

# ANALYZING OPTICAL SYSTEM FOR EDGE DETECTION USING 4F SYSTEM

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# BACKGROUND

- In computer vision or robotic surgery vision edge detection is the prior step to the object localization.
- The image processing algorithm performs the edge detection algorithm. But using the 4F system, there is an idea to perform the edge detection.
- The goal here is to vary the object for which the edge has to be detected and varying the filter size as to check what are the limitation of the optical edge detection system comparing to the edge detection image processing algorithm.

# BACKGROUND

- Along with high pass filter, band pass filter have also been checked for edge detection.
- The normal 4f system has been modified to check the possibility for better result.
- Stay tune to see what we got here!!

# OPTICAL CORRELATOR SYSTEM

Basic optical Fourier techniques used for image processing

This system is ideal to transform the small spatial filtering variation process in the focal plane into large variations of the intensity in the image plane[1]

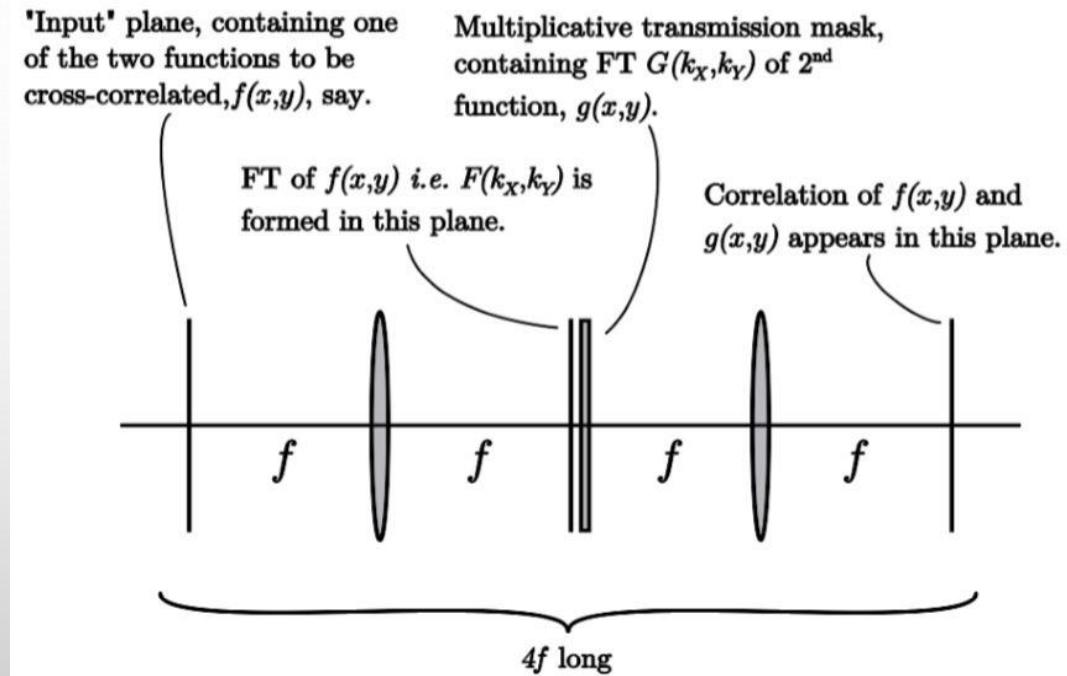


Figure.1. Optical correlator system[2]

