Ahilan Kumaresan

Lab $\boxed{1}$ Session $\boxed{4}$ SF

Prelab Question 3.

1. Let the grating be perodic in x with period d. Over one period, model its amplitude transmittance as a rectangular pulse:

$$t(x) = \begin{cases} 1, & 0 \leq x \leq \omega \\ 0 & \omega \leq x \leq d \end{cases}$$, perodic with period d

$\Rightarrow$ Duty Cycle; $f = \frac{\omega}{d}$ $(0 < f < 1)$

Fourier Series form:

$$t(x) = \sum_{n=-\infty}^{\infty} C_n e^{i 2\pi n x/d}$$

& fourier coffecients: $C_n = \frac{1}{d}\int_0^d t(x) e^{-i2\pi n x/d} dx$

$$= \frac{1}{d}\int_0^{\omega} e^{-i2\pi n x/d} dx$$

DC offset term, $c_0 = f$

for $n \neq 0$

$$C_n = \frac{1}{d}\left[\frac{e^{-i2\pi n x/d}}{-i2\pi n/d}\right]_0^{\omega} = \frac{-1}{i2\pi n}\left(e^{-i2\pi n f} - 1\right)$$

$$C_n = \frac{\sin(\pi n f)}{\pi n} e^{i\pi n f} \qquad (n \neq 0)$$

2) In a 4f imaging system, fourier plane contains discrete diffraction orders n with complex amplitudes proportional to C_n. A spatial filter modifies these orders by a complex factor M_n (amplitude & phase)

Filter is modelled as:

$$E(x) = \sum_{n=-N}^{N} (C_n M_n)\, e^{i 2\pi n x/d}$$

As usual, $I = |E(x)|^2 = E(x)\, E^*(x)$ ← complex conjugate

<u>Code Below:</u>

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Pre-lab Question 3

January 20, 2026

Ahilan Kumaresan

[4]:
```
import numpy as np
import matplotlib.pyplot as plt
```

[15]:
```
def ronchi_coeffs(N, duty_cycle):

    f = duty_cycle
    n = np.arange(-N, N+1, dtype=int)

    c = np.zeros_like(n, dtype=complex)

    # n=0
    c[n == 0] = f

    # n != 0
    nz = (n != 0)
    nn = n[nz].astype(float)
    c[nz] = (np.sin(np.pi * nn * f) / (np.pi * nn)) * np.exp(-1j * np.pi * nn *␣
 ↪f)

    return n, c

def make_mask(n, mode="", **kwargs):

    M = np.ones_like(n, dtype=complex)

    if mode == "":
        return M

    if mode == "block_dc":
        M[n == 0] = 0
        return M

    if mode == "keep_orders":

        keep = set(kwargs.get("keep", []))
        M[:] = 0
```

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```
        for k in keep:
            M[n == k] = 1
        return M

    if mode == "lowpass":
        nmax = int(kwargs.get("nmax", 1))
        M[np.abs(n) > nmax] = 0
        return M

    if mode == "attenuate":
        scale = kwargs.get("scale", {})
        for k, s in scale.items():
            M[n == int(k)] *= complex(s)
        return M

    if mode == "phase_shift":

        phase = kwargs.get("phase", {})
        for k, ph in phase.items():
            M[n == int(k)] *= np.exp(1j * float(ph))
        return M

    raise ValueError(f"Unknown mode: {mode}")

def field_and_intensity(d, duty_cycle, N, x, mask=None):
    n, c = ronchi_coeffs(N, duty_cycle)

    if mask is None:
        M = np.ones_like(c, dtype=complex)
    else:
        M = mask

    # Build exp(i 2  n x/d) efficiently: shape (num_orders, num_x)
    phase = np.exp(1j * 2*np.pi * np.outer(n, x) / d)
    E = np.sum((c * M)[:, None] * phase, axis=0)
    I = np.abs(E)**2
    return n, c, M, E, I

def normalize(I):
    return I / np.max(I)

# PARAMETERS
d = 100e-6  # period [m]  (example: 10 lp/mm => d=0.1 mm = 100 µm)
f = 0.50       # duty cycle (open fraction); use your measured/assumed value
N = 15   # truncation order
x = np.linspace(-2*d, 2*d, 4000)  # evaluate over several periods
```

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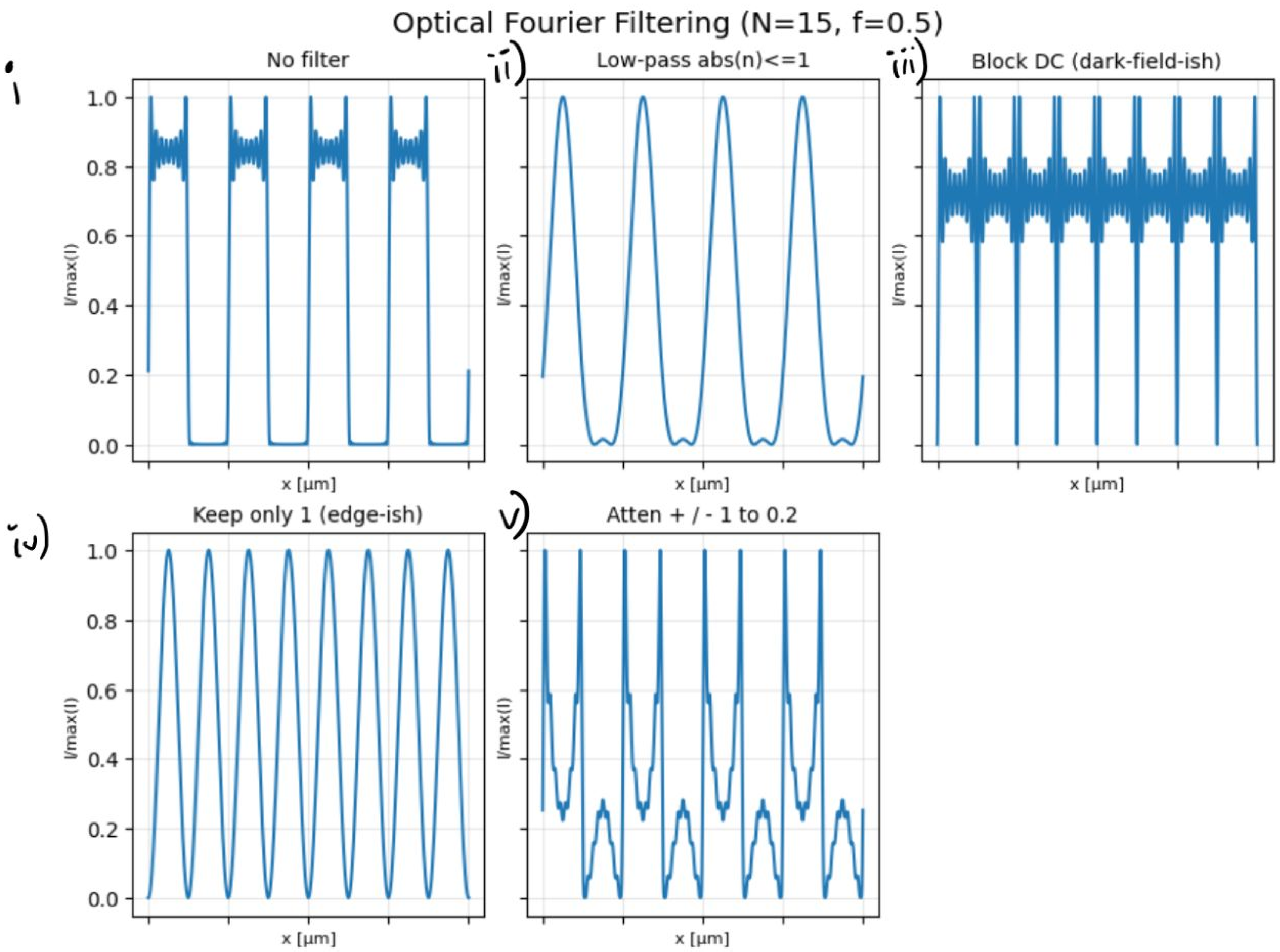
```python
# EXAMPLE
cases = [
    ("No filter",                  make_mask(np.arange(-N, N+1), mode="")),
    ("Low-pass abs(n)<=1",          make_mask(np.arange(-N, N+1),␣
 ↪mode="lowpass", nmax=1)),
    ("Block DC (dark-field-ish)",make_mask(np.arange(-N, N+1),␣
 ↪mode="block_dc")),
    ("Keep only 1 (edge-ish)",  make_mask(np.arange(-N, N+1),␣
 ↪mode="keep_orders", keep=[-1, 1])),
    ("Atten + / - 1 to 0.2",          make_mask(np.arange(-N, N+1),␣
 ↪mode="attenuate", scale={-1:0.2, 1:0.2})),
]


