A LOW-COST, RECONFIGURABLE THIN-FILM INSPECTION SYSTEM

TOWARDS LARGE AREA THIN-FILM REFLECTOMETRY

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OVERVIEW

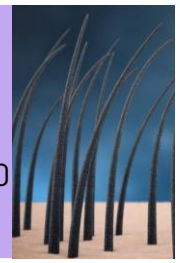
- What are Thin Films?
- Motivation
  - Challenges
- State of the Art
- Approach
- Status
- Future work

THIN-FILMS

$$T \pm 1nm$$

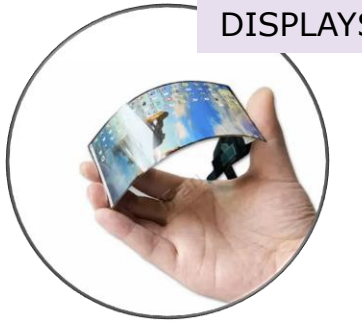
min: 2 nm;
max: 150 nm

For Reference, A single strand of human hair is approximately 60,000 to 120,000 nm wide



BATTERY CELLS

DISPLAYS



FOOD PACKAGING

SOLAR CELLS

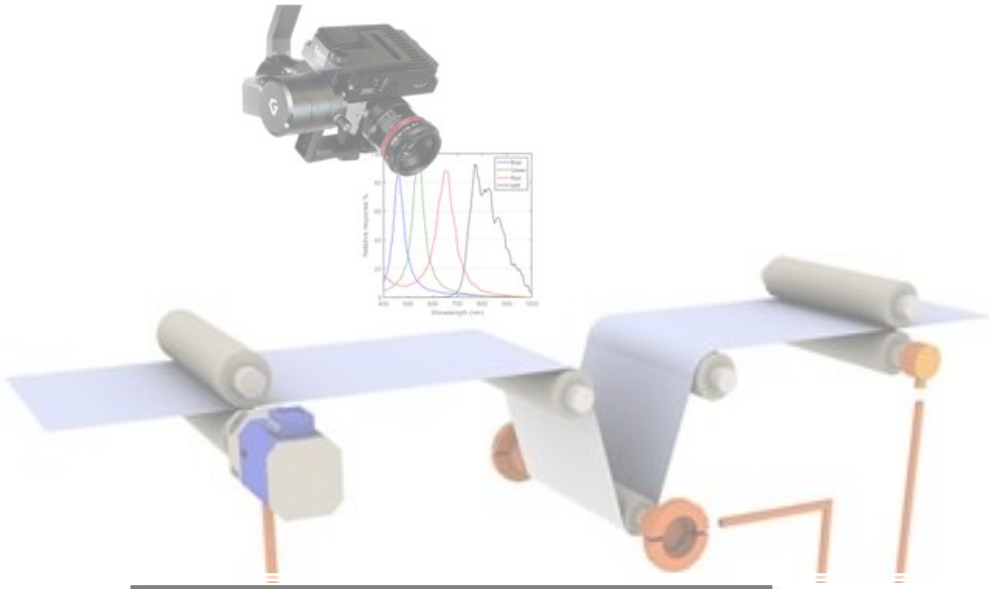
ILLUSTRATION OF INDUSTRIAL THIN-FILM INSPECTION

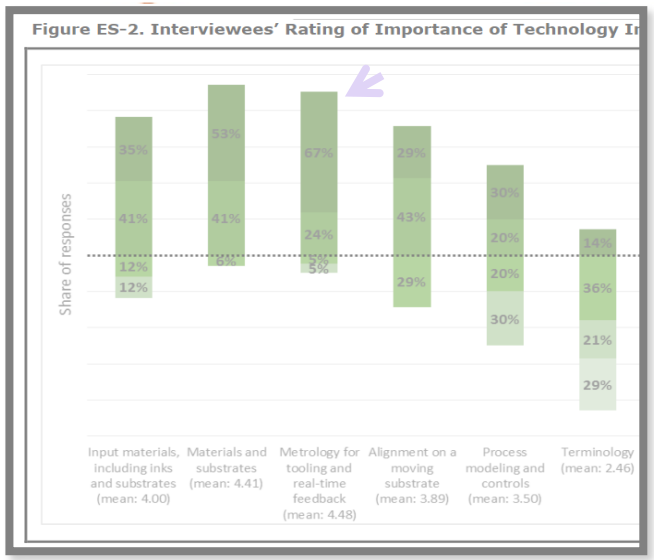
MOTIVATION

- "Metrology has not kept up with thin-film manufacturing speeds" (Maize et al, 2022; NIST 2016)
- Large-area thin films are everywhere!
  - used in PV, displays, batteries, and packaging
- Industry often needs 100% inline, real-time inspection

