U.S. ARMY

DEVCOM CSISR CENTER

Can Structured Illumination Be Used To Reconstruct An Image Of An Object?

End of Summer Presentation

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AGENDA

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Introduction and Goals

02
Structured Illumination

03
Spatial Light Modulators (SLM)

04
Optics and Optical Setup

05
Data Collection

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Data Processing: Fast Fourier Transform (FFT) of Digital Images

07
Accomplishments and Future Work

08
Takeaways

WHAT IS THIS PROJECT?

Proof-of-concept: Can active **structured illumination** be used to identify a target?

Goals for the outcome of the project:

– Reconstruct an image

– Does it work?

– Is it practical?

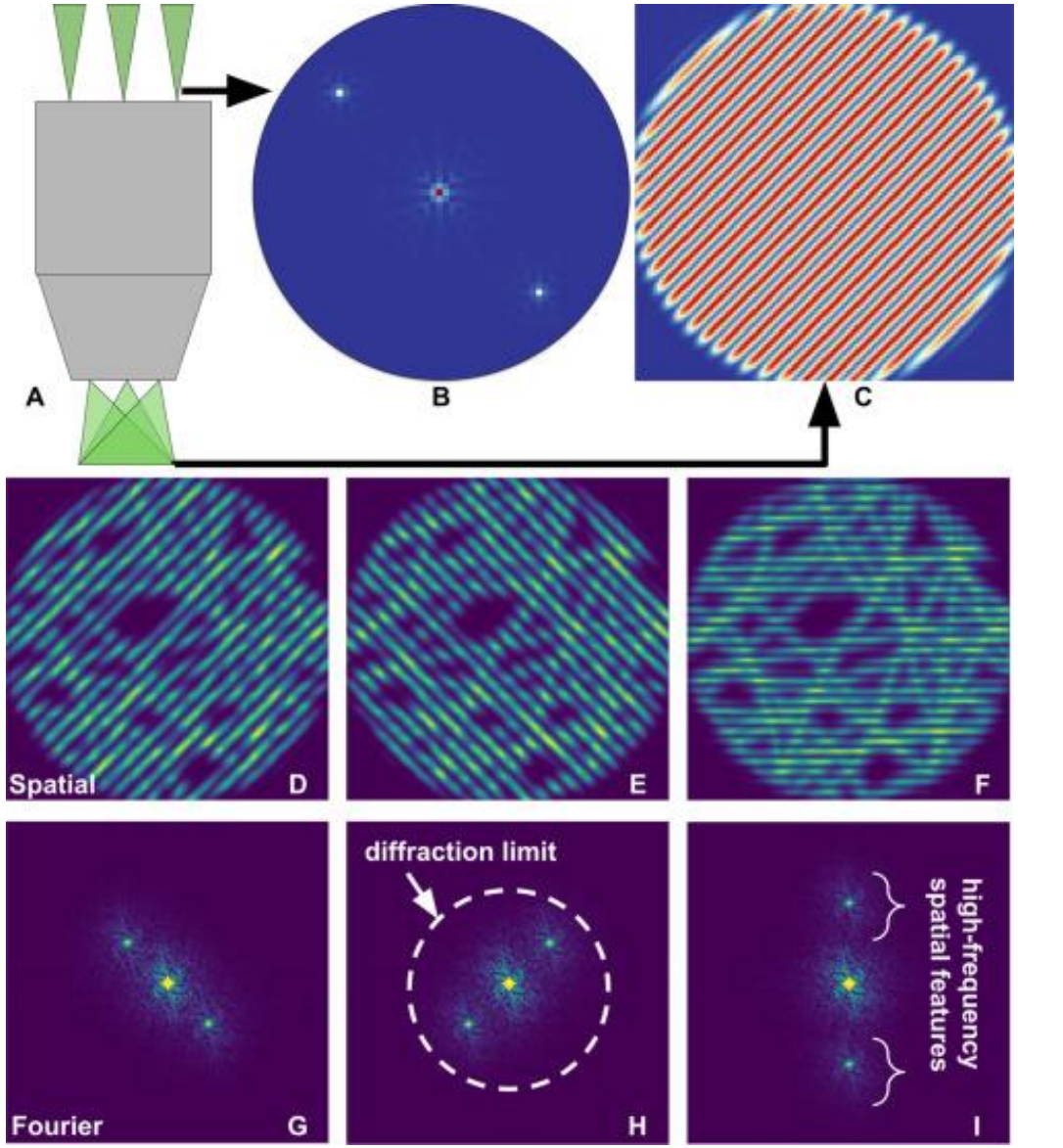
Personal Goals

– Learn!

– What does research in a professional setting look like?

STRUCTURED ILLUMINATION

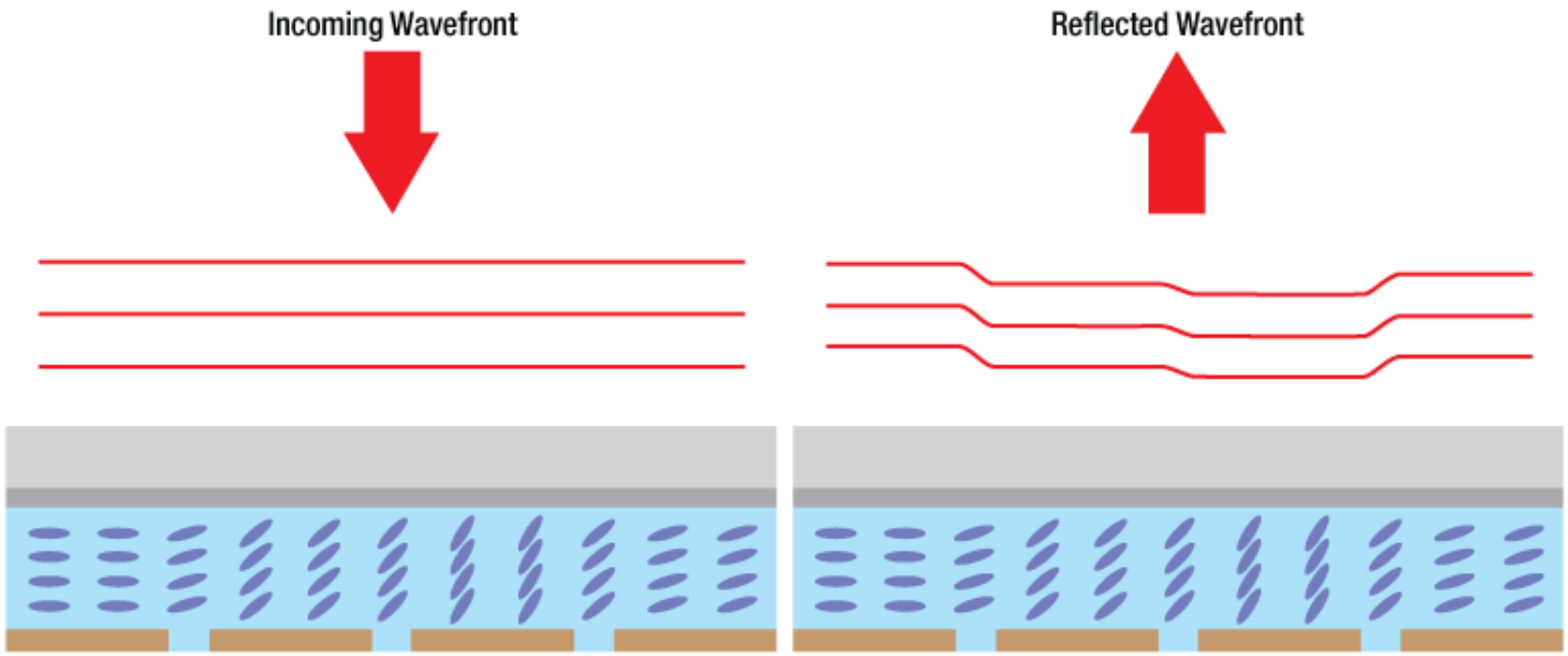
- Generate high resolution images by illuminating a target with spatially structured patterns of light
- Amplitude and spatial frequency
- Previous use in microscopy
  - Super-resolution images beyond the diffraction limit



Advanced Optical Microscopy Techniques for the Investigation of Cell-Nanoparticle Interactions

