

Single-pixel camera enhanced with deep learning protocols for the characterization of diffractive optics working in the THz region

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Optoelectronics Group – ICFO

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ROTATING DISK

EXPERIMENTAL RESULTS

→ FUTURE WORK

→ CONCLUSIONS

6G

FAST DATA SPEEDS

LOW LATENCY

OUTSIZED CONNECTION

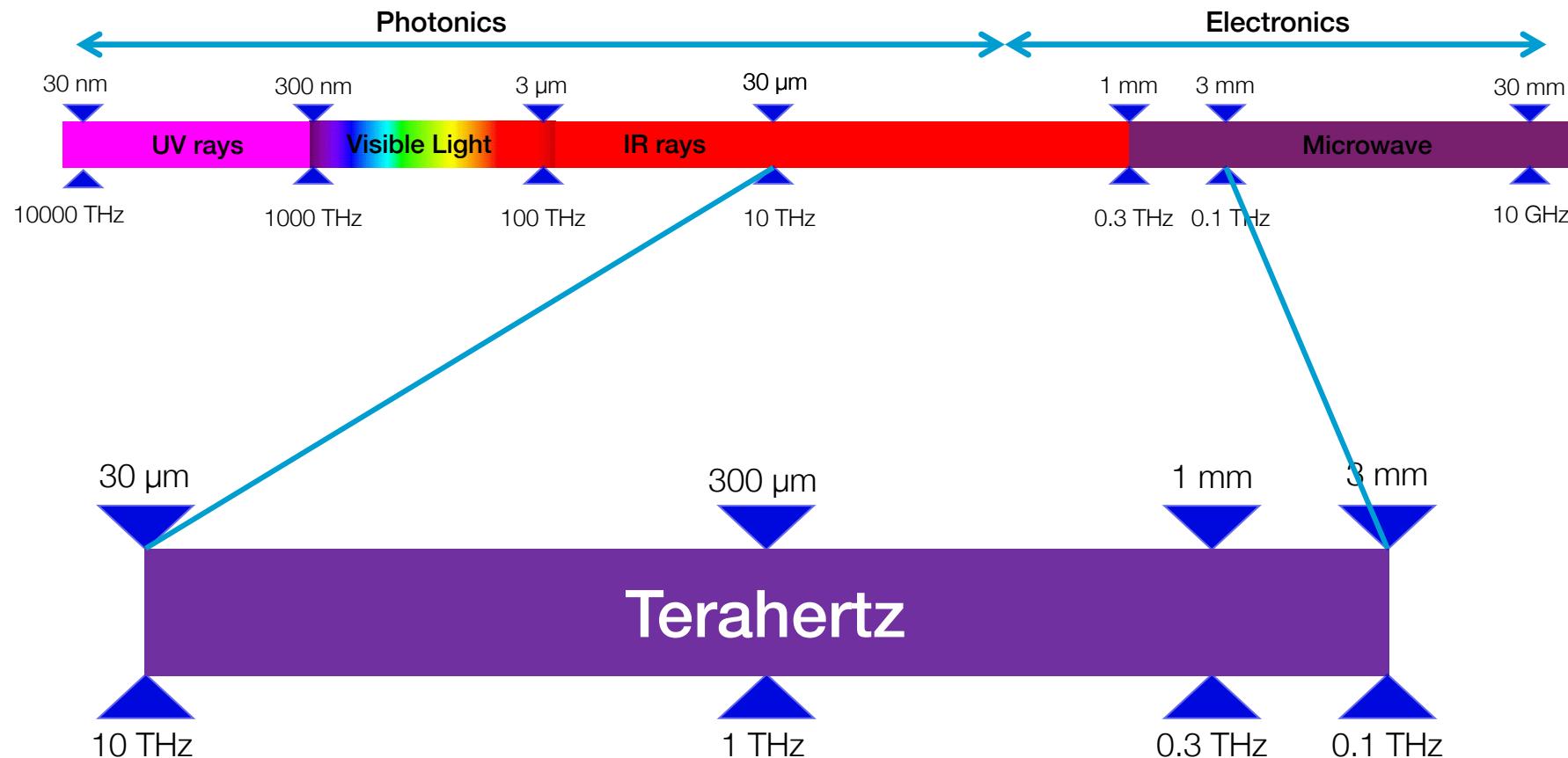
THANKS TO

THz

**WIDE BANDWIDTHS,
GREATER THAN 4G & 5G**

**MORE INFORMATION CODED
INTO NEW CHANNELS**

TERAHERTZ RADIATION



CHALLENGES OF

THz

SIGNAL PROPAGATION
AND DETECTION

POSSIBLE SOLUTION

↓
DIFFRACTIVE
OPTICS

