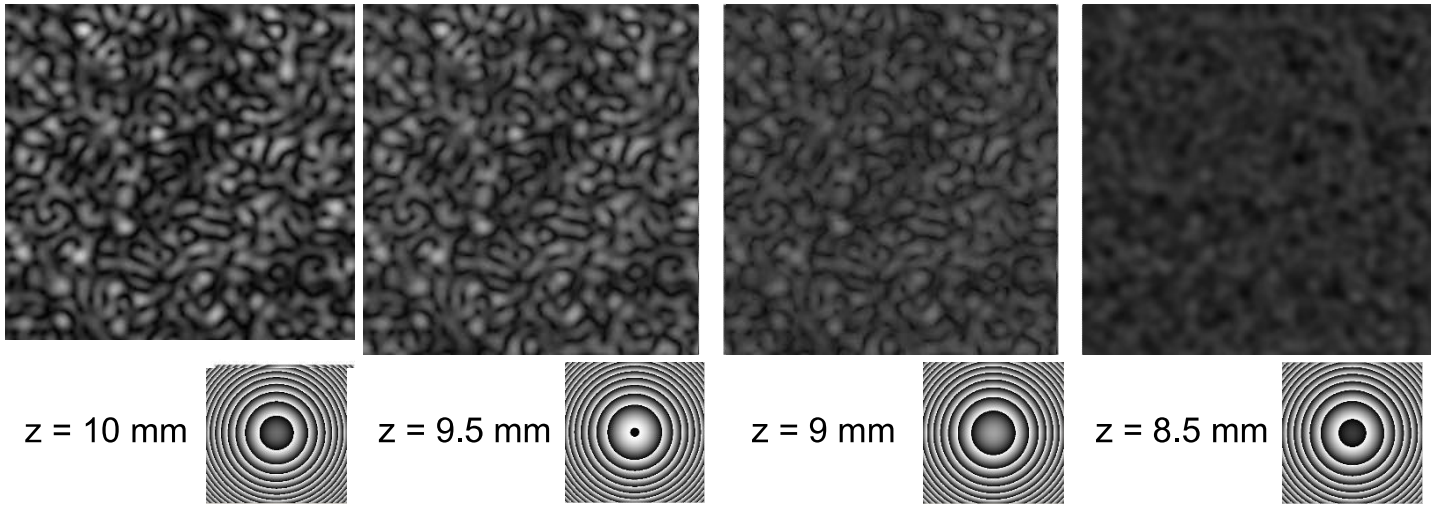
- a partially coherent wavefield

⇒ For partially coherent illumination, the area of high contrast is restricted to the vicinity of the surface