CHALLENGES

- Metrology is too computationally heavy or too slow
- Also, too expensive

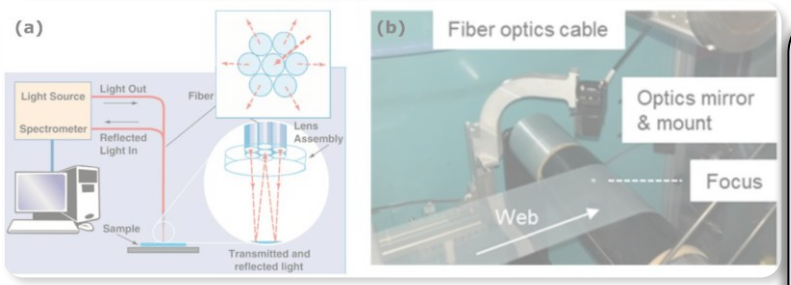


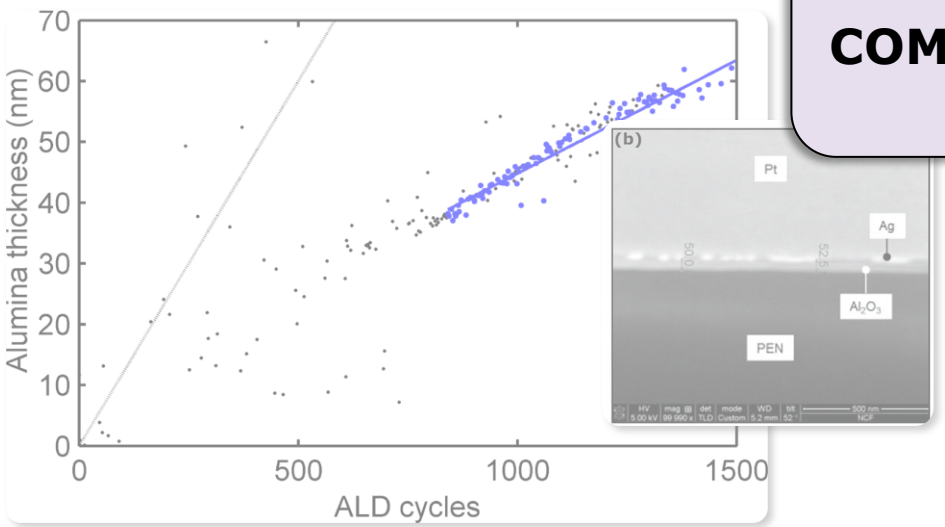


IMPORTANCE OF METROLOGY IN R2R MANUFACTURING

STATE OF THE ART

POINT THIN FILM INSPECTION



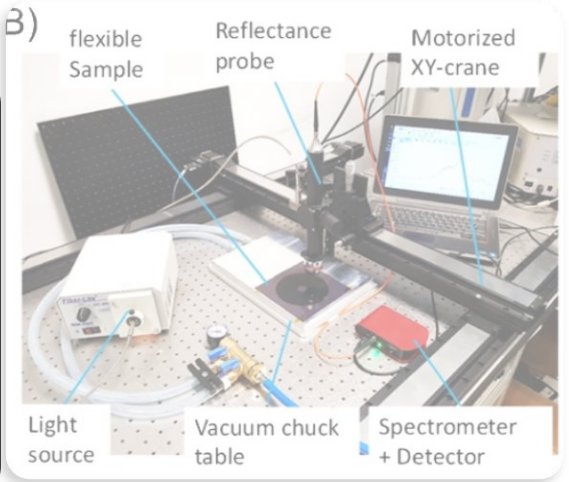


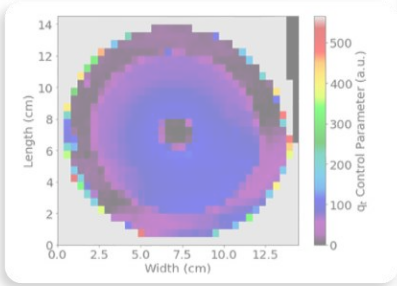
FOR 52NM ALD MOVING AT 1M/S AL_2O_3 (2014)