MOTIVATION

THz
WORLD

INVESTIGATION OF TECHNIQUES FOR
OAM MODULATION

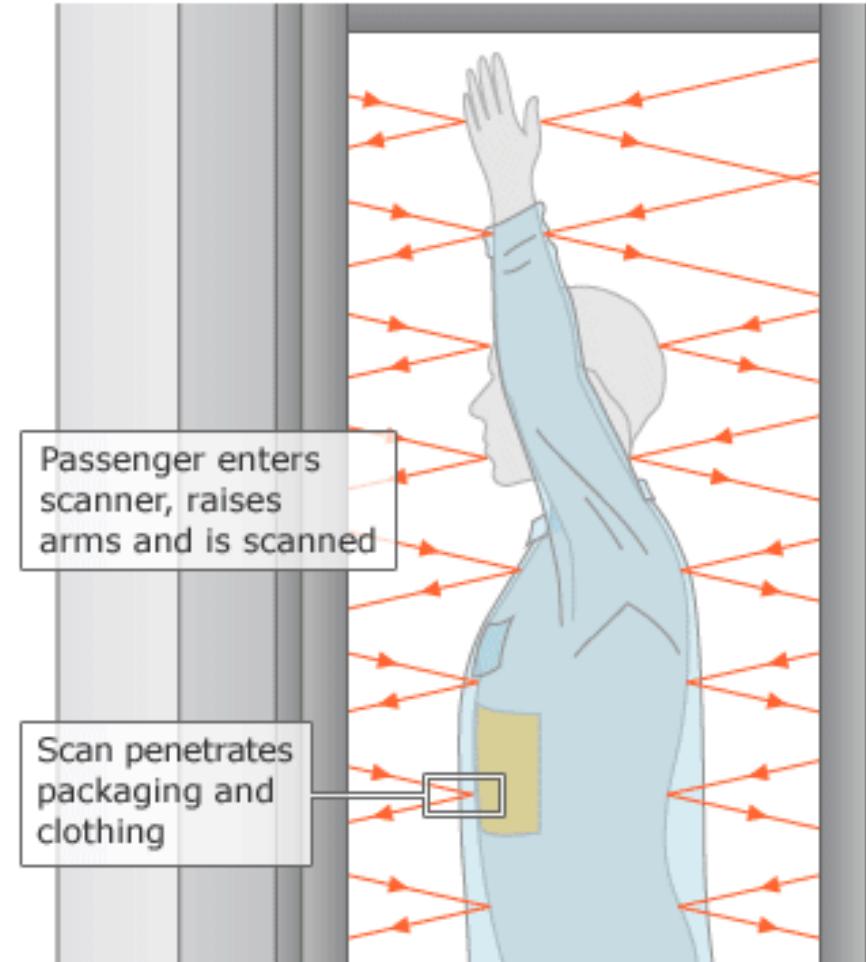
DEVELOPMENT OF A SINGLE-PIXEL
CAMERA FOR SECURITY
APPLICATIONS

OUR GOAL

ON THE RUN SECURITY SCREENING



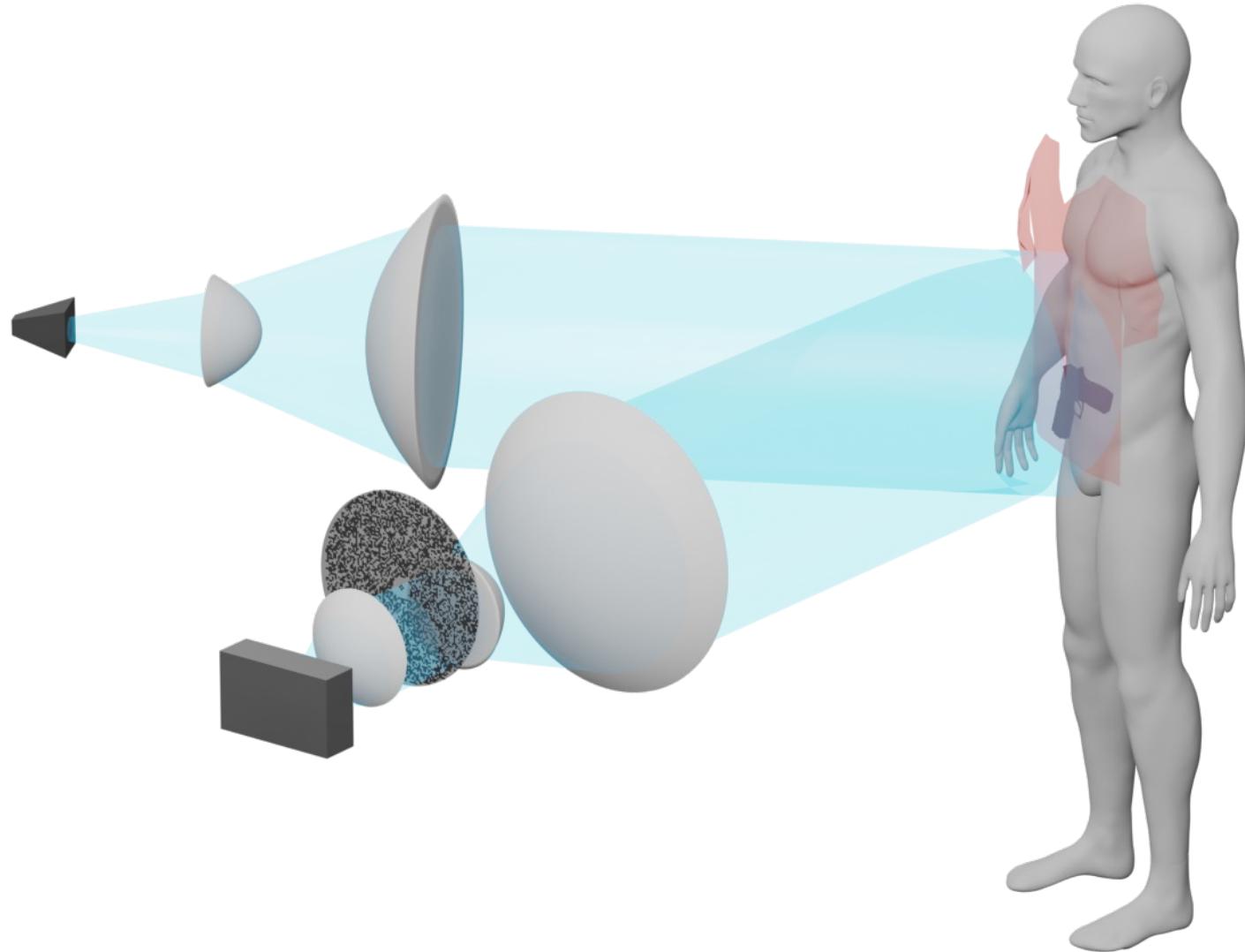
How the airport scanners work



TRANSMISSION



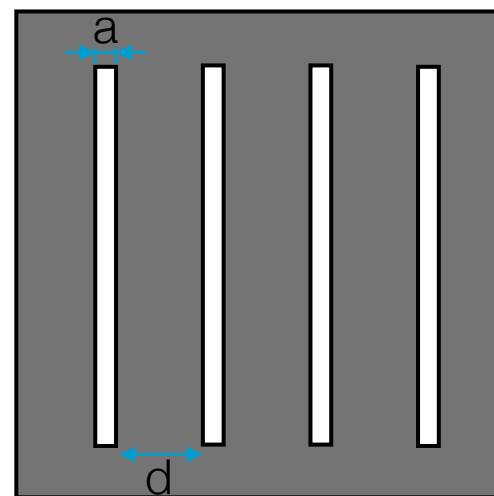
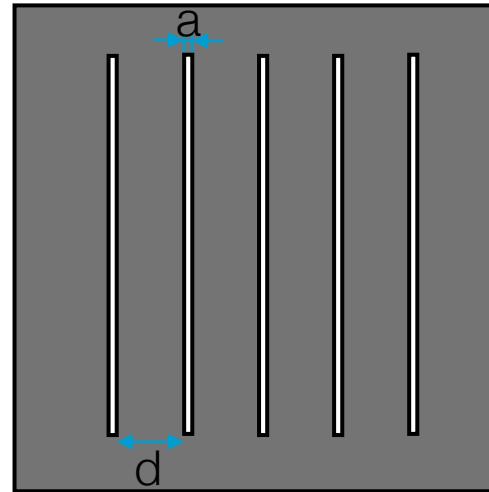
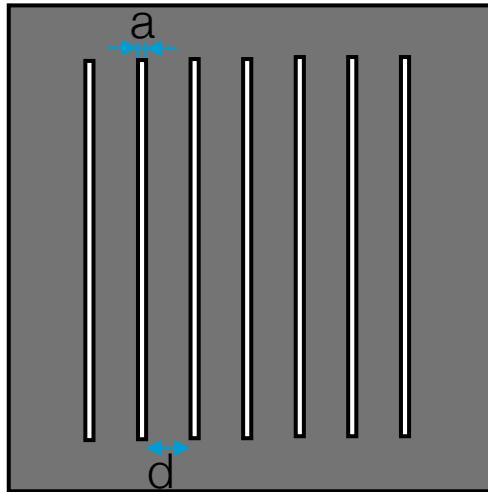
TRANSMISSION —————→ **REFLECTION**



**WE NEED
NEW LENSES**

BUT FIRST...

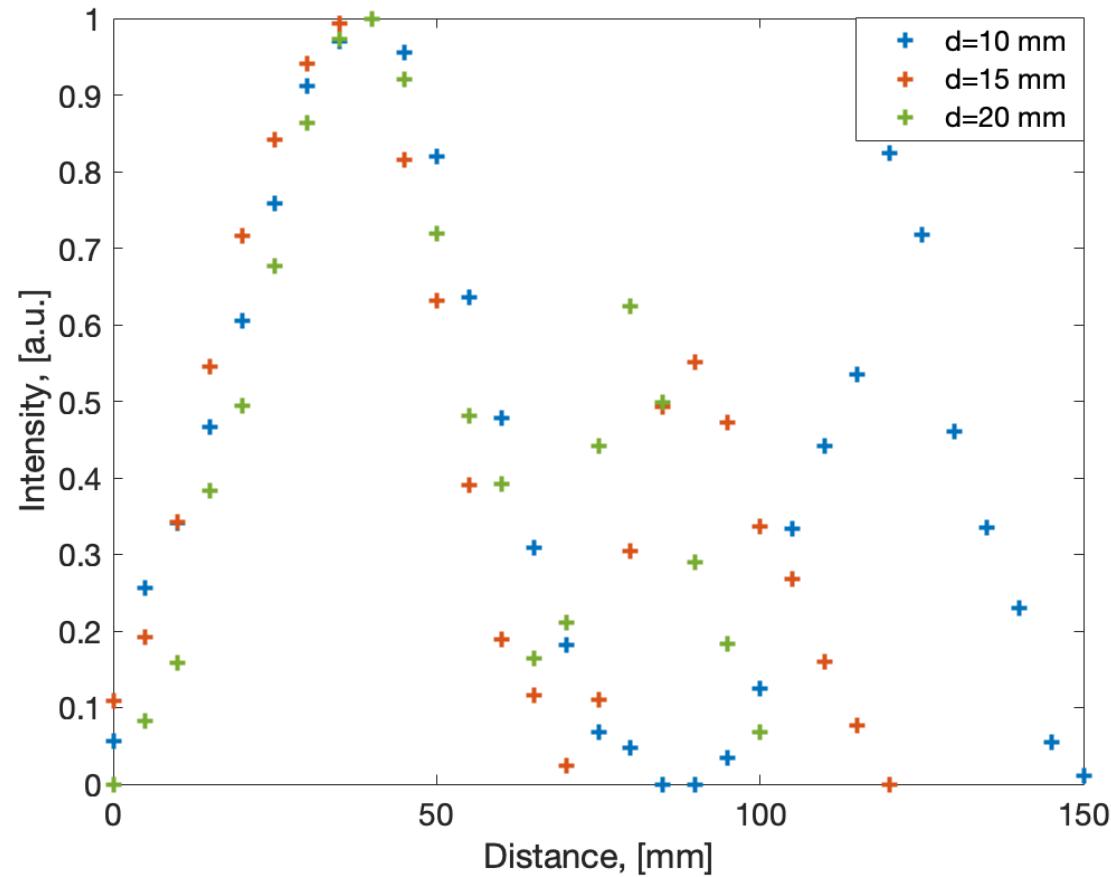
WAVELENGTH CHARACTERIZATION



**DIFFRACTION
GRATING
SETUP**

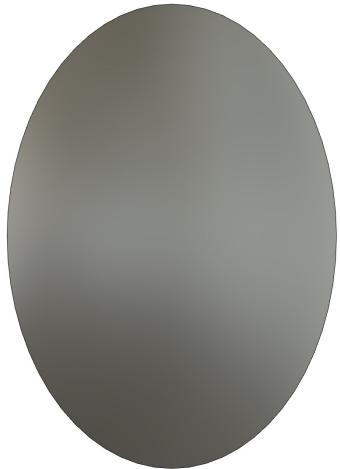
BUT FIRST...