# 4f System Diagram

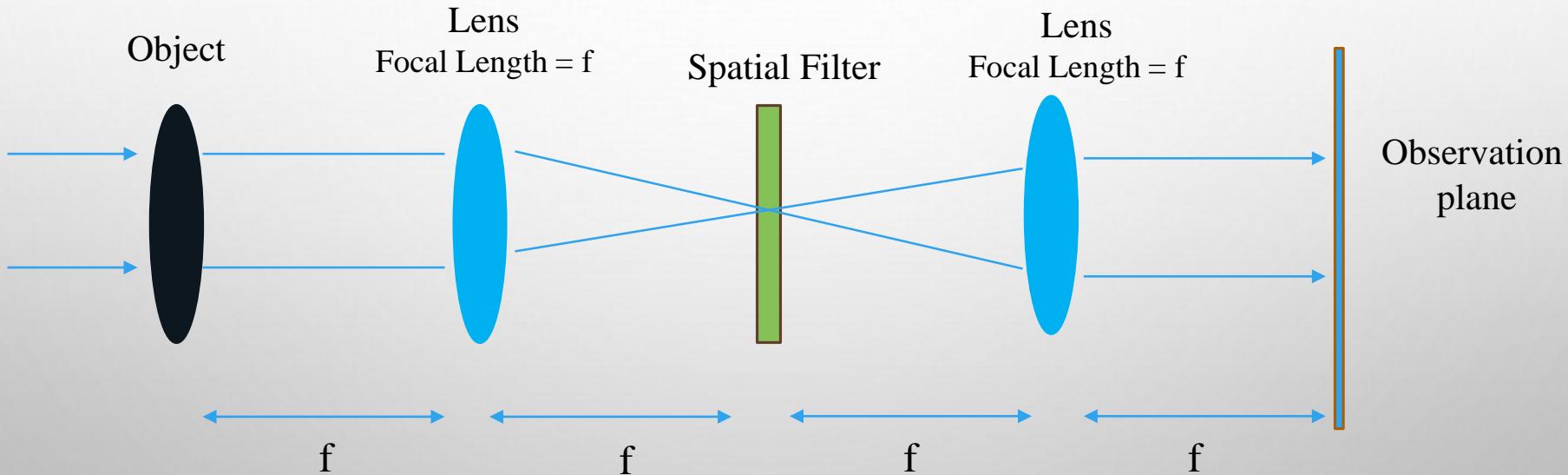


Figure 1. 4F system diagram

# 4F System Set up

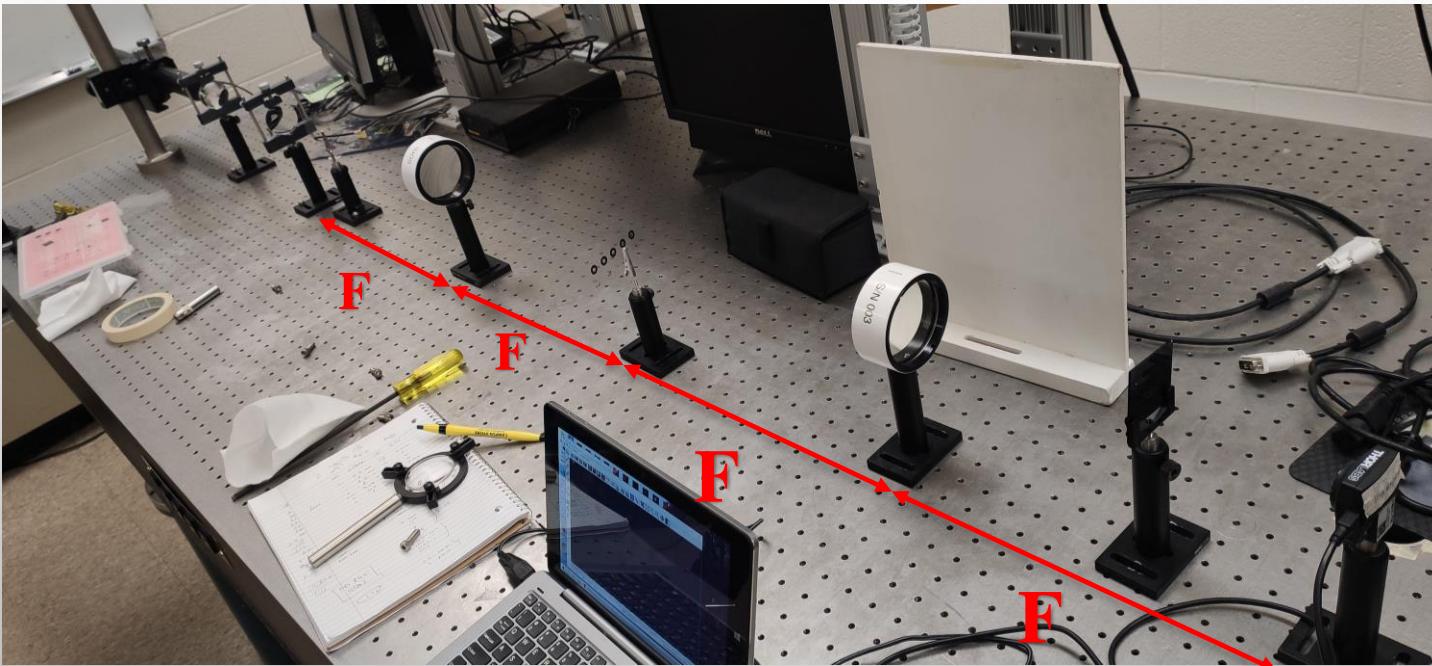


Figure.2.4F system set up

# Laser

He-Ne Laser

Laser Class: III B

Wave length: 632.8 nm

Maximum power : 30mW

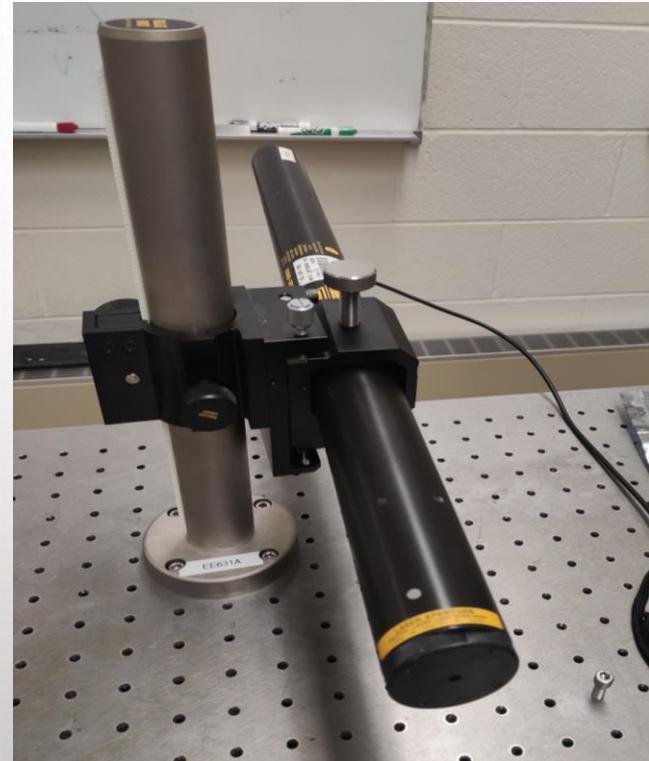


Figure.3. He-Ne Laser

# Beam Expander

Optical device which expand optical size diameter:

$$D = \frac{f_1}{f_2} d$$

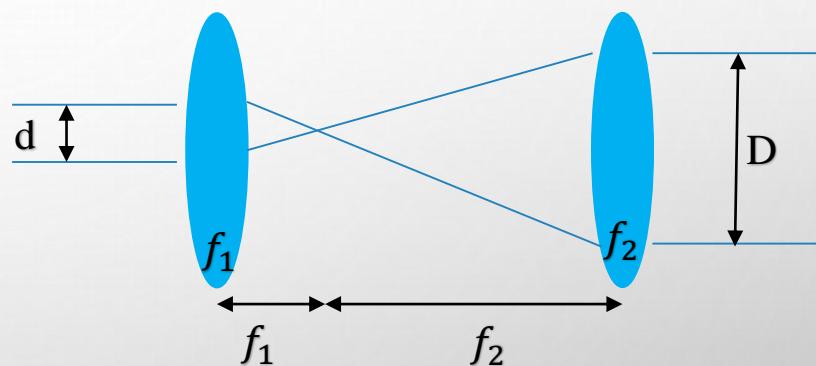


Figure.4. Beam Expander diagram

# Objects

- US Air Force bar target
- Asymmetric letter “F”

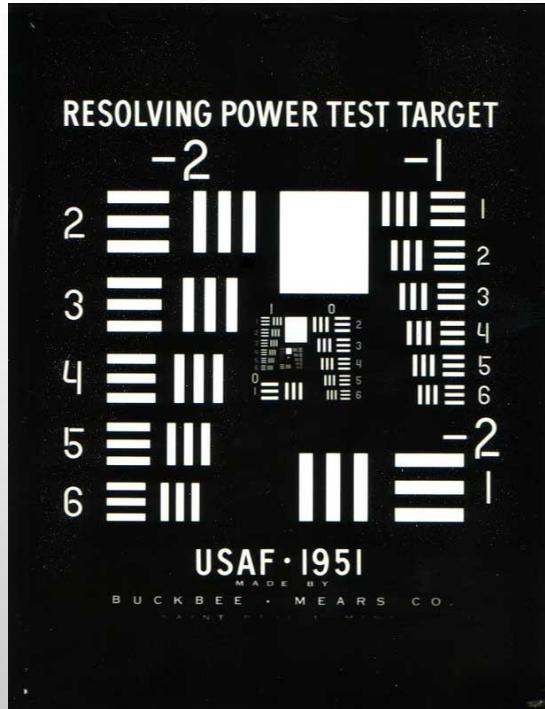


Figure.5.[https://en.wikipedia.org/wiki/1951\\_USAF\\_resolution\\_test\\_chart#/media/File:1951\\_usaf\\_test\\_target.jpg](https://en.wikipedia.org/wiki/1951_USAF_resolution_test_chart#/media/File:1951_usaf_test_target.jpg)



Figure.6.<https://en.wiktionary.org/wiki/F#/media/File:LetterF.svg>

# Objects

1 Thorlabs USAF bar target (bar target 1)

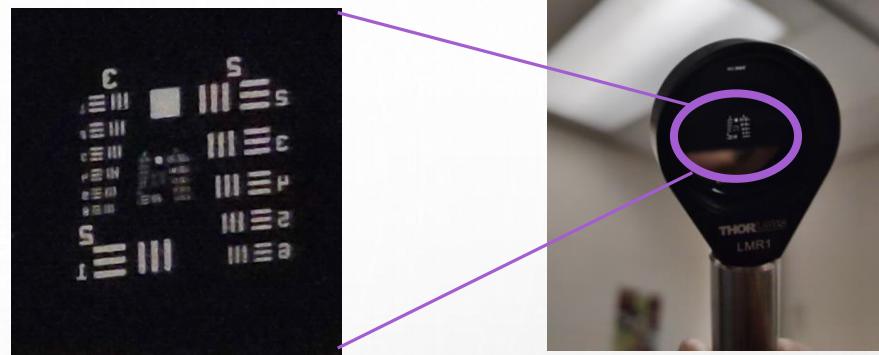


Figure.7. Thorlabs USFA bar target

3 Printed USAF bar targets(bar target 2)

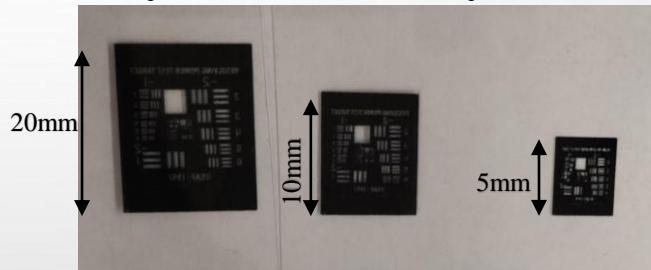


Figure.8. Printed USFA bar targets

8 Printed "F" letters (F target)

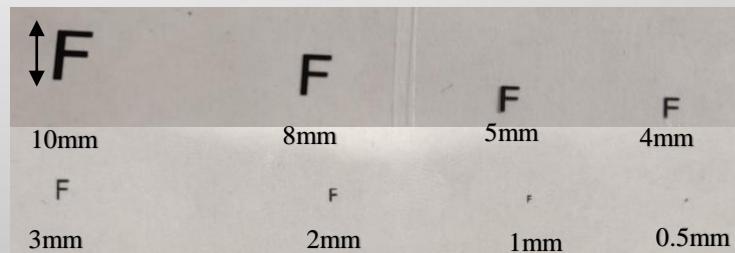


Figure.9. Printed "F" letter

# Transparency and printer

## Transparency

- Transparency printable sheet
- Size: 11inchs\* 8.5 inches

## Printer

- Brand: xerox
- Model: workcentre 7855
- Maximum resolution: 1200\*2400 dpi

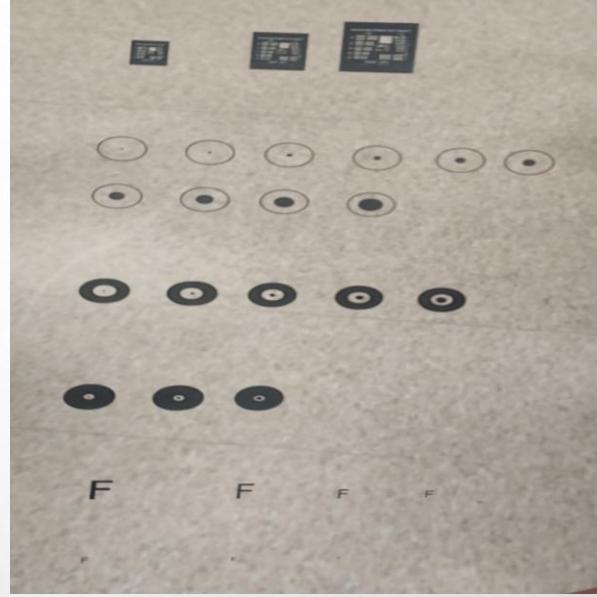


Figure.10. Printed Transparency



Figure.11.<https://www.ebay.com/item/5PCS-A4-Transparent-Sheet-PVC-APET-Folding-Box-PET-Window-Plastic-PET-Film-DIY-/254298965306>

