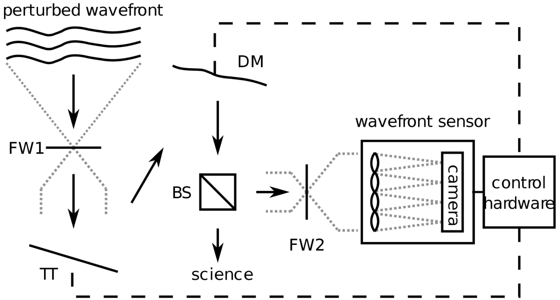
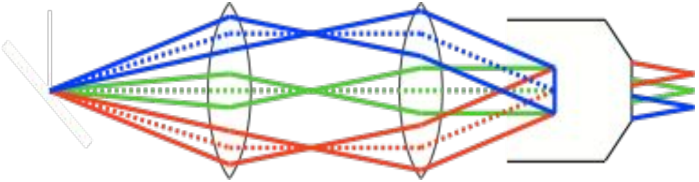
P

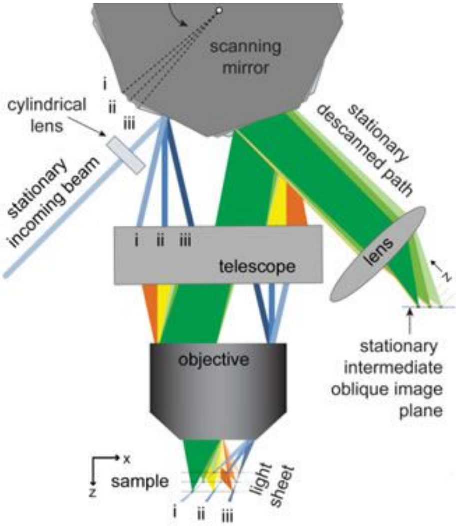
# SLM? Yes LM!

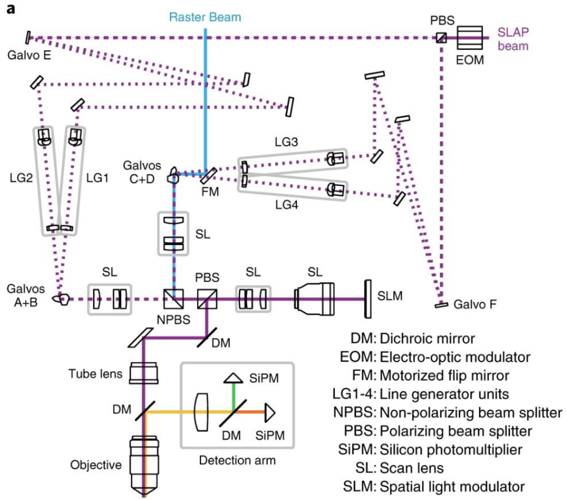
Phase Blaze
(Vivek, Vijay, Jeff)