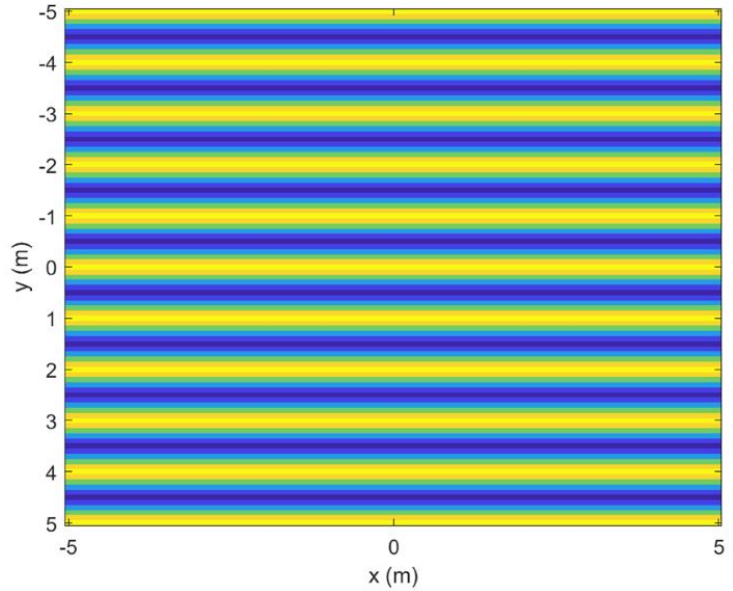
SPATIAL LIGHT MODULATION

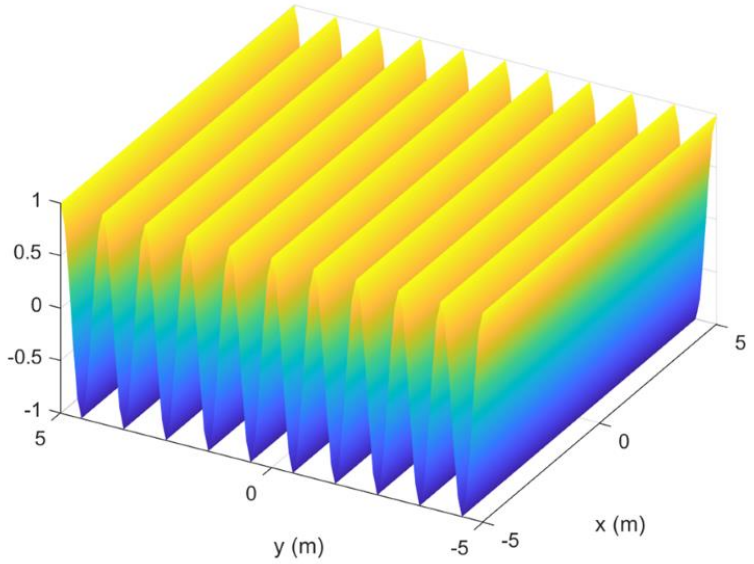
- Efficiency through software
- SLM window includes an array of liquid crystal “pixels” between a transparent and a reflective electrically conductive layer
- Orientation of crystals and modification of phase via delay

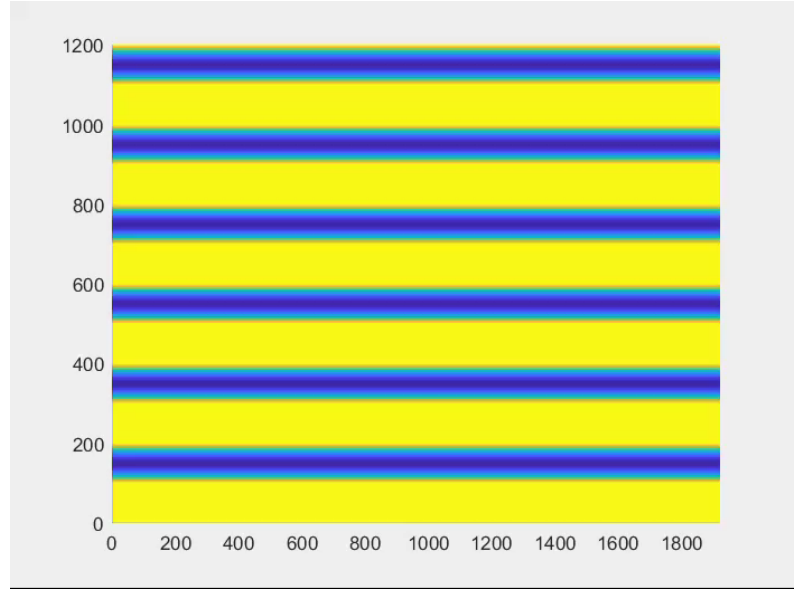


SLM PATTERNS

- Sine waves at various frequencies, phases, and angles are uploaded individually into SLM software
- Optimization in the works for custom patterns for each target