# Spatial Filters

$$k = 2 \text{ } NA \text{ } k_o$$

k = spatial frequency

$$NA = \frac{d}{2f}$$

$\lambda_o$  = wave length of light source

$$k_o = \frac{1}{\lambda_o}$$

d = spatial filter pupil size

f = focal length

For d= 0.5mm, f= 381mm,  $\lambda_o$  = 632.8nm:

$$k = 2073 \text{ Hz}$$

# Spatial Filters Printed by photoplotter(Set 1)

- 8 Band pass filter was printed by photoplotter
- 7 of them was used in the experiment

Inner circle:

1mm

2mm

3mm

4mm

3mm

Outer ring :

2mm

3mm

4mm

5mm

5mm

Inner circle:

2mm

4mm

Outer ring :

4mm

6mm

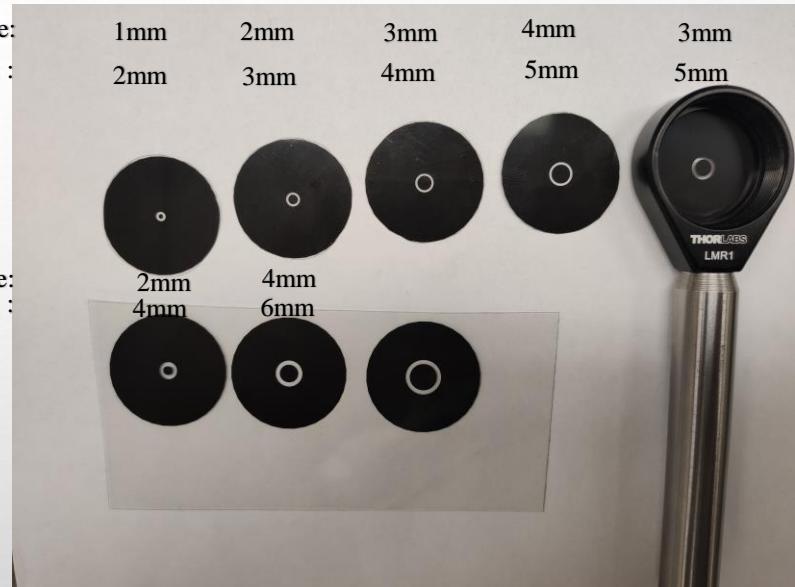
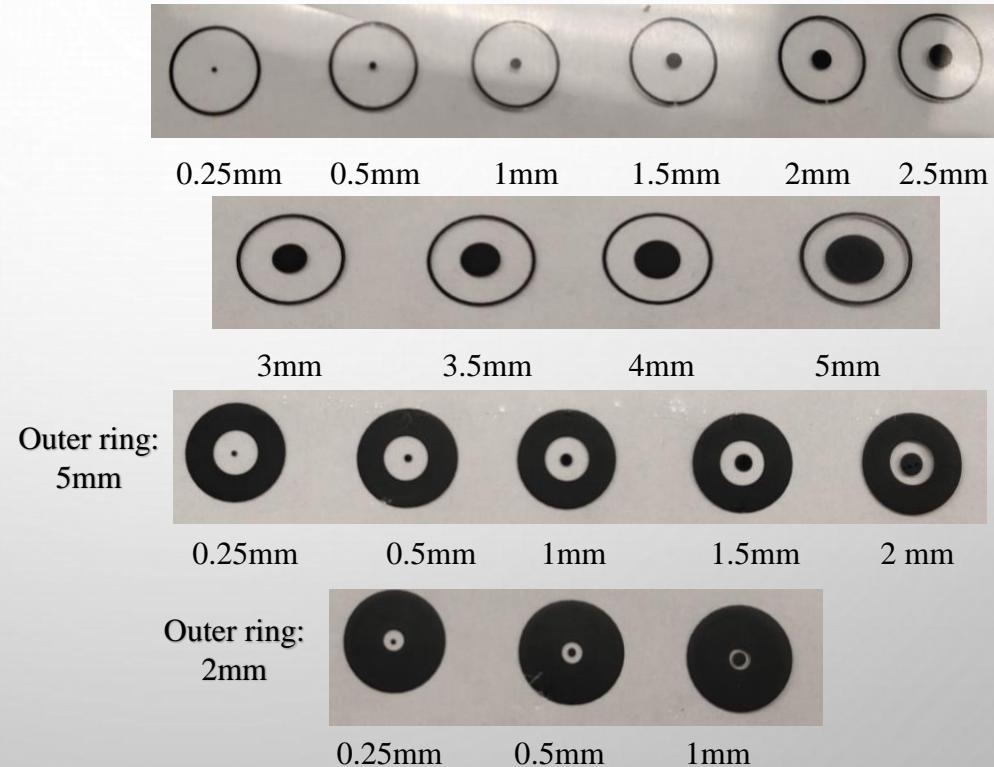


Figure.12. Spatial filters(set1)

# Spatial Filters Printed by xerox printer(Set2)

- 10 High pass spatial filters
- 5 Band pass filter with 5 mm outer ring
- 3 Band pass filter with 2mm outer ring
- 18 Spatial filters in total



# ND Filter

Neutral-density filter is a filter reduces the light intensity

0.2 ND filter was used which has 0.7 fractional transmittance

$$\log 2 = 0.30$$



Figure.13. ND filter

# Camera

Thorlabs camera DDC1645C

Sensor type: CMOS

Color camera

Detection resolution: 1280\*1024 pixel (1.31 megapixel)