WAVELENGTH CHARACTERIZATION



d, [mm]	Wavelength, [mm]
10	3,048
15	2,942
20	3,160
*Theoretical	3

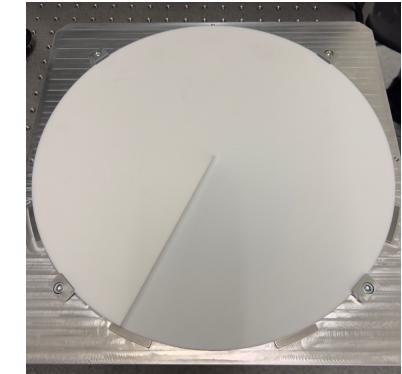
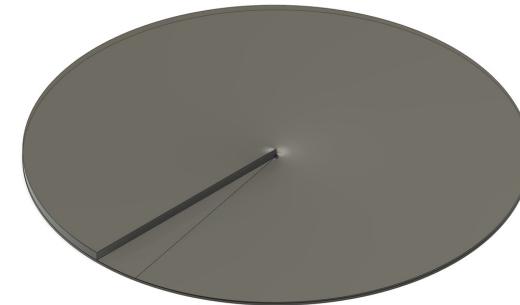
**PLANOCONVEX
LENS**



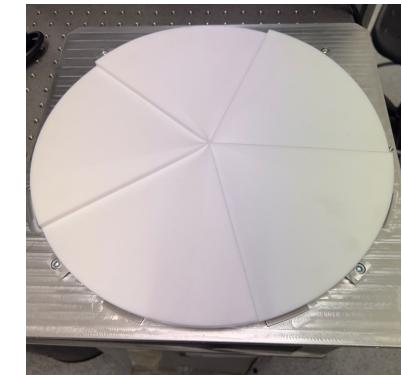
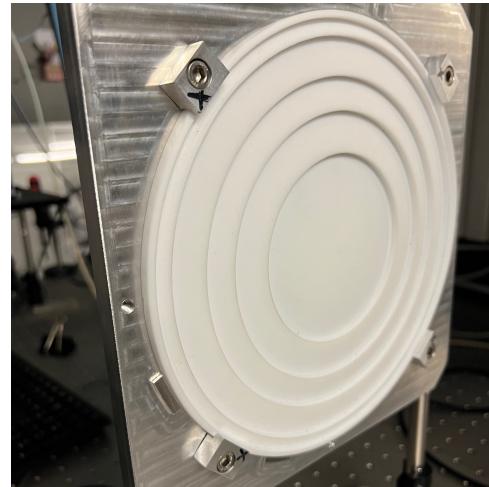
**FRESNEL
LENS**



SPIRAL PHASE PLATES



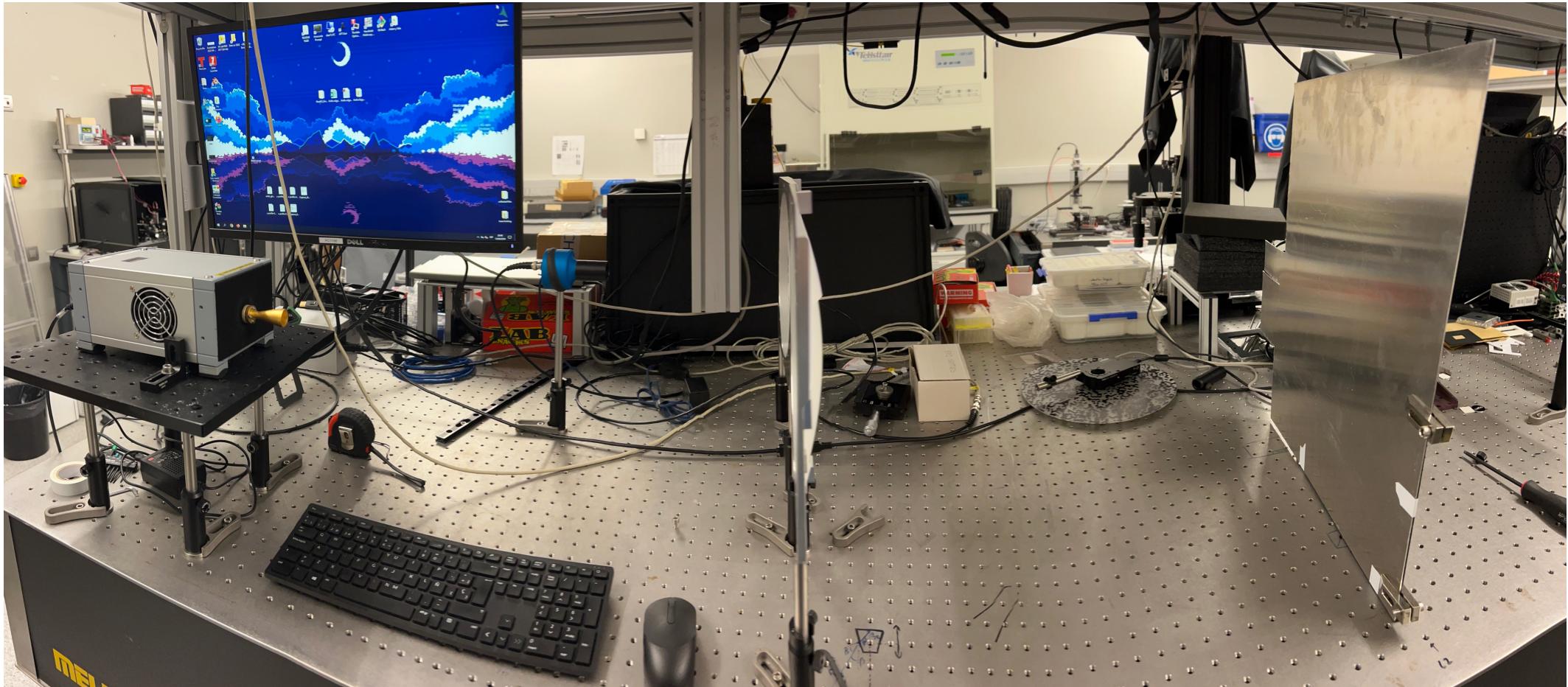
$\ell = 1$



$\ell = 5$

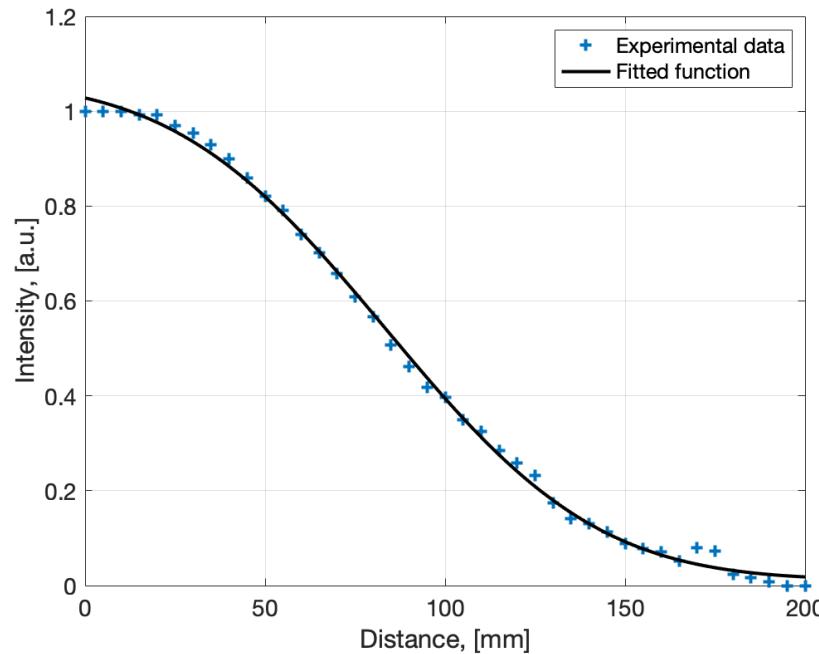
PC LENS CHARACTERIZATION

KNIFE EDGE TECHNIQUE



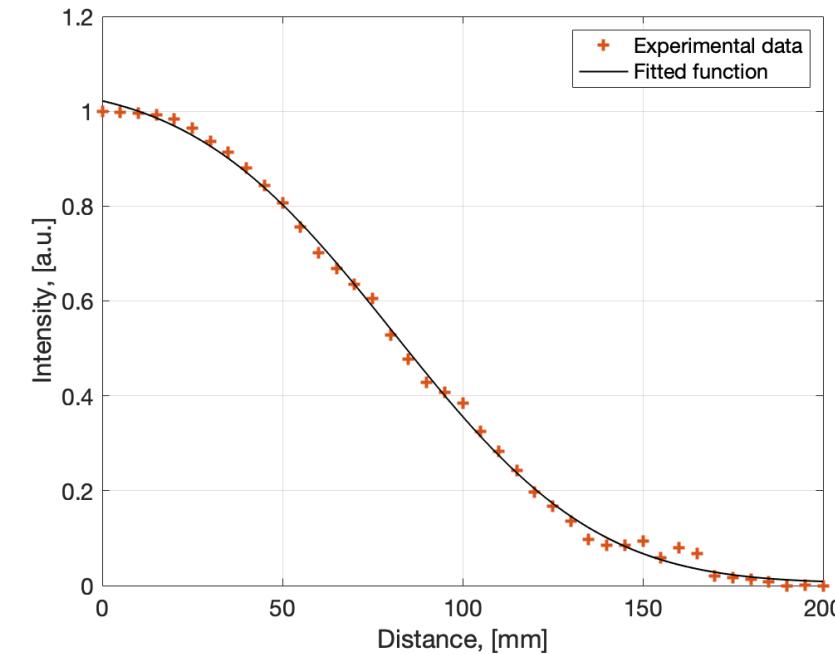
PC LENS CHARACTERIZATION FOR TRANSMISSION SETUP