Simulation: Partial Coherence



Simulated Results



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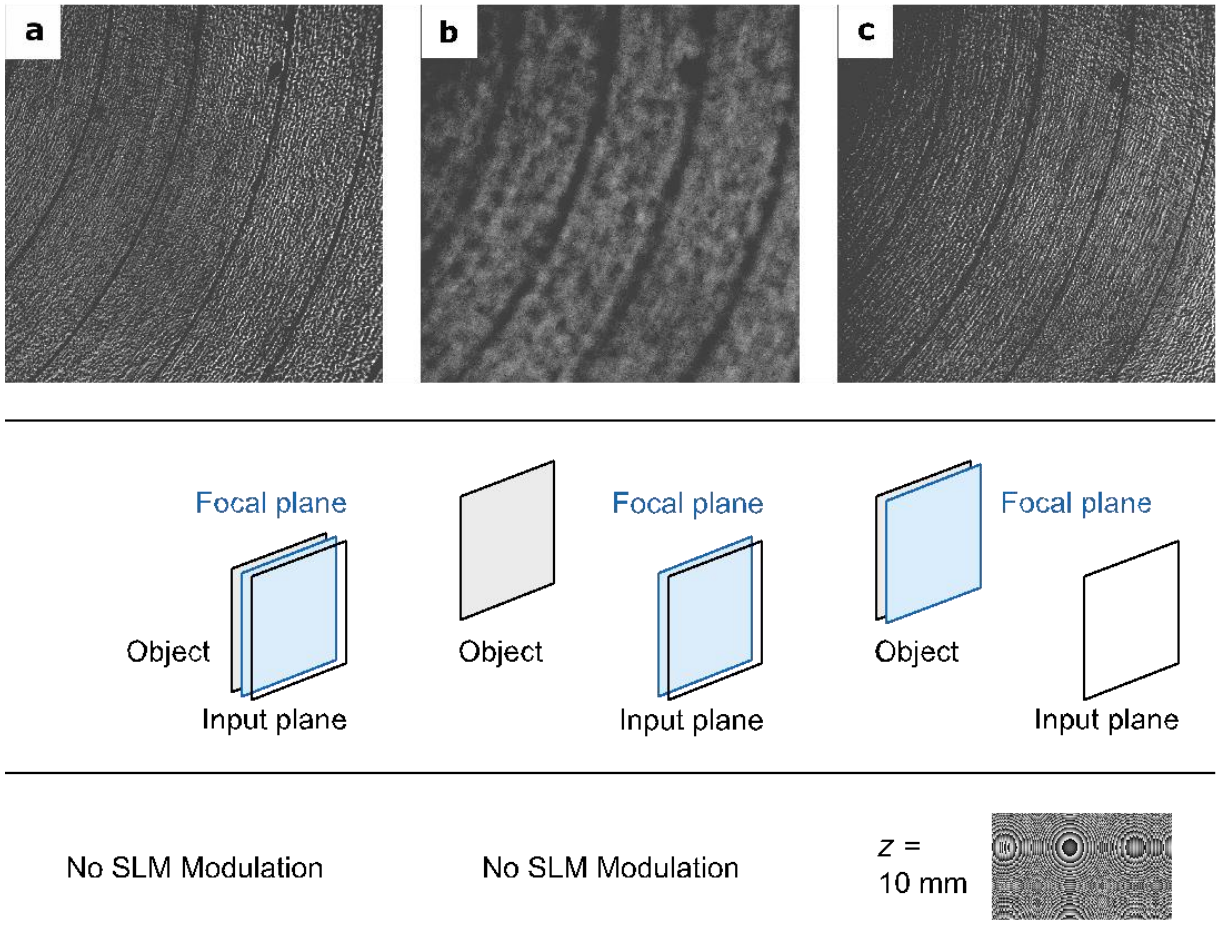
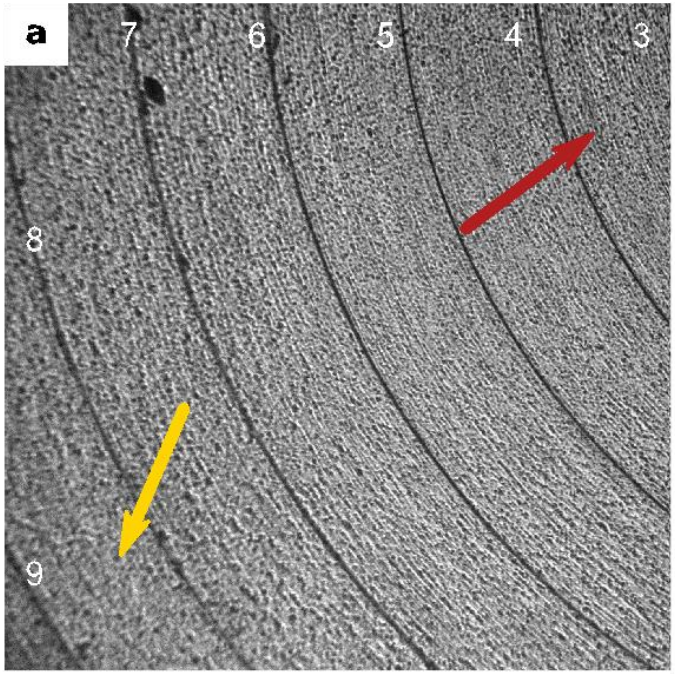
Experimental Results

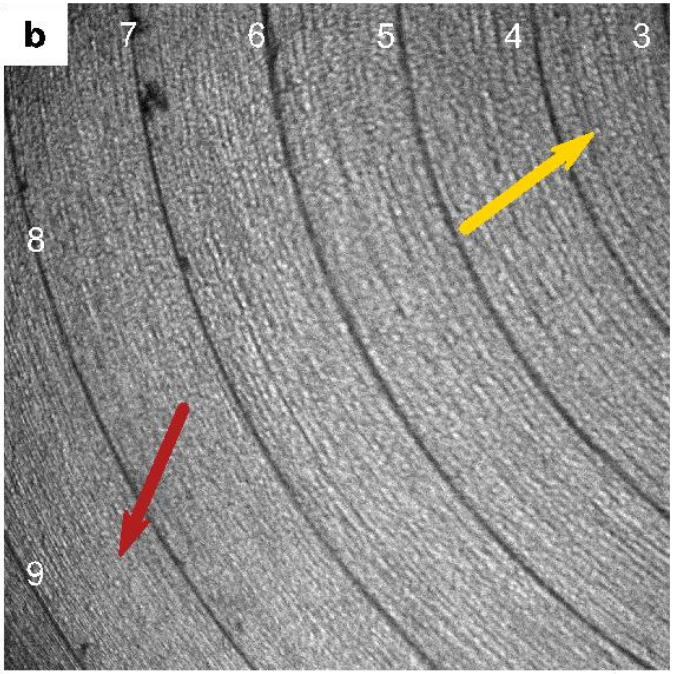
SLM Propagation



Experimental Results

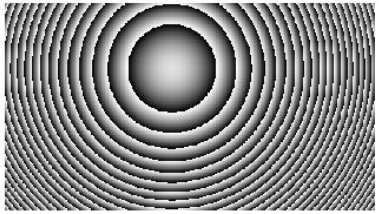
Contrast Difference





No SLM Modulation

z = 3 mm



Conclusion

	Simulation	Experiment
I. Simulation of the 4f setup on the basis of Fourier optics	✓*	
II. Predictability of Speckle size from parameters of the 4f setup and the light source	✓	(✓)
III. Spatial light modulator based propagation	✓	✓
IV. Predictablity of the area of high contrast for partially coherent illumination	✓	(✓)

Conclusion

Hypotheses:

I. Validation in part
II. Full validation in simulation
validation in part experimentally
III. Full validation in simulation &
experiment
IV. Evidence strongly sugesst validity