Exact sensitive area: 4.608\*3.686 mm

Pixel size:  $3.6 \mu\text{m}$ , square

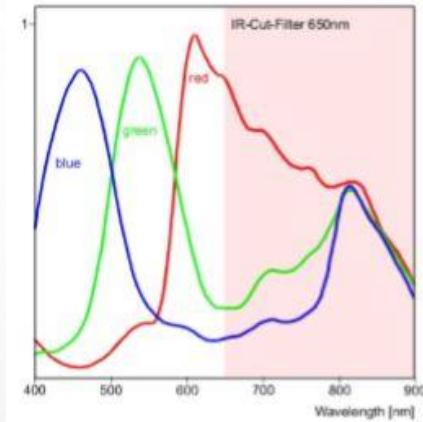


Figure.15. Sensor sensitivity of the DCC1645



Figure.16. Camera DDC1645C

# Set up Diagram

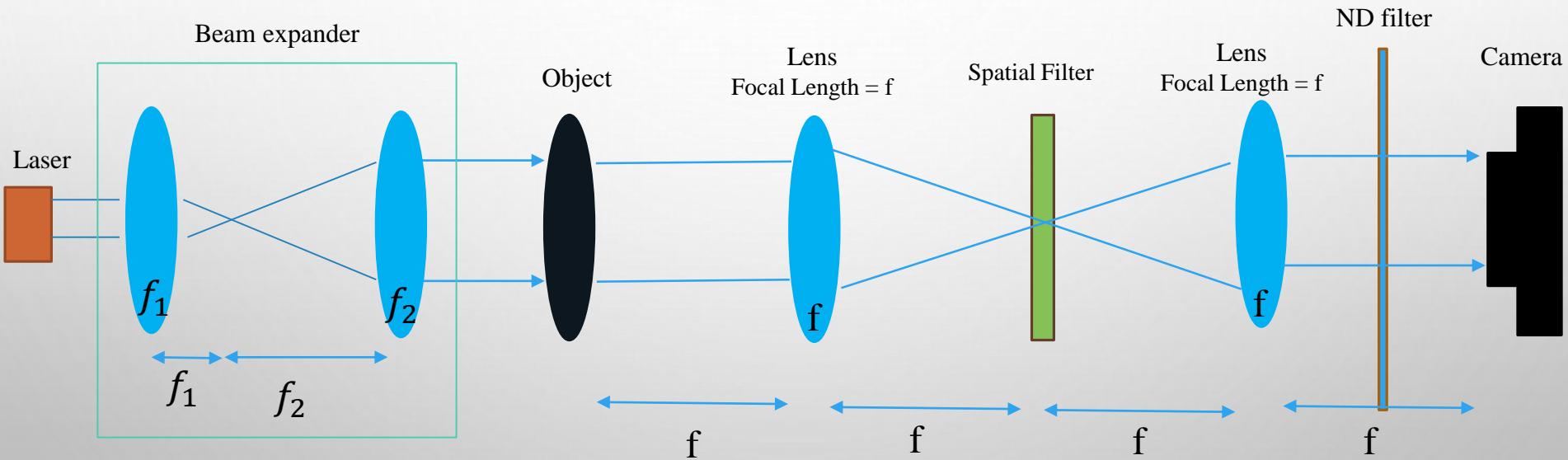
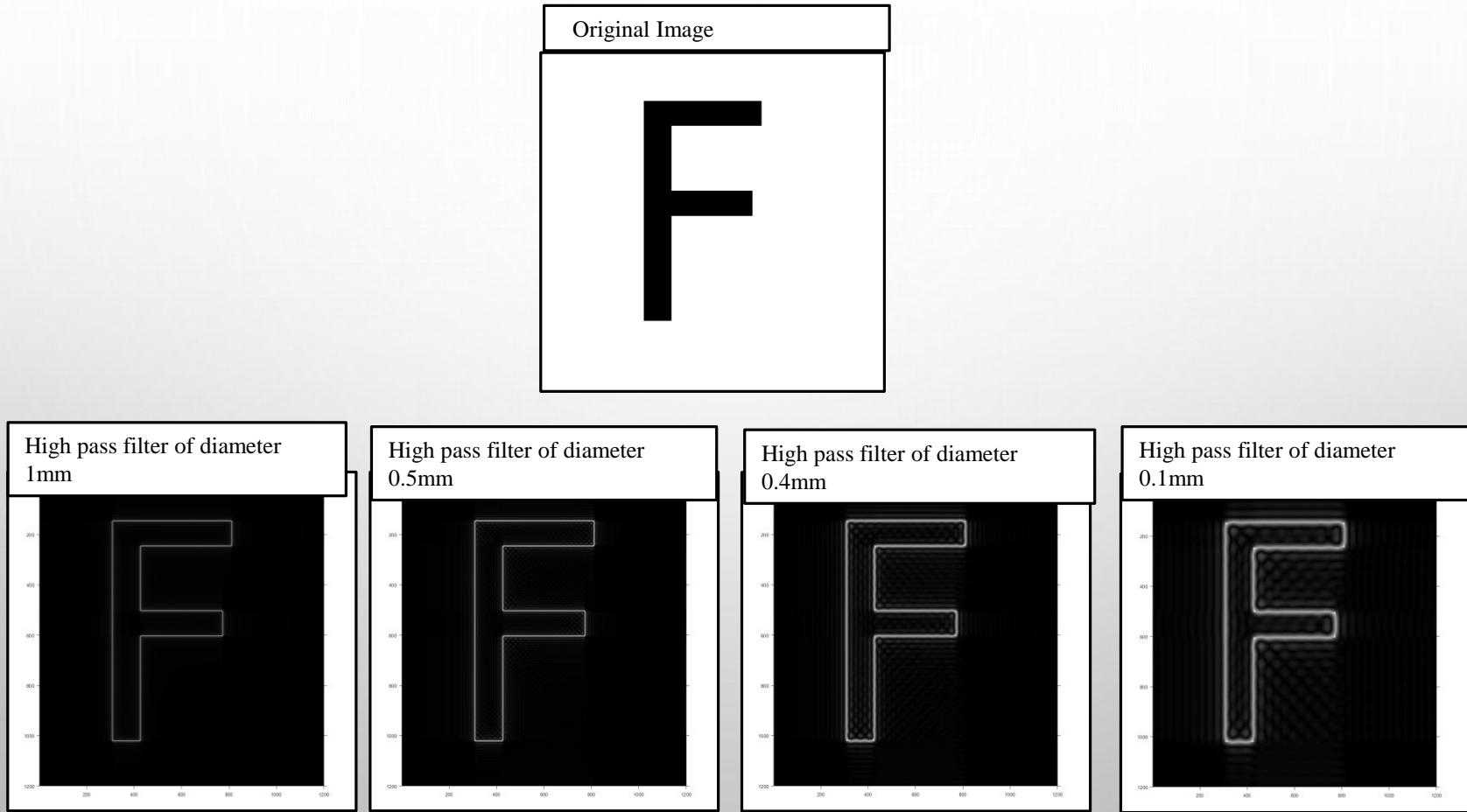


Figure.17. Set up diagram

# MATLAB SIMULATION RESULT

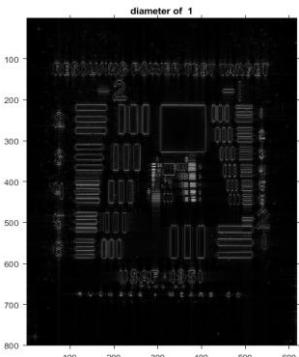


# MATLAB SIMULATION RESULT

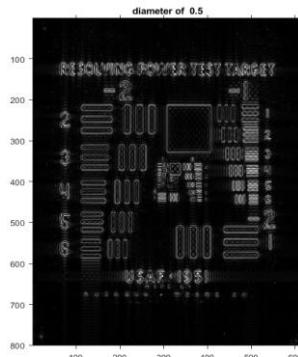
Original Image



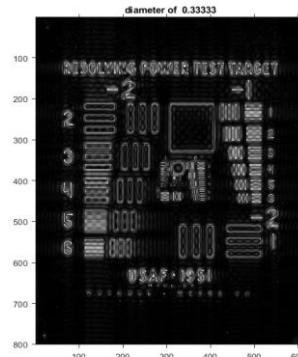
High pass filter of diameter  
1mm



High pass filter of diameter  
0.5mm



High pass filter of diameter  
0.3mm



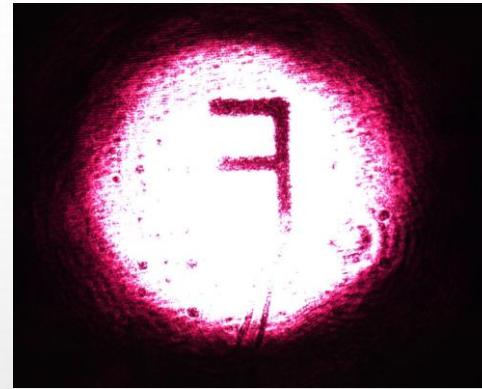
High pass filter of diameter  
0.1mm



# THE IMAGE FORMATION



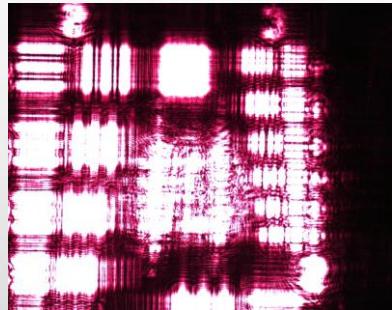
In the observation filter



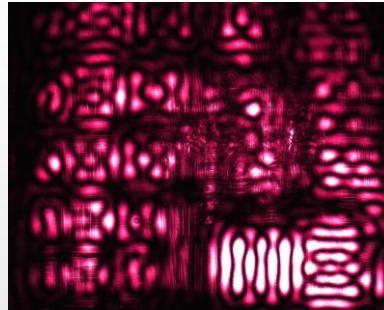
In the detector

- In the observation plane we got the inverted F, which is the actual optical physics behind the image formation.
- The reason is simple...The detector is upside down giving the flipped F image.