KNIFE EDGE
TECHNIQUE



AFTER L1

Beam diameter: 93,987 mm

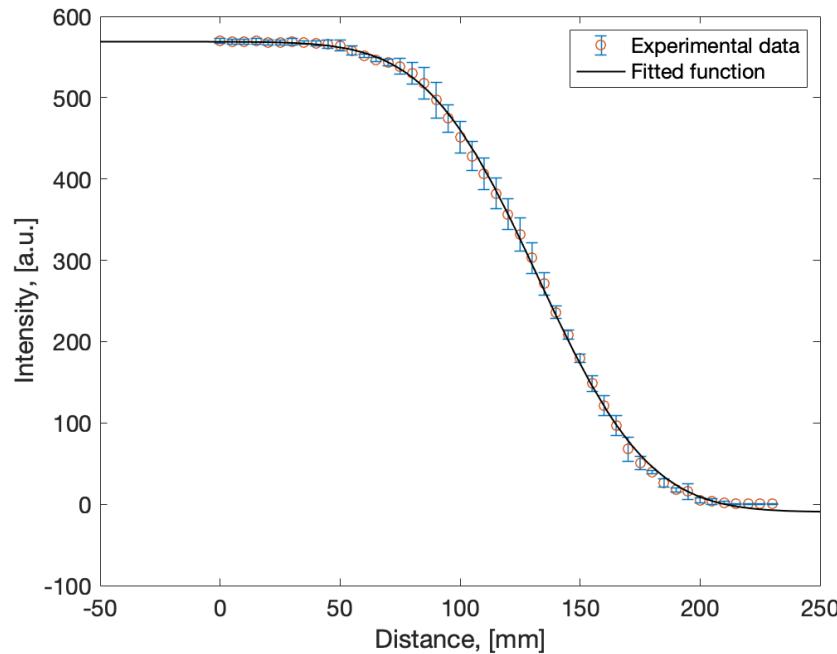


BEFORE L2

Beam diameter: 89,430 mm

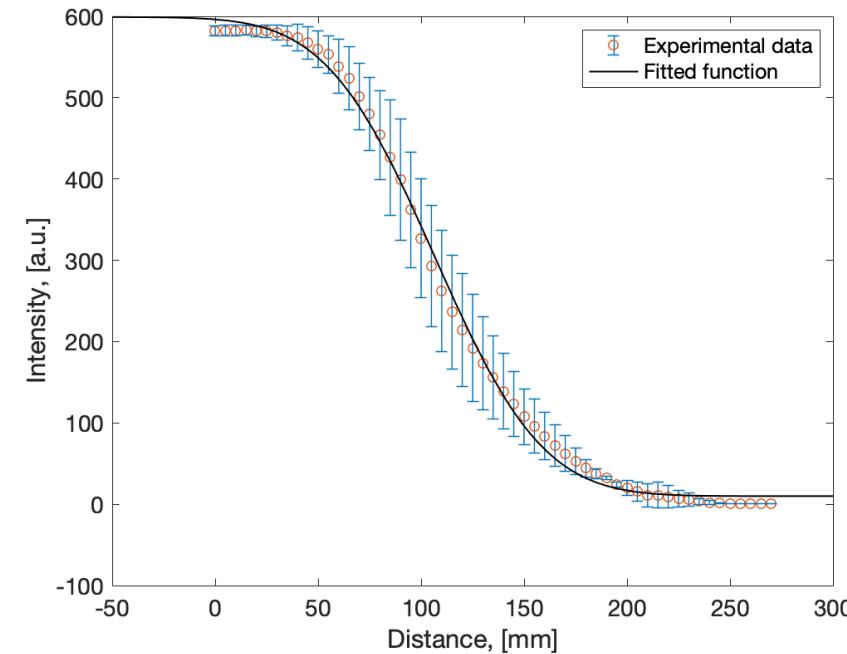
PC LENS CHARACTERIZATION FOR REFLECTION SETUP