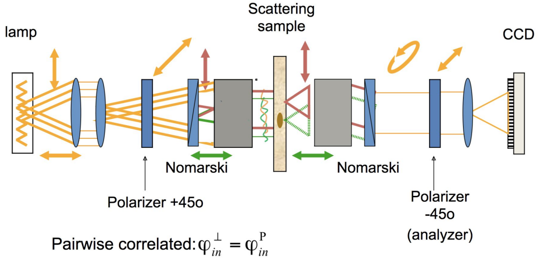
# Photonics toolbox



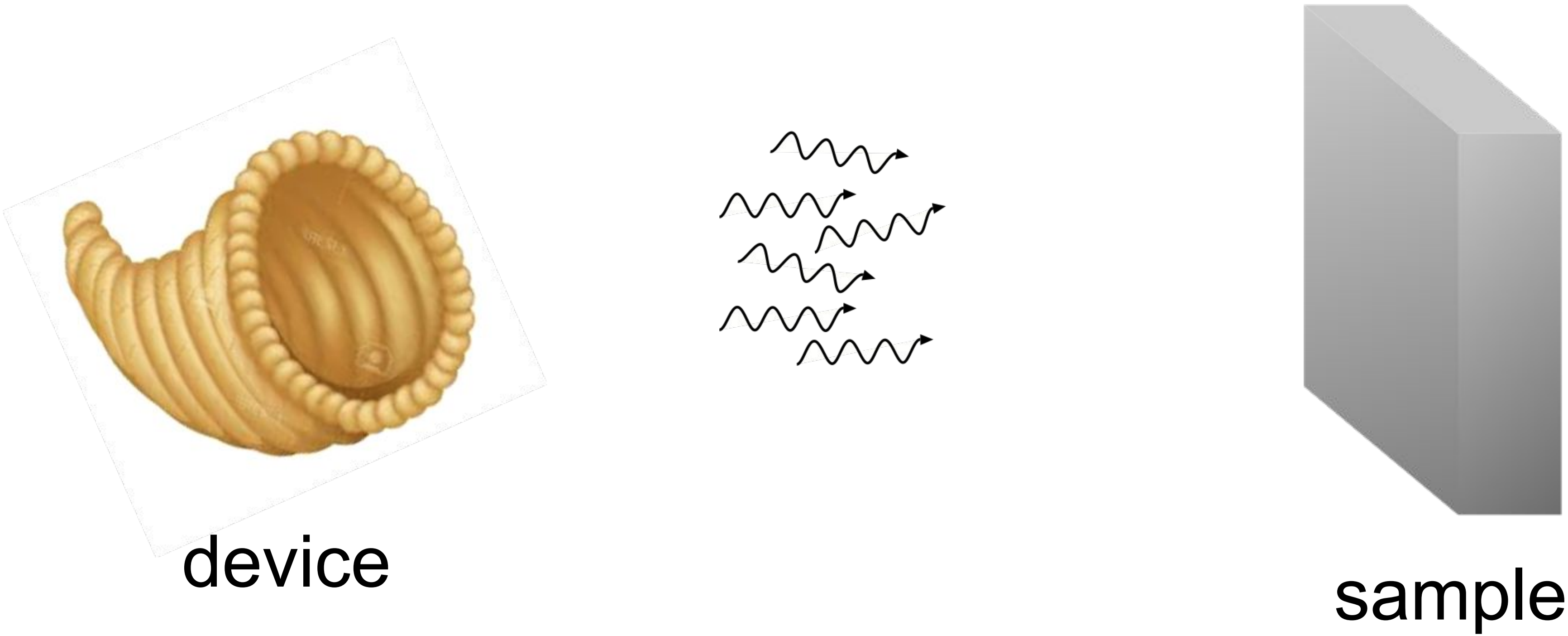





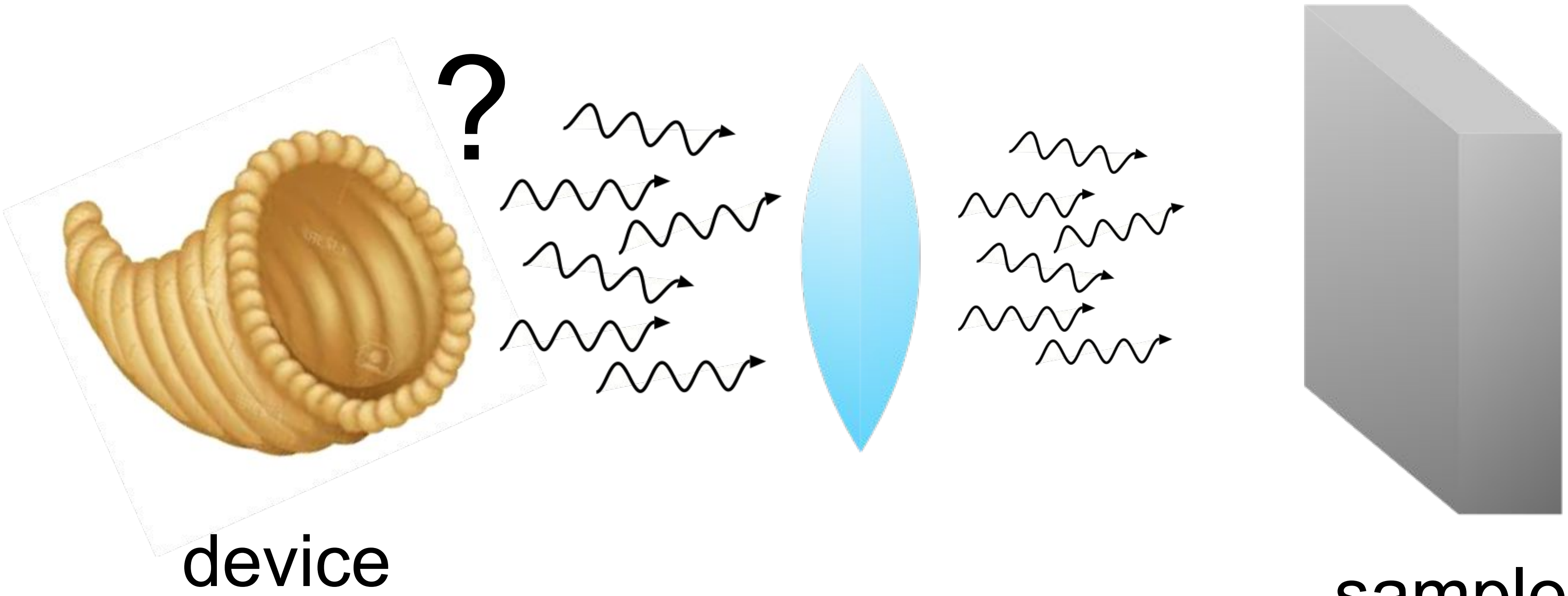



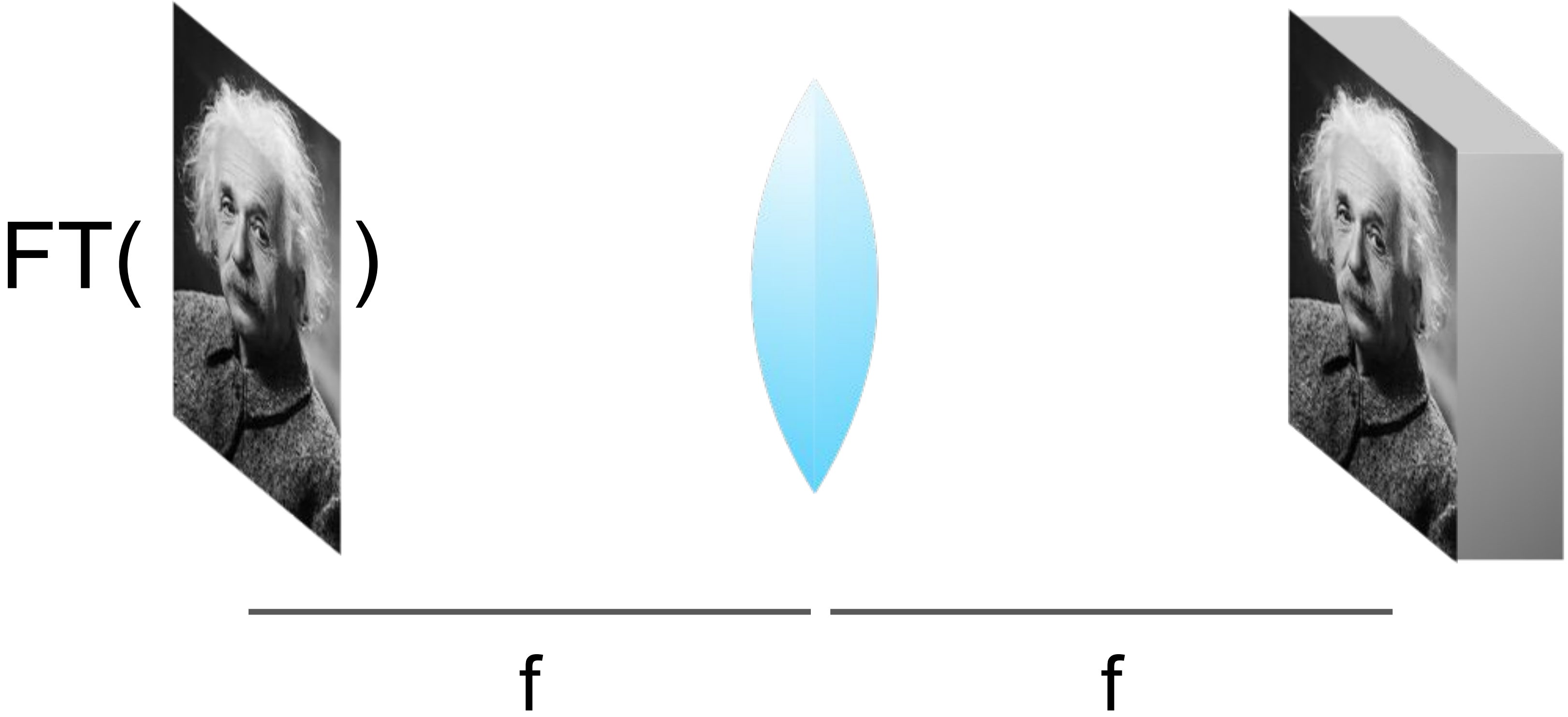
# Goal: fully flexible light shaping



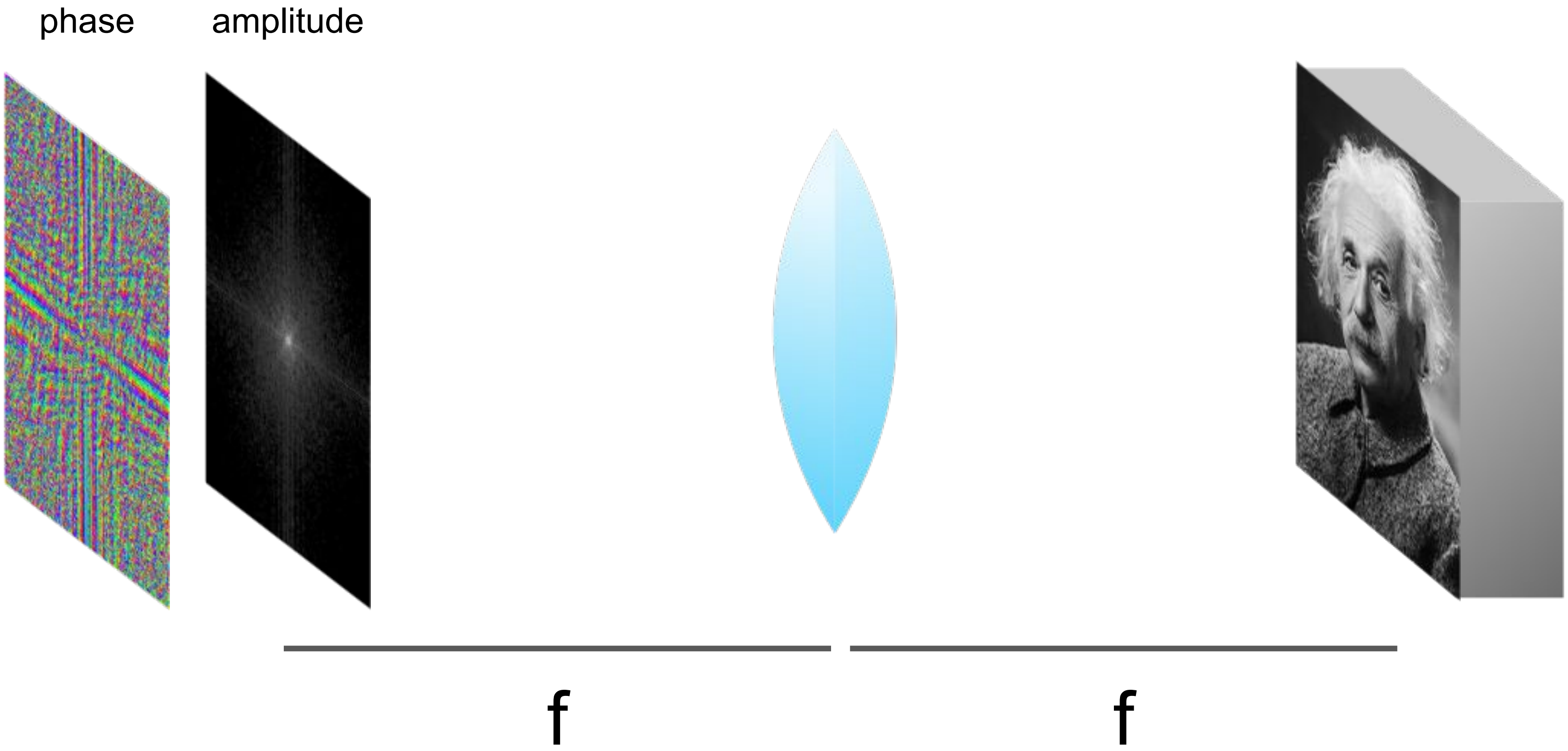
# Goal: fully flexible light shaping



# Goal: fully flexible light shaping

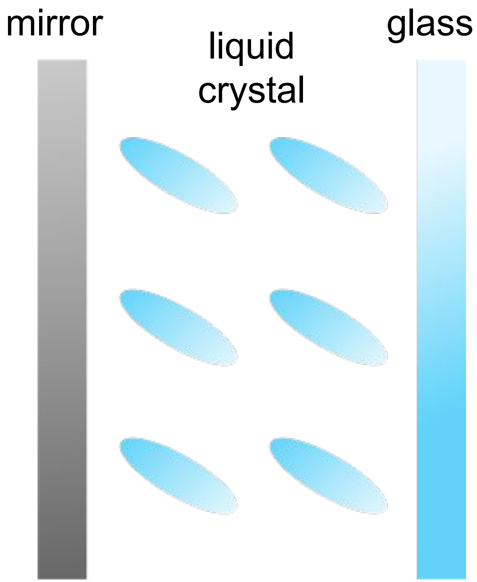


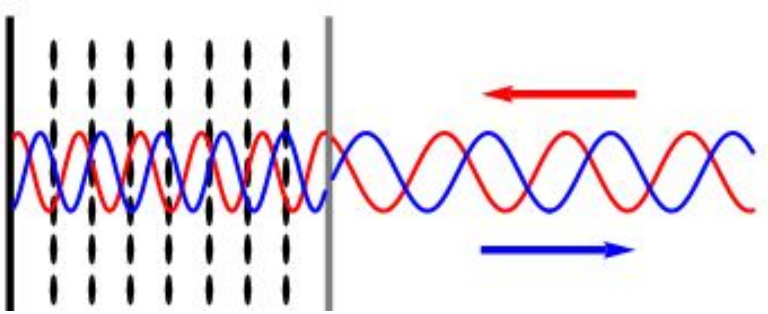
# Goal: fully flexible light shaping



# a solution for *mostly* flexible light shaping

## Spatial Light Modulator (SLM)



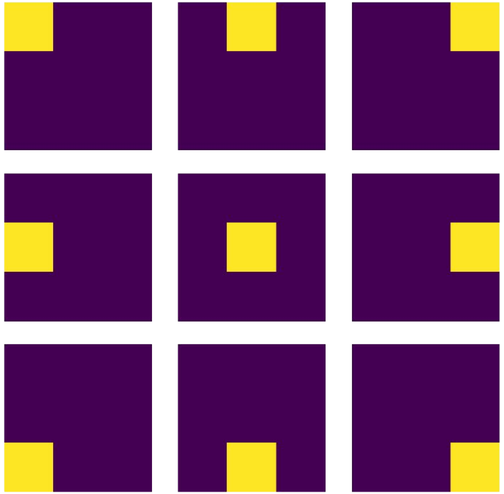
gif from Wikipedia

sets *phase* but not *amplitude*

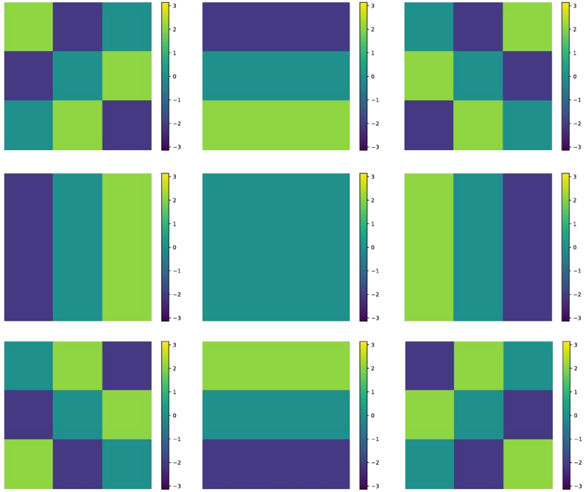
# Intuition for Fourier transform

Fourier transform: Converts between pixel and wave representation

Pixels: local in space



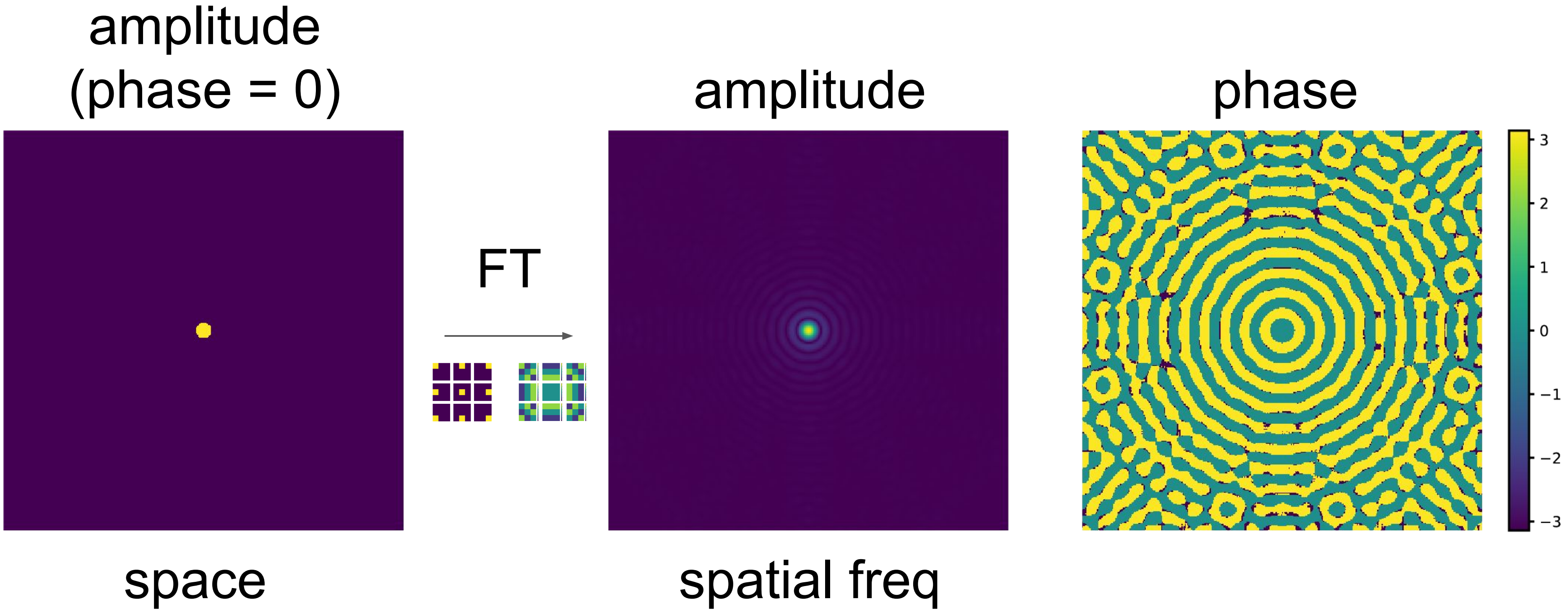
Waves (phase): broad in space



**Images:** Weighted sum of pixels

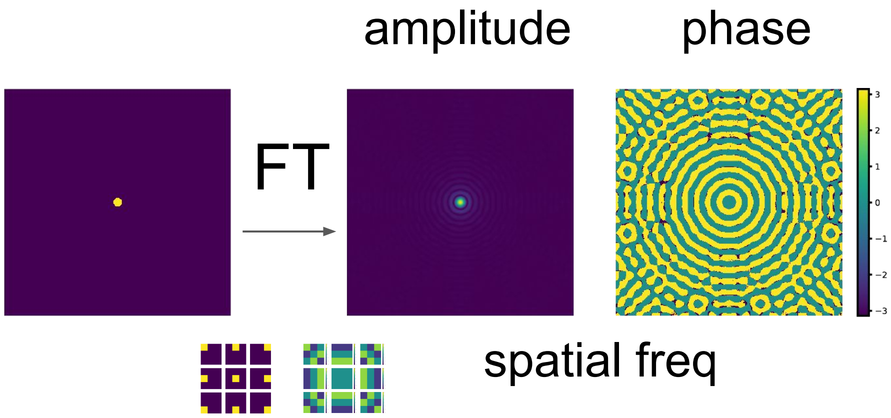
Weighted sum of waves with frequencies, phases

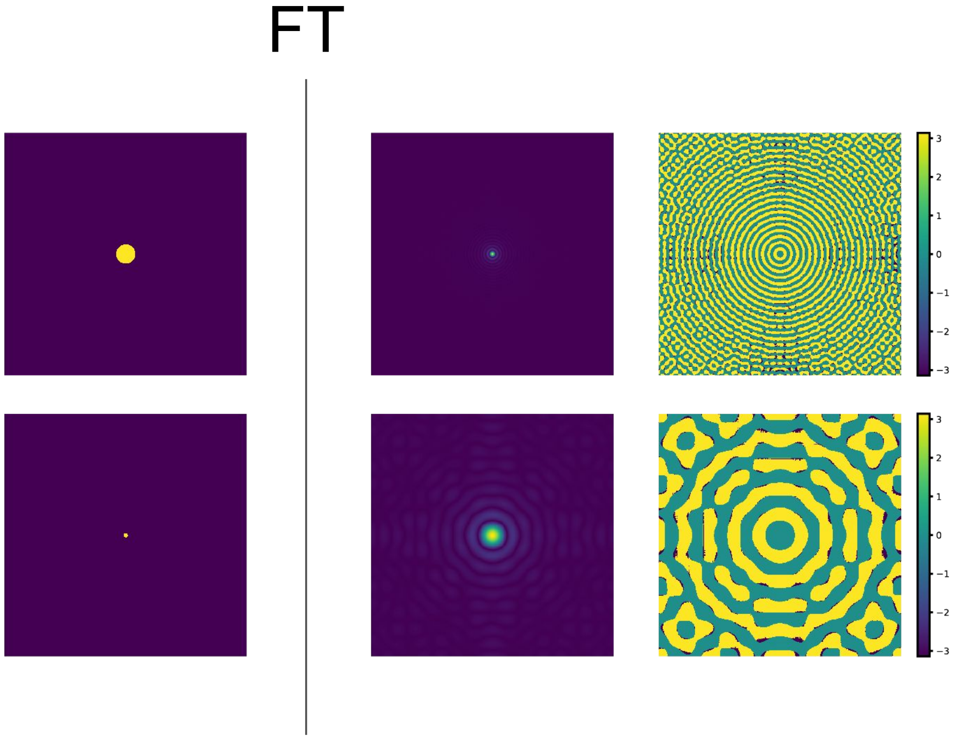
# Intuition for Fourier transform



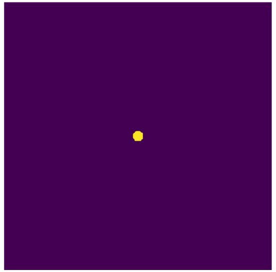
# Intuition for Fourier transform:
# **Scaling**