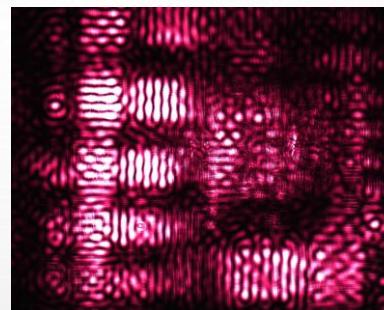
# BAR TARGET 1 WITH FILTER SET 1



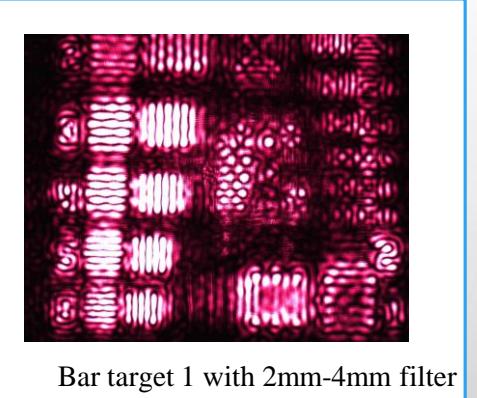
Bar target 1 with no filter



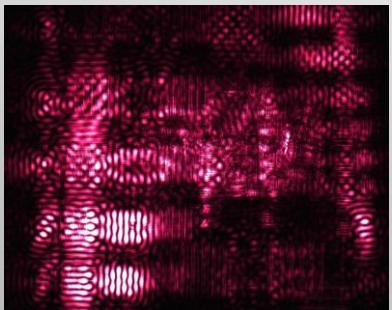
Bar target 1 with 1mm-2mm filter



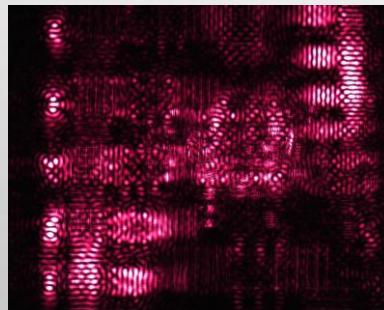
Bar target 1 with 2mm-3mm filter



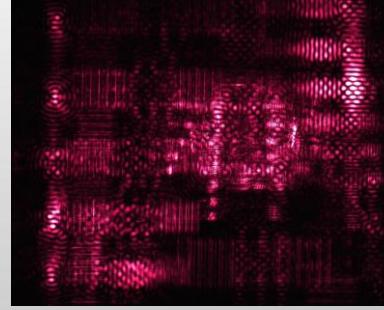
Bar target 1 with 2mm-4mm filter



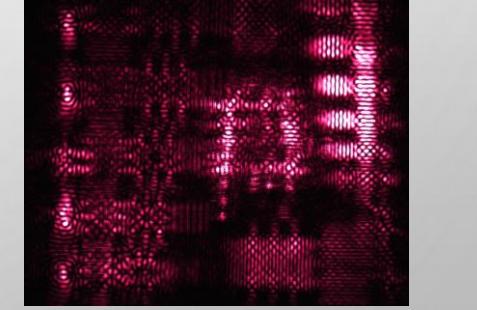
Bar target 1 with 3mm-4mm filter



Bar target 1 with 3mm-5mm filter

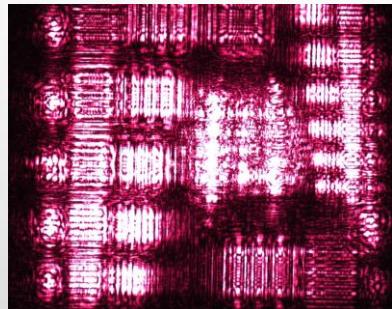


Bar target 1 with 4mm-5mm filter

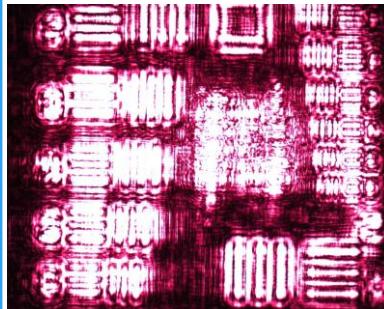


Bar target 1 with 4mm-6mm filter

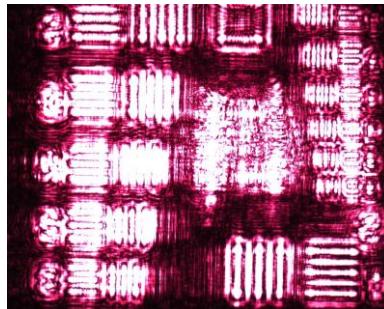
# BAR TARGET 1 WITH FILTERS SET 2(HIGH PASS FILTERS)



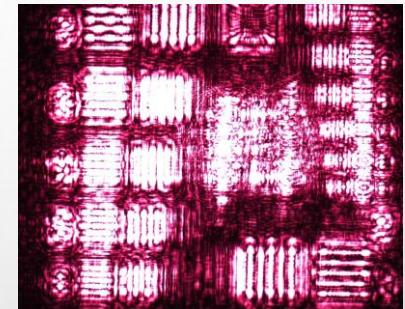
Bar target 1 with 0.25mm filter



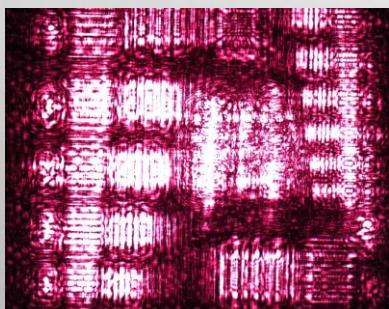
Bar target 1 with 0.5mm filter



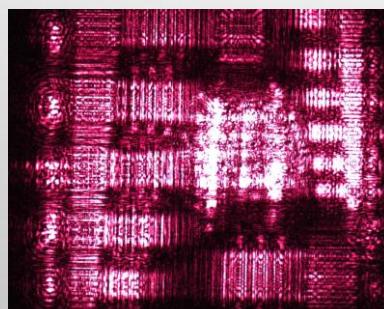
Bar target 1 with 1mm filter



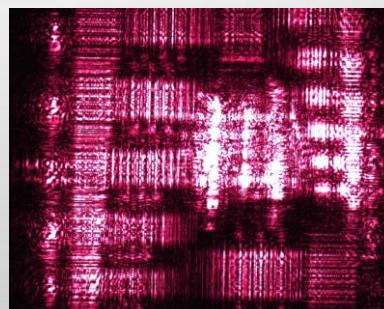
Bar target 1 with 1.5mm filter



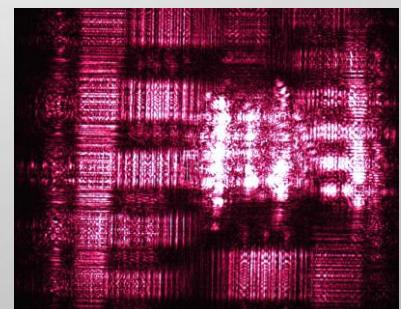
Bar target 1 with 2mm filter



Bar target 1 with 3.5mm filter

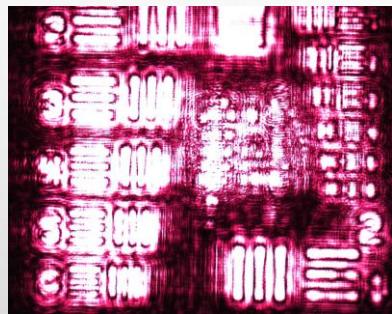


Bar target 1 with 4mm filter

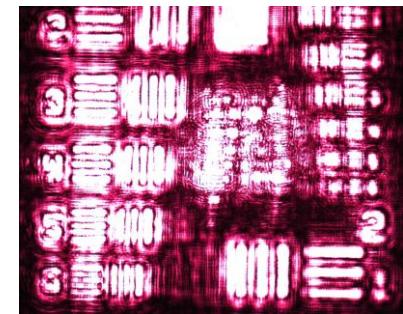


Bar target 1 with 5mm filter

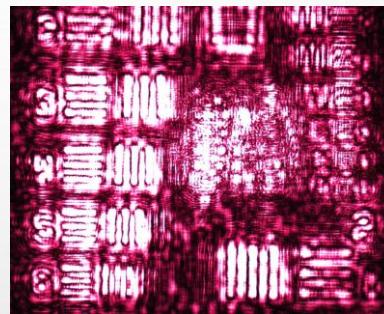
# Bar target 1 with filters set 2(Band pass filter of outer ring 5mm)