KNIFE EDGE
TECHNIQUE



AFTER L1

Beam diameter: 79,051 mm

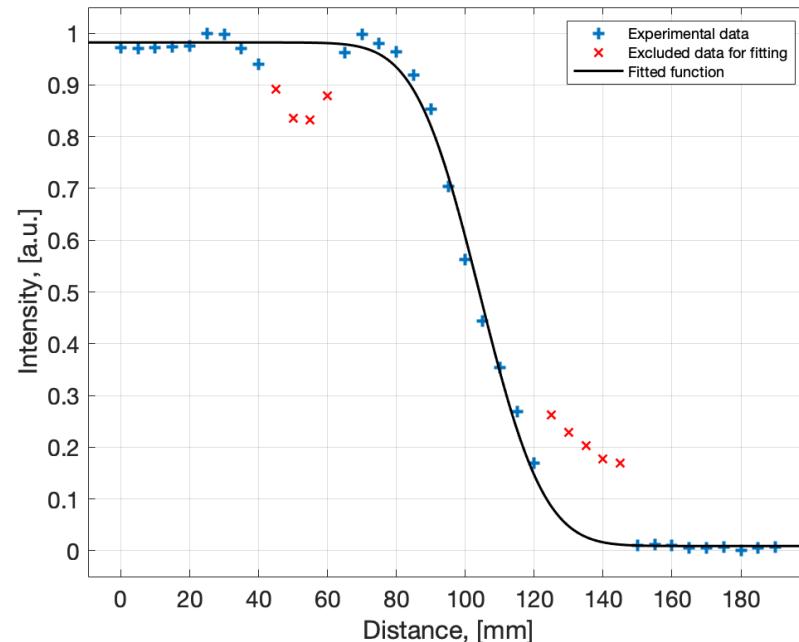


BEFORE L2

Beam diameter: 89,395 mm

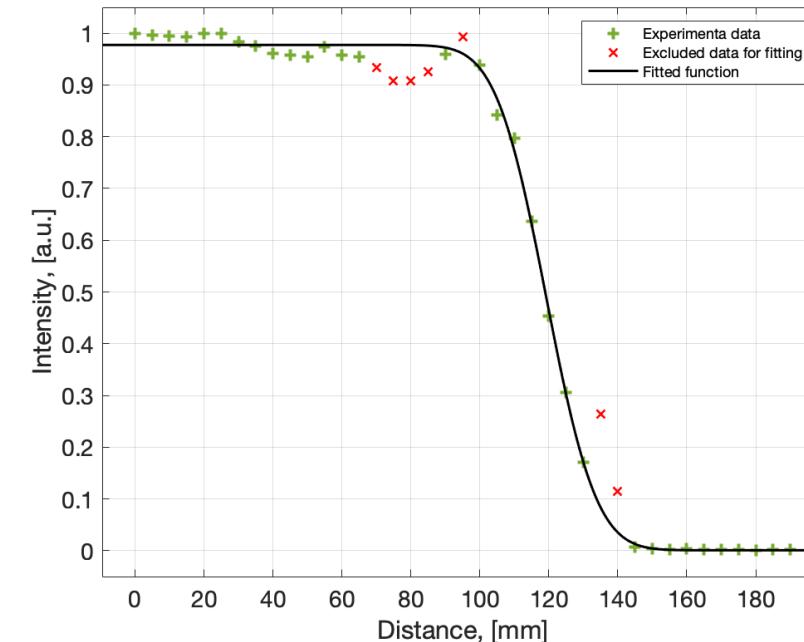
FRESNEL LENS CHARACTERIZATION FOR TRANSMISSION SETUP

KNIFE EDGE
TECHNIQUE



AFTER L1

Beam diameter: 33,035 mm

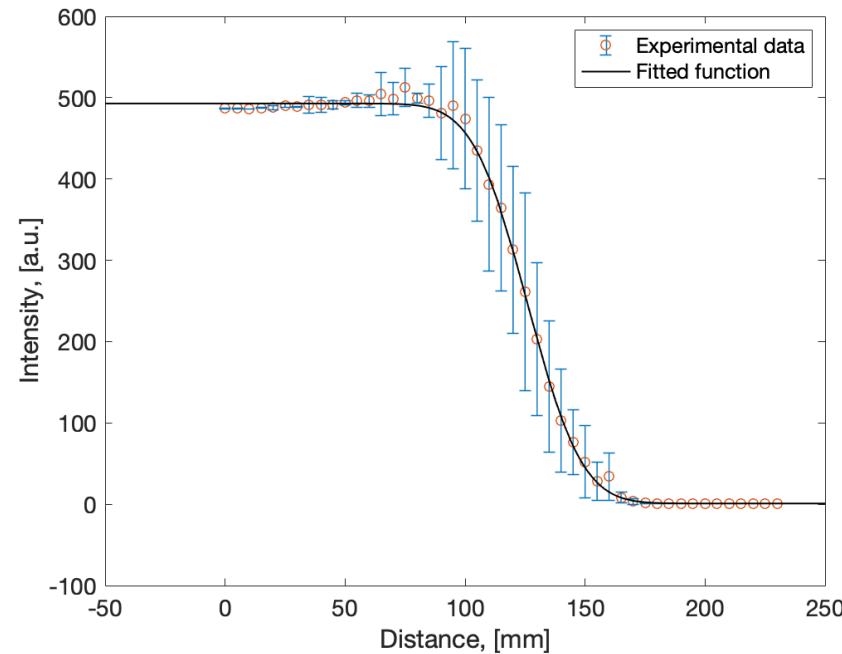


BEFORE L2

Beam diameter: 25,736 mm

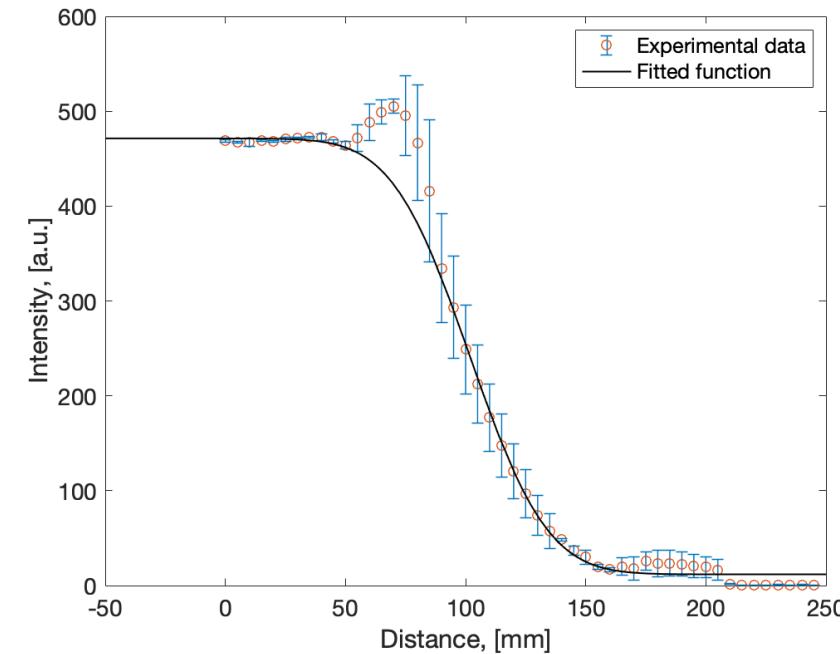
FRESNEL LENS CHARACTERIZATION FOR REFLECTION SETUP

KNIFE EDGE
TECHNIQUE



AFTER L1

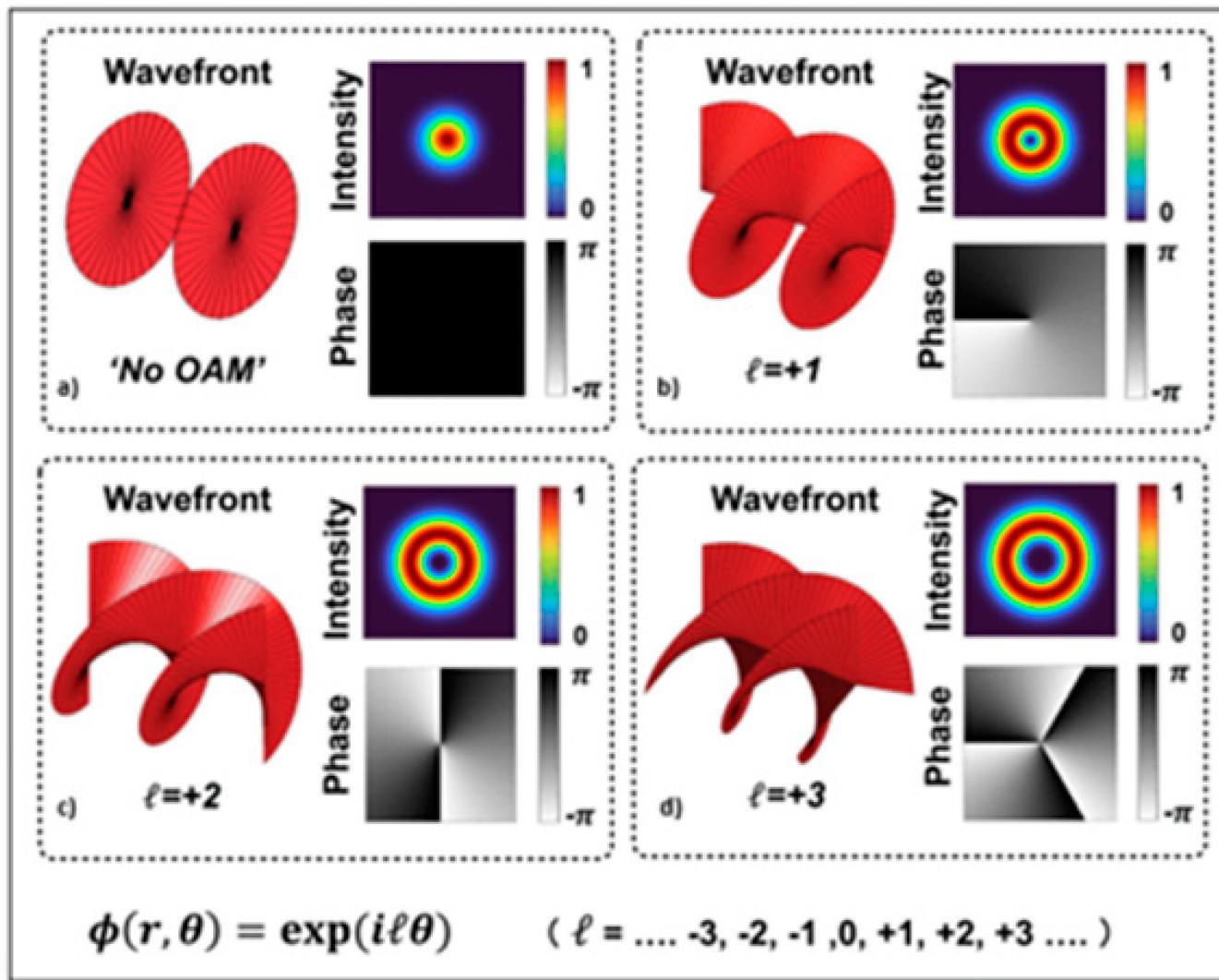
Beam diameter: 38,646 mm



BEFORE L2

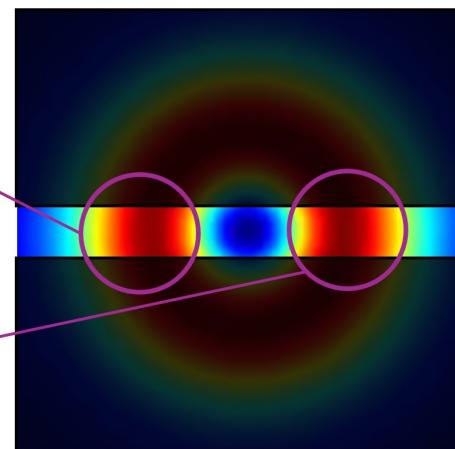
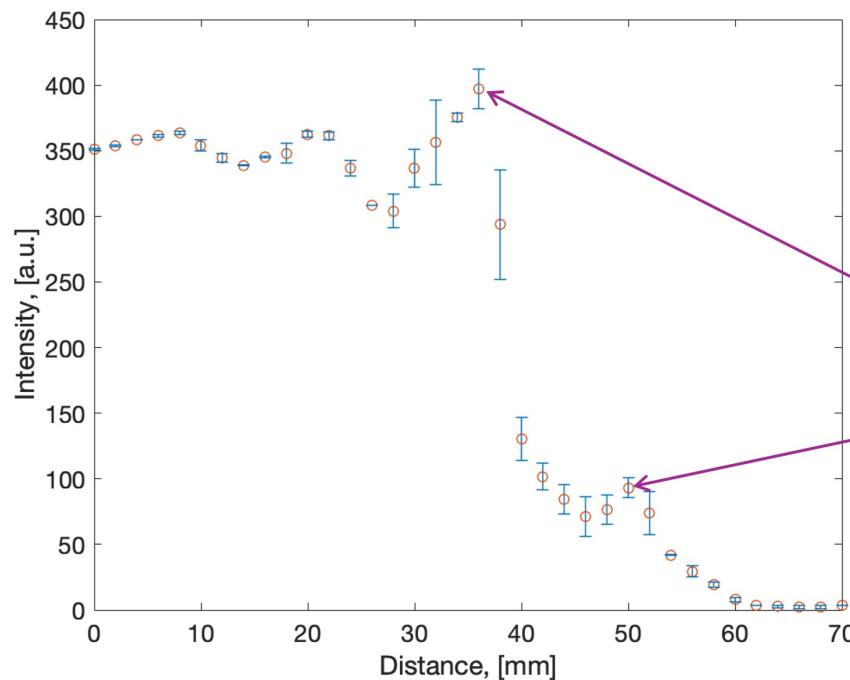
Beam diameter: 55,279 mm

ORBITAL ANGULAR MOMENTUM

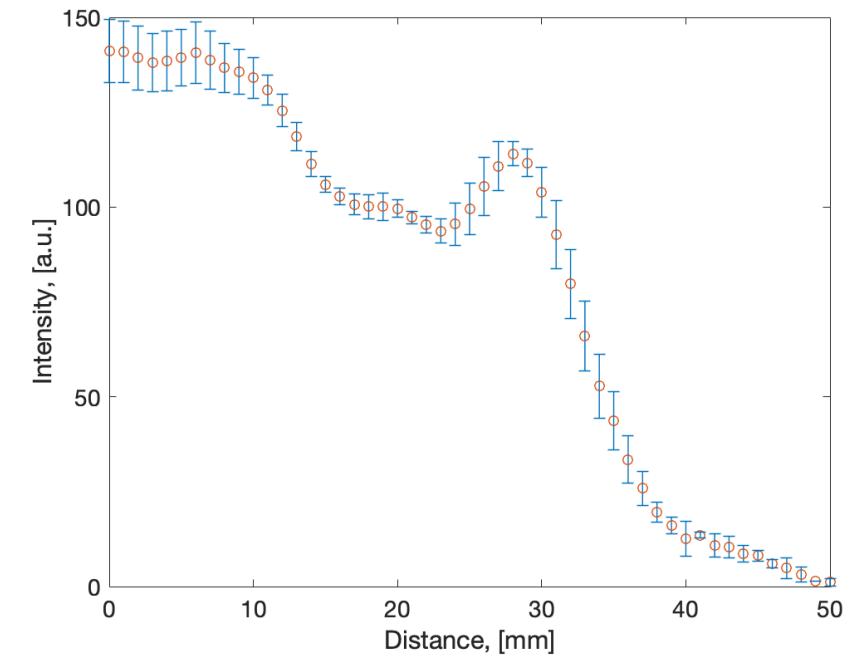


SPP MEASUREMENTS FOR TRANSMISSION SETUP

KNIFE EDGE
TECHNIQUE



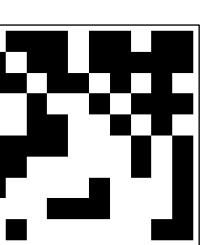
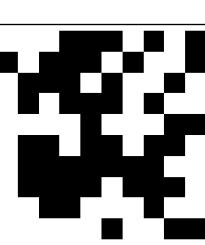
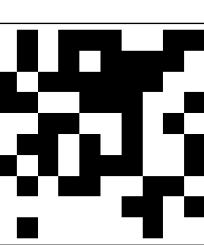
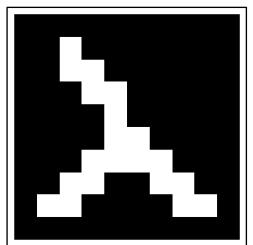
SPP FOR $\ell = 1$