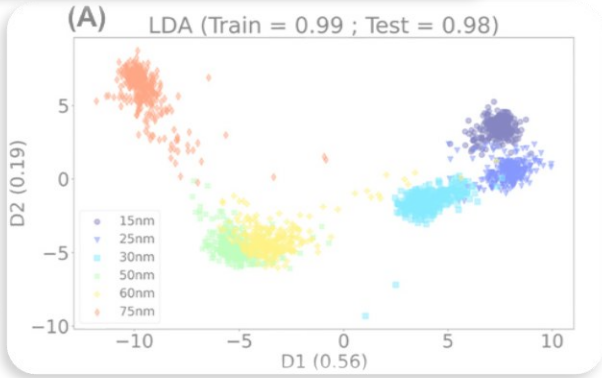
ALL USE **FULL REFLECTANCE SPECTRA (HYPERSPECTRAL)**

WHICH CAN BE **COMPUTATIONALLY HEAVY and COSTLY**

AREA MAPPING INSPECTION





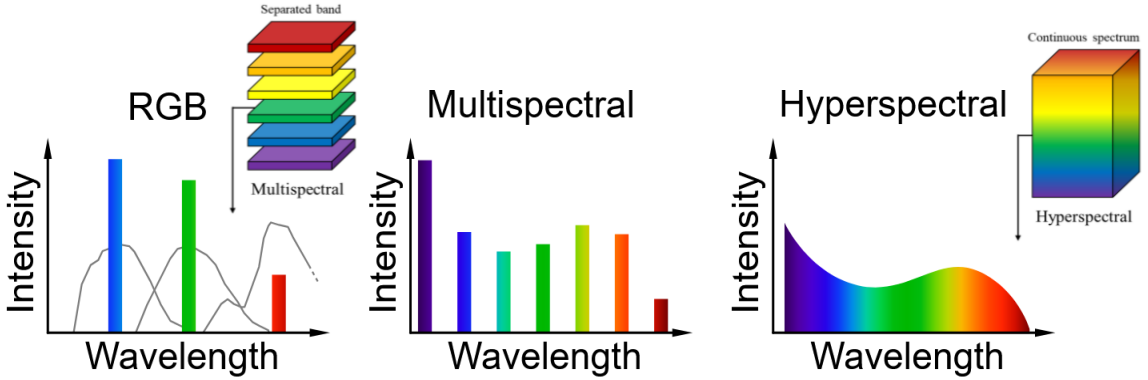


25NM ALxO FILM ON SILICON, (ENRIC, 2021)

BACKGROUND

Multispectral and RGB Cameras have **less spectral resolution**

- Each pixel adds spectral/color data
- **3 channels for RGB, ~1000 for Hyperspectral**



REDUCED SPECTRAL RESOLUTION WITH HYPERSPECTRAL

APPROACH

- Use multispectral/RGB cameras instead.

- Less computation = Fast!
  (3 Channels vs 1000 Channels)
- Less expensive!
  ($300 vs $100,000)