Signals broad in space are narrow in spatial freq
Signals narrow in space are broad in spatial freq



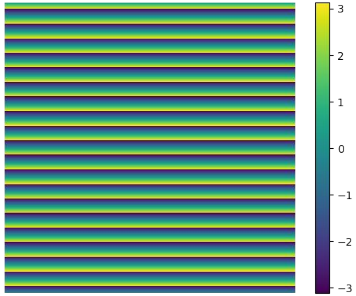



# Intuition for Fourier transform:
# **Translation and Phase**

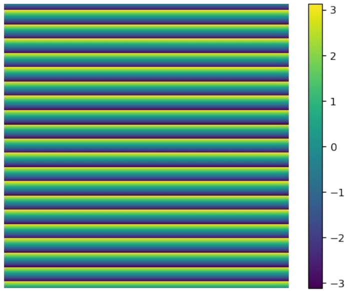


FT →

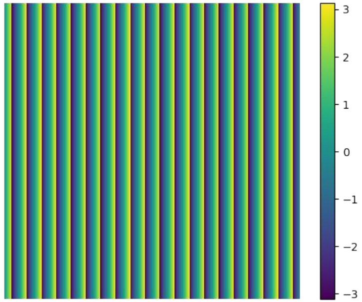
Translate up



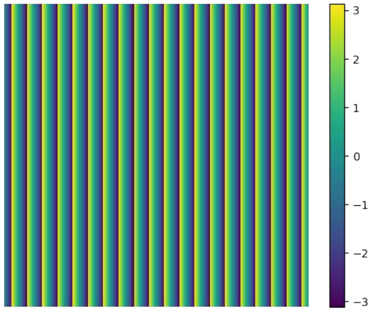

Translate down




Translate left



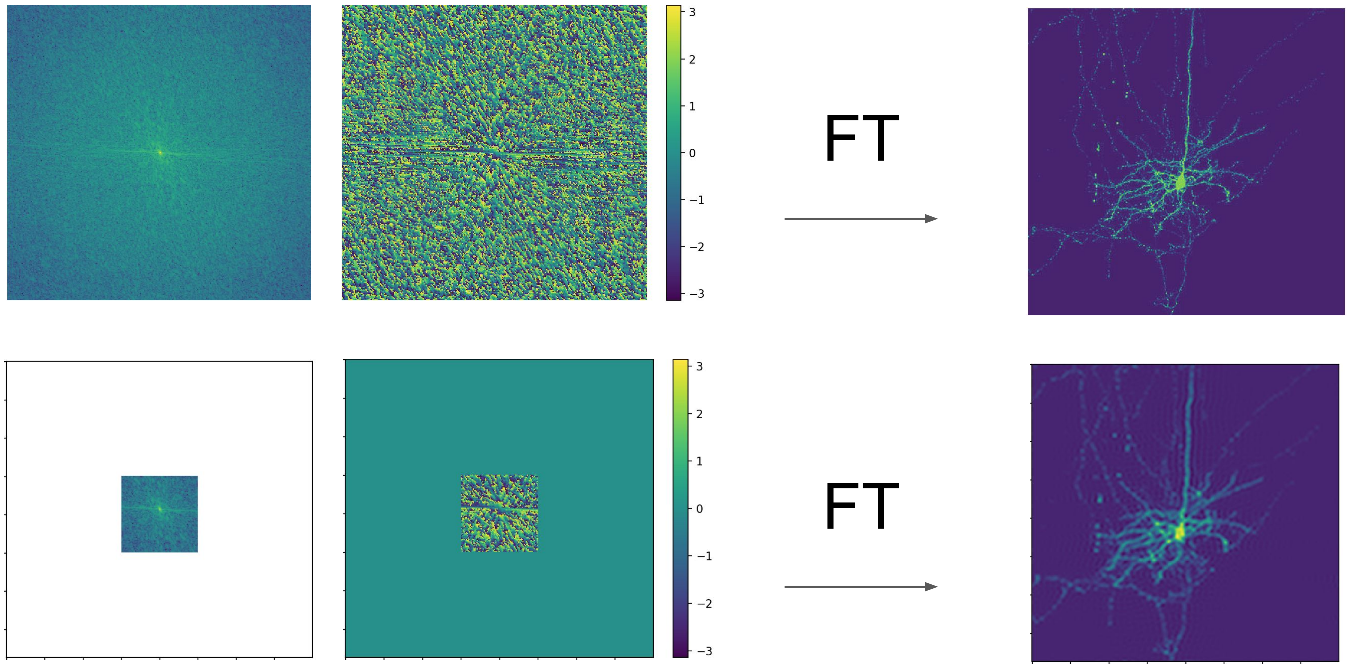

Translate right




Multiplication by plane wave in one domain
is shift in the other domain
Consequence for steering a pattern.

# Intuition for Fourier transform: **Windowing and Resolution**

Windowing in one domain is blur in the other.
Consequence: if you don't fill your SLM, you get blur in hologram



# Intuition for Fourier transform:

Broad in one domain, narrow in the other domain

Shift in one domain, multiply by plane wave in other domain

Window in one domain, blur in the other domain

(Multiplication in one domain is convolution in other domain)

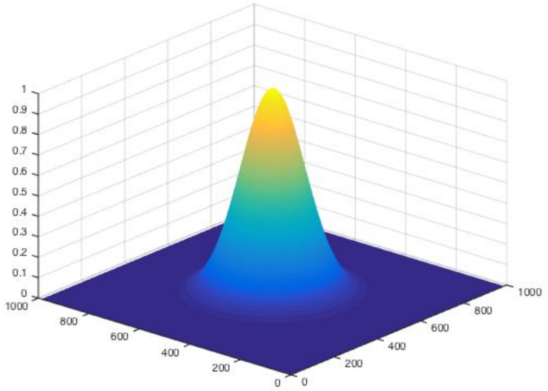
(These help for guiding / interpreting Design of Holograms)

# Hologram Miracle: Phase modulation is enough

```
Gerchberg–Saxton Algorithm(Source, Target, Retrieved_Phase)
 A = IFT(Target)
 while error criterion is not satisfied
   B = Amplitude(Source) * exp(i*Phase(A))
   C = FT(B)
   D = Amplitude(Target) * exp(i*Phase(C))
   A = IFT(D)
 end while
 Retrieved_Phase = Phase(A)
end Gerchberg–Saxton Algorithm
```

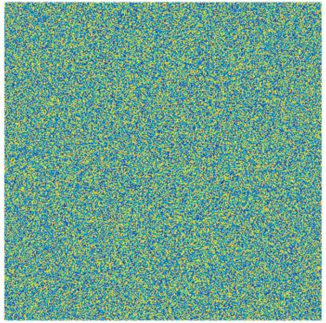
Target: Orger Hologram

Input: Gaussian Beam Intensity




x

Solved: Phase for spatial freq

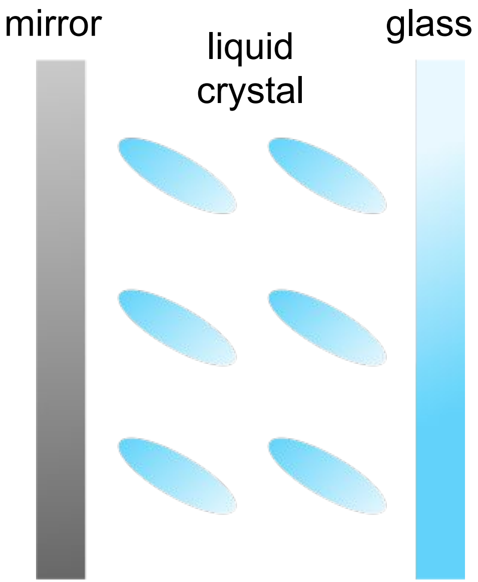


FT →

Result: Orger Hologram (speckle)