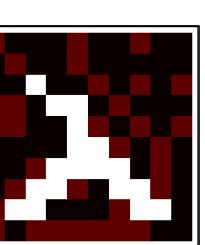
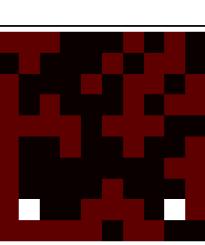
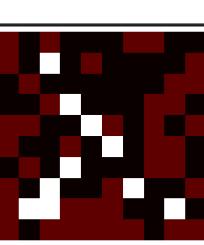
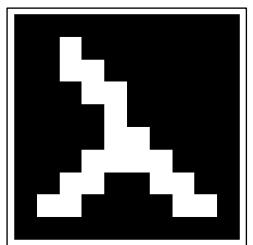


SPP FOR $\ell = 5$

SINGLE-PIXEL IMAGING (SPI)

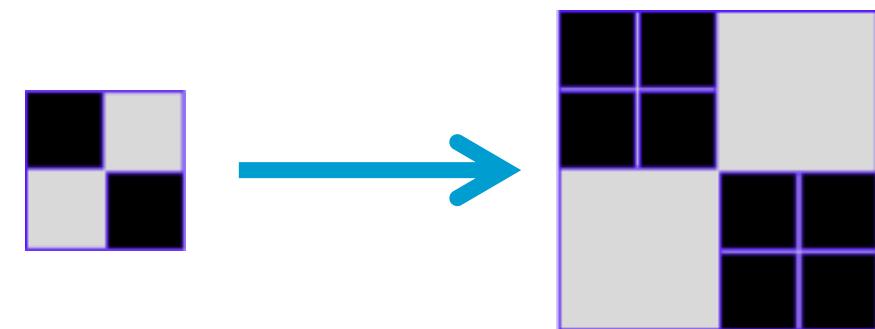
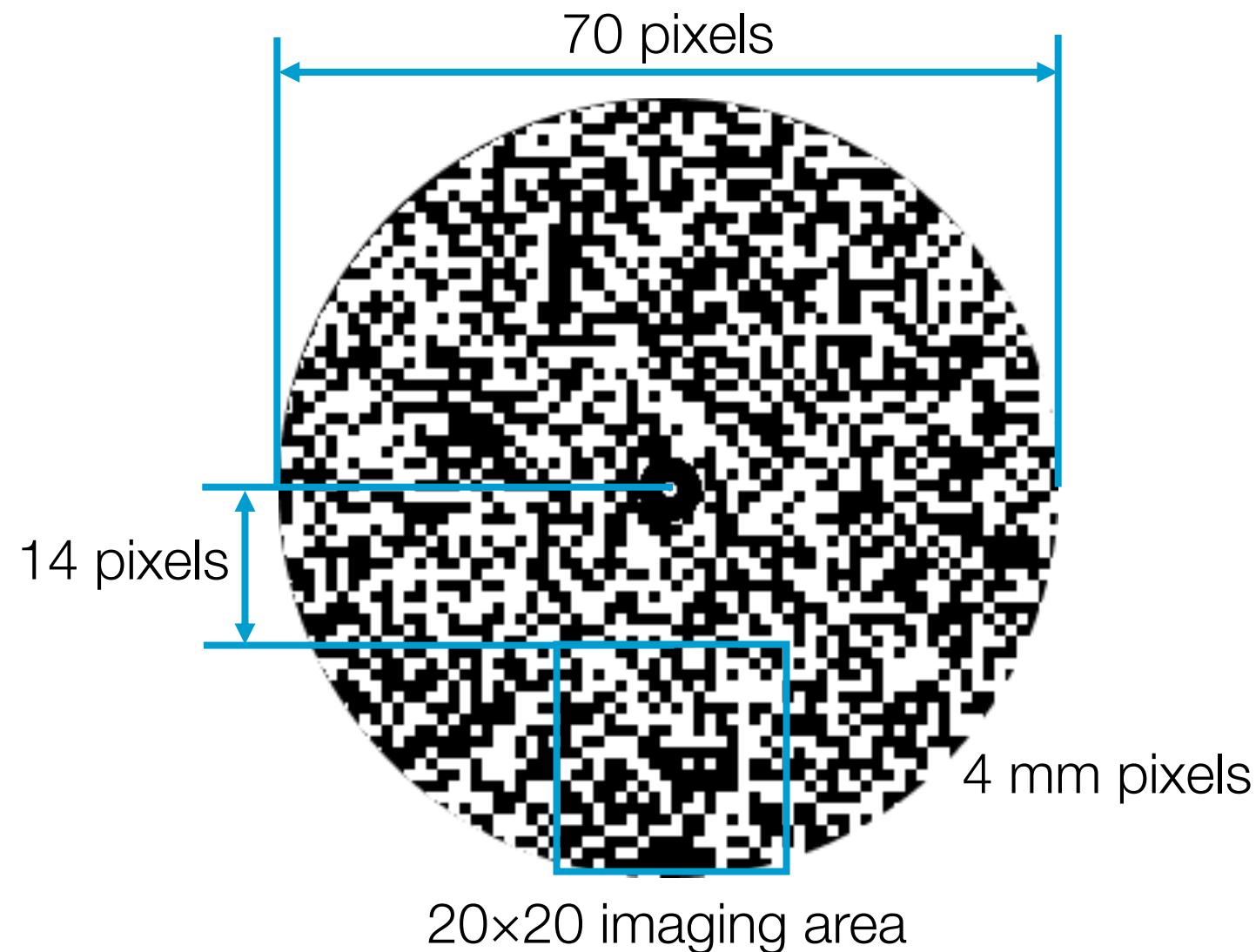
**BRUTE FORCE
ALGORITHM**  **IMAGE RECONSTRUCTION
USING RANDOM MASKS**

$$\begin{matrix} \text{Image} \\ = x_1 \text{ Mask}_1 + x_2 \text{ Mask}_2 + x_3 \text{ Mask}_3 + \dots \end{matrix}$$


$$\begin{matrix} \text{Image} \\ = 10 \text{ Mask}_1 + 2 \text{ Mask}_2 + 18 \text{ Mask}_3 + \dots \end{matrix}$$