A4_WIDTH = 8.27
A4_HEIGHT = 11.69

fig, axs = plt.subplots(4, 3, figsize=(A4_WIDTH, A4_HEIGHT),
                        layout='constrained', sharex=True, sharey=True)

for (label, M), ax in zip(cases, axs.flat):
    n, c, M, E, I = field_and_intensity(d=d, duty_cycle=f, N=N, x=x, mask=M)

    ax.plot(x*1e6, normalize(I))


    ax.set_title(label, fontsize=10)
    ax.set_xlabel("x [µm]", fontsize=8)
    ax.set_ylabel("I/max(I)", fontsize=8)
    ax.grid(True, alpha=0.3)

for ax in axs.flat[len(cases):]:
    ax.set_visible(False) # Hiding other non printing plots

fig.suptitle(f"Optical Fourier Filtering (N={N}, f={f})", fontsize=14)

plt.show()
```



Optical Fourier Filtering (N=15, f=0.5)
i
No filter
ii)
Low-pass abs(n)<=1
iii)
Block DC (dark-field-ish)
iv)
Keep only 1 (edge-ish)
v)
Atten + / - 1 to 0.2
I/max(I)
x [µm]
1.0
0.8
0.6
0.4
0.2
0.0

Figure i - v)

Lab 1 Session 4: SF (Completing Setup 1 & Testing Image)
Date: 20-Jan-2026 Lab Partner: Absent

Table of Contents (For Session 4 & 5)

Table of Contents:

1. Goals

- Capture an image for the real panel, also one image of the real panel after the beam splitter is installed. For seeing the reduced intensity.
- Adjust exposure to have better contrast and visibility in th real plane.
- Complete Lab Set up 1 and Testing

2. Apparatus

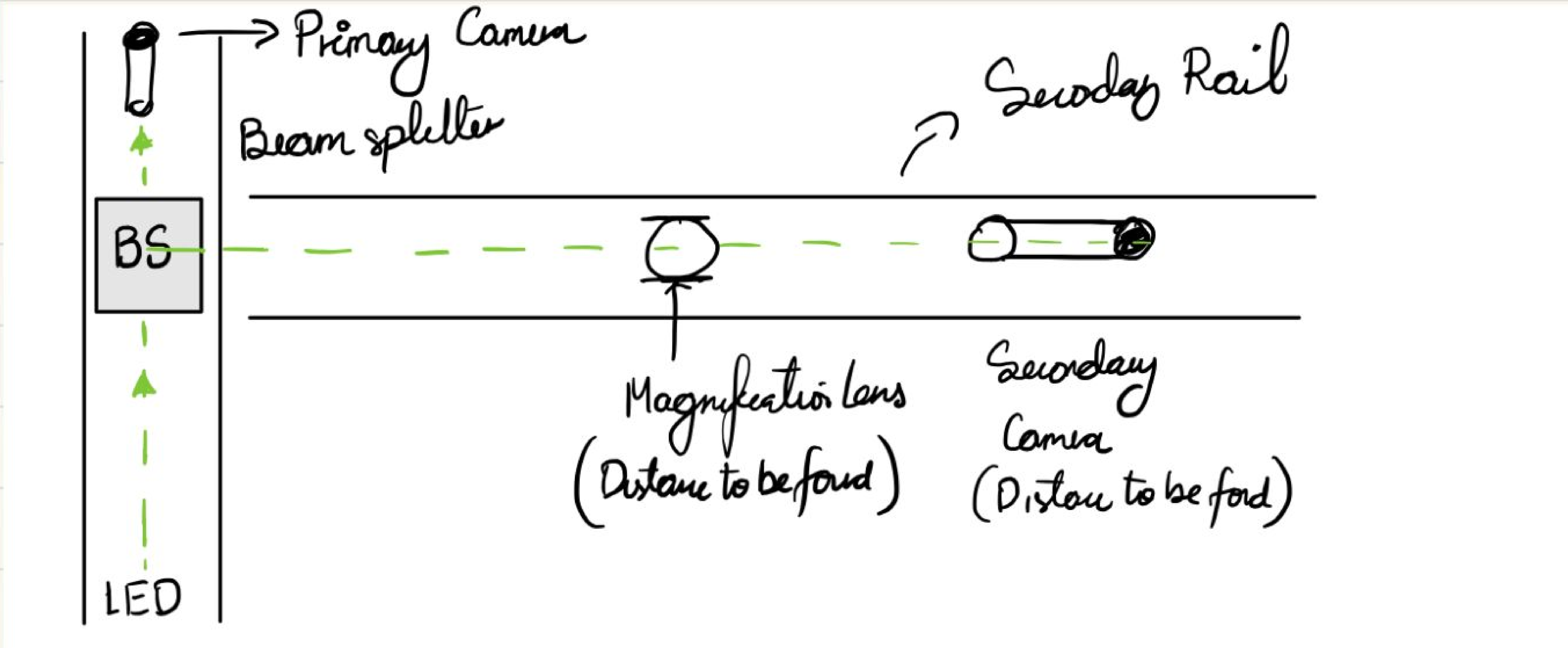
Optics / mounts
- Beam splitter
- 90° short optical rail + feet (leveled)
- 2irises/apertures for alignment on 90° rail
- Fourier imaging lens: 50 mm, f = 100 mm
- Lens tube for Fourier camera
- (Later) transverse translation stage + iris for Fourier plane filtering (confirm clearance)

Cameras
- Fourier camera (FLIR Blackfly): mounted on transverse translation stage (XY)
- Real-space camera already aligned from Setup Part 1

Tools
- Alignment cap with central dot
- Viewing card (white card / paper)
- Hex drivers, ball driver, post collars, spare saddles/posts (3", 4", 6")

Software
- LabVIEW: Dual_Camera_Line_Profile_v2.vi
- NI Vision Assistant (optional, but close it before LabVIEW)

3.Sketch:



Sketch1: Top View of Secondary Rail & Elements Setup

4.References:

- Optical Systems Guide J.M. McGuirk
- An Introduction to Optics. Lipson
- Spatial Filtering Lab Script

5.Useful Background

Field Plane Conjugates (image of light source structure):
Field Stop   Object   Real-space Camera

Field stop controls illuminated area (field of view)
Changing field iris changes FOV but NOT resolution

Aperture Plane Conjugates (image of source angular distribution):
Aperture Stop   Fourier Plane   (determines resolution)

6. Detailed Procedure

i) VerifiedBeam Splitter Insertion and 90° Rail Alignment

Place beam splitter in main beam

- Verified beam splitter is approx. 22 cm downstream of objective lens (L4).

Verify:

This spacing must leave room between BS and Fourier plane for a transverse translation stage with iris (spatial filter later).

- Visually confirm clearance: stage can mount on a saddle and sit near BS without collision.

Record

- Objective lens reference point: 104 ± 0.05 cm
- BS placed at: 82 ± 0.05 cm downstream of objective (target 22 cm)
- Clearance check for future iris/stage: /