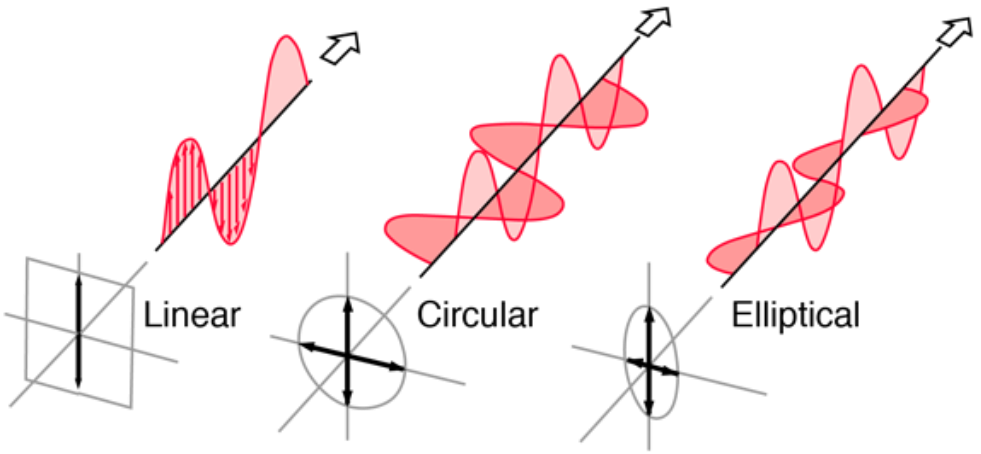


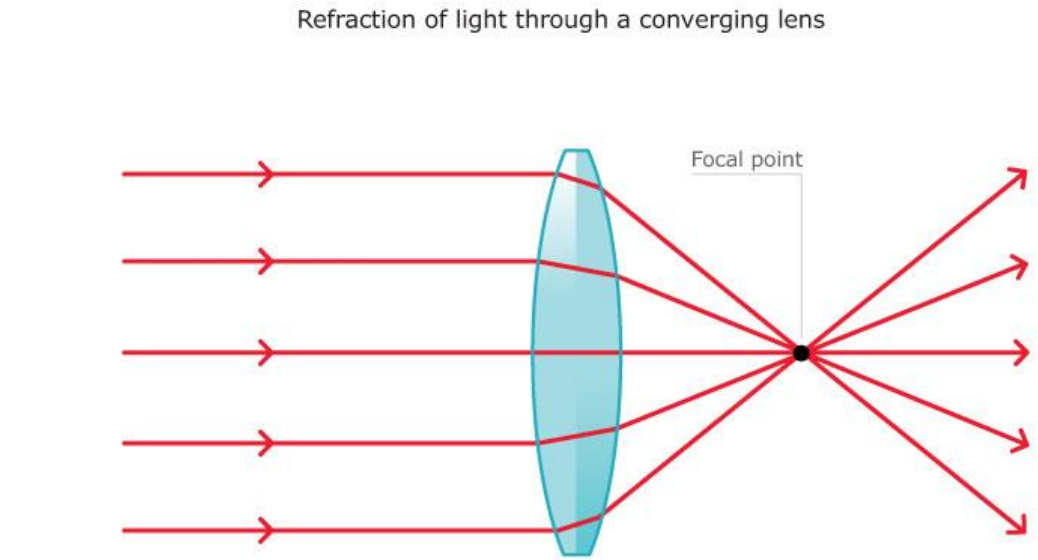




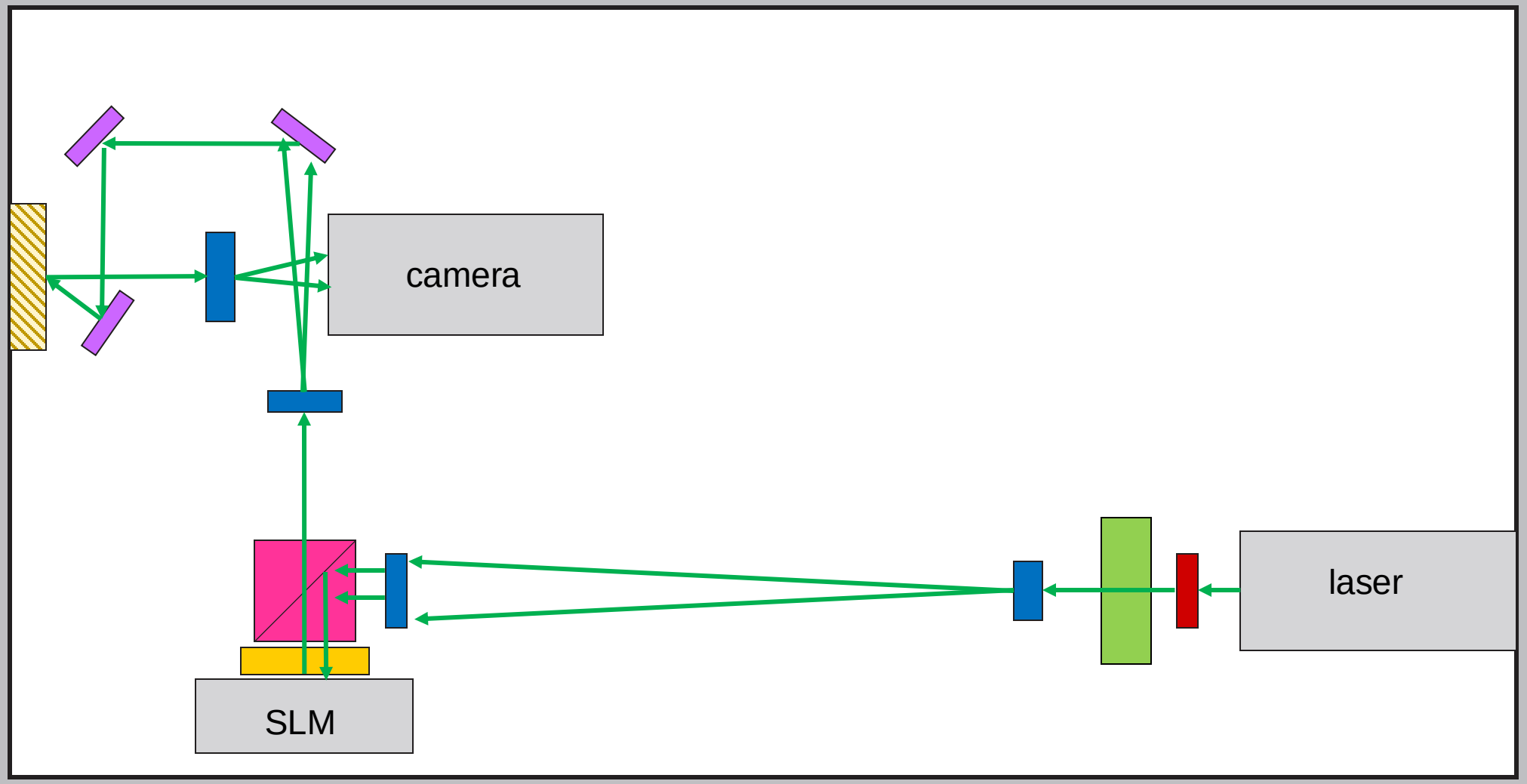
OPTICS

- Modification of a light from a laser: collimation, expansion, contraction with lenses
- Flat phase front of an oscillating electric field (laser)
- Ideally linearly polarized – need for a polarizing filter