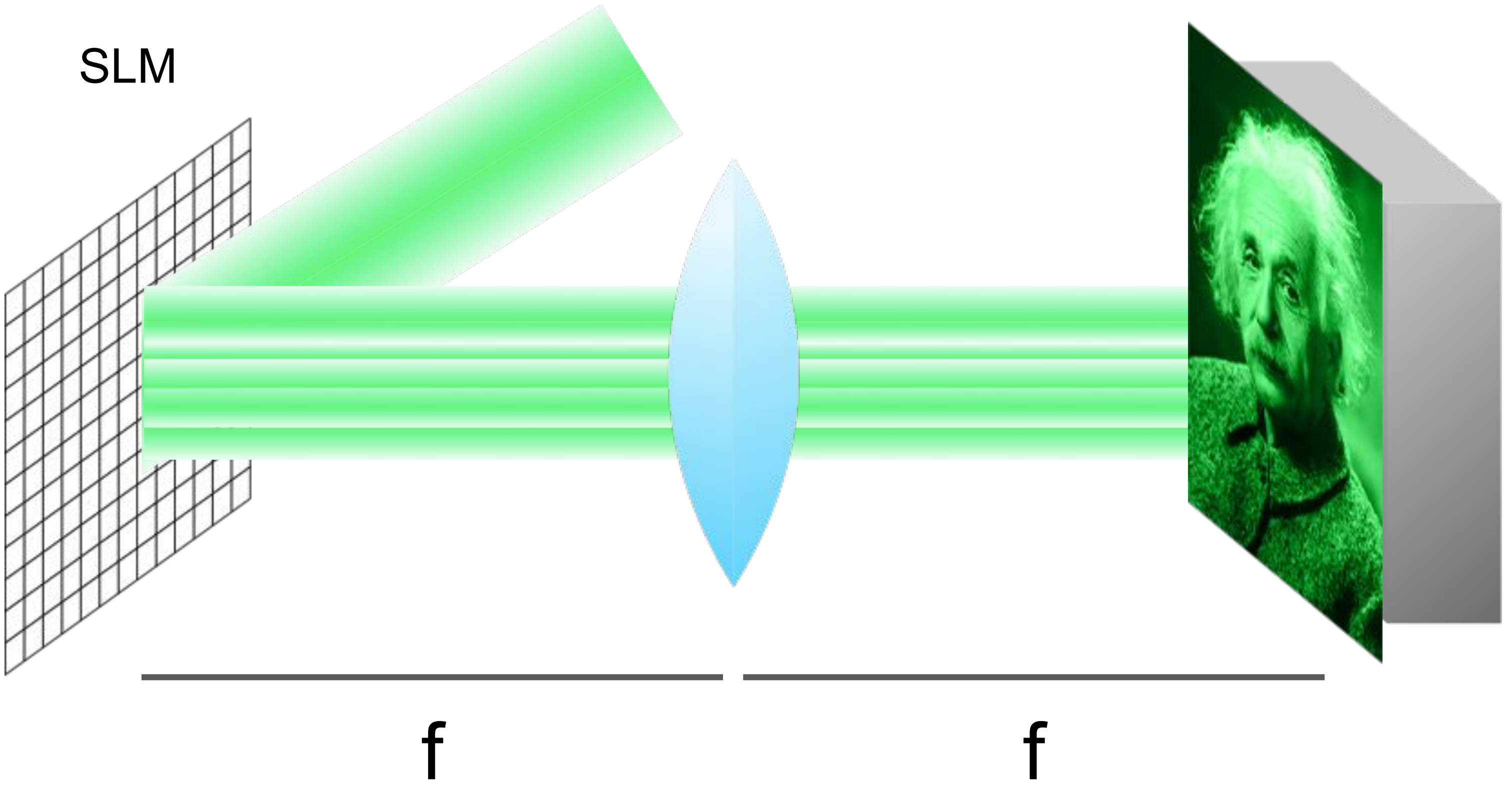
# Theoretical capabilities

## SLM

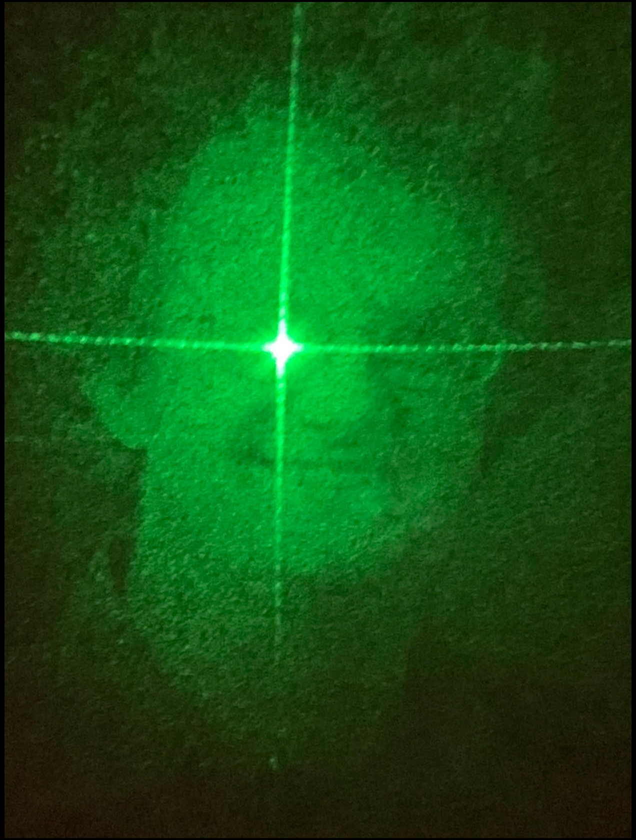



- arbitrary stimulation pattern
- scanning
- adaptive optics
- lensing

# first test: can we project an image?

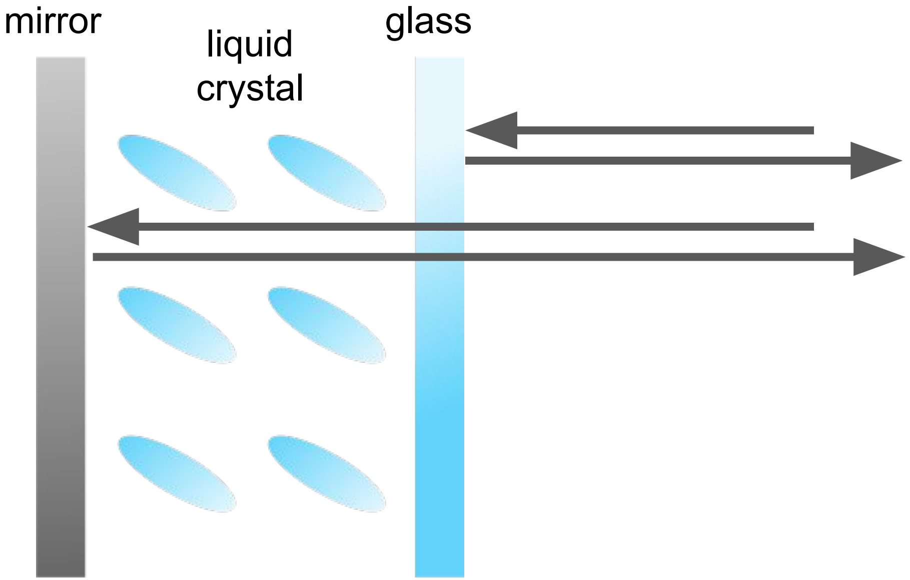


# Proof of principle

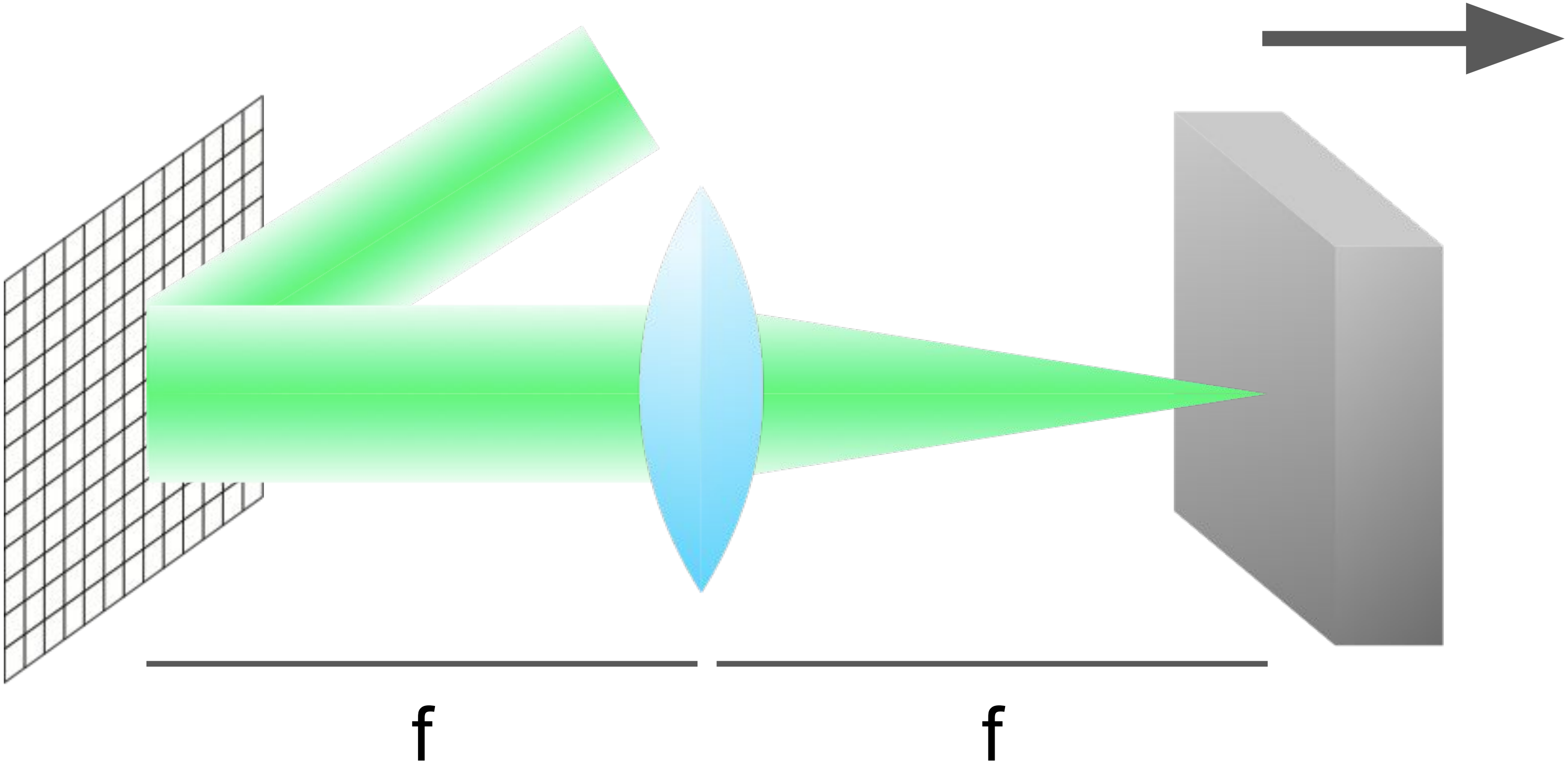


zero Order
reflection

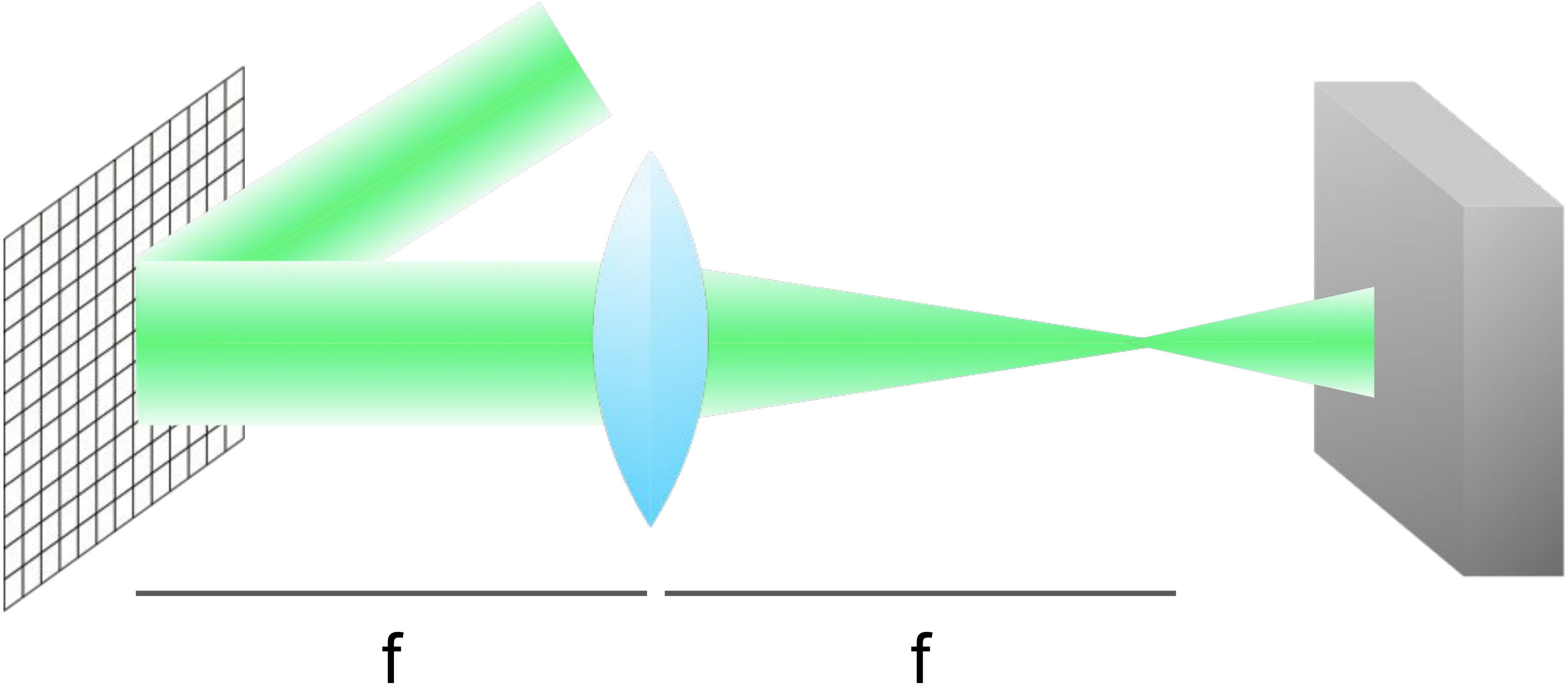
# Problem 1/3: zero order reflection



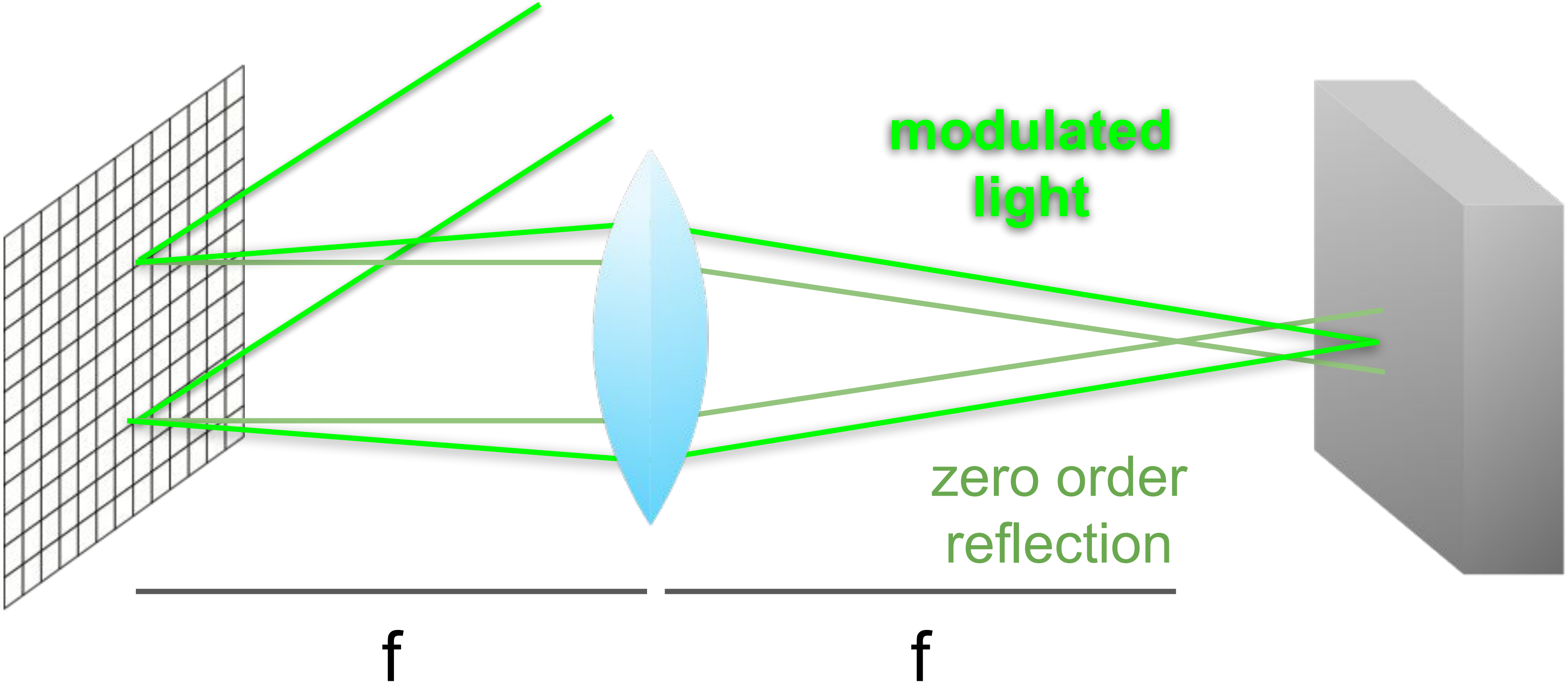
# Problem 1/3: zero order reflection



# Problem 1/3: zero order reflection



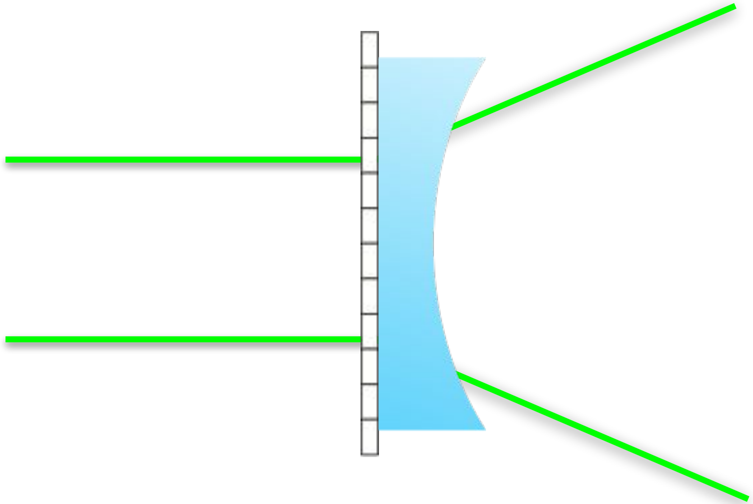