Notes:

Issue:

There is space but I do not see the fourier Plane image

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ii) Rotate BS (using a collar) so that the reflected beam propagates straight on one arm and away from the edge on the other.

- Place the smaller rail with the secondary camera perpendicular to the beam splitter, so that the ray from the beam splitter hits the camera.
- Use Iris and Apperture to verify the centre.

USE the white card and the raw from the BS to see and align the Camera Sensor to the light.

Expected: I expected to see a diffraction pattern, just as before in page ()

Saved Image at Session4/Notes/

Name: Fourier-Image-Pinhole.tiff

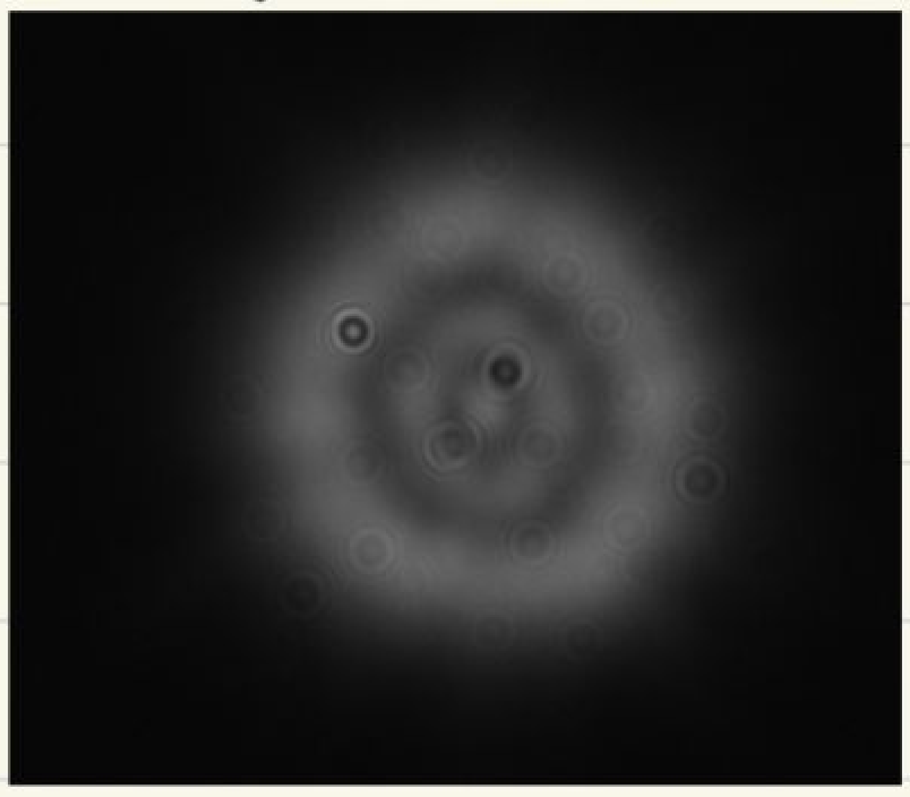


Image 1: Fourier Image Through a pin hole.

Check 2:20

Could not see a diffraction pattern, maybe we are out of focus? There seems to be some blurring. Perhaps the BS is unclean, too.

However, Success! As I slide the card along the rail, the beam always stays within the Secondary Rail (with secondary camera)

1. Fourier imaging lens and Fourier camera
2. Placed the Fourier Lens (FL) (50 mm diameter, f = 100 mm) in the secondary rail. Ensure correct placement by facing the side with the infinity symbol towards the BS.

This was the last lens available, so it matches the description, giving confidence that our lenses are being used correctly.

Check: iii) Verified that the foureir camera is on the trnaslational stage and added a Lense tube in front to block stray light from the room.

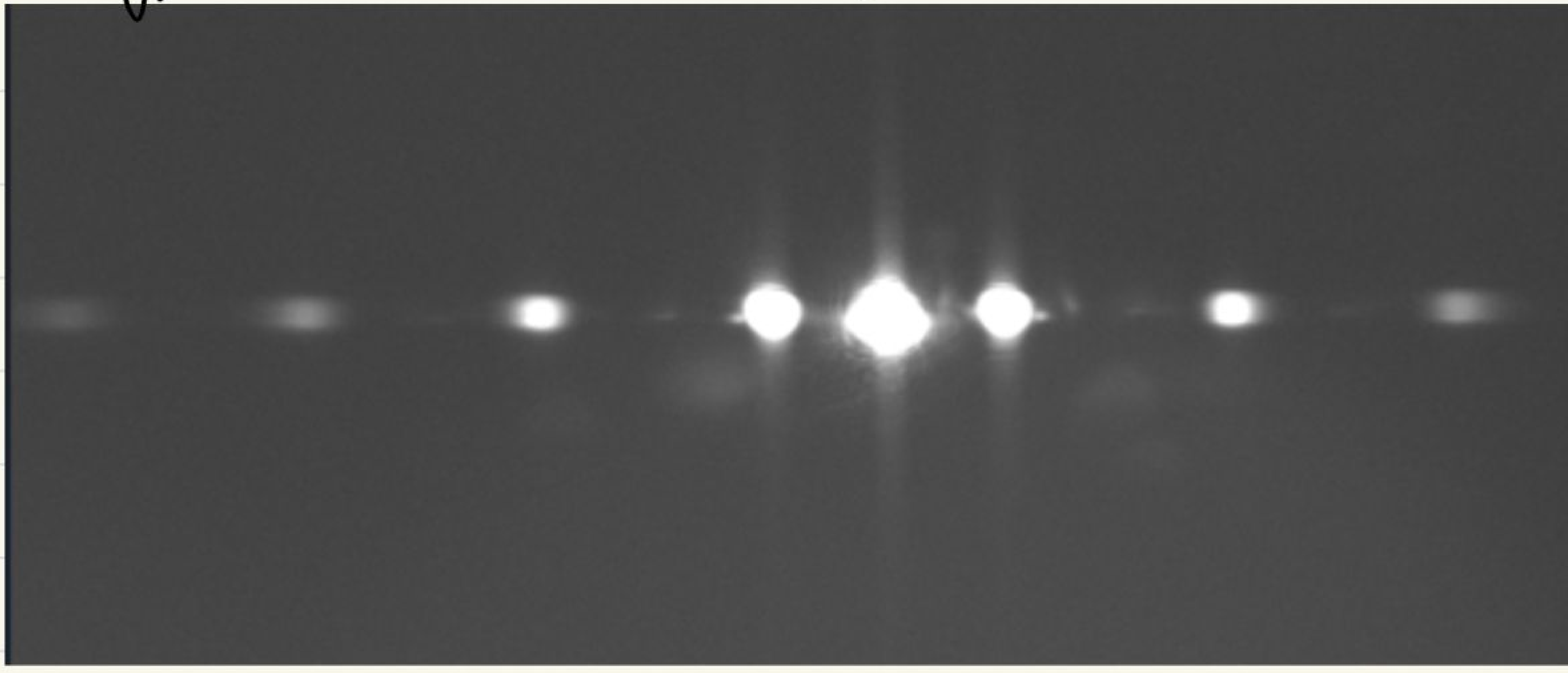
Imagine the Fourier plane onto the Fourier camera so that up to the 7th diffraction orders fit on the CCD for a 10 Lp/mm grating on the test object. ()

Adjusted the Fourier Lens (FL) along the rail until we finally saw the diffraction pattern, for Best Focus!! Yay!! FL pos: 29cm along secondary rail

Manually adjusted the railing a little, just the centre, to diffuse the pattern better.

Saved Image at Session 4/Notes/
Name: diffraction-pattern-secondary-rail-01.tiff.

Image 2: Diffation Pattern from secondary rail Camera



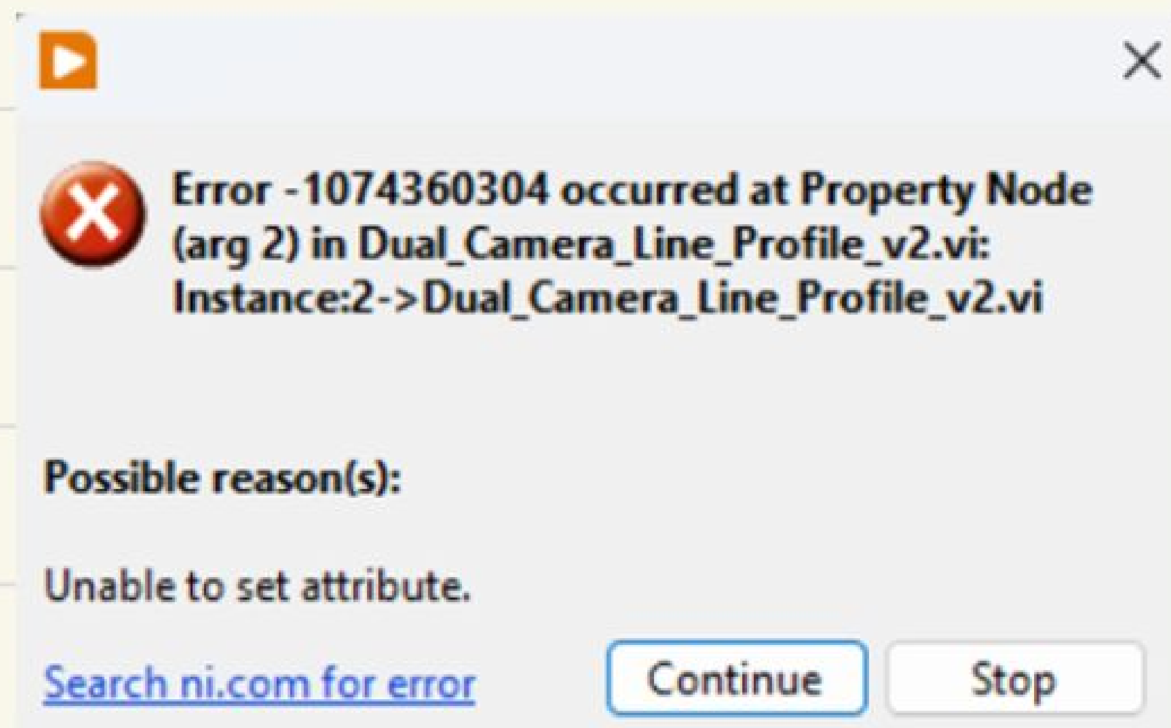
Issue: Can only see 4 diffraction orders, Thereis probably more as when we adjust the mirror horizontally, we can see more but. How do I make all of them visible?

I tried to full the Camera and Lense Set up towards the BS, that did not work too well, it only got zoomed in.

Asked Zack (TA) for help, the idea was to either pull as we did before or take multiple images with different exposure times to get the lower intensity images.

something new was the error happening in adjusting the Exposure,
error message: "Error - Occured at Property Node"
Screenshot saved at Session4/Notes
Name: error-changing-exposure.png

Image 3: Screenshot of Error Message.



3:00 The fix is: go to BOTH camera Acusiation in the Block Diagram for the Preset and Switch off the Auto Gain and Exporeusre. We had done it.

Success: The diffraction patter is Centro Symmetrical, Sharp and Can see multiple orders.

iv) Final Notes for Set up 2:

Goal Met: We have a dual-camera spatial filtering setup. LabView shows the Fourier and Image Plane.