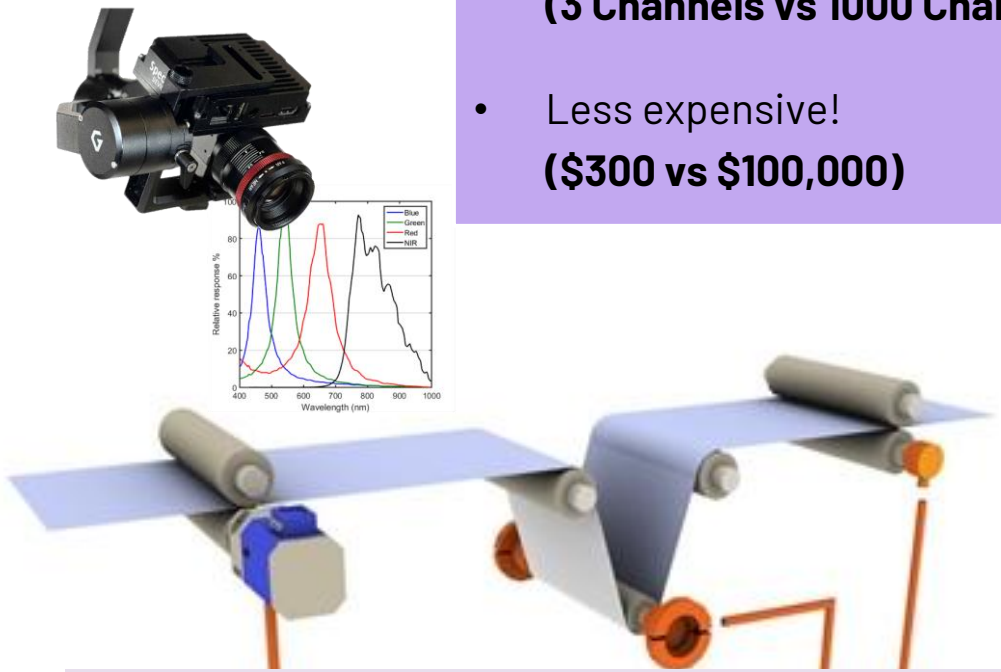
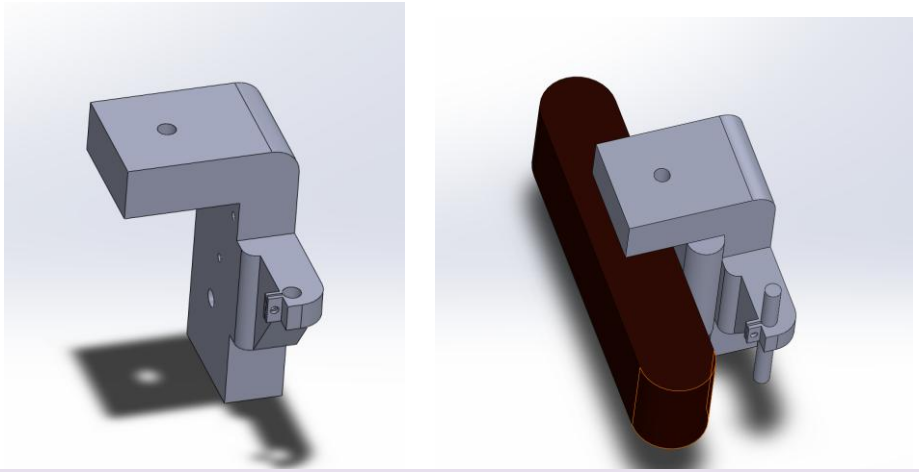