OUR RANDOM MASK

RANDOM PATTERN DISK



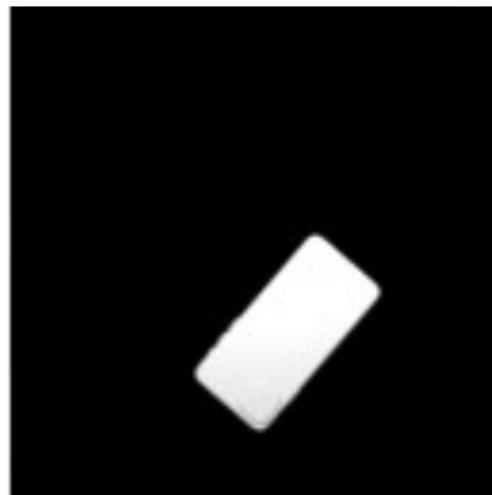
PIXEL DIGITAL SUBDIVISION

OUR NEURAL NETWORK

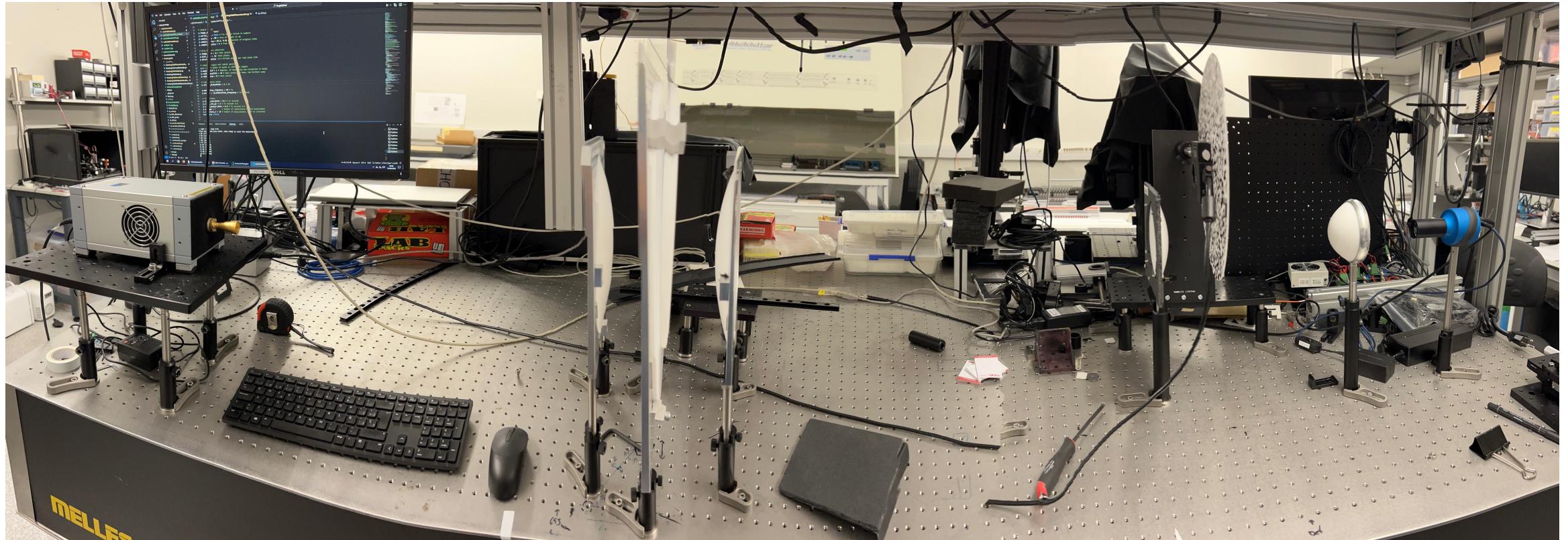
50.000 IMAGES



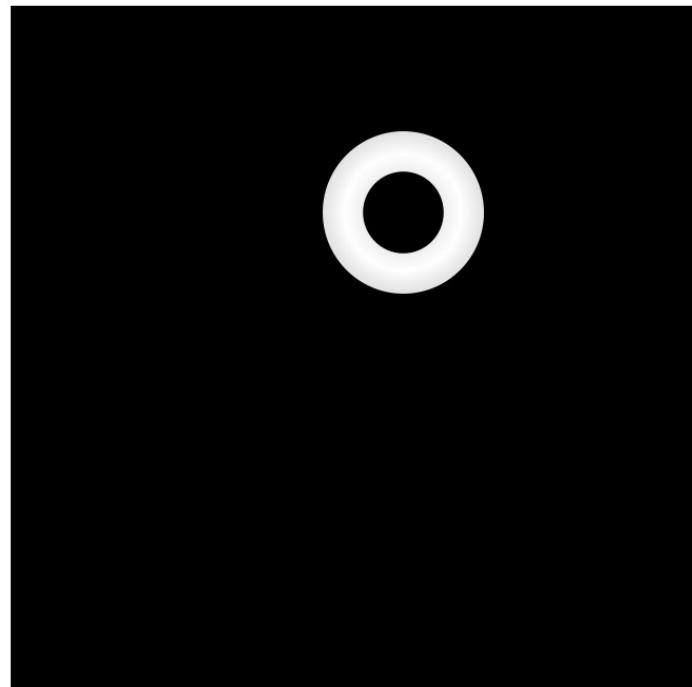
RANDOM LOCATION
AND ORIENTATION



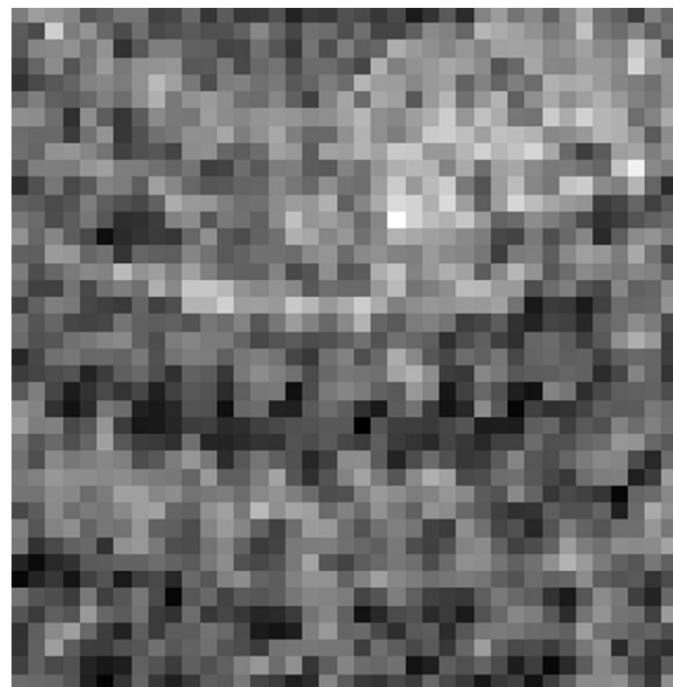
SPP MEASUREMENTS USING BRUTE FORCE



SPP MEASUREMENTS USING BRUTE FORCE

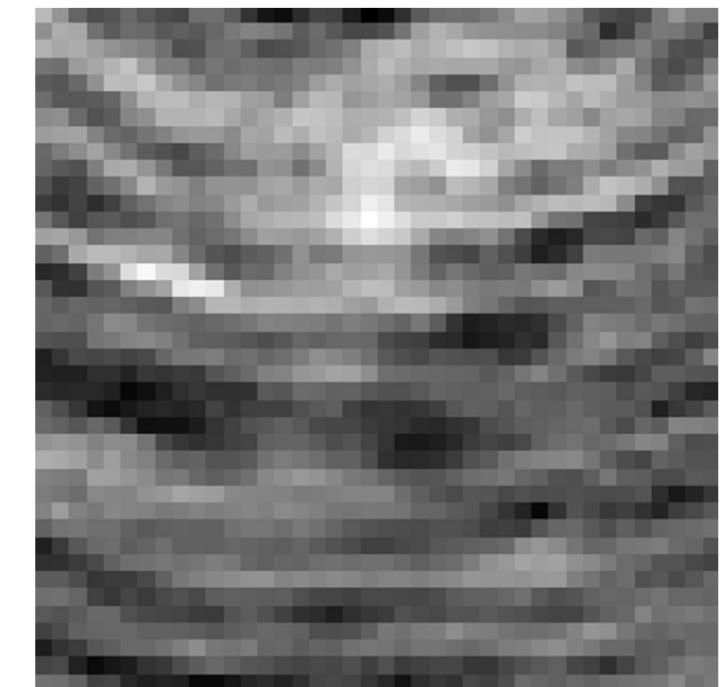


INTENSITY PROFILE



BRUTE FORCE 1

72 steps
 5° per step



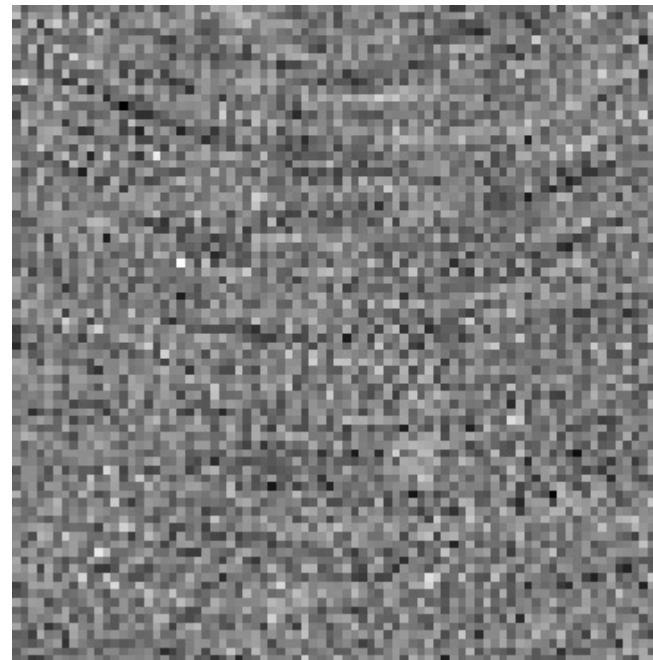
BRUTE FORCE 2

360 steps
 1° per step

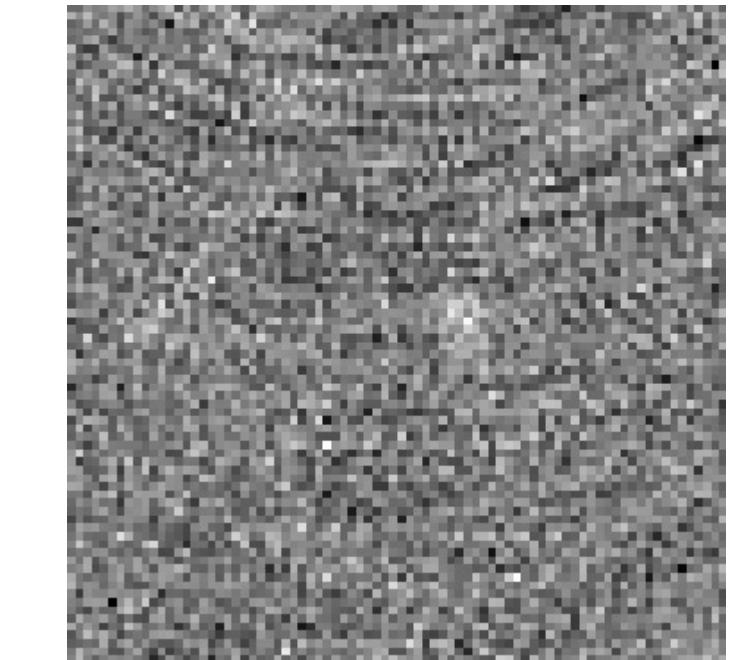
SPI MEASUREMENTS



**ORIGINAL OBJECT
BENT**



BRUTE FORCE
180 steps
 2° per step

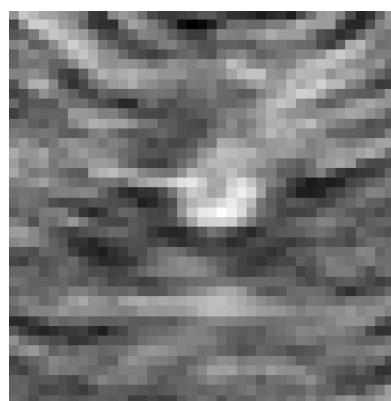
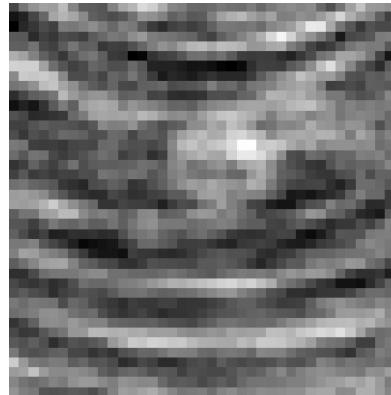