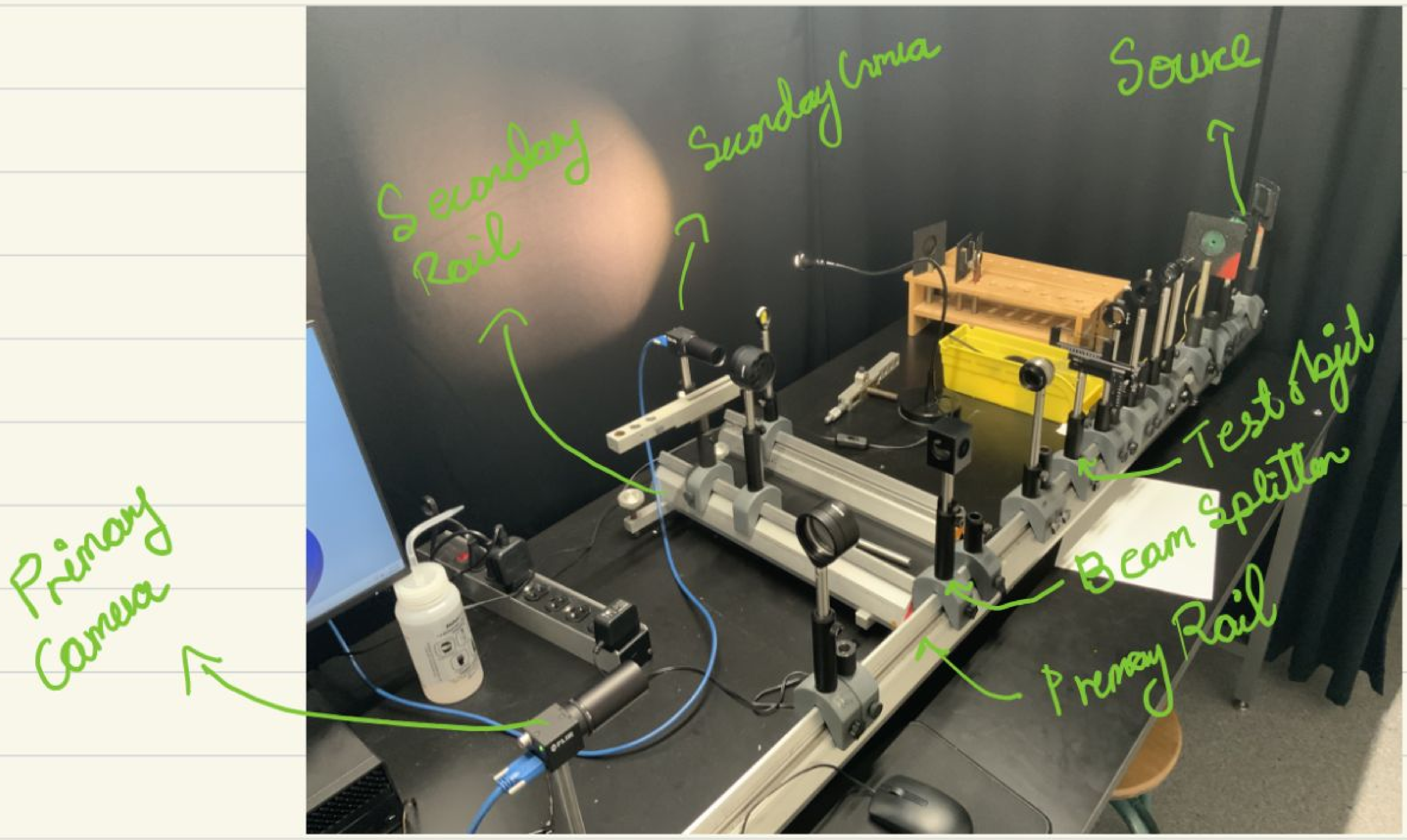


Image 4, Our Optics Setup

Added cross sections on both the Panels and explored the Live intensity profile.

Save images and a screenshot of the setup.
in Session 4/Notes
Name: labView-Setup-Screenshot.png"

That is the line intensity Pattern! wow!

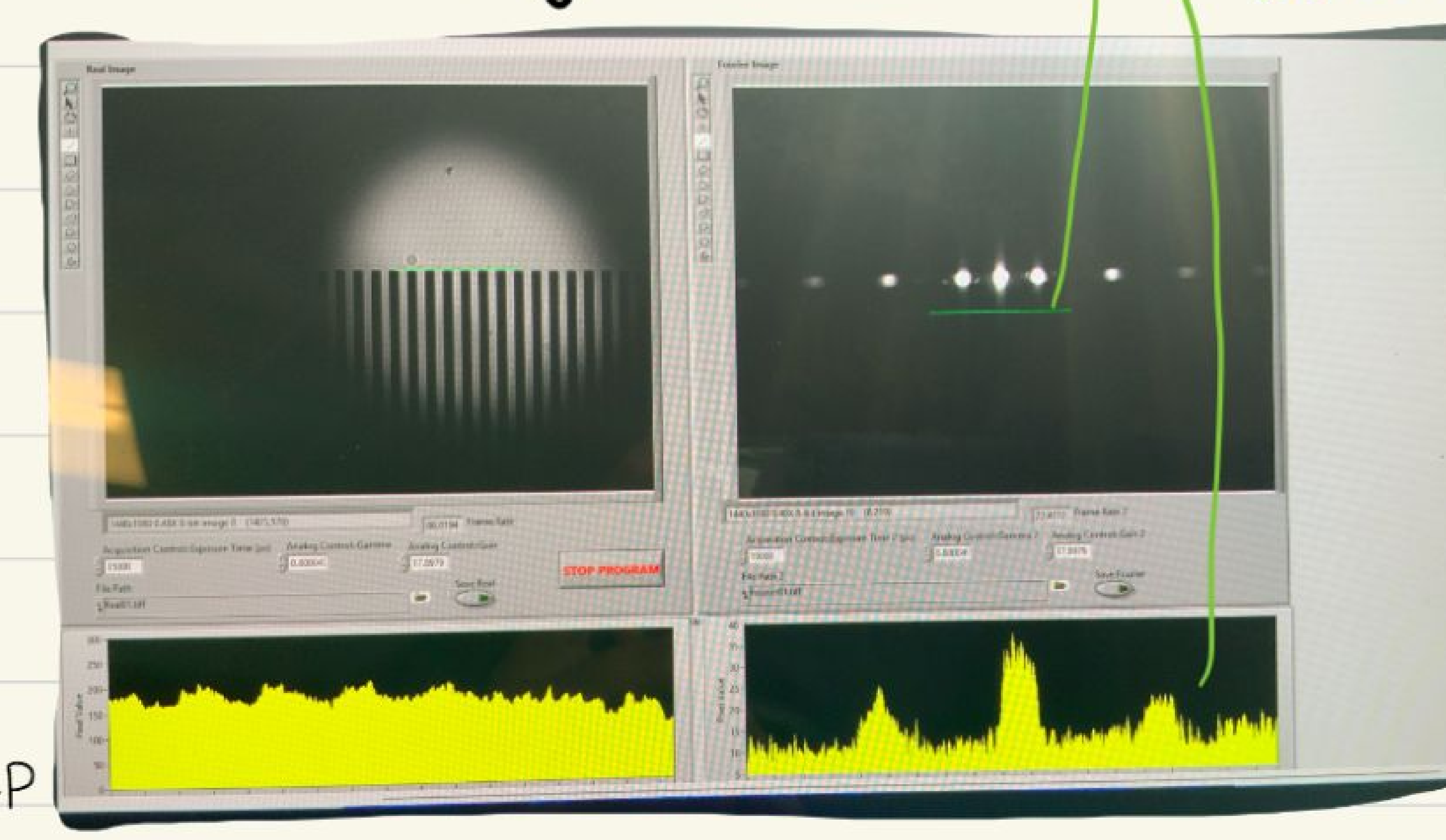


Image 5, Our LabView Setup

7. Testing

i) Test 1

New Approach to Note Taking:
Zach, our TA recomended only refering procedure from our sources (like lab Script) and writing only that is new and our personal notes!

This changes everything!
Ahilan kumaresan

Observe 3 things simultaneosly

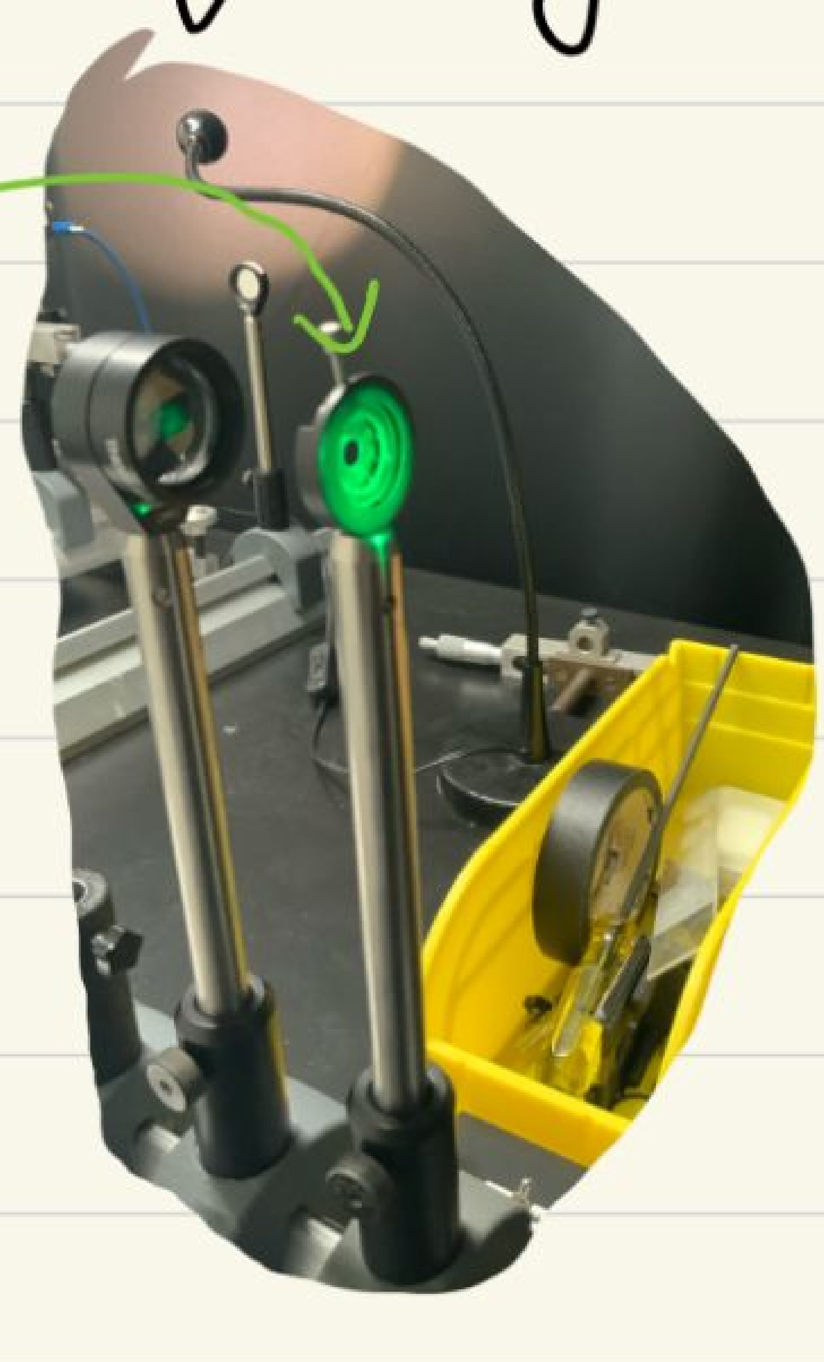
1. The fourier Camera image
2. The real-space image
3. With a card, the illuminated region on object

3:25 PM Did test 1 on (pg 36) of lab NoteBook.
↳ Varying field stop (field iris), pupil size

Expectation ⇒ We observed area on object & camera field of view change on images.

⇒ On Fourier Camera: Spot Size stays same but Intensity increases with more light let in.
We actually see more orders & more blurring actually

image 6: Field Iris



Stored images in Session 4/Notes

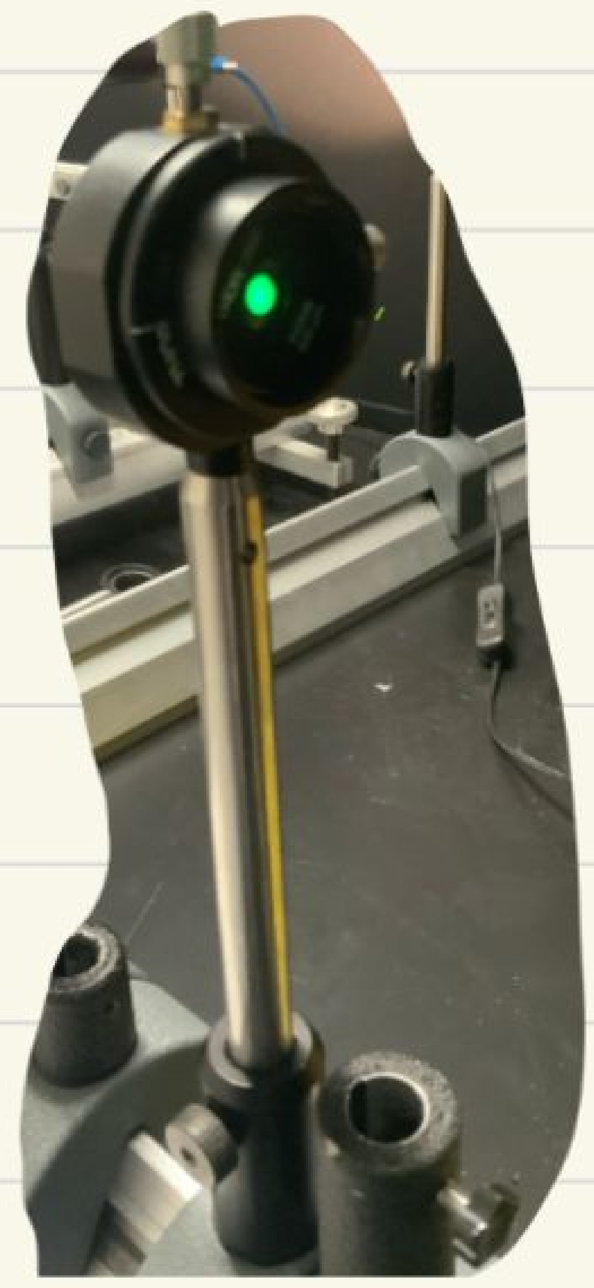
Saved 3 images of 3 different heuristic puplil size.

"Smallest-pupil-field-iris.tiff", "1-10th-pupil-fild-iris.tiff" & "2-10th-pupil-field-iris.tiff"

ii) Test 2

Test2 procedure on (pg 36) of lab Script

Varying Aperture Stop using an iris at Aperture stop plane.



Appeture Stop (Pin hole)
Image 7:

The Zeroth order on the Fourier Camera
is at pixel (713, 508)
↳ Marked the Zeroth order with a line
↳ Using a adjacent Saddle & remove the
(AS) pinhole & insert an iris at appeture stop plane

As usual make sure it is square & using a up
stream pinhole it is centred.

4:06PM Facing an error because the new iris is not fully on the centre of the Screen.
Looking at the light travel, looks like the problem might be down stream too: Using a white card & another pinhole.
Trying to fix light travel, making it alligned to optical rail.

Put Back the pinhole & trouble shooting.

Resolved:

4:21PM Finally!! The issue was on (L3) Condensor lense

Adjusting Secondary Rail elements for centered lens.
new centre (709, 620) pixel.

(51)

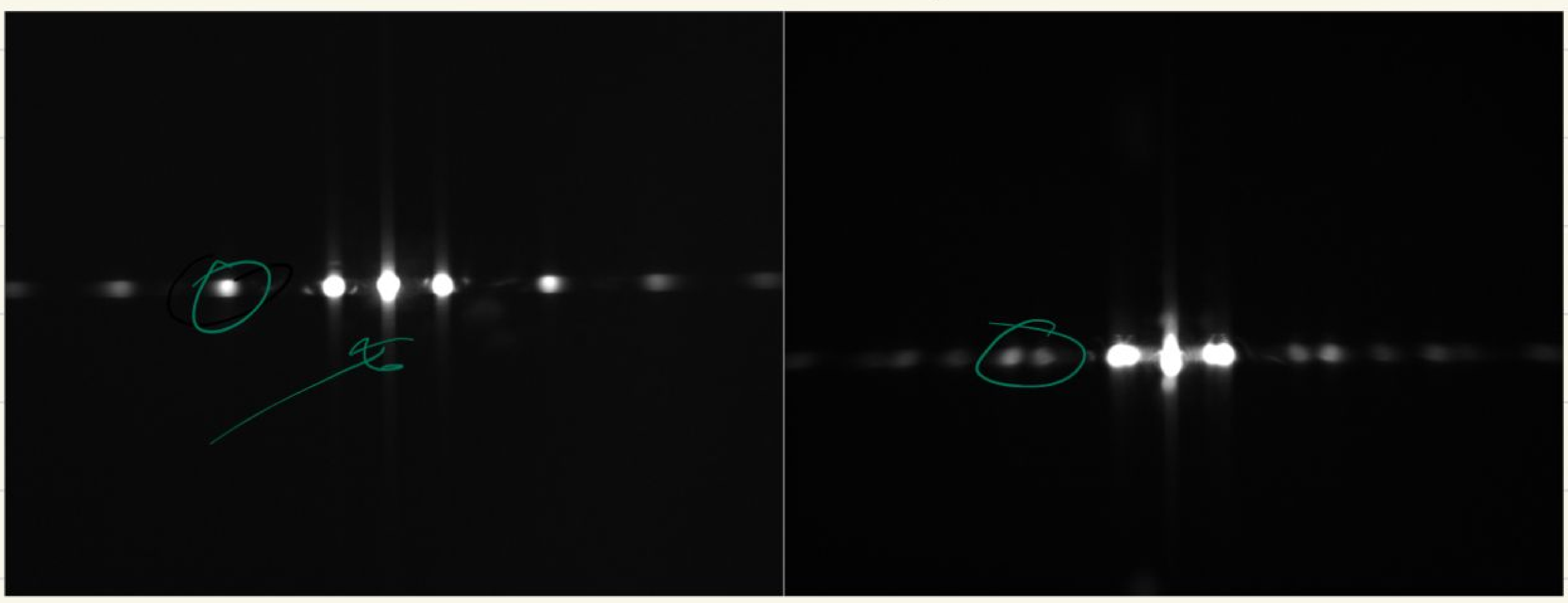
However something changed, its more tear drop shaped
Saved image in Session 4/ Notes

Name: new-diffraction-pattern.tiff (See below)

8. Post Lab Reflection:

I made some significant headway, a lot of the accumilated errors were resolved:
1) Optics element mis alignment
2) Errors in Lab View Exposure Settings

However Some new errors popped up:



old diffraction pattern New diffraction pattern

Probably this shows some unclean lense?

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i) Goal Standing

Goal 1: Capture real-space image before/after beam splitter MET ✓

- Successfully observed intensity reduction after BS insertion
- Adjusted exposure to compensate

Goal 2: Adjusted Exposure and got a better understanding of exposure settings. MET

Goal 3: Take image of real plane and uplode it. Yes Done.