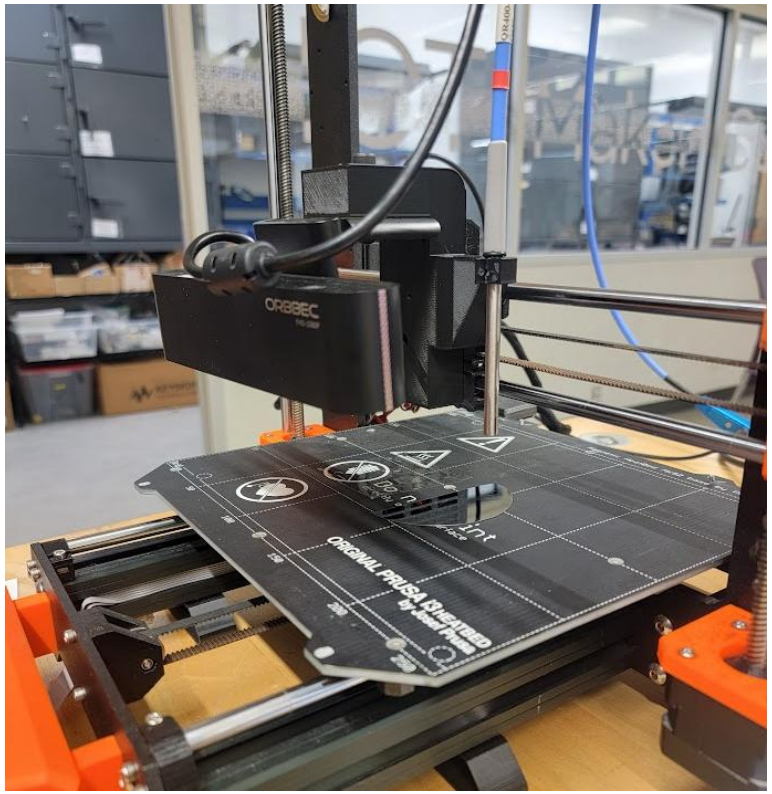
ILLUSTRATION OF INDUSTRIAL THIN-FILM INSPECTION

APPROACH – GANTRY DESIGN

- Prusa 3D MK3s was adapted to create an operational gantry
- A rig was designed and built to attach camera and spectrometer to the gantry



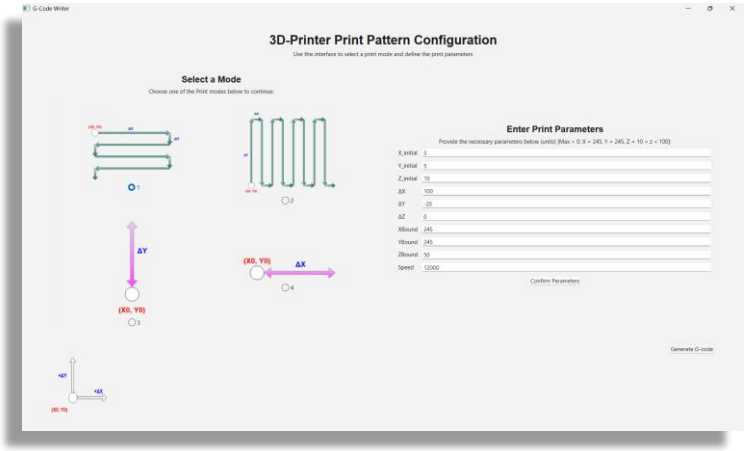
3D CAD OF CAMERA AND SPECTROMETER JIG



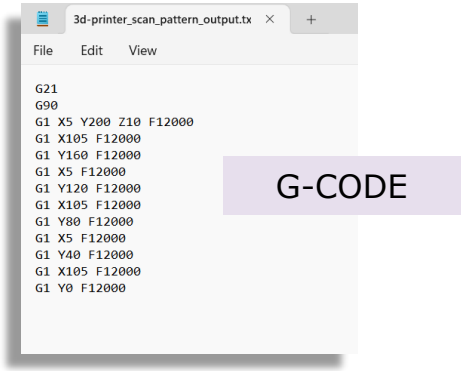
PICTURE OF ASSEMBLED SYSTEM

APPROACH - USER INTERFACE

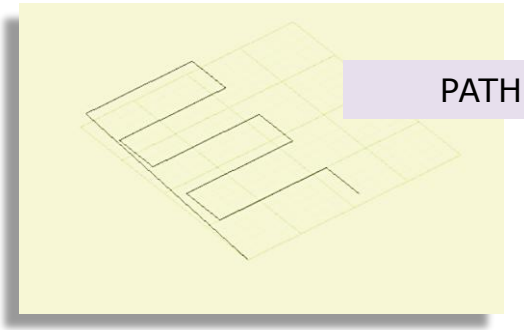
- A user interface was built to turn user instruction into machine procedure