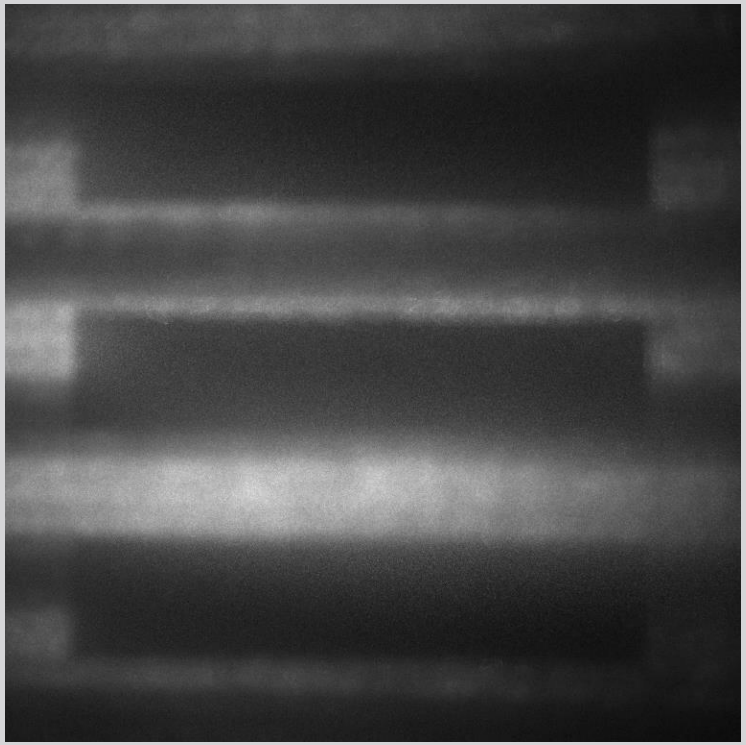
OPTICAL SETUP



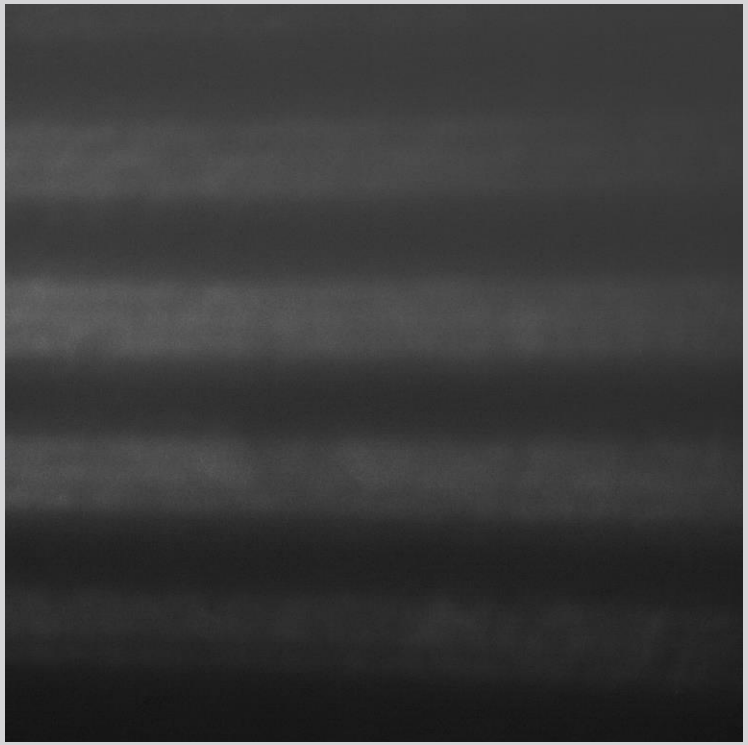
TAKING DATA

- Generated pattern

- Illuminated target

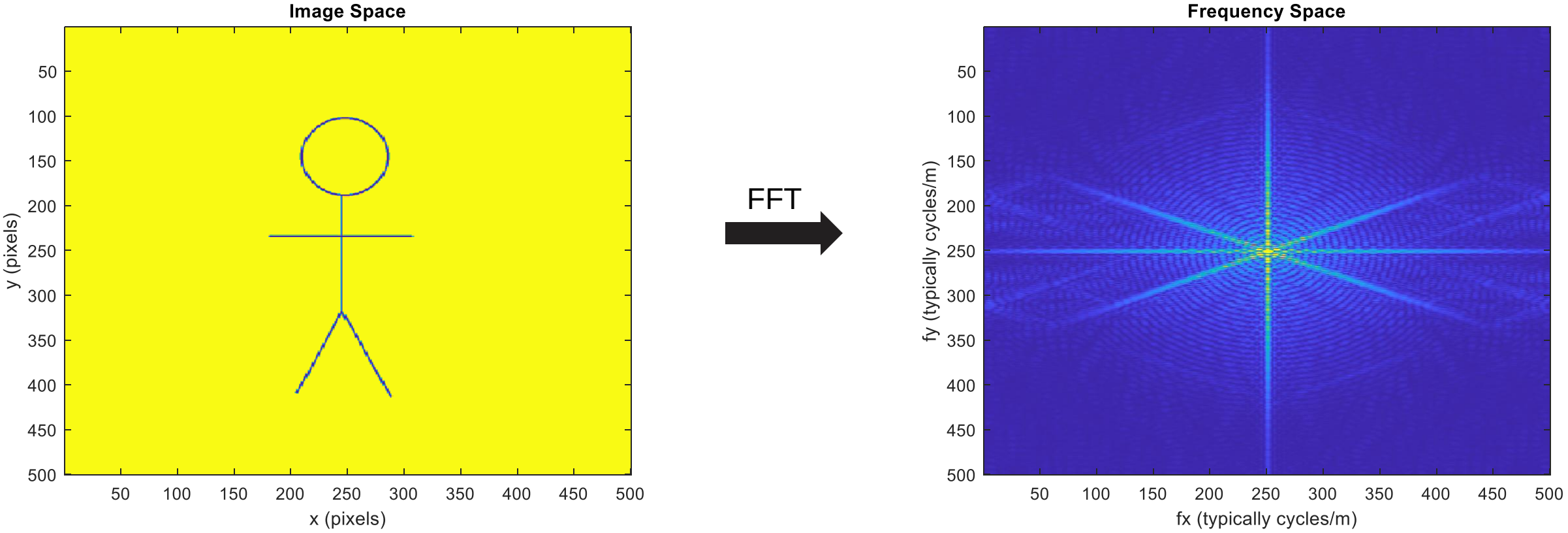


- Illuminated background



DIGITAL IMAGE PROCESSING AND FFTS

- Digital images can be represented in both image and frequency space



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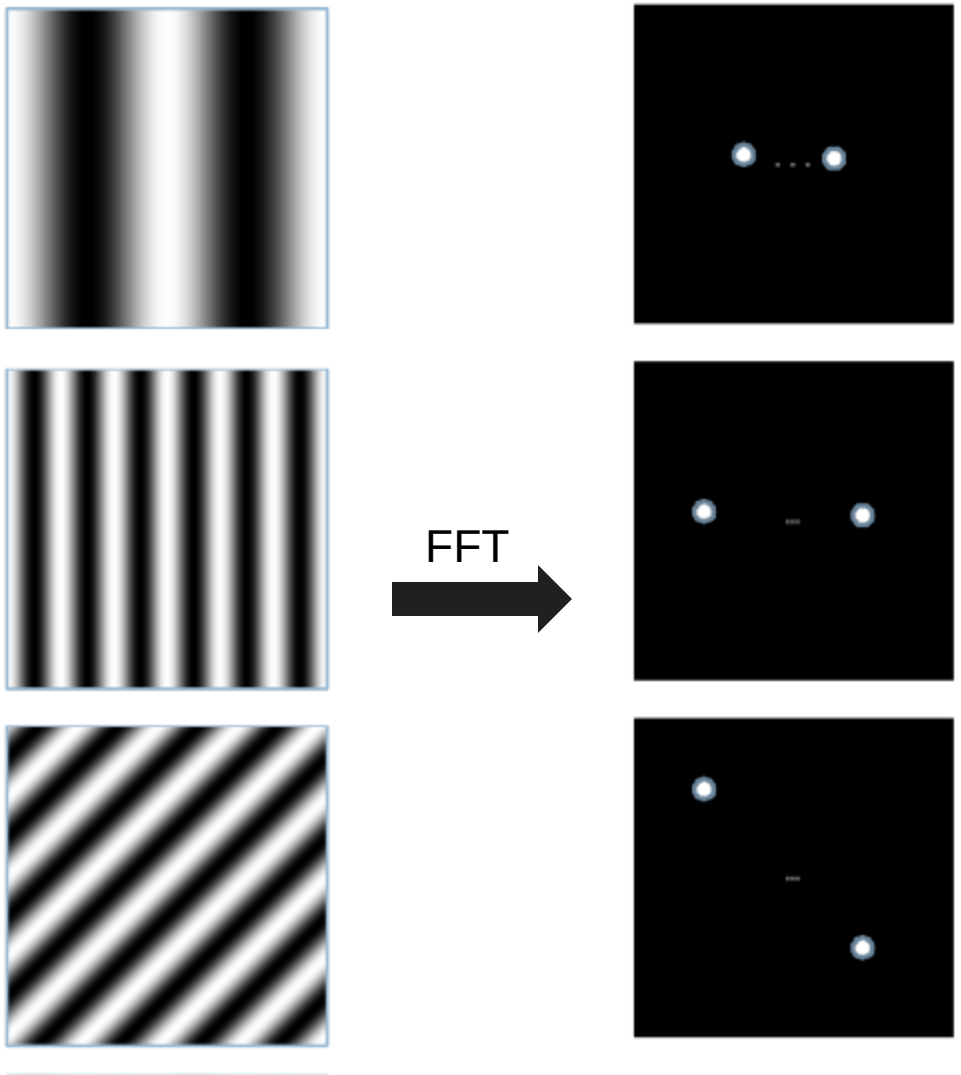

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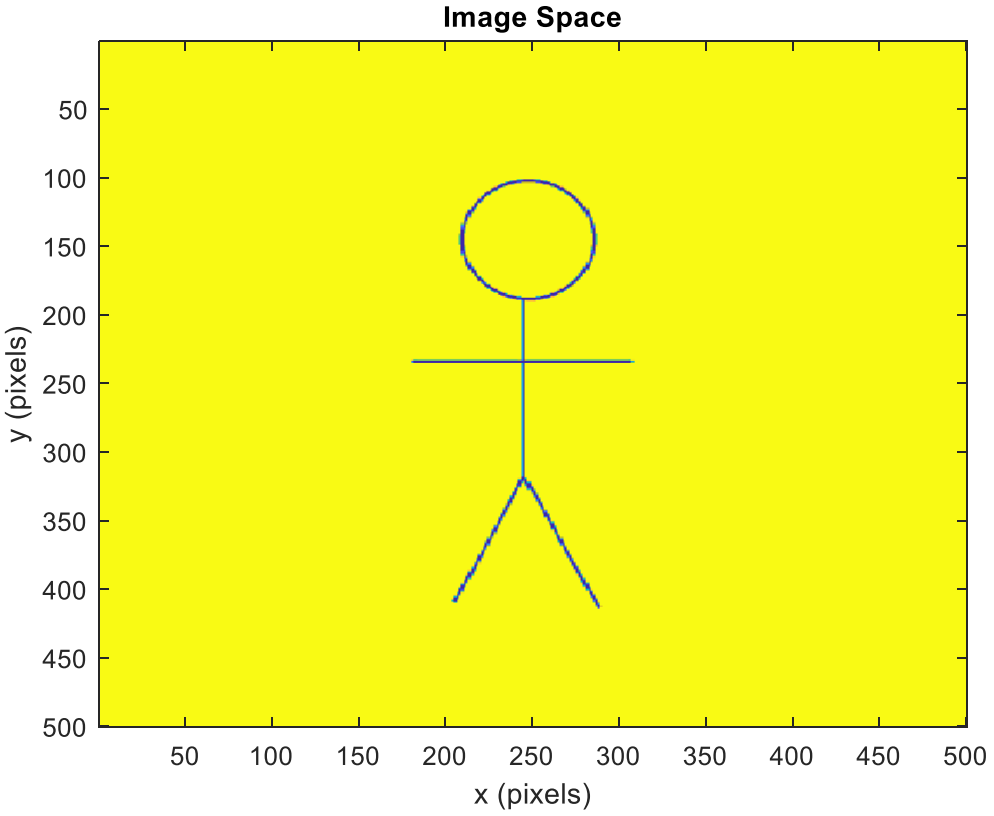
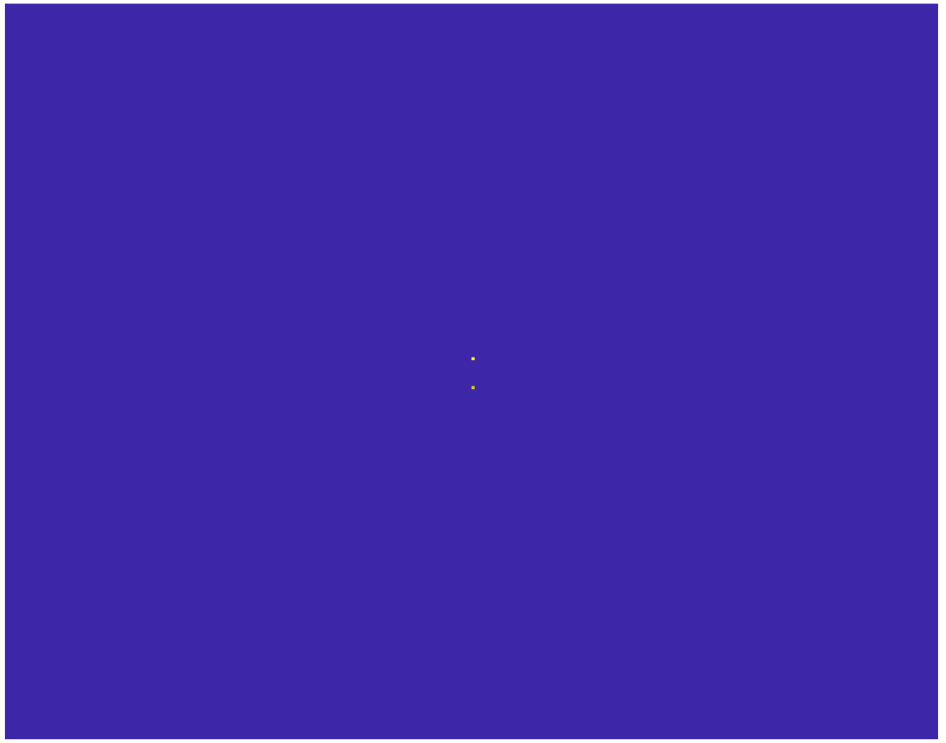
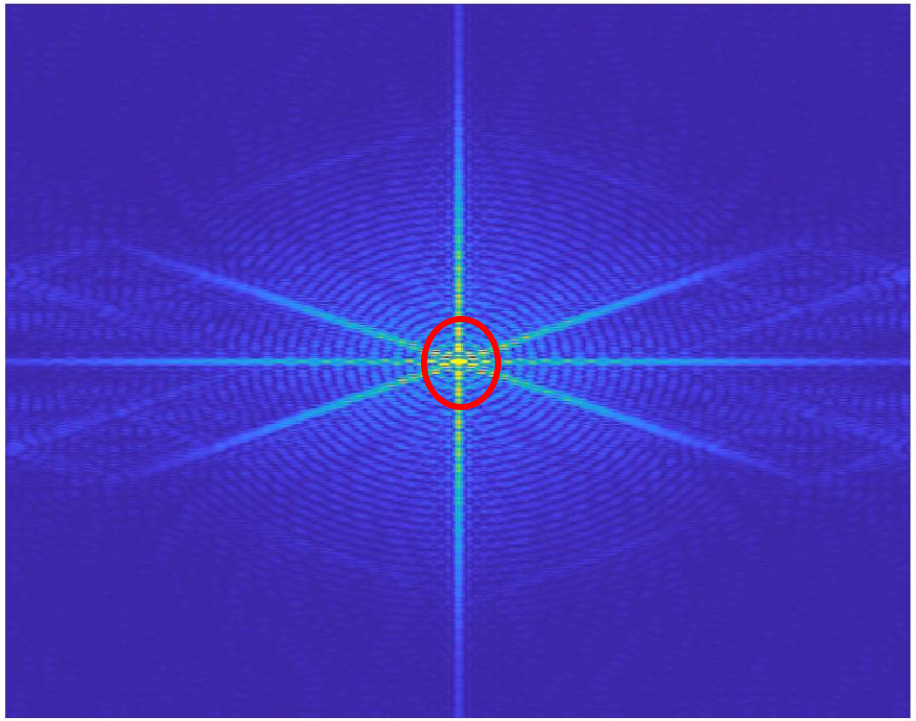
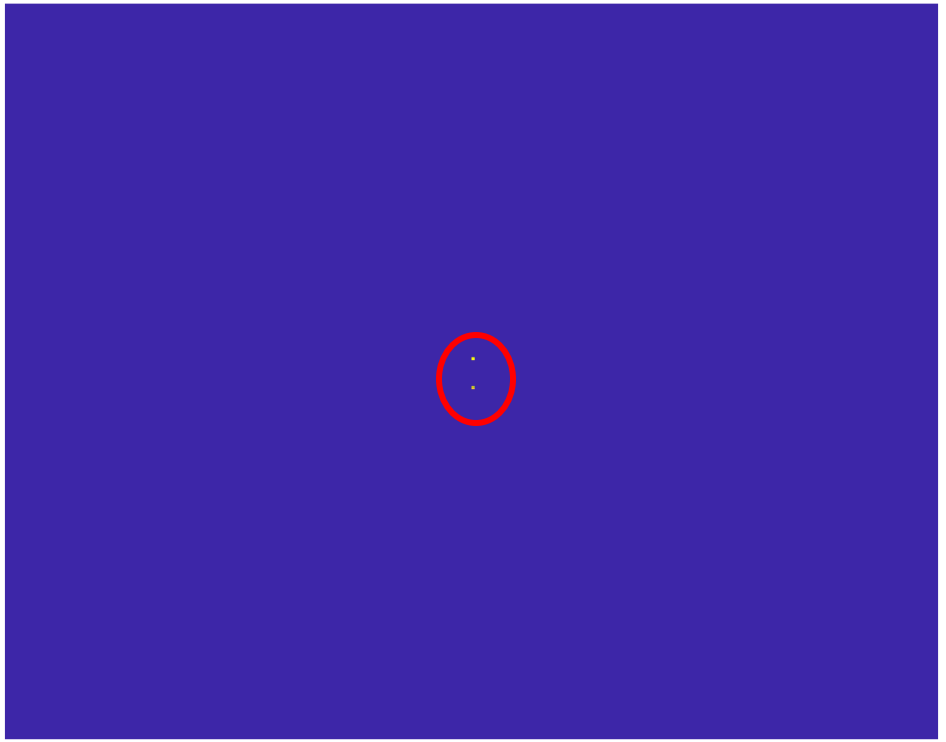