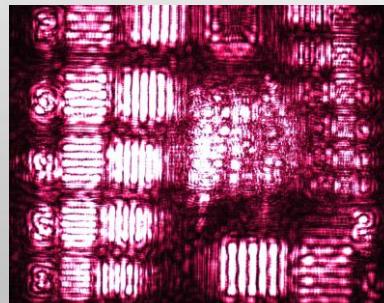
Bar target 1 with 0.25mm-5mm filter



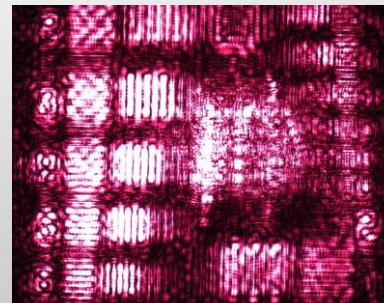
Bar target 1 with 0.5mm-5mm filter



Bar target 1 with 1mm-5mm filter

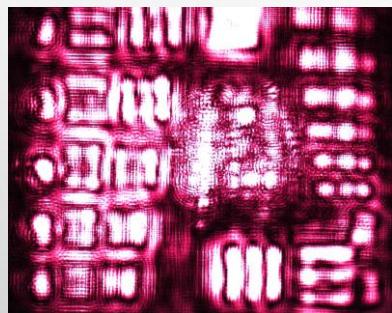


Bar target 1 with 1.5mm-5mm filter

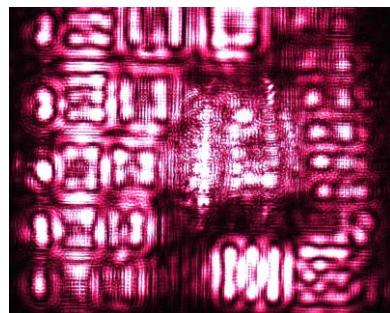


Bar target 1 with 2mm-5mm filter

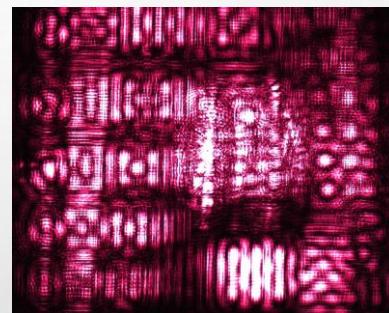
# BAR TARGET 1 WITH FILTERS SET 2(BAND PASS FILTER OF OUTER RING 2MM)