# potential solution

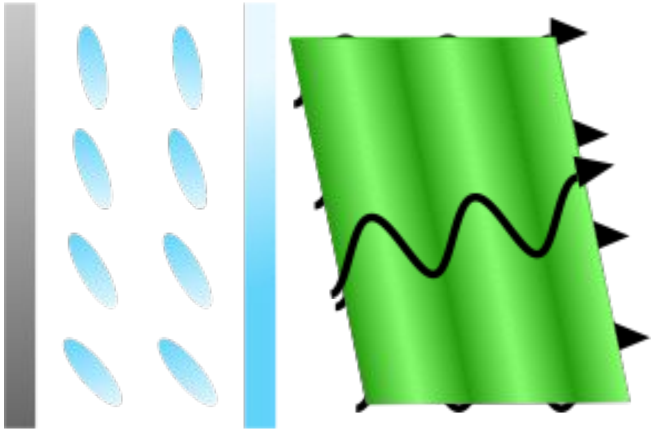



developed by Emiliani Valentina, pointed out by Stephan

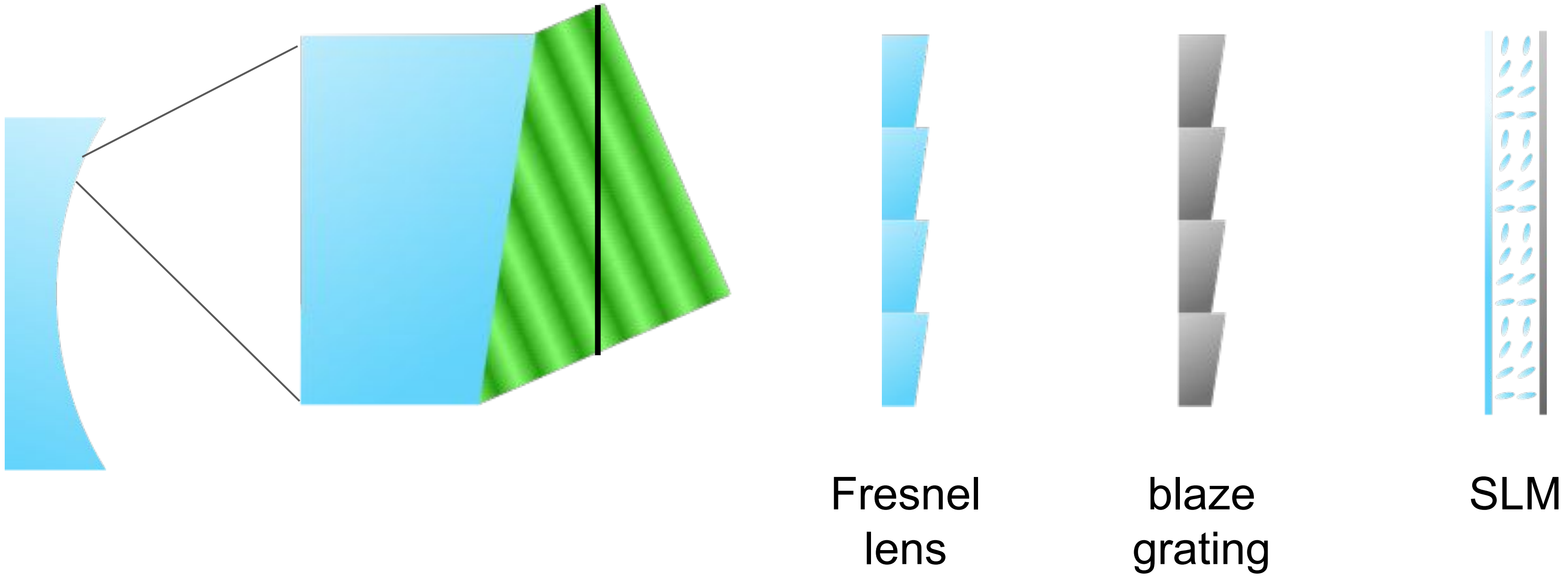
# Problem 1/3: zero order reflection

*Solution: make the SLM like a lens*





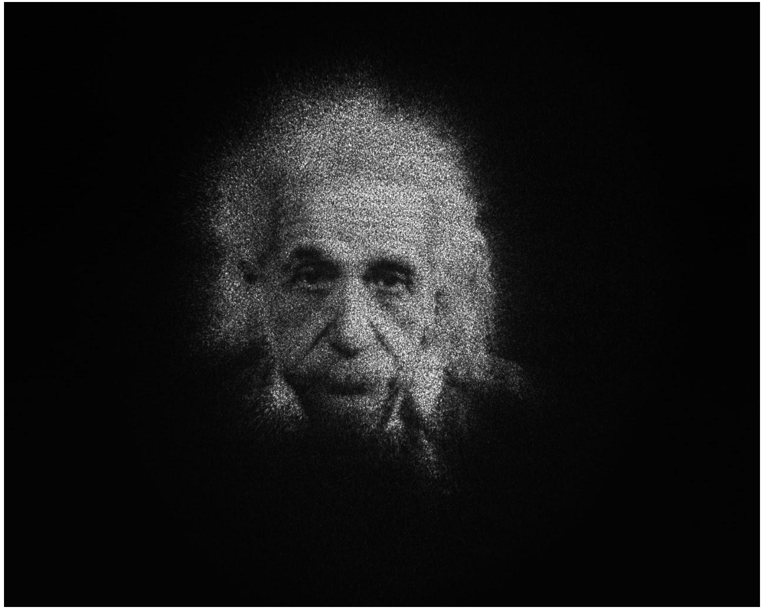
# Problem 1/3: zero order reflection



# improvement by Orgers of magnitude!

before

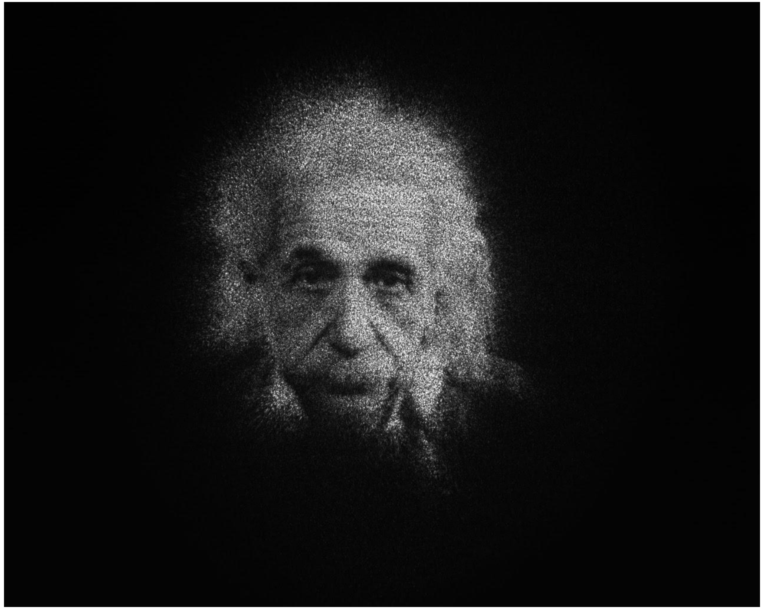
after



# improvement by orders of magnitude!

before

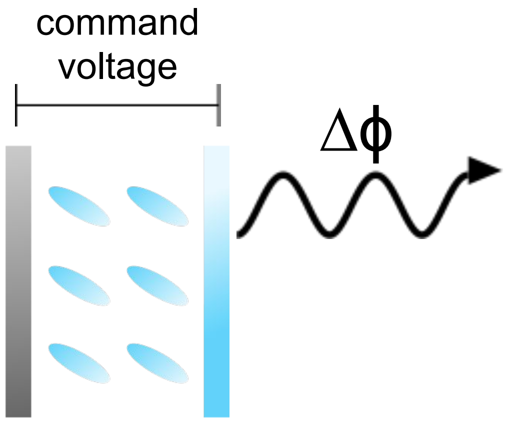
after

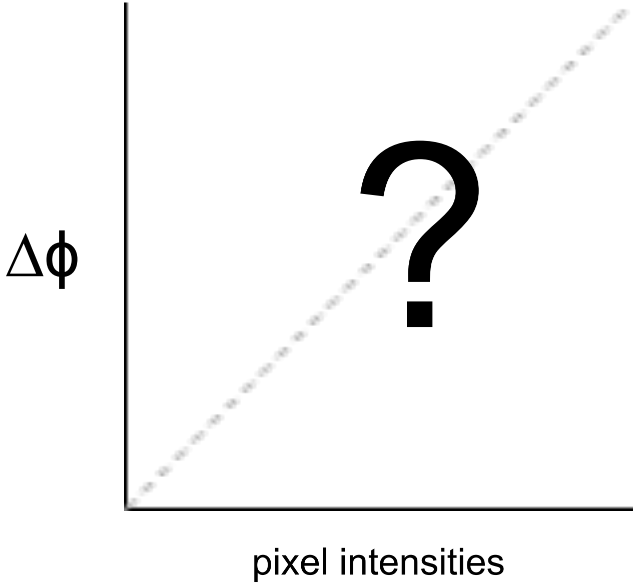


# Application: micro-targeted advertising

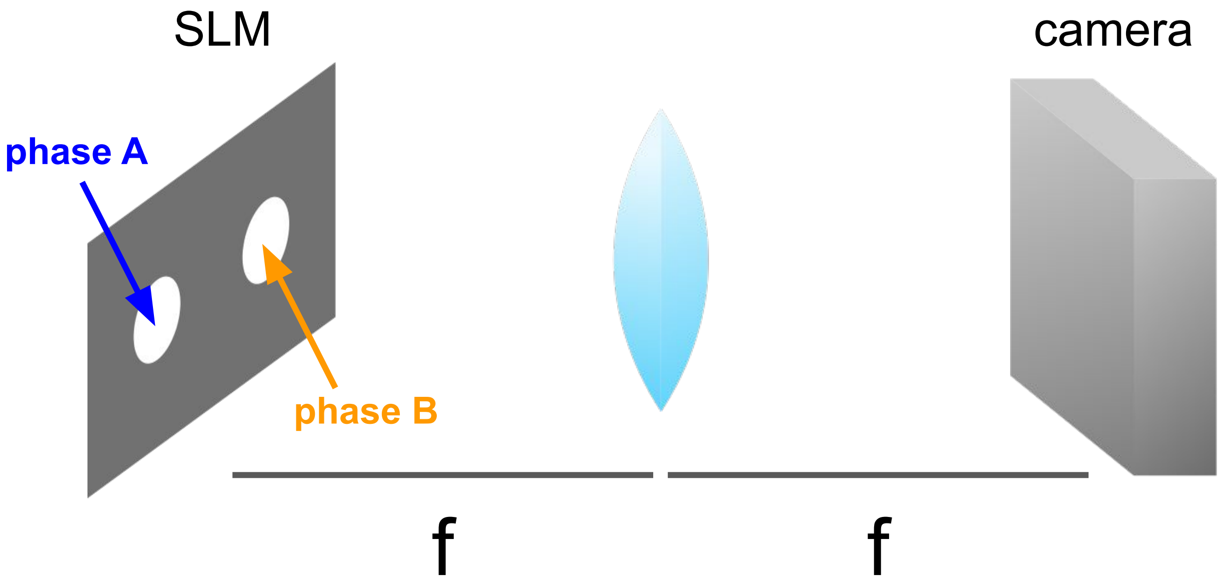