DIGITAL IMAGE PROCESSING AND FFTS

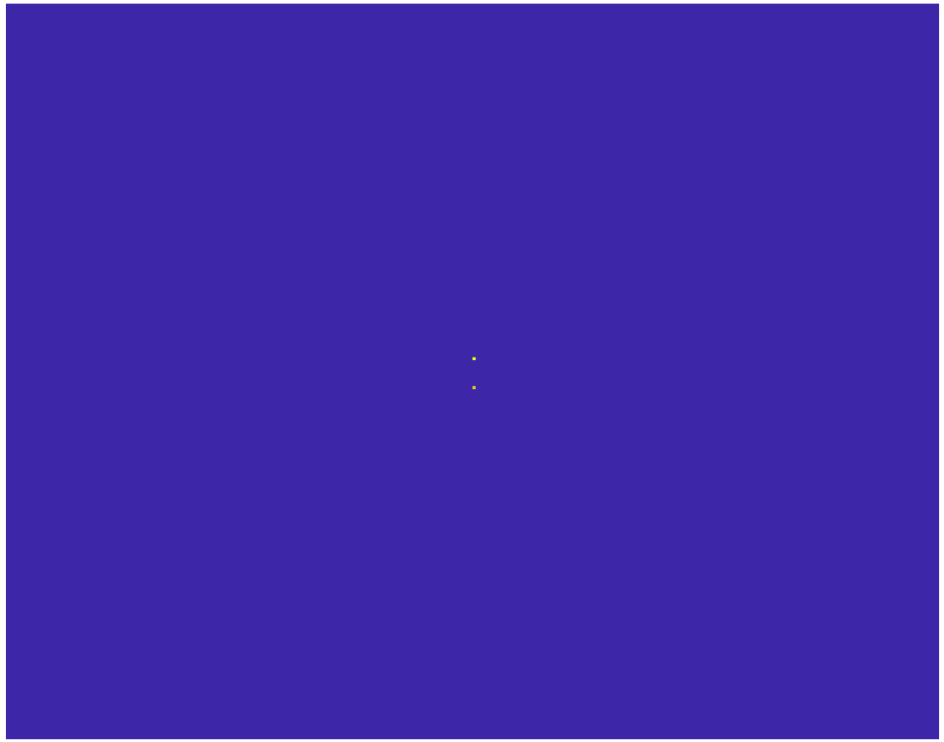
- Digital images can be created by adding their individual frequency components



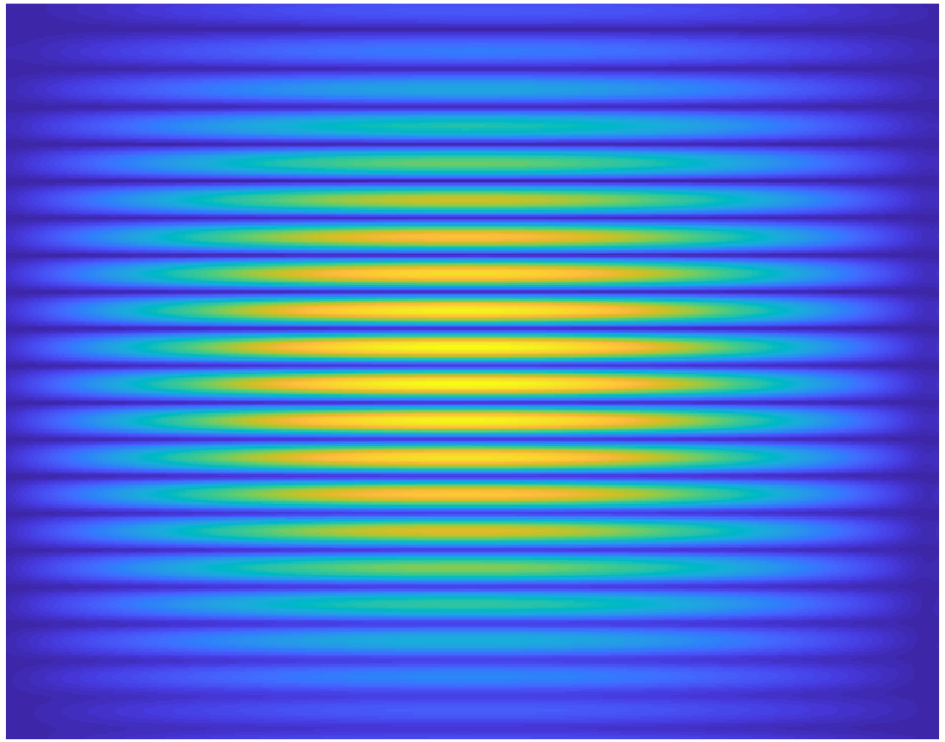


DIGITAL IMAGE PROCESSING AND FFTS

- Digital images can be created by adding their individual frequency components, which are images of a sine wave