Bar target 1 with 0.25mm-2mm filter

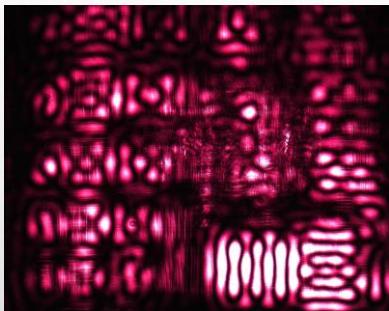


Bar target 1 with 0.5mm-2mm filter

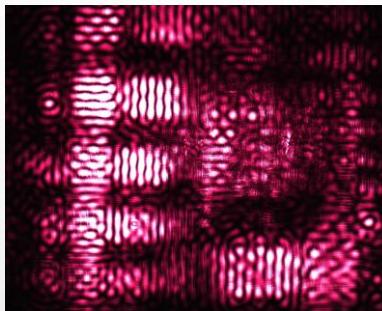


Bar target 1 with 1mm-2mm filter

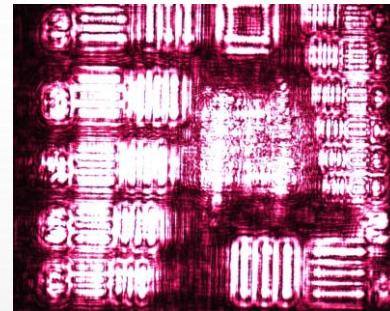
# BAR TARGET 1 CONCLUSION



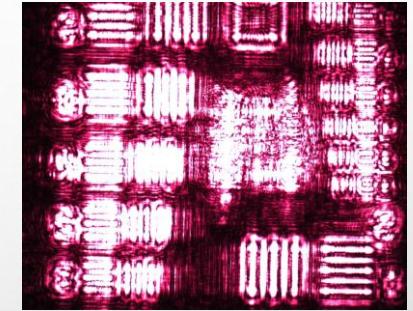
Bar target 1 with 1mm-2mm filter



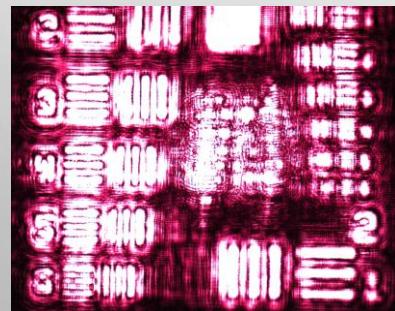
Bar target 1 with 2mm-3mm filter



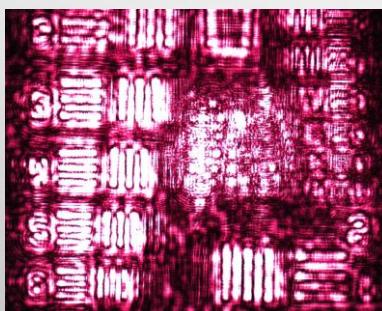
Bar target 1 with 0.5mm filter



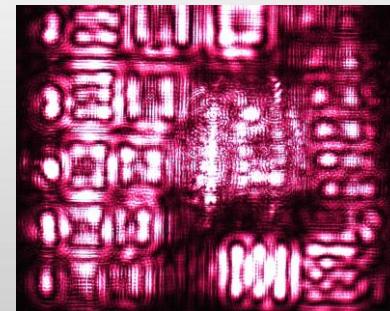
Bar target 1 with 1mm filter



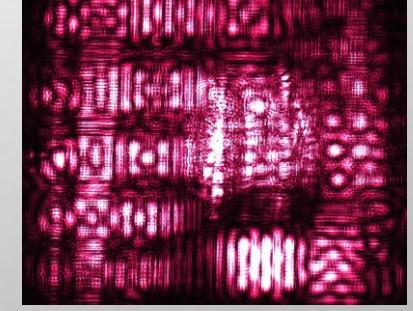
Bar target 1 with 0.5mm-5mm filter



Bar target 1 with 1mm-5mm filter



Bar target 1 with 0.5mm-2mm filter

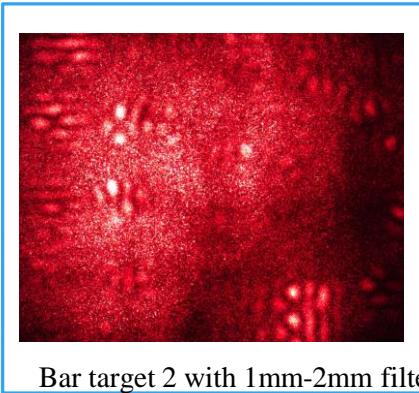


Bar target 1 with 1mm-2mm filter

## Bar target 2 with filter set 1



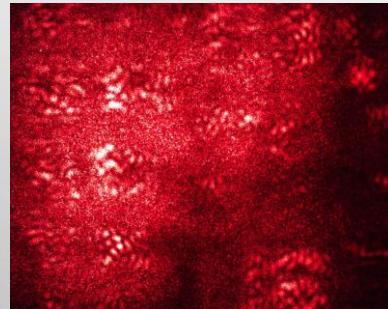
Bar target 2 with no filter



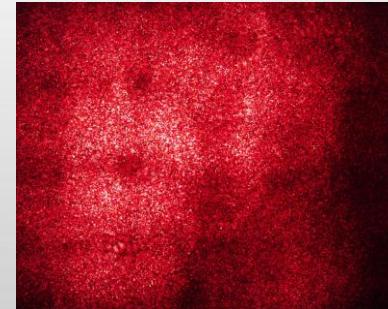
Bar target 2 with 1mm-2mm filter



Bar target 2 with 2mm-3mm filter

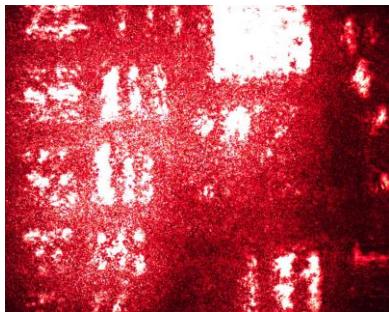


Bar target 2 with 2mm-4mm filter



Bar target 2 with 3mm-4mm filter

## Bar target 2 with filters set 2(High pass filter)



Bar target 2 with 0.5mm filter



Bar target 2 with 1mm filter

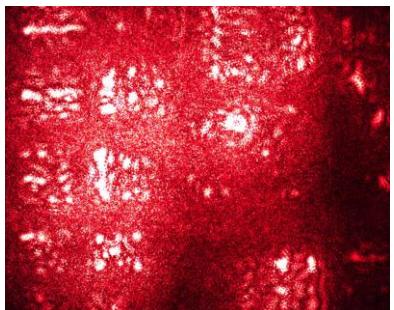


Bar target 2 with 1.5mm filter



Bar target 2 with 2mm filter

## Bar target 2 with filters set 2(Band pass filter with outer ring of 5mm)



Bar target 2 with 0.5mm-5mm filter



Bar target 2 with 1mm-5mm filter



Bar target 2 with 1.5mm-5mm filter

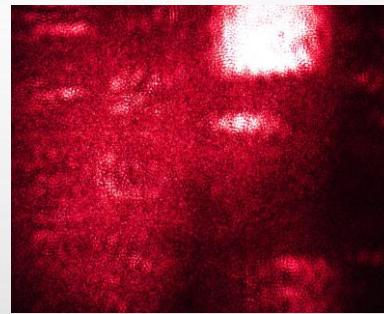


Bar target 2 with 2mm-5mm filter

# Bar target 2 with filters set 2(Band pass filter with outer ring of 2mm)

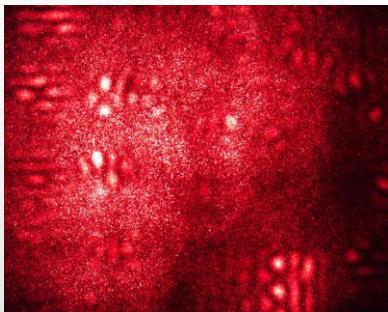


Bar target 2 with 0.5mm-2mm filter



Bar target 2 with 1mm-2mm filter

# BAR TARGET 2 CONCLUSION



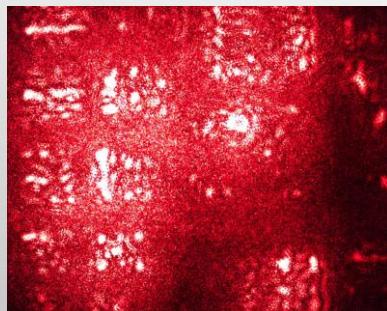
Bar target 2 with 1mm-2mm filter



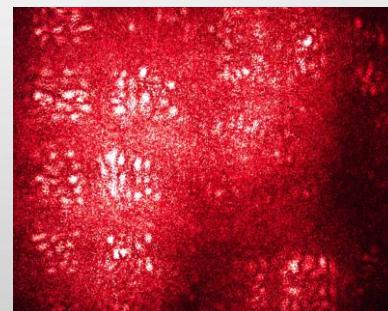
Bar target 2 with 0.5mm filter



Bar target 2 with 0.5mm-2mm filter



Bar target 2 with 0.5mm-5mm filter

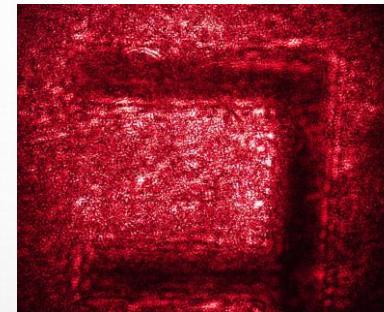


Bar target 2 with 1mm-5mm filter

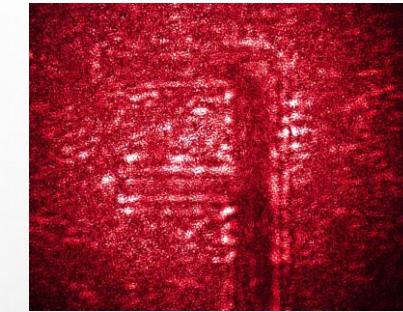
# F TARGET OF DIFFERENT SIZE WITH FILTER SET 2 (BAND PASS FILTER WITH OUTER RING 5MM)



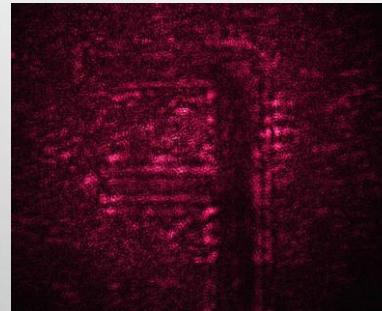
F target 1(1mm) with 10mm filter



F target 1(1mm) with 8mm filter



F target 1(1mm) with 5mm-exp time 0.06ms filter

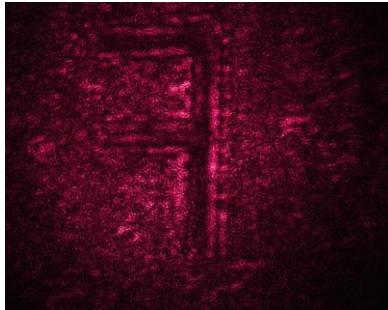


F target 1(1mm) with 5mm-exp time 0.26ms filter

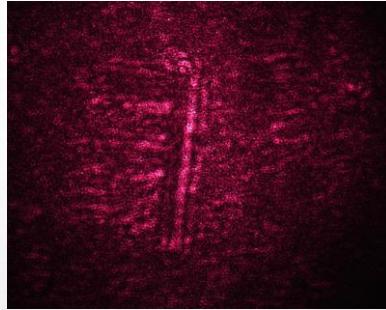


F target 1(1mm) with 4mm-exp time 0.06ms filter

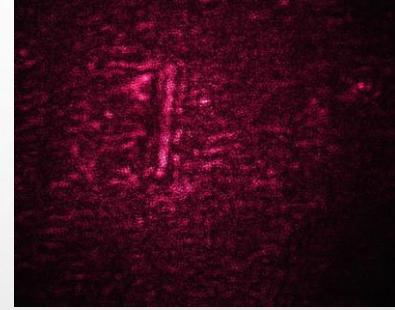
# F target of different size with filter set 2 (Band pass filter with outer ring 5mm)



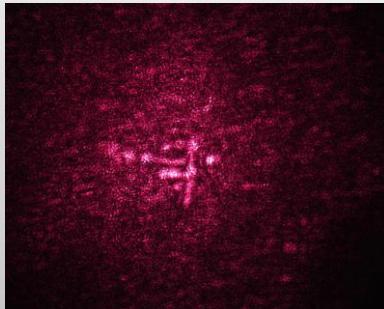
F target 1(1mm) with 4mm-exp time 0.06ms filter



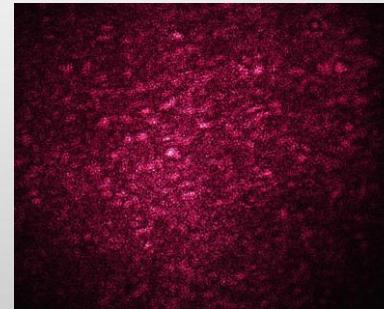
F target 1(1mm) with 3mmfilter



F target 1(1mm) with 2mm filter



F target 1(1mm) with 1mm filter

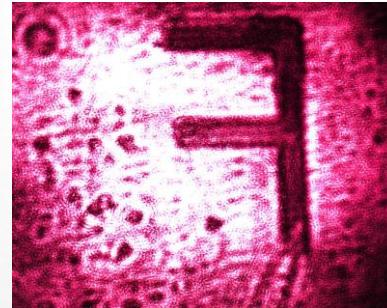


F target 1(1mm) with 0.5mm filter

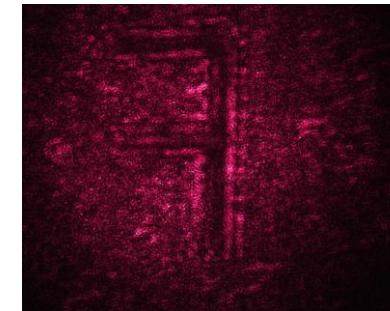
# 4MM F TARGET WITH FILTER SET 2 (BAND PASS FILTERS OUTER RING OF 5MM)