Goal4: Complete Lab set up 2 and Testing. Partially. Testing to be redone next lab.

ii) Learnings:

1. Alignment is critical - small misalignments cause visible artifacts
2. The Fourier plane location can be found by sliding a card along
   the beam path - first you see real-space image, then diffraction patt
3. LabVIEW errors often require checking BOTH camera settng
4. The intensity cross-section tool is very useful for quick alignm

iii) What I Would Do Differently:
Record more quantitative measurements (pixel positions, peak widths)
- Take systematic images at each alignment step for comparison
- Note iris/aperture settings when taking images

iv) Questions to Investigate in Session 5:
1. Why are diffraction spots teardrop-shaped instead of circular?
2. Can I see all 7 orders for 10 lp/mm as expected?
3. What happens when I vary the field iris vs aperture iris?

Lab 1 Session 5:

Spatial Filtering (Finishing Setup 2 & Improving diffraction Image Resolution)

Date: 22-Jan-2026 Lab Partner: Nathan Unhu

FOR TABLE OF CONTENTS, REFER TO SESSION 4 pg 40

1. Goals:

i) Labscript procedure testing after setup
ii) Error correction during setup
iii) Understand how the forrier plane spots are formed and how "sharpness" or "detail" shows up as one spot while brightness shows up as another

2. Background Information Physical intuition (no math)

i) Light behaves like a wave. A wave cannot make an abrupt change without involving many different directions of motion.

11:46 AM

ii) A sharp edge is like telling the wave:
"Go from zero to full amplitude instantly."
The only way a wave can do that is by combining many plane waves at different angles.

- Few angles smooth variation
- Many angles sharp transitions;

iii) Slit intuition (classic example)

- A wide slit ;(smooth spatial variation) narrow diffraction pattern
- A narrow slit ;(sharp spatial confinement) wide diffraction pattern

This is the same reason:

- Fine details large angles
- Coarse features small angles

iv) Filtering methods:

- Low pass filter: removes noise
- High pass filter: sharpness improvement
- Band-pass filtering: specific frequencies selected to show texture/patterns otherwise hidden by bright or sharp detail
- Directional filtering: orthogonal structures removed (only vertical or horizontal features)
- Notch filtering: removing specific noise
- Phase-contrast filtering: shifting frequencies to make transparent objects more visible
- Dark-field filtering: Reduce white highlights to see dark/small features
- Amplitude filtering: changes contrast
- Spatial frequency weighting: custom contrast foe spec. freq.
- Order selection: resolution control
- Spacial differentiation: for edge/feature detection
- Holographic and correlation filtering (advanced): pattern recognition in real time

3. Detailed Procedure

i) Image Doubling: Trouble Shooting

We got a suggestion to use a filter paper that is translucent. Go through the different elements and try to determine which element starts the double first.
The issue could be the back reflection from one of the shiny oarts of the elemtns.

However, My hunch is some miss alignments of the equipments.

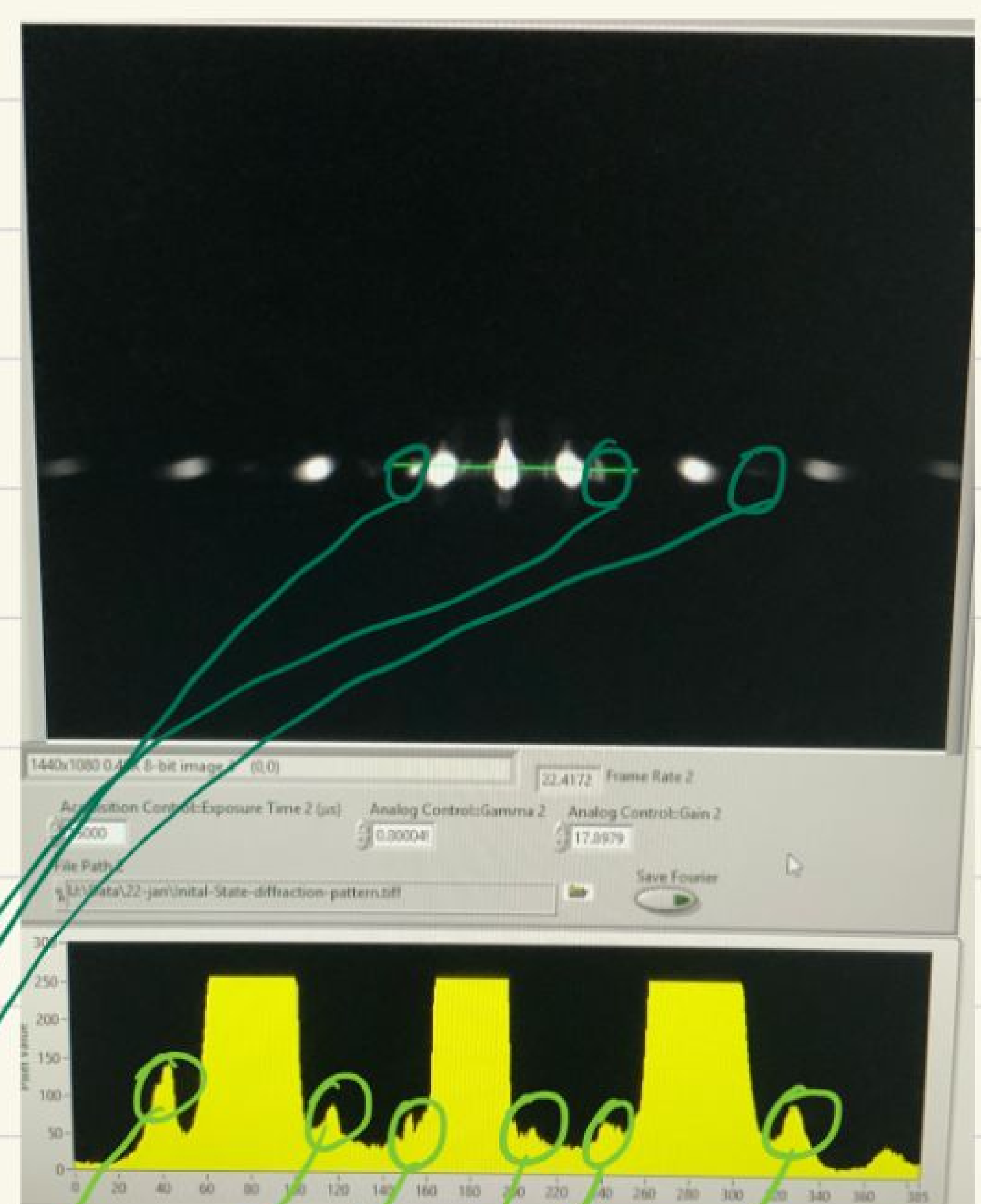