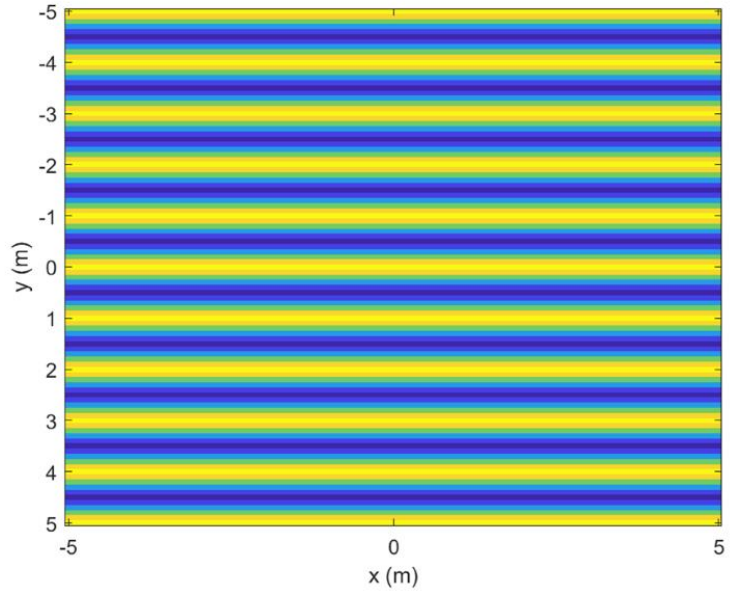


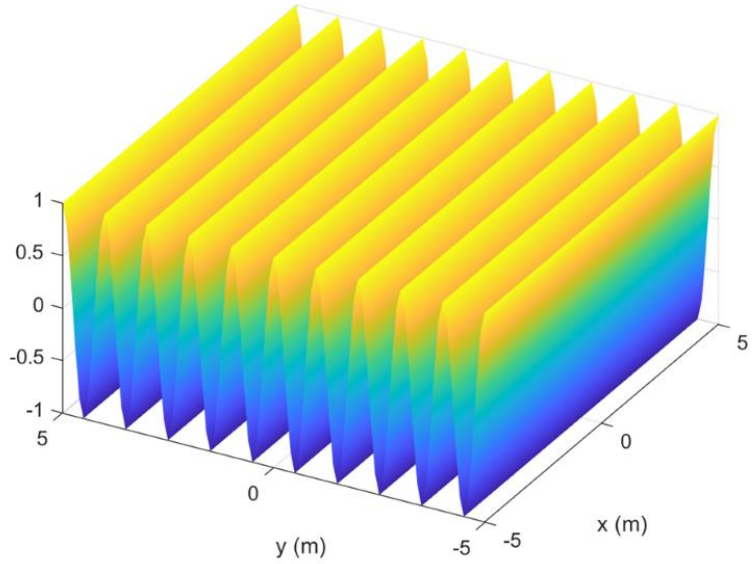
Inverse FFT

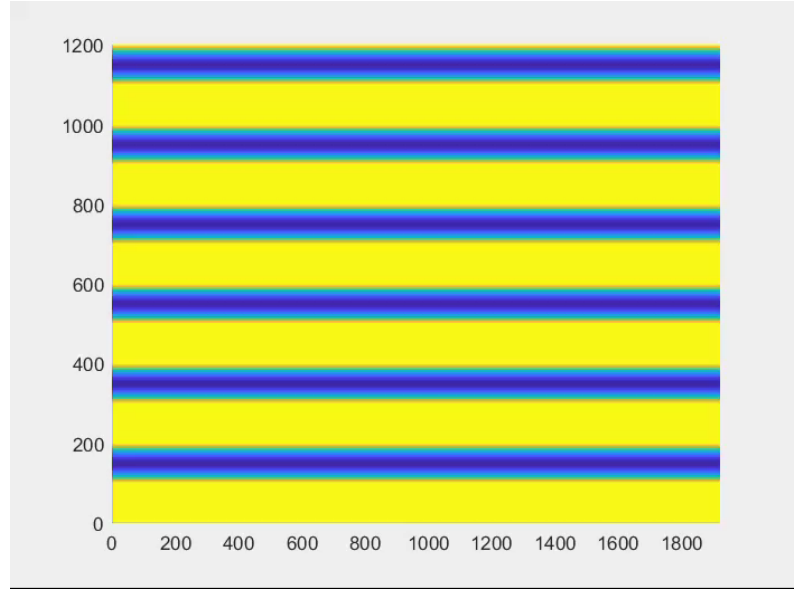


DIGITAL IMAGE PROCESSING AND FFTS

- Sine wave… look familiar?



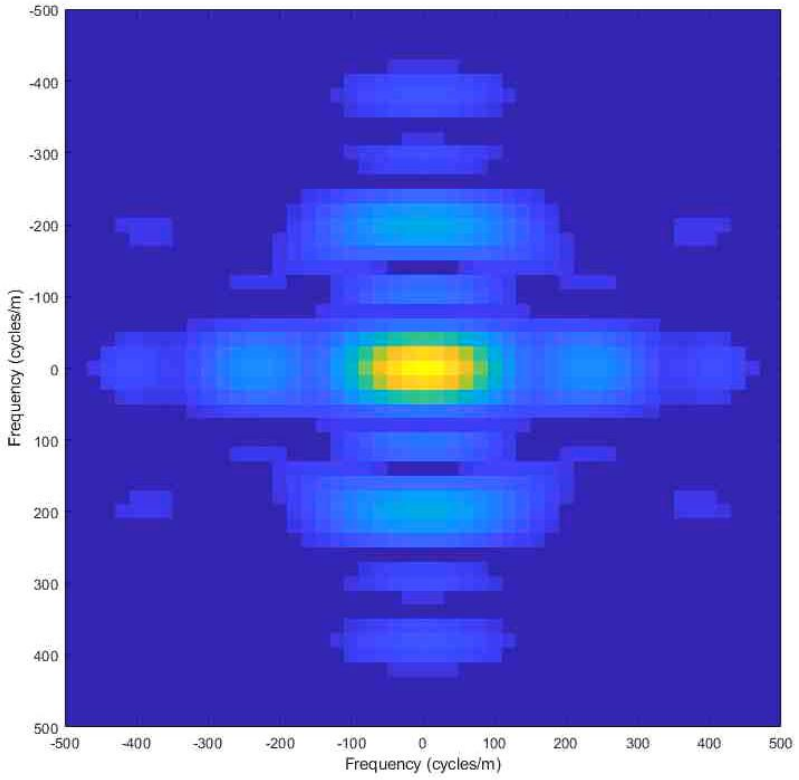




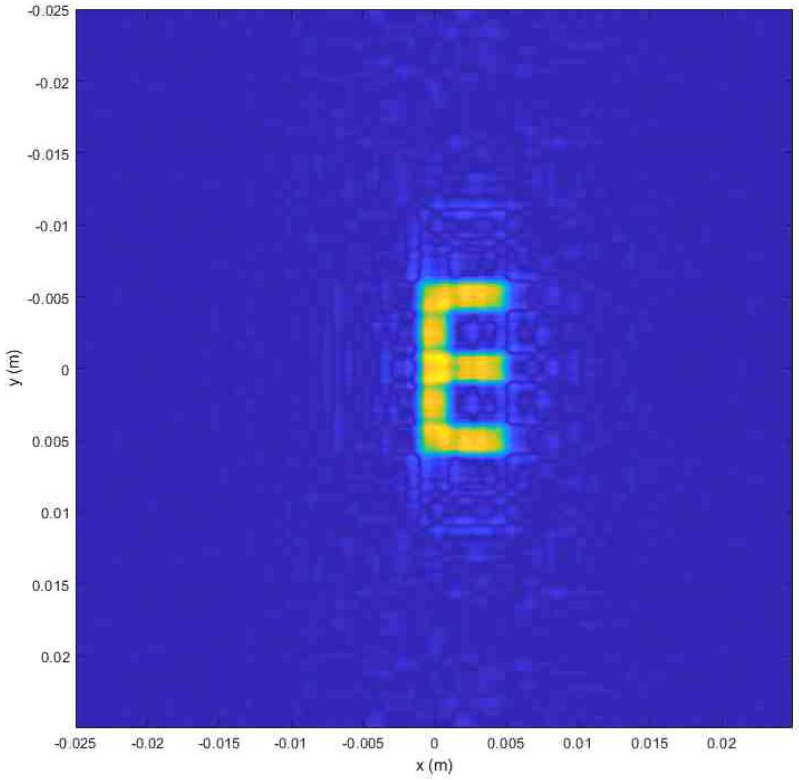
DIGITAL IMAGE PROCESSING AND FFTS SIMULATION

- Adding together the frequency components of the sine waves and taking the IFFT of that should give us our original image!