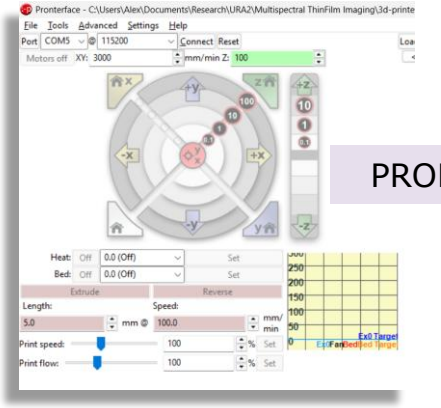
USER INTERFACE



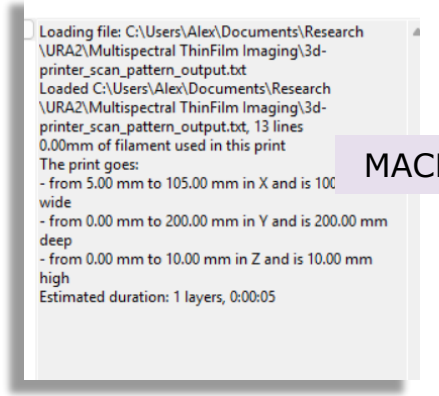
G-CODE



PATH

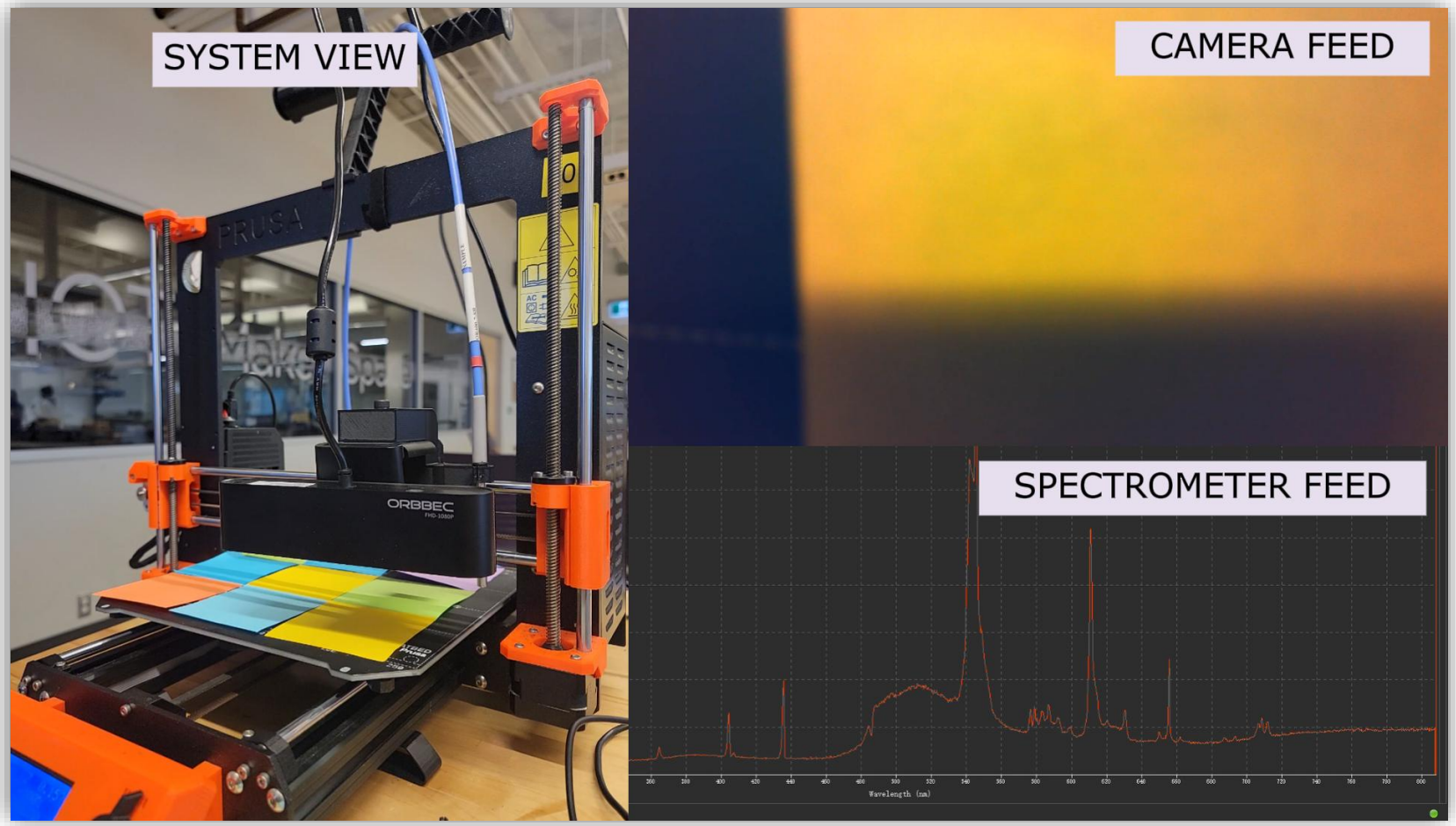


PRONTERFACE



MACHINE CODE

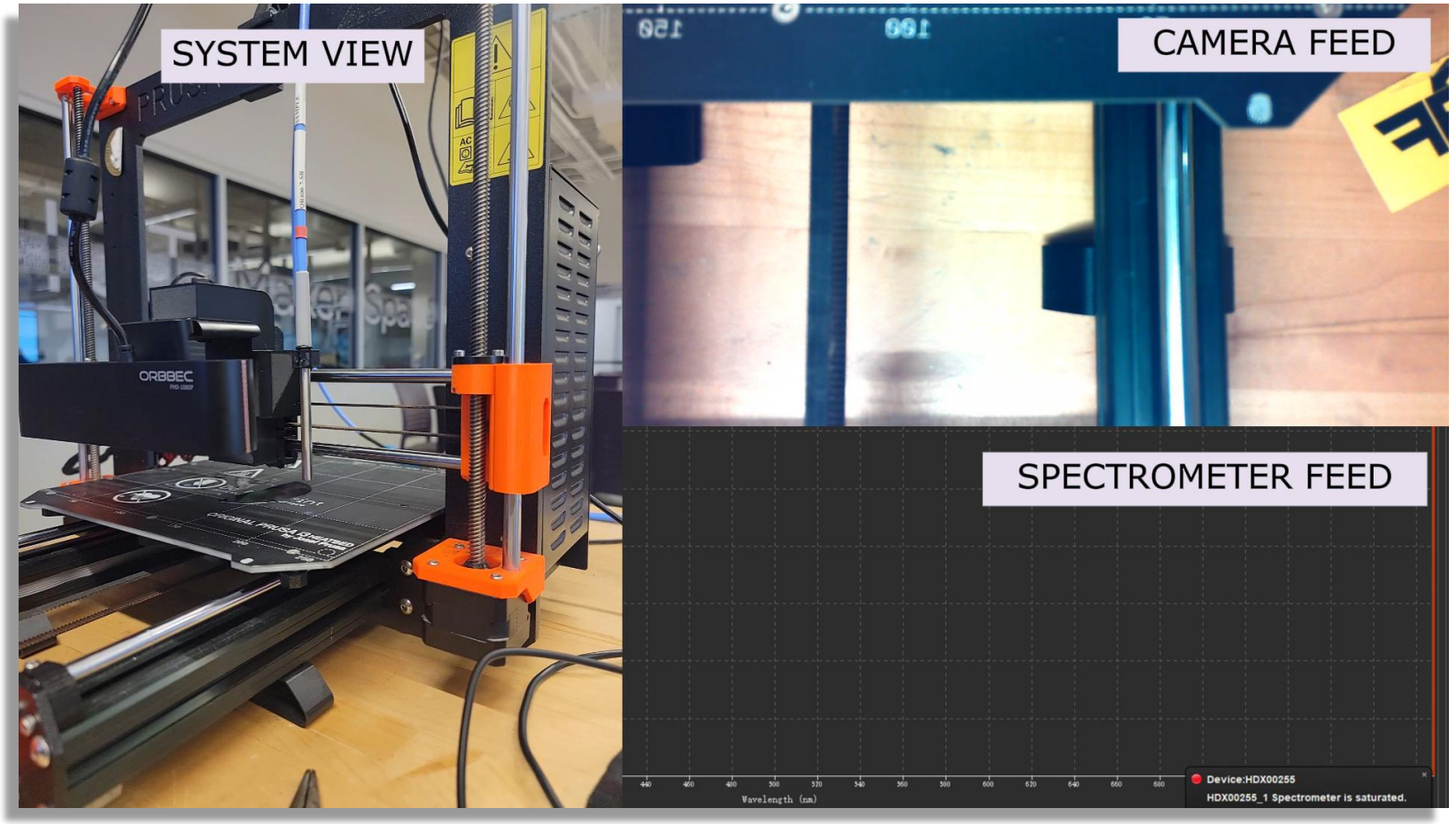
STICKY NOTE TEST!