Looking at the current state, maybe this issue isnt too bad. The internsity patterm definetly show multiple values. But Maybe this isnt too bad ???

Saved as initial-state - diffraction pattern.tiff

Observation

I can say that because there is both more dots on the fourier image but also, the intensity patterns reveal multiple smaller peaks.
These are not diffraction orders.

Image 1: Initial State Screenshot



Clearly There are multiple reflections

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1:42PM

ii) Correction of Lense

Correction of error (image is off center and doubling of forrier plane spots

- Starting from test step 2 in setup 2 of labscript (vary the aperature)
- Placing a paper filter behind condensor lens fixed the doubling, concluding that the doubling was cause by misalignment of either incoming light onto condensor or condesor alignment. Realigning the condensor lens should correct this.
- Fixed doubling by pitching lens forward on track and right very slightly.

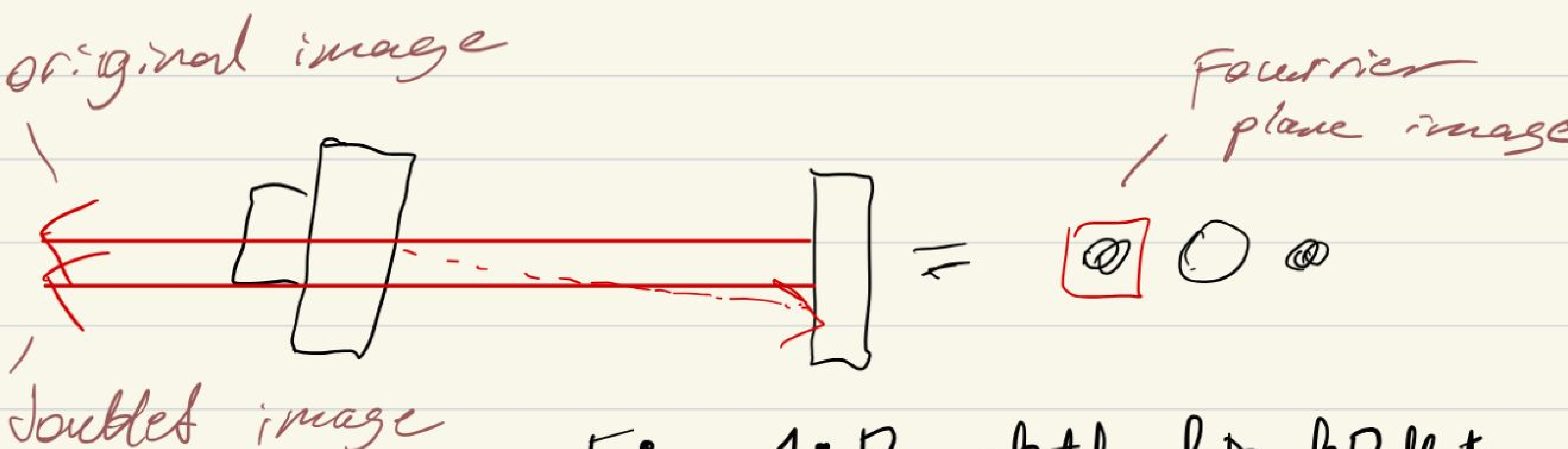


Figure 1: Ray sketch of Back Reflection

iii) Correcting Fersnel Fridnges

New Issue: Fersnel Fridnges on the real Image, This makes it clear that our has been image is out of focus! This could explain the doubling of our diffraction pattern! So my previous hunch of an "Un clean lense" is incorrect.

Saved this image as: fersnel-frindge-issue.tiff under Session5/Notes

Observation

Noticed how there are frindges around the letters we are focusing on.

Previously we thought this was insifnificant but this seems to matter more for resolution as we move towards more tests.

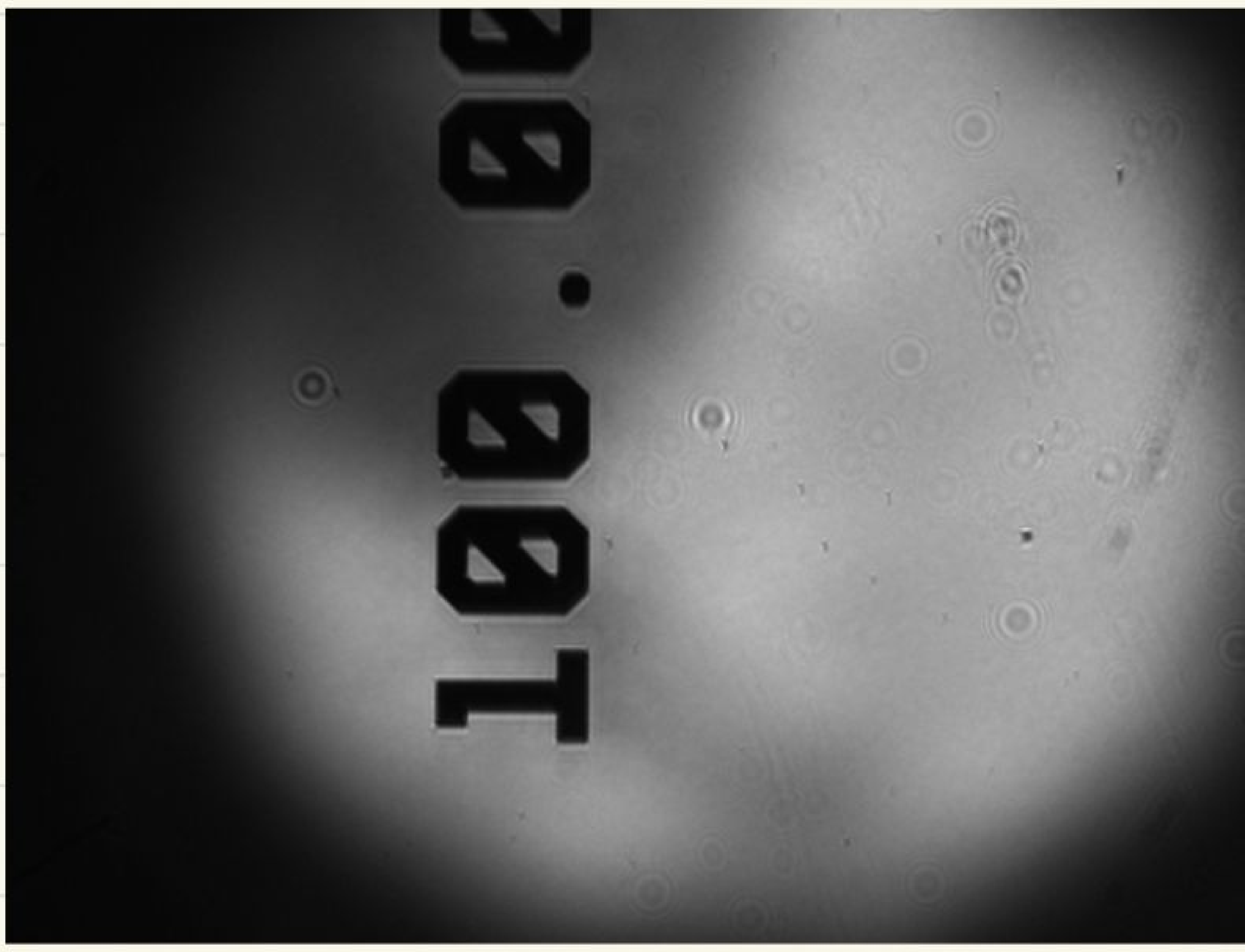


Image 2: Fresnel Frindges on Image

Tip

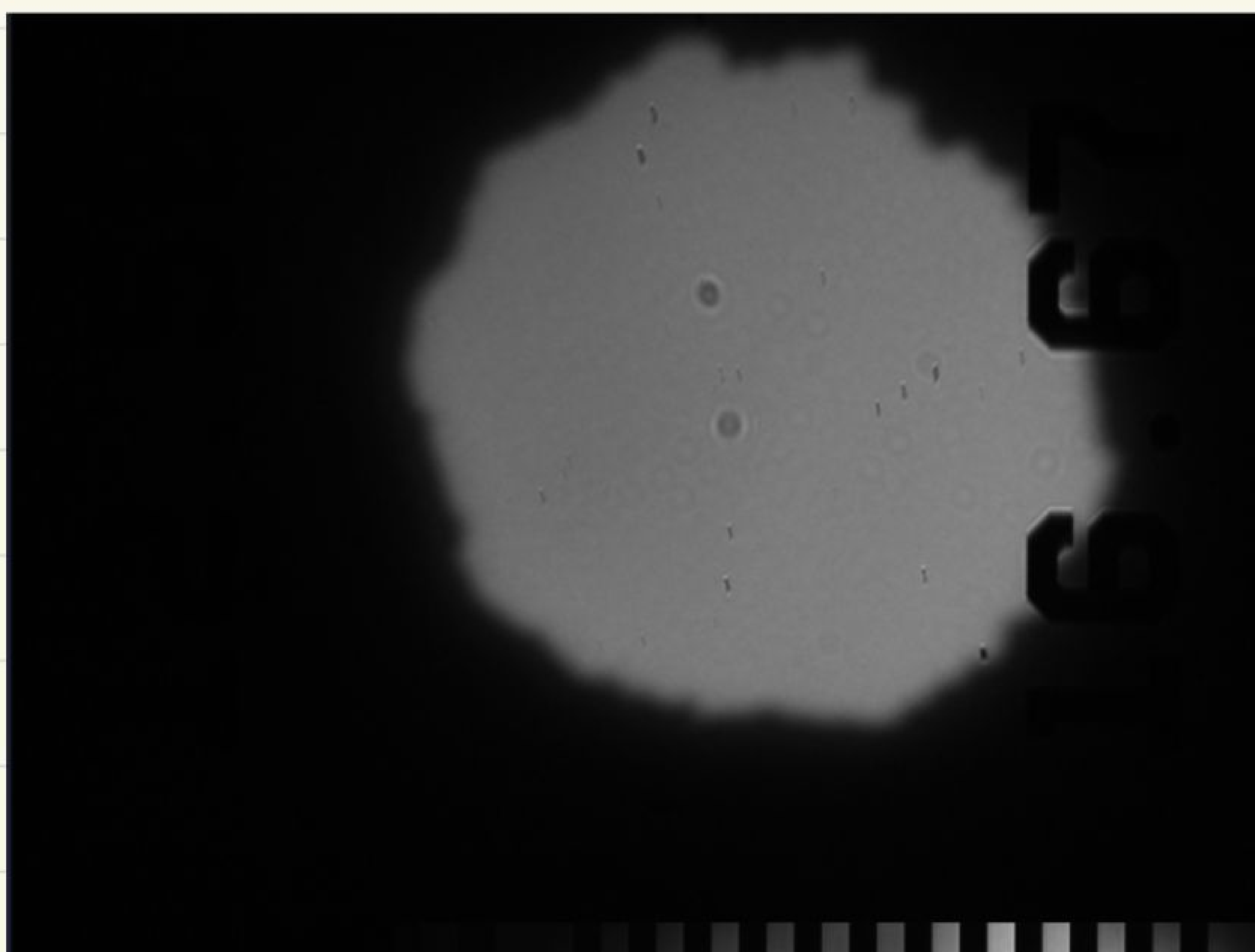
When trying to focus & eleminiate fresnel frindges try to focus on a small defect on the test object & make it Sharp.

iii) Continuing with Test 2 again

- added the aperature stop before the forrier plane splitter, closing the aperature blocked the outer diffraction orders which blurs the image (outer orders at higher frequency contain the sharp detail information)
- Position of 0-order: 819, 655 pixels (zeroth-order-image.tiff) saved at session 4 notes
- Removed the pinhole temporarily and added the iris aperature in its place. This changed the brightness of the image without changing the illumination area much.
- Moved the small iris back towar da the LED source and make the image edges sharper
- Saved Image: Correct-iris-position.tiff

Image3:
· Corrected sharp real Image after correcting iris

Compared to our previous images the edges are way sharper!



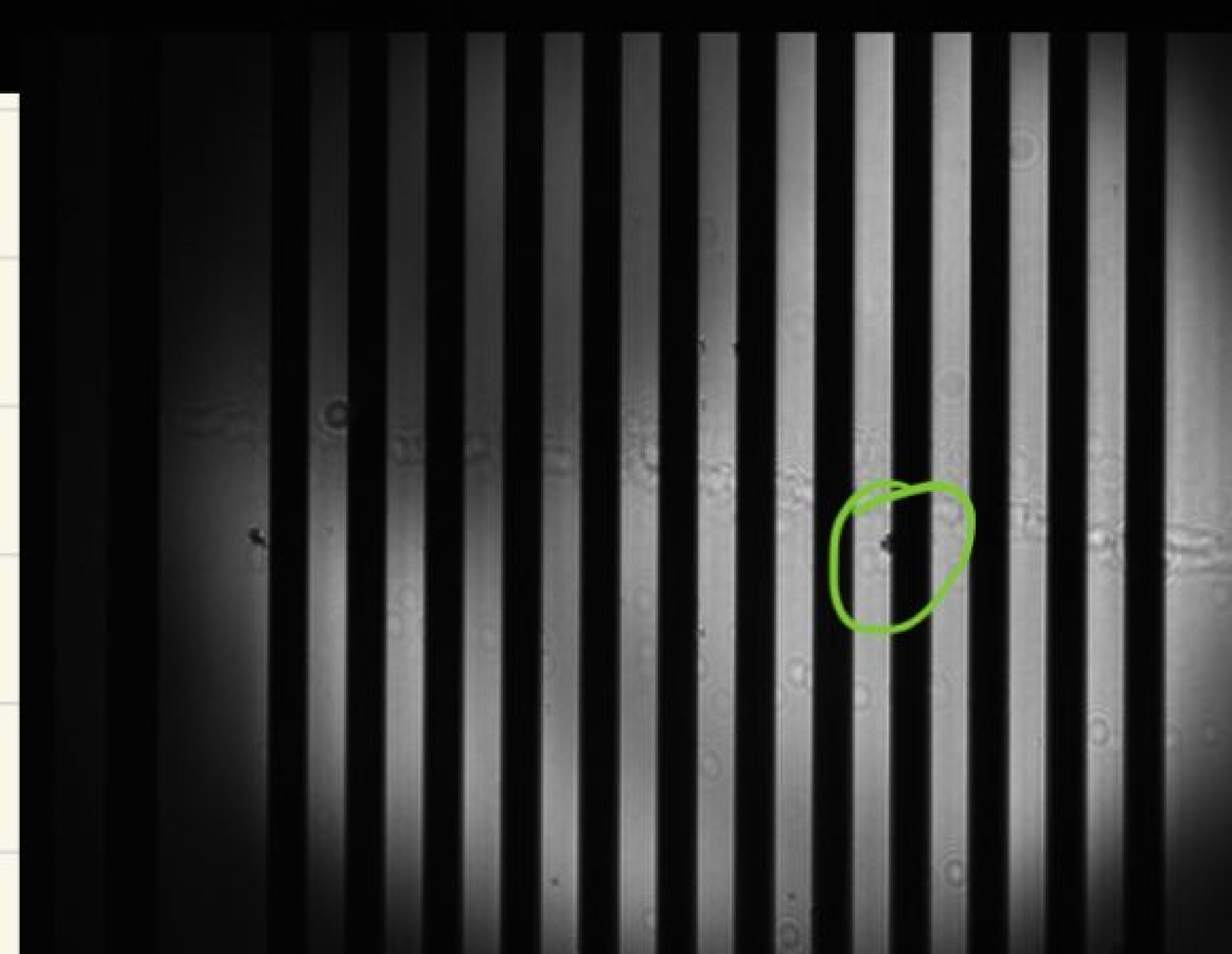


Image4: Showing an example of a defect on grating we focused on

- inserted 10nm band filter in front of LED, eliminated the non-zero order diffraction patterns (collapsed to single frequency peak with black image)

iv) Resolution Test:
started with 10 lp /mm grading. With increased exposure and 10nm filter image is clearer (original wavelength is 525 +-35nm)
Recorded images of 12 and 16.67l/mm. Spacing between 16 (0th -> 1st order) is 202 pixels. Spacing for 12 is 132 pixels