FFT



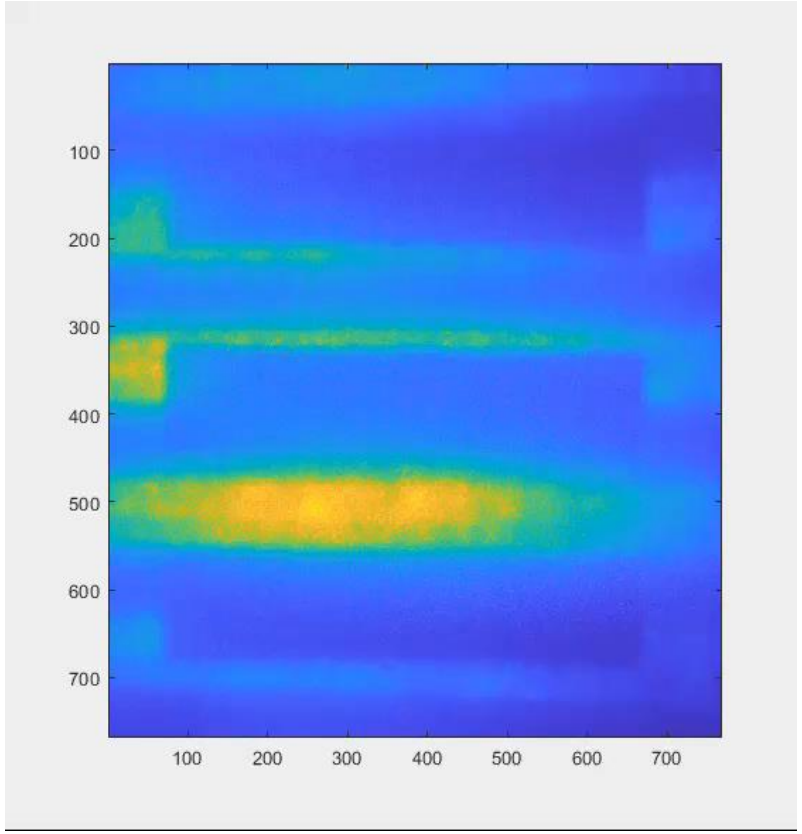
IFFT



Simulation

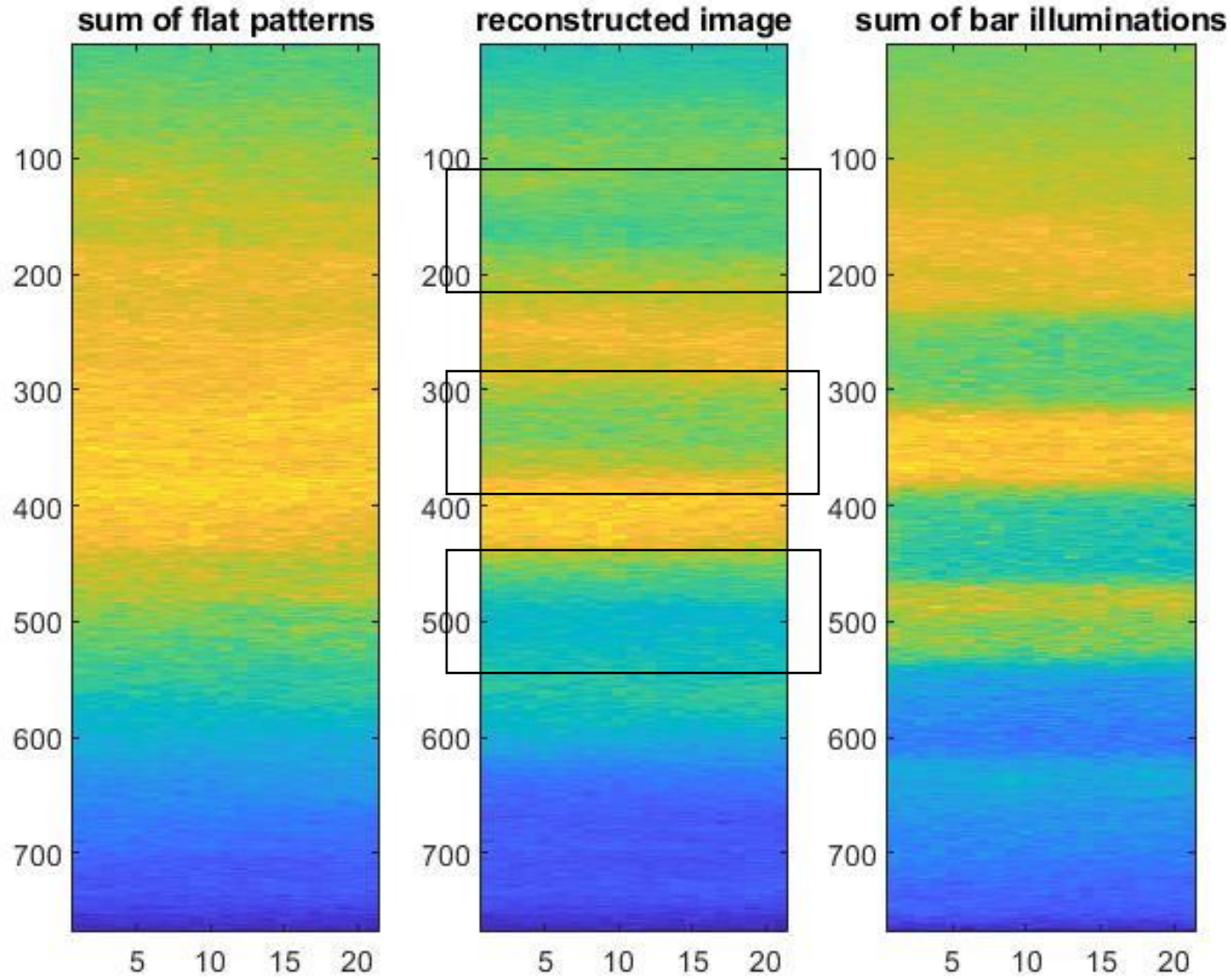
DIGITAL IMAGE PROCESSING AND FFTS REAL RESULT

- Three-bar target illuminated with the sinusoidal pattern at one frequency and angle, only adjusting phase since that is an unknown component