~X µm

# Problem 2/3: “gamma” correction

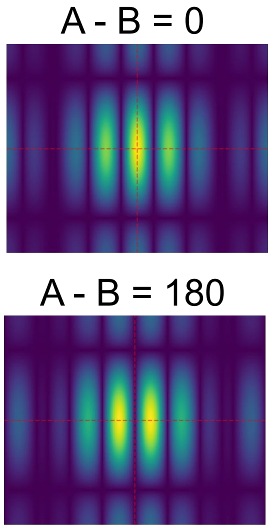


# strategy



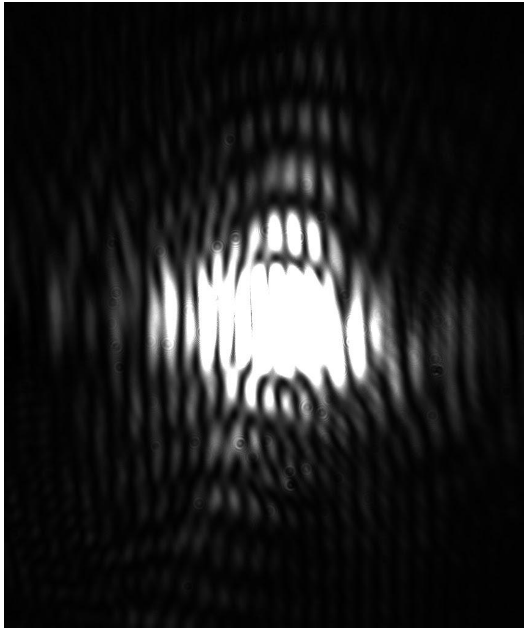

expected result from simulation



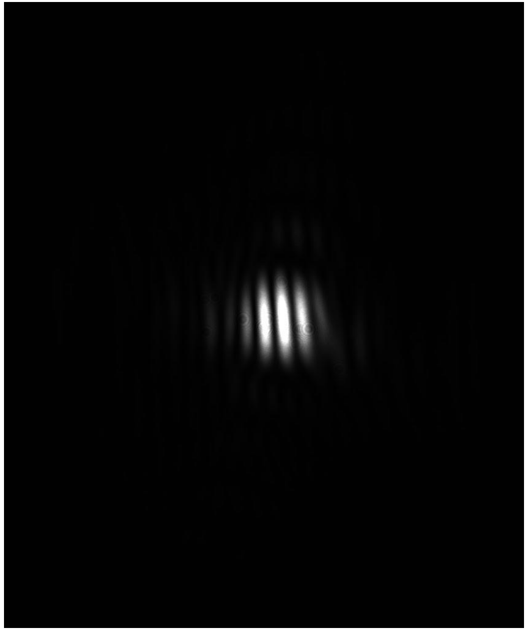

offset = A - B

# two-spot calibration

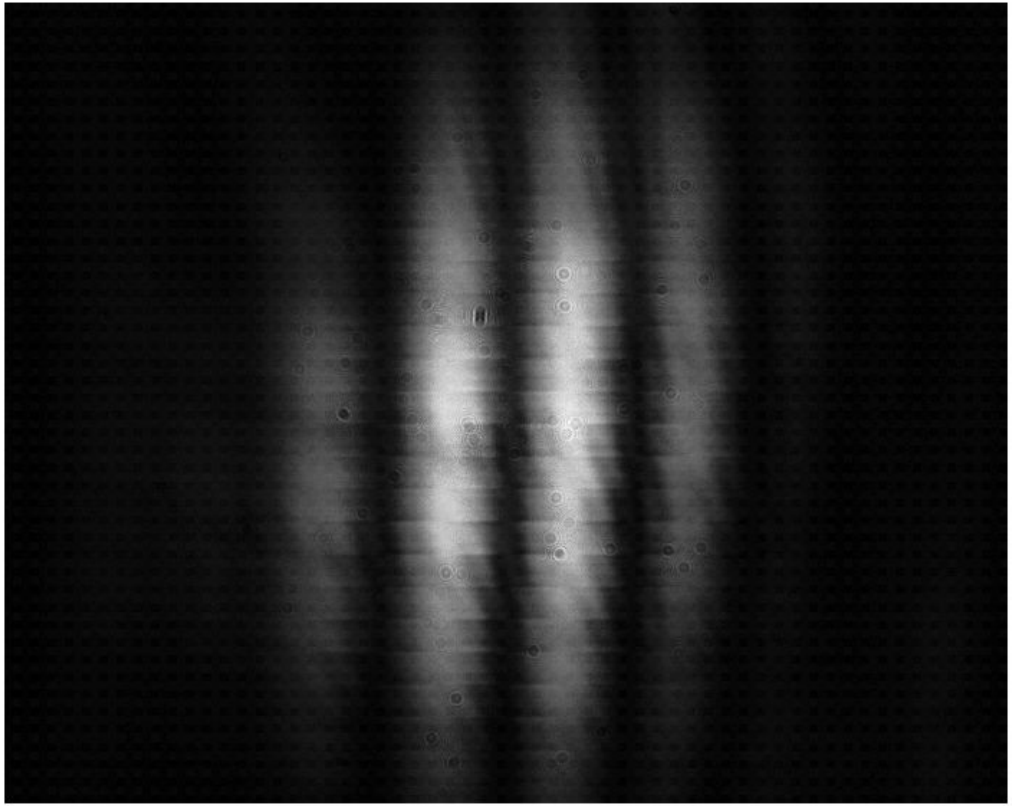
long exposure



short exposure



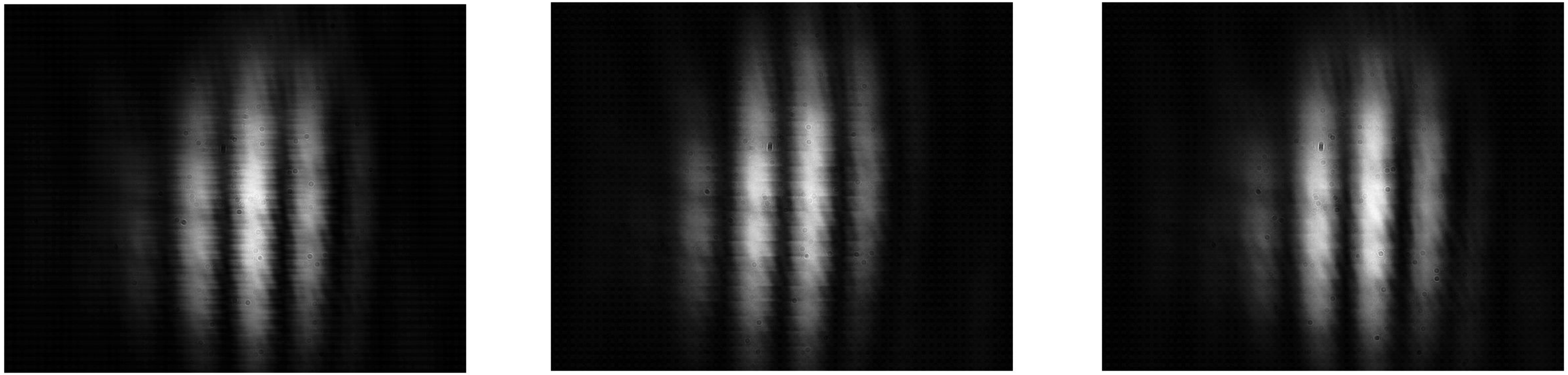
# two-spot calibration



# two-spot calibration

specified gray value

small ⟷ large

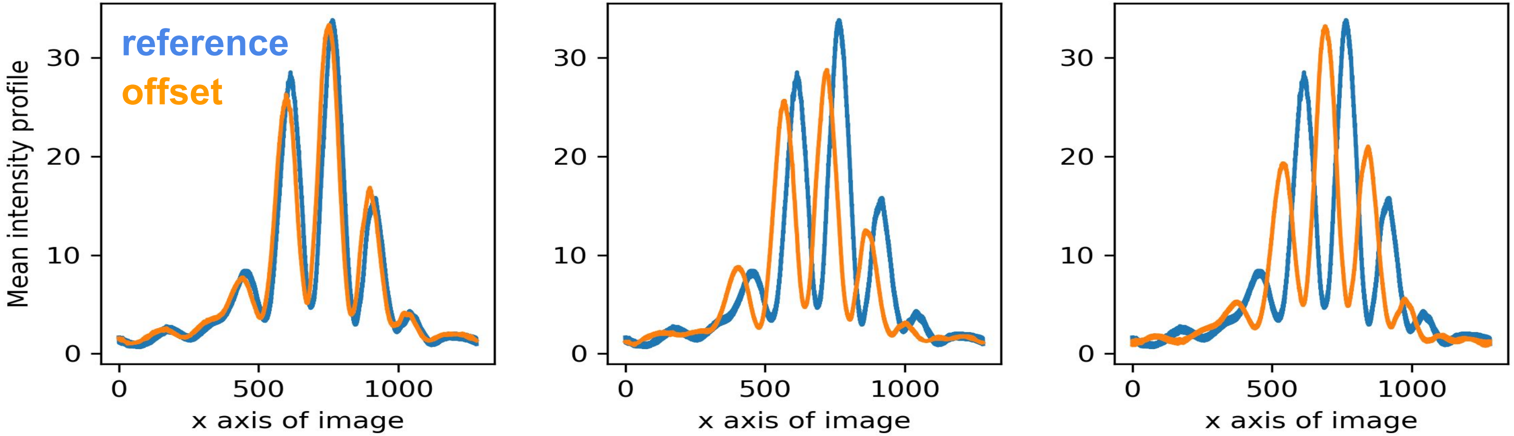


# two-spot calibration

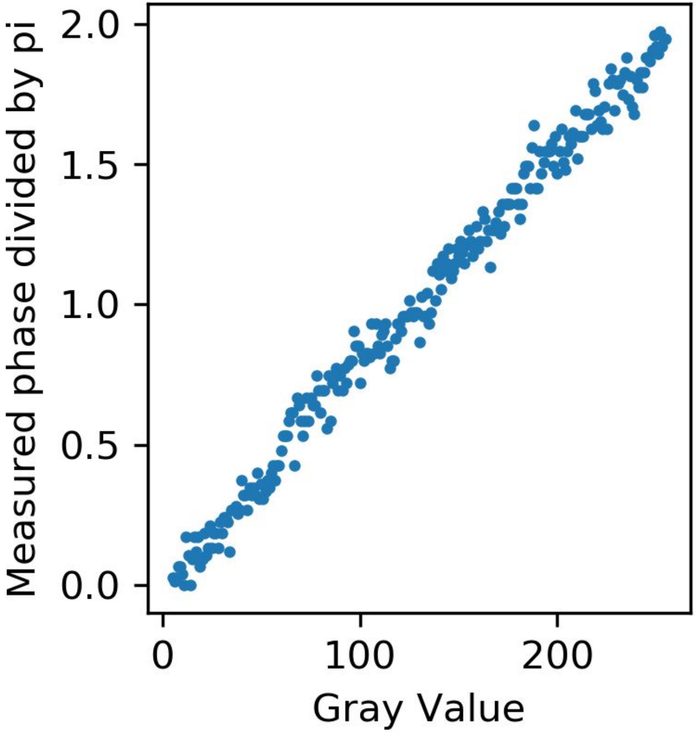
specified gray value

small