(space below for calculation of magnification level)

$$\theta_1 = \sin^{-1}\left(\frac{\lambda}{d}\right) = \left(\frac{525 \cdot 10^{-9}}{\frac{1}{16.67 \cdot 1000}}\right)$$

$$= 0.501^\circ$$

$$202\,\text{pxl} \div 0.501^\circ = 403\,\text{pxl/deg.}$$

$$f_{eff} = \frac{\Delta x}{\theta_1} = \frac{202\,\text{pxl} \cdot 3.45\,\mu\text{m/pxl}}{0.501^\circ}$$

$$= 139\,\text{mm}$$

v) Resolution test

- chose 26 and 50 lp/mm (easy and difficult to resolve)

- Prediction: closing the apperature iris slightly should block the higher order diffraction spots tied to the finner line spacing, blurring that section without blurring the coarse line spacing.
- Added an iris at the forrier plane. Reducing aperature eliminates higher order diffraction spots, reducing fine detail first (high frequencies = finest detail = farthest diffraction orders)
- Closed the iris halfway to make the finner grading lines blurred while the coarser ones still sharp (insert image of blured fine lines and sharp coarse lines)

Second order | 1st order | Zeroth order | first order

Image 5 :
26 lp/mm

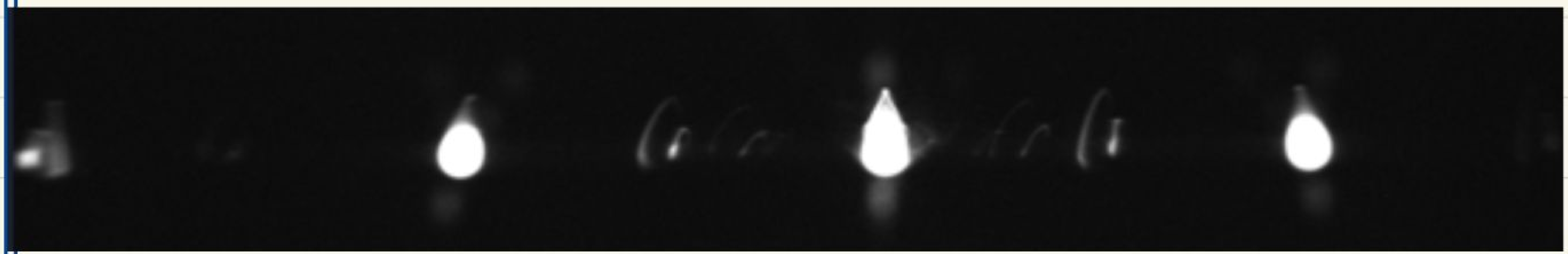
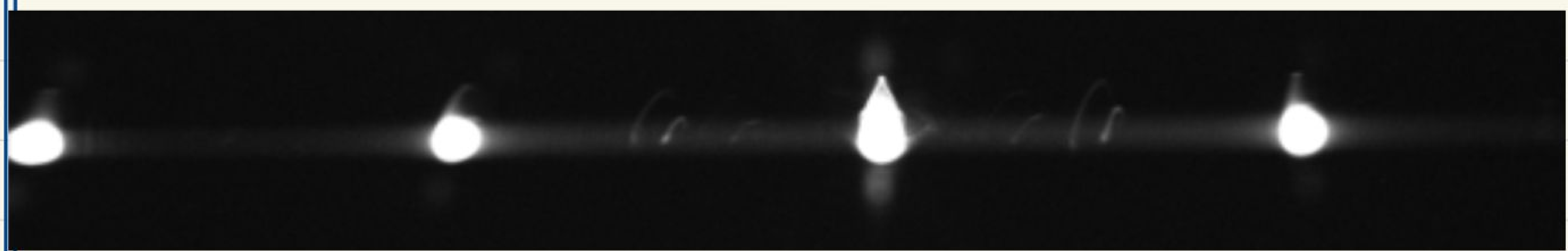


Image 6 :
50 lp/mm

Image 7 :
26 and 50 lp/mm



All files Saved under Session 5/Notes

Name : "26lp mm-fourier.tiff"
"50lp mm - fourier. tiff"
"26-50lpmm-fourier. tiff"

Observation: We notice how in the 26lp/mm Grating, the first Order is very clear and bright. While Higher Orders are dim

On the 50 lp/mm we observe the second order birght while the first order is relatively dim.

We can see that when we position the grating such that the feild of view has 26lp/ mm on one side and 50 lp/mm on the other, we get a combined patter! This is pretty cool!

Success! : confirmed overlap between forrier images of 26 and 50 lp/mm diffraction orders.

5) Post Lab Reflection and Suggestions for next Lab

The Diffraction Pattern (Page 63) was illuminating.
1) We were not able to see higher diffraction orders.
A solution we recommend is to tilt the Fourier camera so that the 0th order goes to one end. That way, we could imagine more orders.

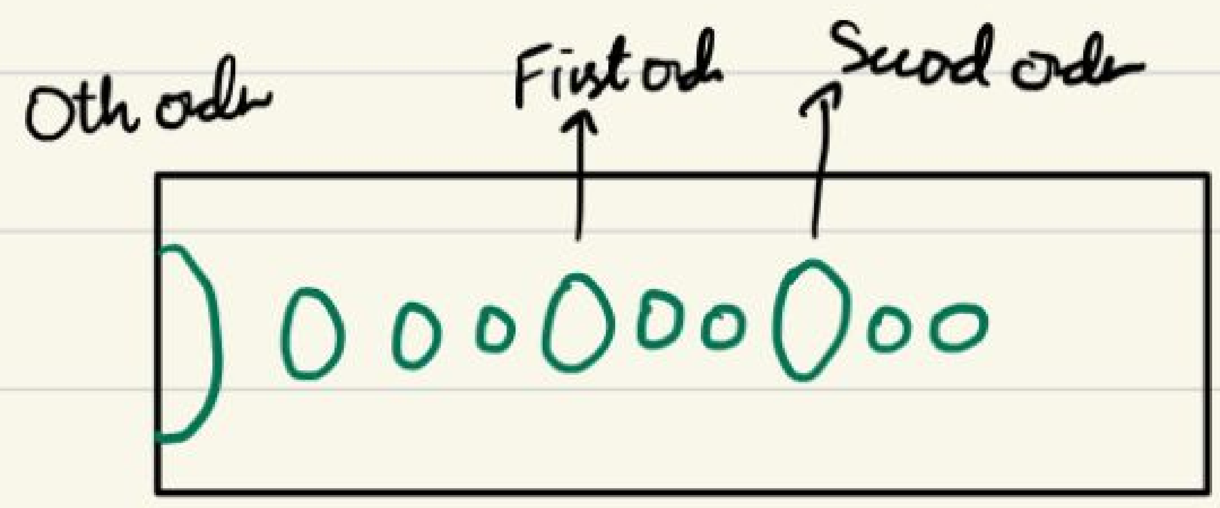


Figure 2: Fourier Image Idea

2) While our image light illumination has dark spots, it is decently in focus after making some alignment corrections, and we are now able to see the effects of altering the fourier diffraction orders on the image results. We achieved our intial goals of correcting the focus and alignment of the fourier plane peaks. Our setup is sufficient to proceed with Ronchi ruling next session.

3) This lab fundamentally changed how I conceptualize image formation. Rather than thinking of lenses as simply "focusing light," I now understand them as performing spatial Fourier transforms, with the image plane representing the inverse transform of filtered frequency components. The ability to physically manipulate frequency content by placing objects in the Fourier plane --- and immediately see the effect on the image --- made abstract mathematical concepts concrete and intuitive.

Lab Notebook Submission Summaries

Spatial Filtering Lab (Lab 1) – Sessions 4 & 5