**INVALID
RESULTS**

SPI MEASUREMENTS

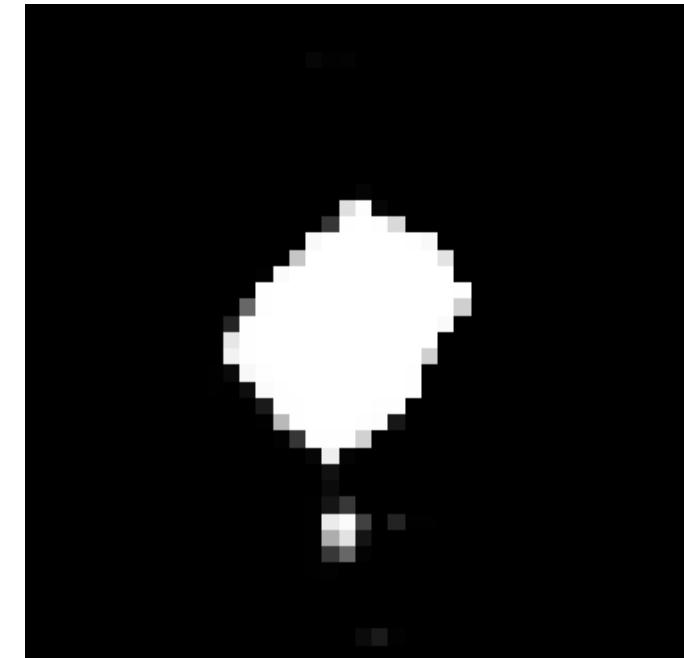


ALUMINIUM OBJECT



BRUTE FORCE

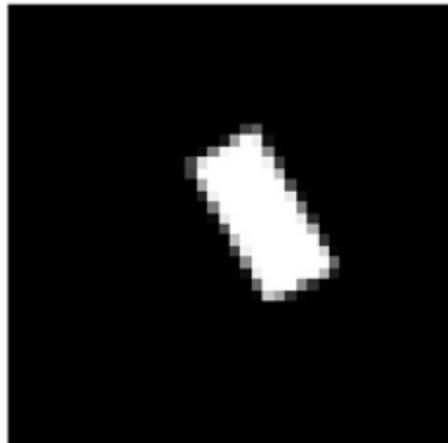
360 steps
 1° per step



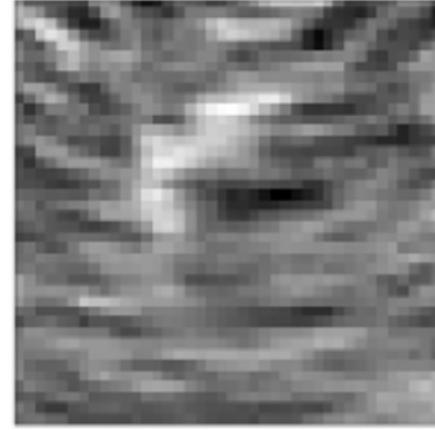
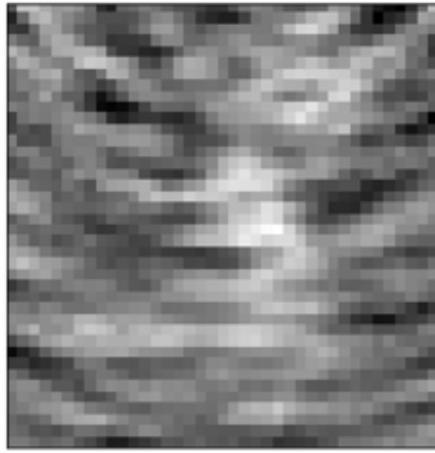
NEURAL NETWORK

INVALID RESULTS

SPI MEASUREMENTS COMPARING BF AND NN



INTENSITY PROFILE



BRUTE FORCE 1

720 steps
0,5° per step



NEURAL NETWORK

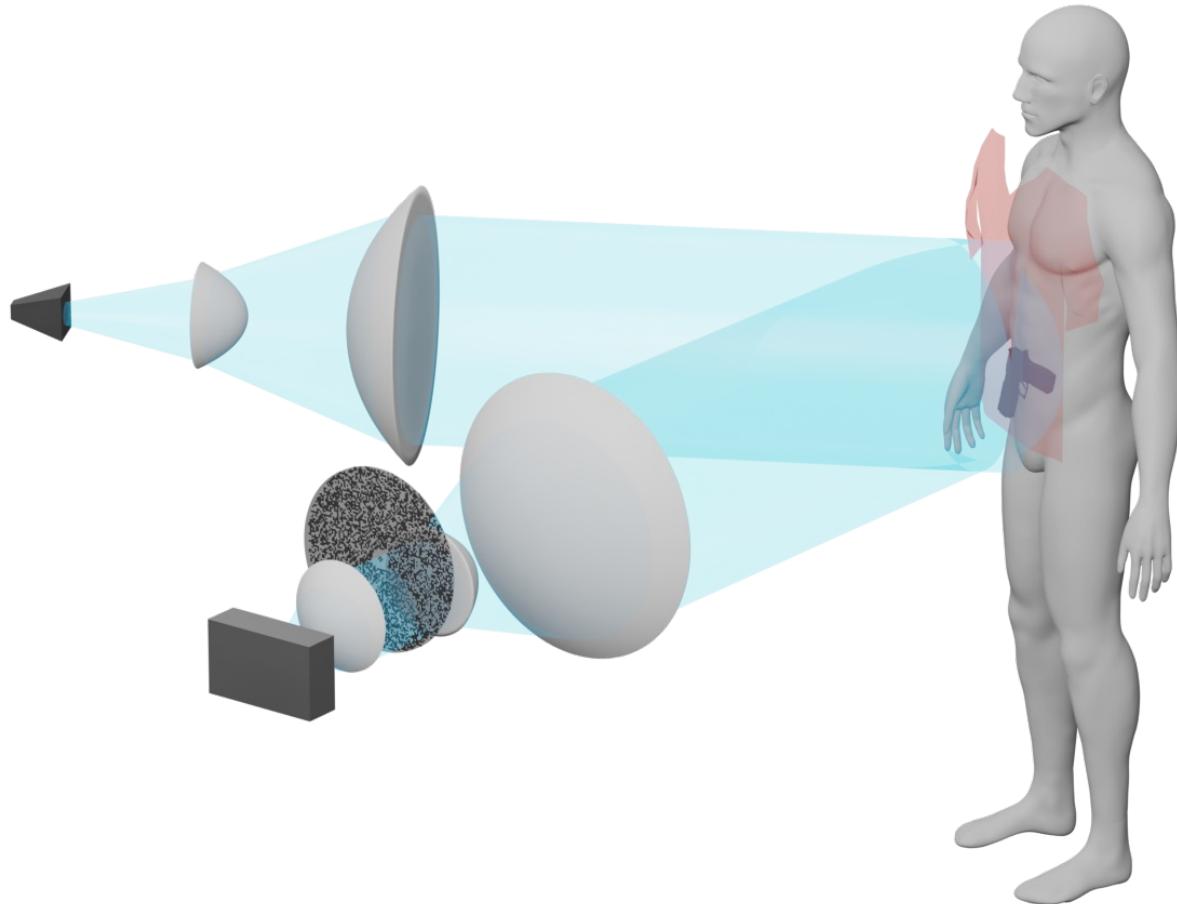
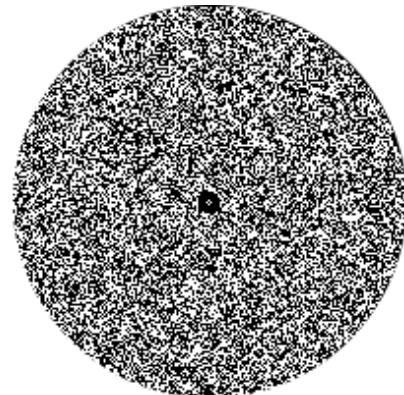
180 steps
1° per step

FUTURE WORK

0,3 THz SOURCE



SMALL PIXELS DISK



PROTOTYPE FOR
SECURITY CONTROLS

CONCLUSIONS

- **FRESNEL LENSES PRESENT MANY ABERRATIONS TO BE USED IN A PROTOTYPE**
- **DOUGHNUT SHAPE INTENSITY PROFILE DEMONSTRATED FOR THE OAM WITH SPIRAL PHASE PLATES**
- **SUCCESSFUL PROOF-OF-CONCEPT THAT CAN BE USED AS A PROTOYPE FOR SECURITY CONTROLS**

Single-pixel camera enhanced with deep learning protocols for the characterization of diffractive optics working in the THz region

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