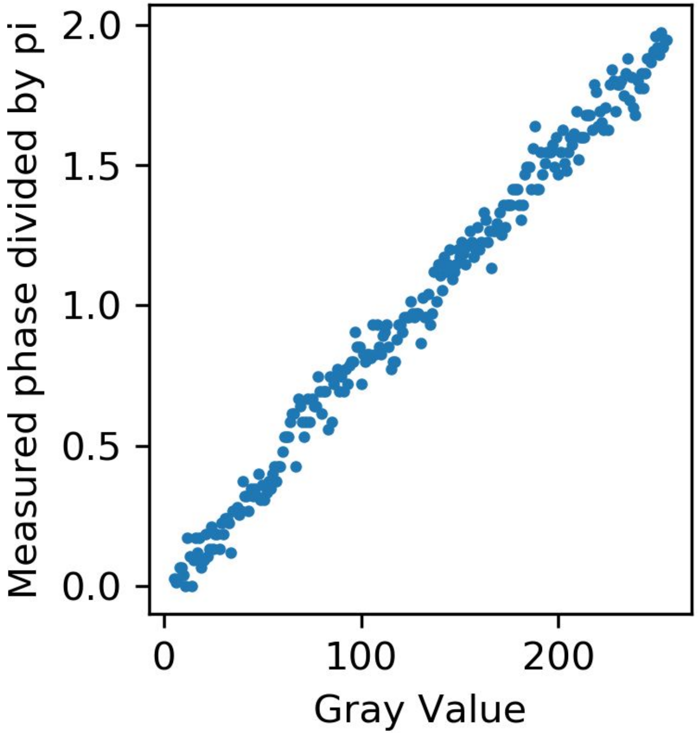
large

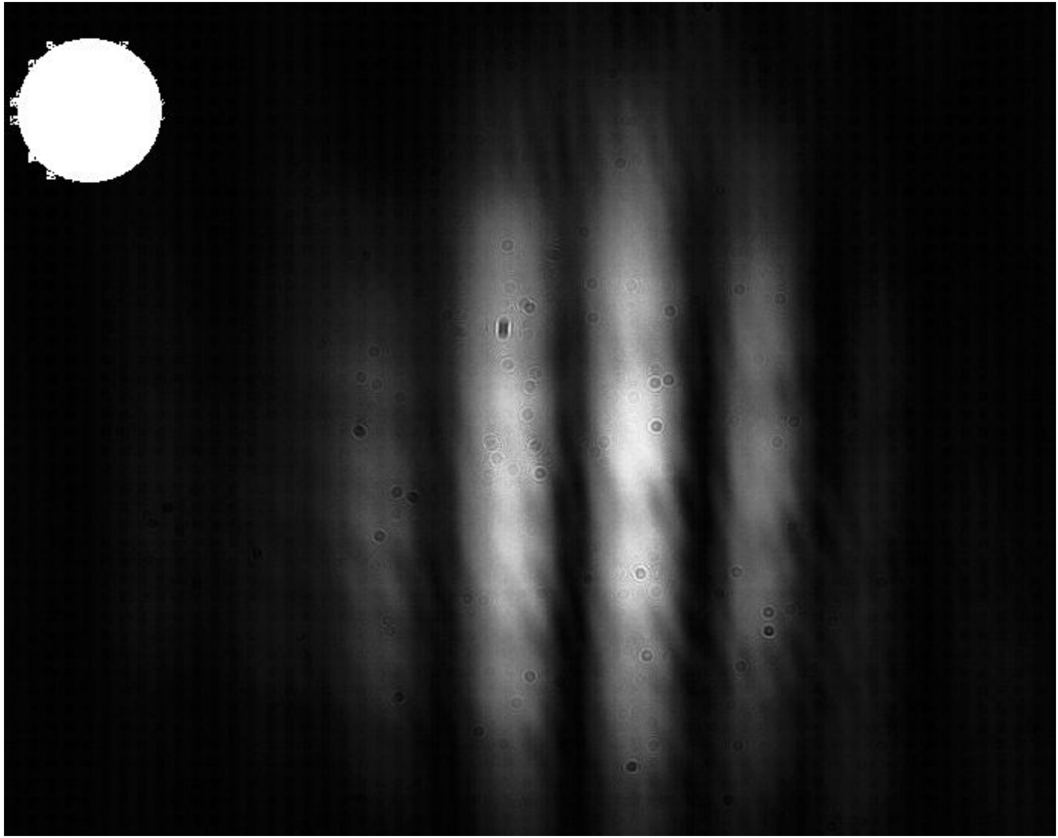


# two-spot calibration

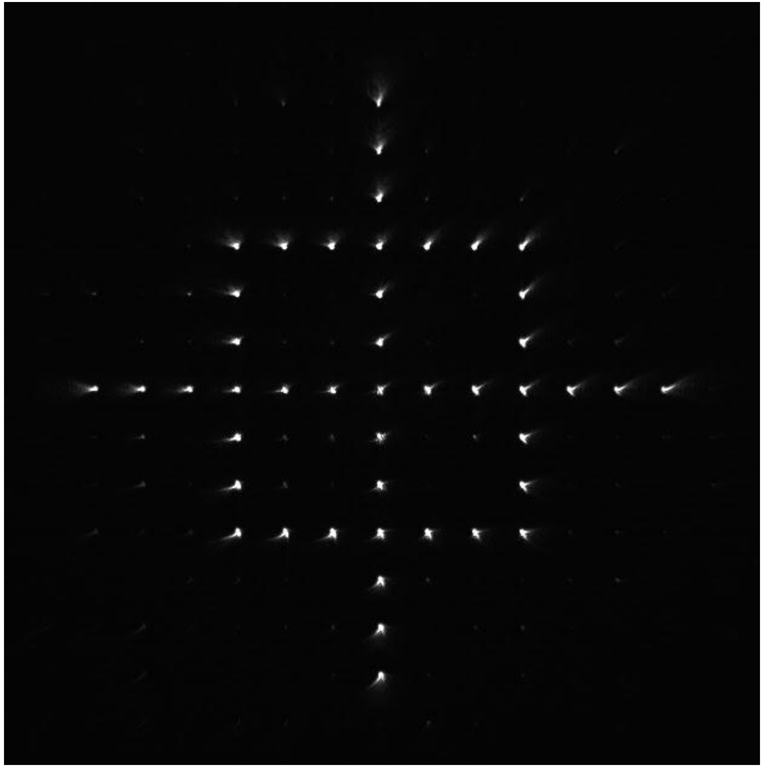


# two-spot calibration

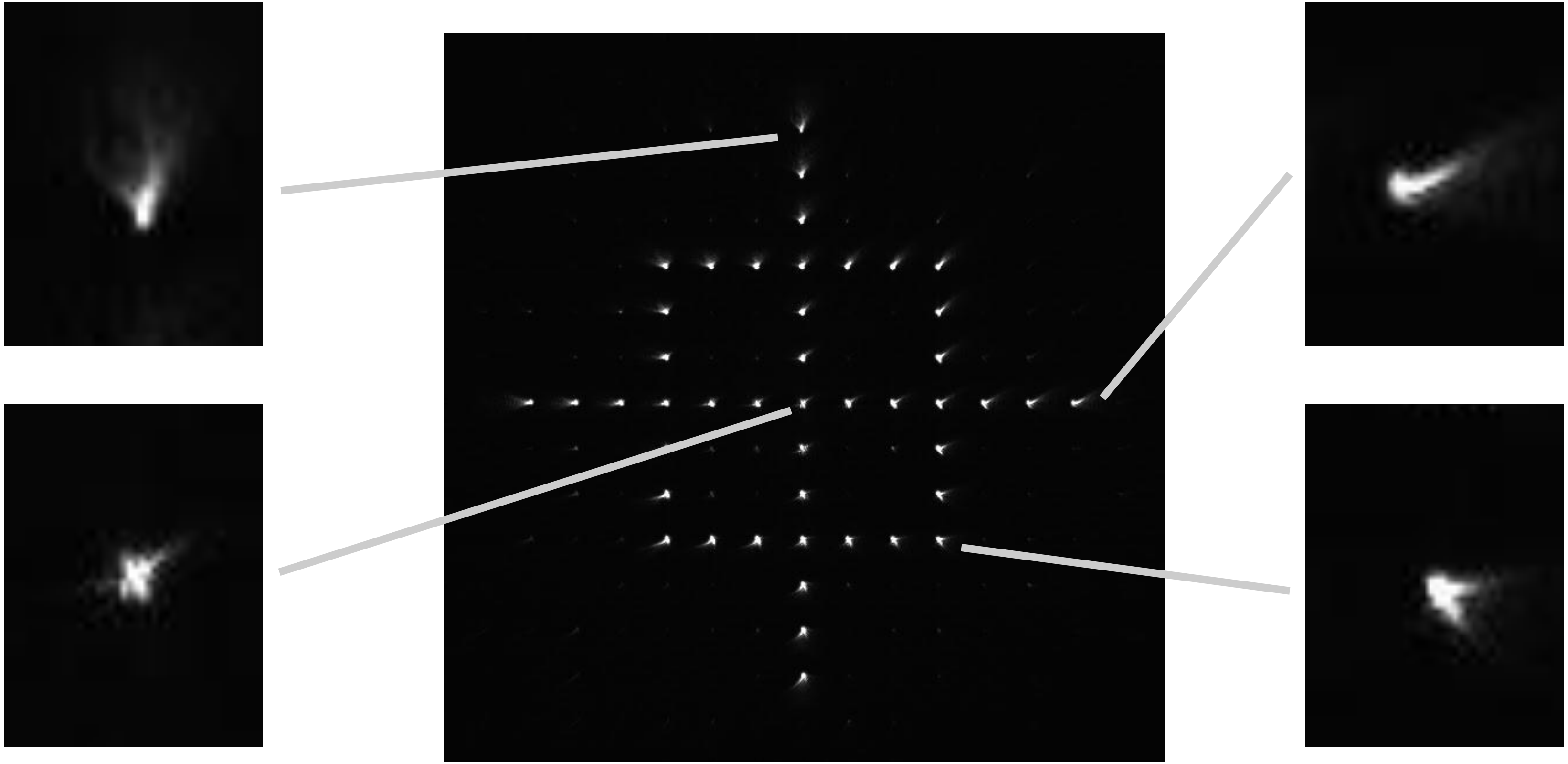


# Problem 3/3: aberrations

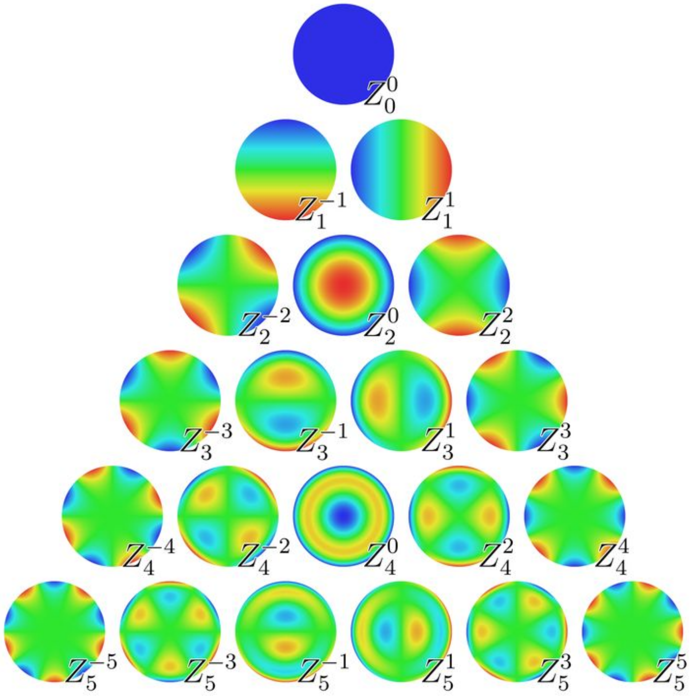


# Problem 3/3: aberrations



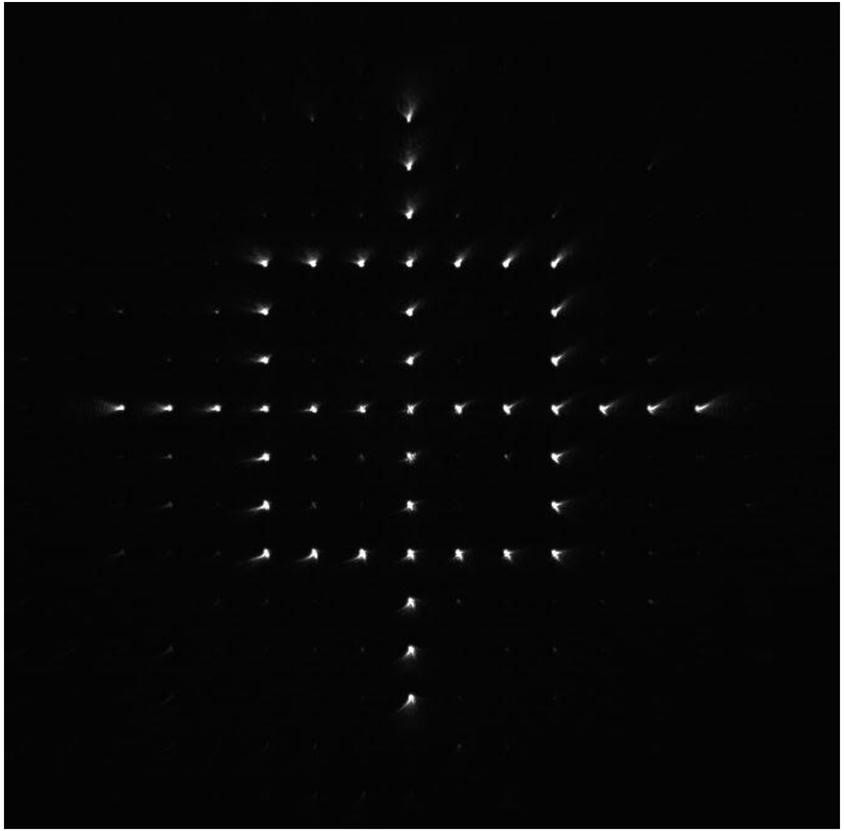
# approach: adaptive optics

Zernike modes

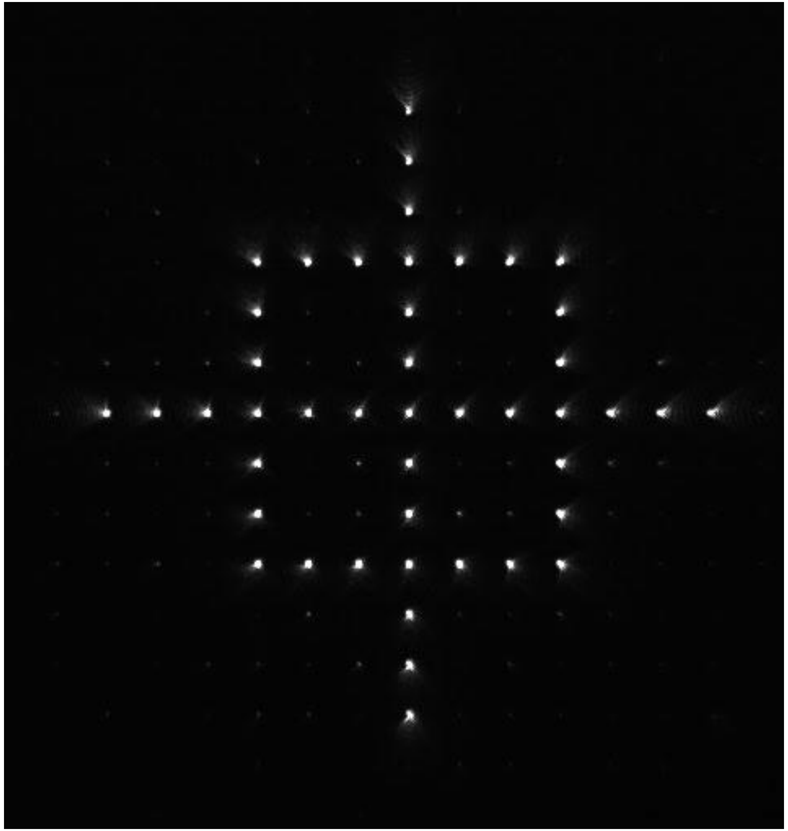


# approach: adaptive optics

original

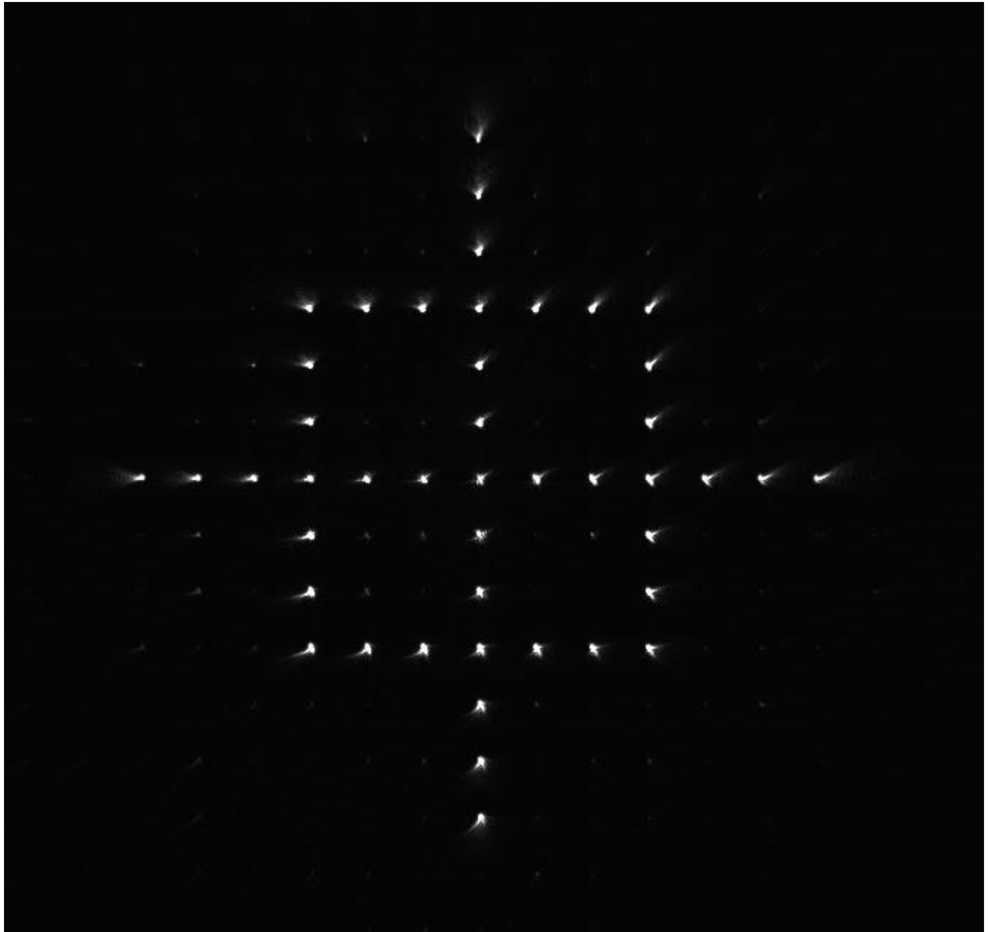


corrected

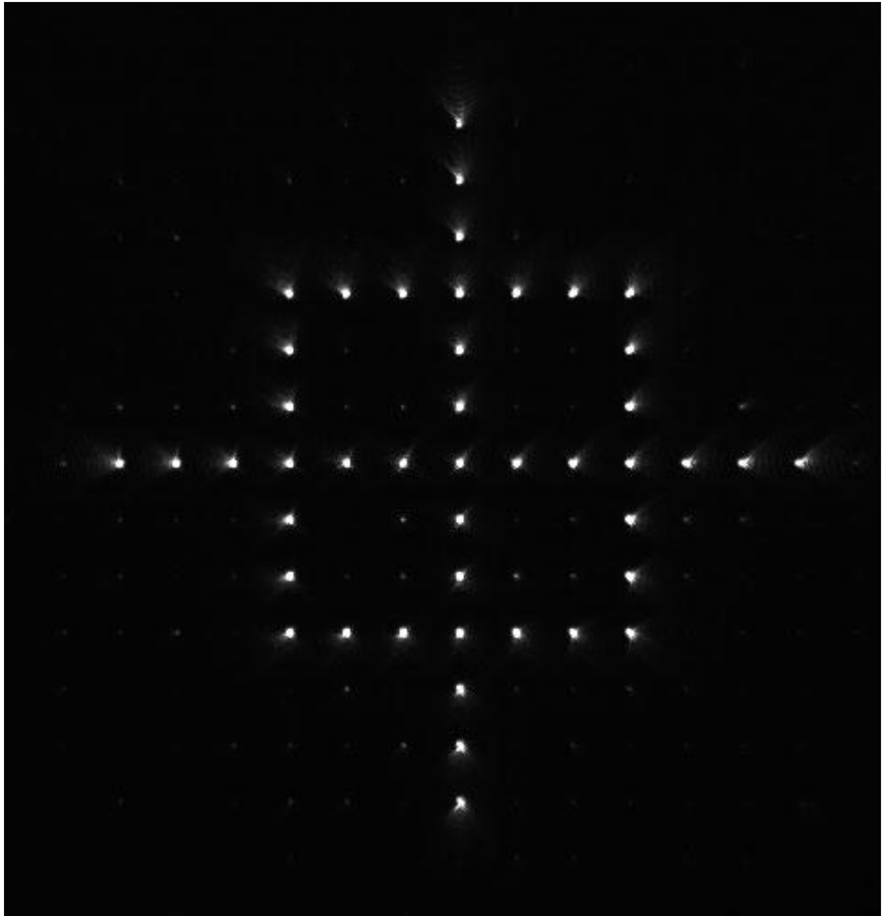


# approach: adaptive optics

original