PHYS 332

Week 1 Submission: Session 4

Session Overview

Date: 20-Jan-2026 **Lab Partner:** Absent **Pages:** 40–53 **Objective:** Complete Setup 2 by adding beam splitter and secondary (Fourier) camera arm; perform initial testing of field and aperture stop effects.

View Next Page: Format Error

Key Files Saved:

- `Fourier-Image-Pinhole.tiff`
- `diffraction-pattern-secondary-rail-01.tiff`
- `error-changing-exposure.png`
- `LabView-Setup-Screenshot.png`
- `new-diffraction-pattern.tiff`
- `Smallest-pupil-field-iris.tiff`
- `1-10th-pupil-field-iris.tiff`
- `2-10th-pupil-field-iris.tiff`

Week 2 Submission: Session 5

Session Overview

Date: 22-Jan-2026 **Lab Partner:** Nathan Unhm **Pages:** 54–64

Objective: Resolve image doubling and focus issues from Session 4; understand physical relationship between Fourier plane spots and image sharpness; perform resolution tests with multiple gratings.

Item	**Page**
Preparation & Background	
Goals: complete testing, correct errors, understand sharpness vs. brightness in Fourier plane	54
Physical Intuition: wave behavior, sharp edges require many plane wave components	54–55
Slit Diffraction: wide slit → narrow pattern; fine details → large angles	55
Filtering Methods Overview (11 methods documented)	56
Procedure & Troubleshooting	
Image Doubling Diagnosis — used filter paper to trace source; multiple intensity peaks	57–58
Resolution: misalignment of light onto condenser; fixed by pitching lens forward/right	58
Fresnel Fringes Issue — fringes around text indicate out-of-focus image	58–59
Focus Tip: focus on small defect on test object and make it sharp	59
Testing & Data Collection	
Test 2 Continued: Aperture stop blocks outer orders → blurs image (high-freq info lost)	60
10 nm Band Filter Insertion — eliminated diffraction spreading, cleaner pattern	61
Resolution Test (10, 12, 16.67 lp/mm) — measured pixel spacings between orders	61
Diffraction Angle Calculation: $\theta_1 = \sin^{-1}(\lambda/d) = 0.501 = 0.00874$ rad	61
Resolution Test (26, 50 lp/mm) — predicted and confirmed selective blurring	62–63
Closing iris halfway: fine lines (50 lp/mm) blur, coarse lines (26 lp/mm) stay sharp	
Combined Grating Pattern — positioned FOV to capture both frequencies simultaneously	63
Post-Lab Analysis	
Reflection: diffraction pattern images illuminating; could not see all higher orders	64
Suggestion: tilt Fourier camera so 0th order at edge to fit more orders on sensor	64

Key Files Saved:

- `initial-state-diffraction-pattern.tiff`
- `fersnel-fringe-issue.tiff`
- `Correct-iris-position.tiff`
- `zeroth-order-image.tiff`
- `26lp-mm-fourier.tiff`
- `50lp-mm-fourier.tiff`
- `26-50lpmm-fourier.tiff`

Key Measurements:

Parameter	Value	Notes
LED wavelength	525 nm	Bandwidth 35 nm
Zeroth order (initial)	(819, 655) px	Before correction
Zeroth order (corrected)	(709, 620) px	After condenser fix
16.67 lp/mm spacing	202 pixels	0th to 1st order
12 lp/mm spacing	132 pixels	0th to 1st order
θ_1 (16.67 lp/mm)	0.501°	Calculated

Equipment: Fourier lens (50 mm dia, $f = 100$ mm), FLIR Blackfly camera on XY stage, 10 nm band filter, resolution target (10–50 lp/mm gratings).