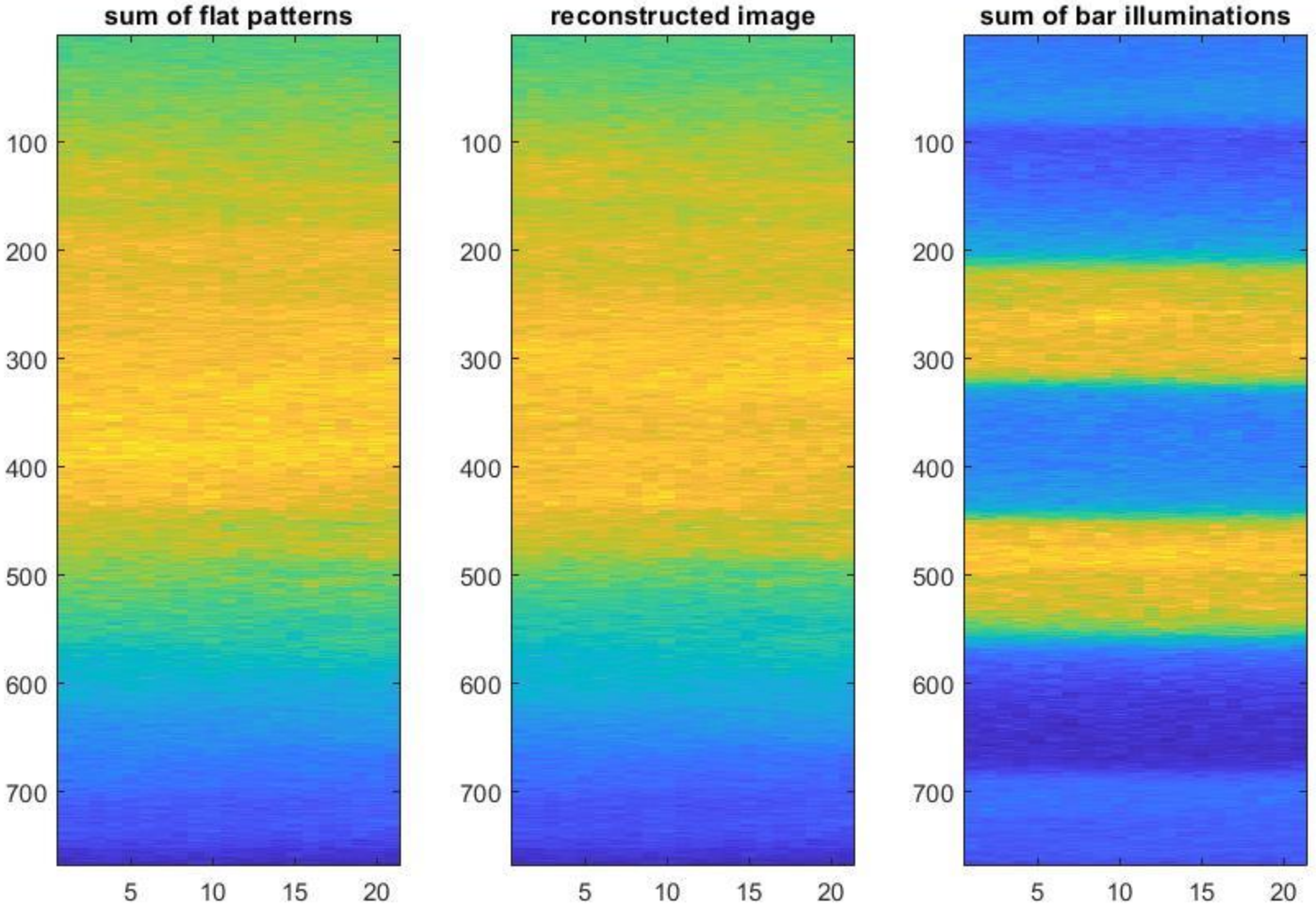


FFT of each image → Sum in frequency space → IFFT → ?

REAL RESULT: PROVING THE CONCEPT



REFINEMENT: PROVING THE CONCEPT



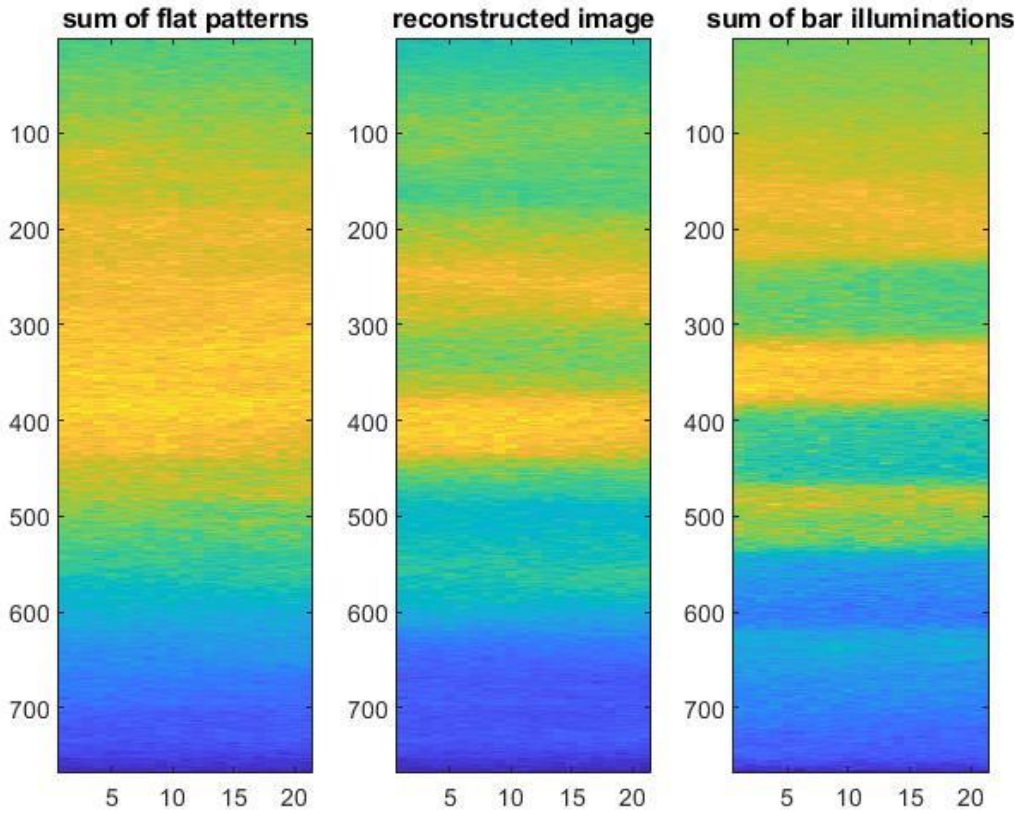
PREDICTION ALGORITHM

- Input camera image of the target
- FFT
- Extract the dominant frequencies
- Generate patterns for that target based on frequencies

- Tested on the E target – unable to reconstruct an image

UP TO THIS POINT…

- Built a Structured Illumination Sensor – enables object reconstruction with coherent light
- Successfully reconstructed an image of our three-bar target!
- Created an algorithm to predict the structures (patterns) to use based on an image of the target – needs refining



FUTURE WORK

- Refine prediction algorithm to accommodate complex structures
- Sync the code with the SLM and camera - eliminate manual data collection
- Use of one pixel of data opens the door for further work

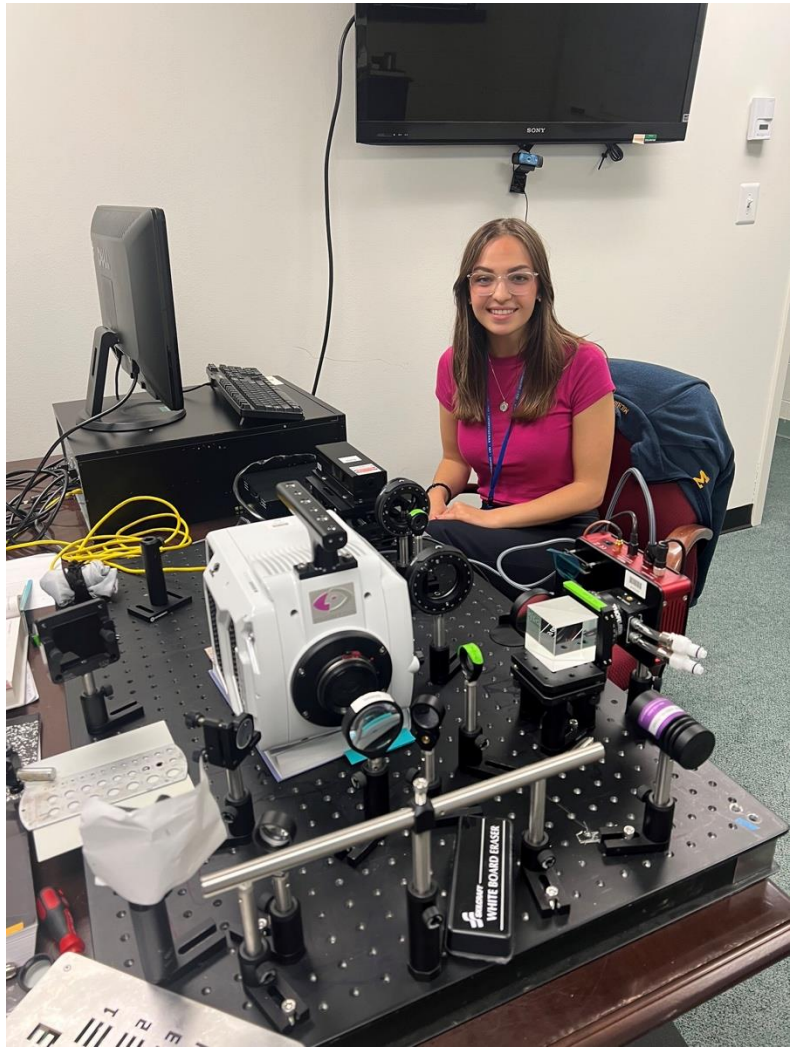
- New laser
- Clean optics
- Filters
- Less background light

TAKEAWAYS

- Structured illumination can be used to reconstruct images of targets on a larger scale than in SIM, though not practical in its current unrefined state

- Skills learned:
  - Matlab
  - Optics
  - Data & Image processing

- Research outside of a university



Questions, Comments, Suggestions?

Thank you to those in the Countermine Technology Branch who supported this project, including (but not limited to) James Perea, advisor of the project, Igor Semyonov who aided us with one of our algorithms, and Jerry Zadnik, Will Clark, and Collin Bright for guiding me to the right people for any lingering questions I came across.