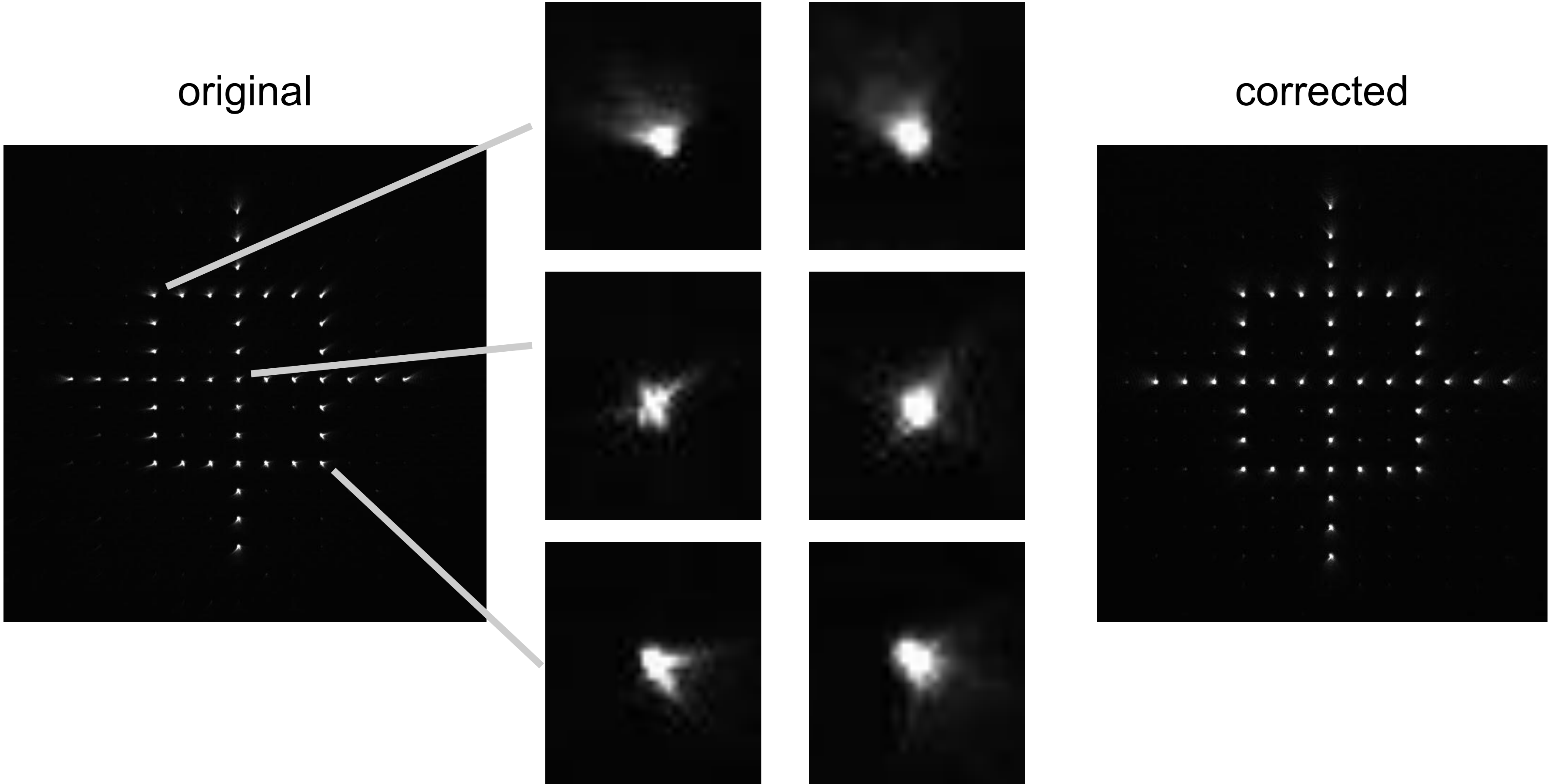


# approach: adaptive optics



corrected

# approach: adaptive optics

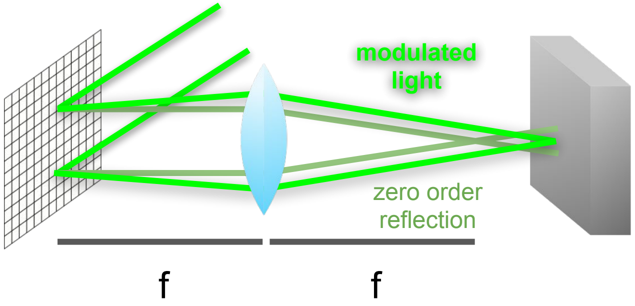


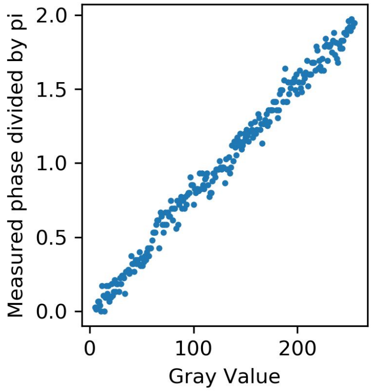
# summary

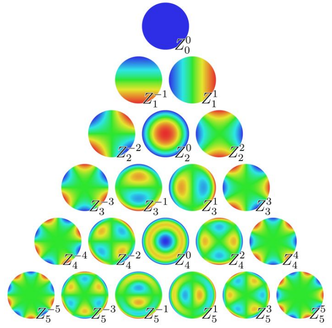
✓ remove zero order

✓ verify "gamma"

✓ adaptive optics

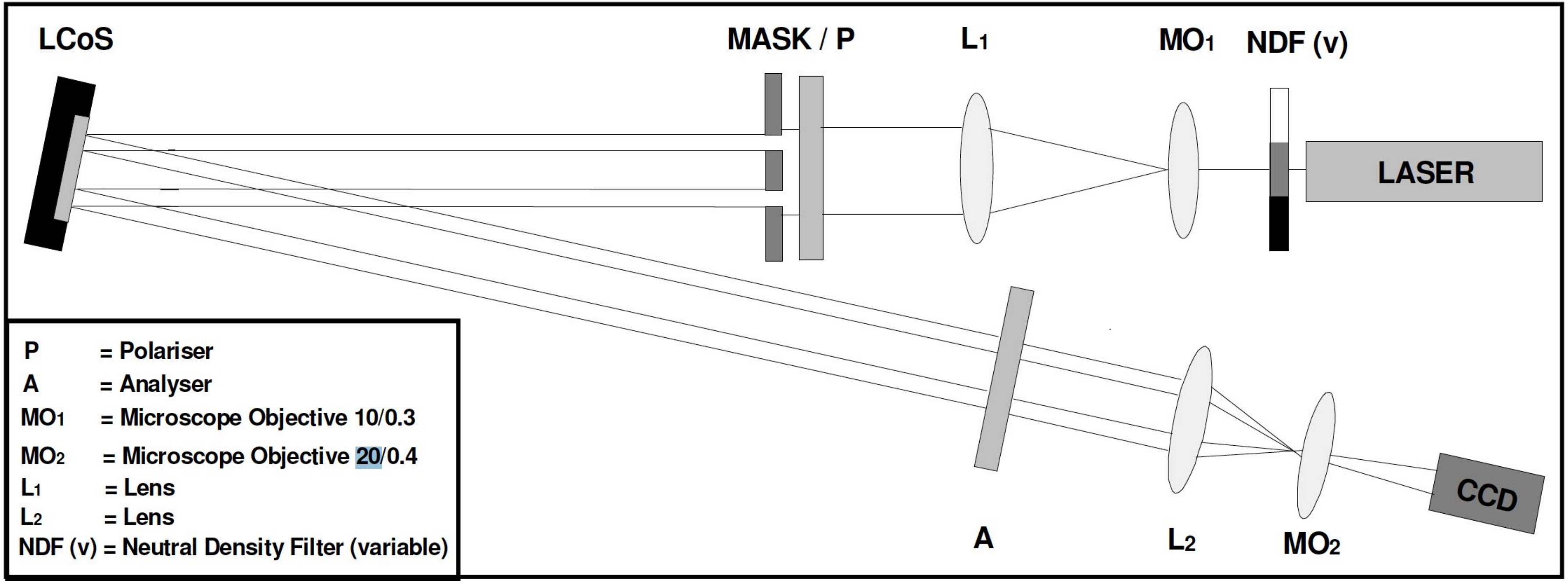


- arbitrary stimulation pattern
- scanning
- lensing

# Application: Fish Fry


LCoS
MASK / P
L1
MO1
NDF (v)
LASER
A
L2
MO2
CCD
P = Polariser
A = Analyser
MO1 = Microscope Objective 10/0.3
MO2 = Microscope Objective 20/0.4
L1 = Lens
L2 = Lens
NDF (v) = Neutral Density Filter (variable)