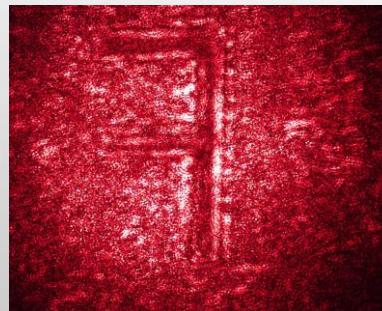
F target 1(4mm) with no filter



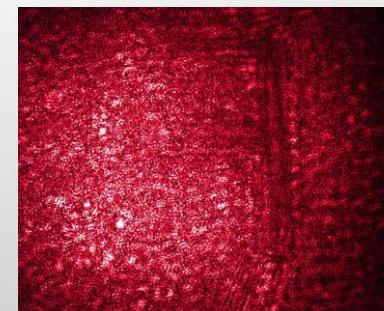
F target 1(4mm) with 0.5mm filter



F target 1(4mm) with 1mm with 0.06ms exp time filter

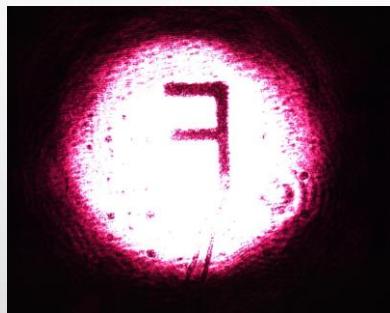


F target 1(4mm) with 1mm with 0.26ms exp time filter

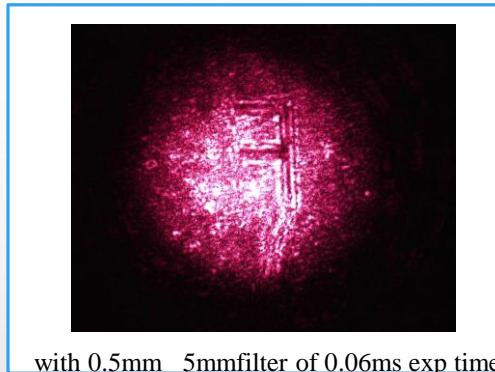


F target 1(4mm) with 1.5mm filter

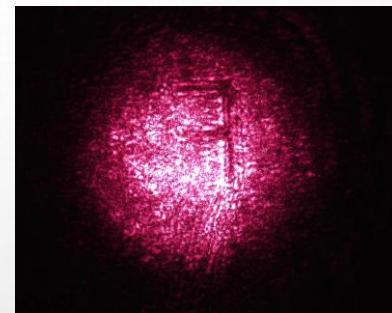
# 4F SYSTEM WITH DIFFERENT FOCAL LENGTH 350/175 ( USING 4MM F TARGET SYSTEM)



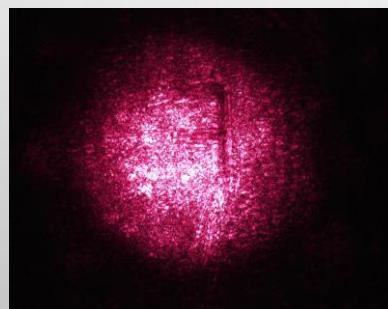
F target 1(4mm) with no filter



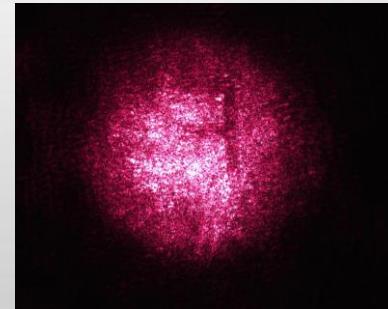
with 0.5mm \_5mmfilter of 0.06ms exp time



with 1mm \_5mmfilter of 0.06ms exp time

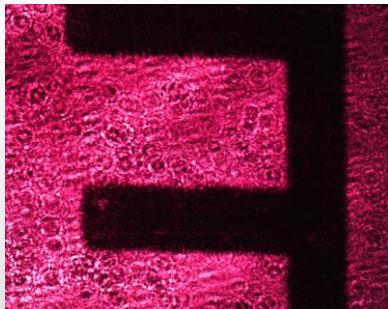


with 1.5mm \_5mmfilter of 0.06ms exp time

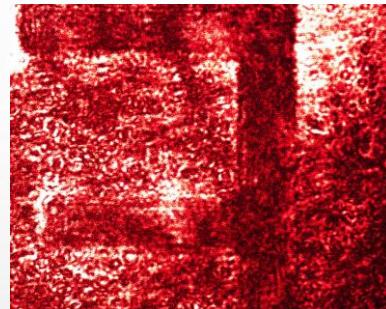


with 2mm \_5mmfilter of 0.06ms exp time

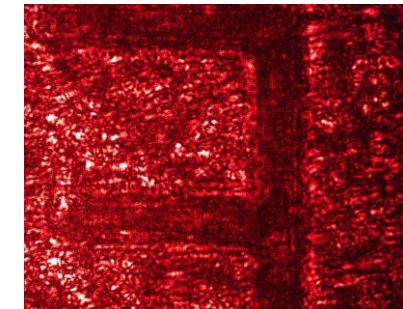
# 4F SYSTEM WITH DIFFERENT FOCAL LENGTH100/200(USING F TARGET 4MM)



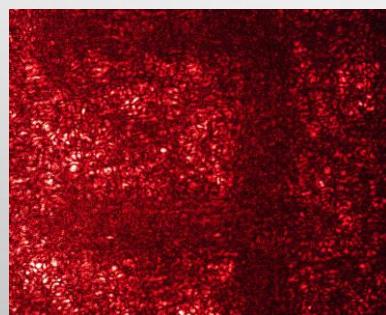
F target 1(4mm) with no filter



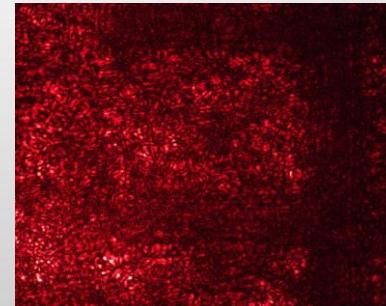
with 0.25mm \_5mmfilter of 0.76ms exp time



with 0.5mm \_5mmfilter of 0.76ms exp time

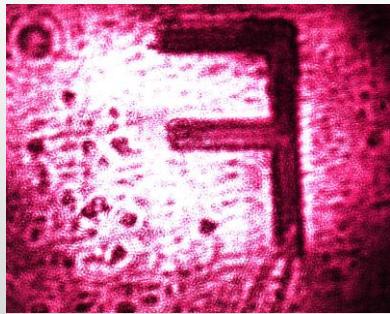


with 1mm \_5mmfilter of 0.76ms exp time

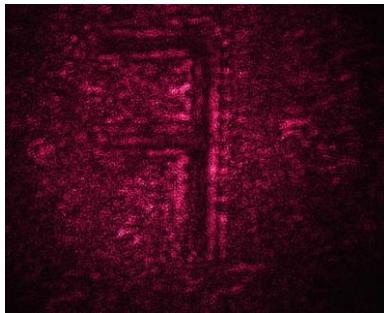


with 1.5mm \_5mmfilter of 0.46ms exp time

# 4F SYSTEM WITH DIFFERENT FOCAL LENGTH CONCLUSION

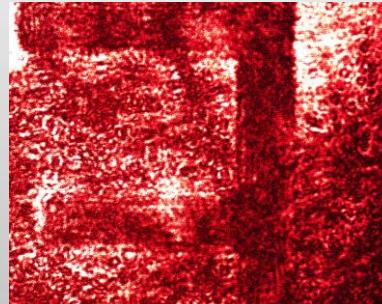


F target 1(4mm) with 0.5mm filter

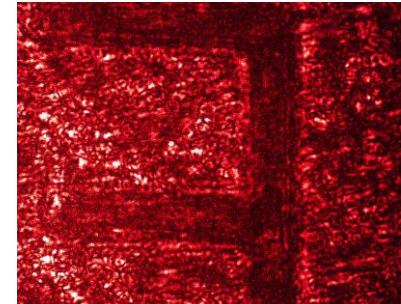


F target 1(4mm) with 1mm with 0.06ms exp time filter

For the focal length ratio of 381/175



with 0.25mm \_5mmfilter of 0.76ms exp time



with 0.5mm \_5mmfilter of 0.76ms exp time

For the focal length ratio of 100/200

# Reference

- [1] k. Fedus , G. Boudebs . experimental techniques using 4f coherent imaging system for measuring nonlinear refraction. Optics communications . november 2012
- [2]. Fourier transform in 4f optical correlator. Kwai.Hei. 7october,2009

# Thanks for your attention



Any Question?