CAPTURE OF STICKY NOTE ARRAY

- Simultaneously capture full spectrum and 3-channel spectrum
- Can analyze spectra to extract thickness

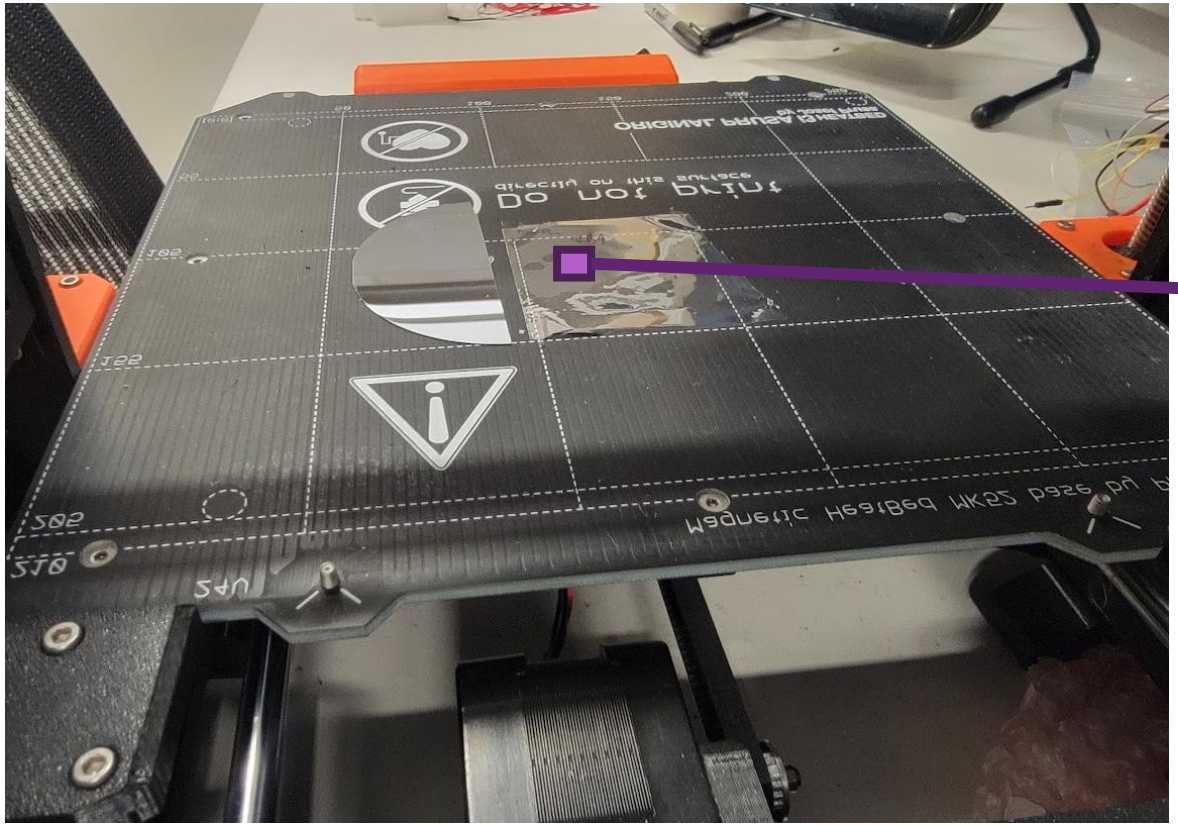
SAMPLE TEST!



CAPTURE OF SILICON WAFER AND PLA SHEET

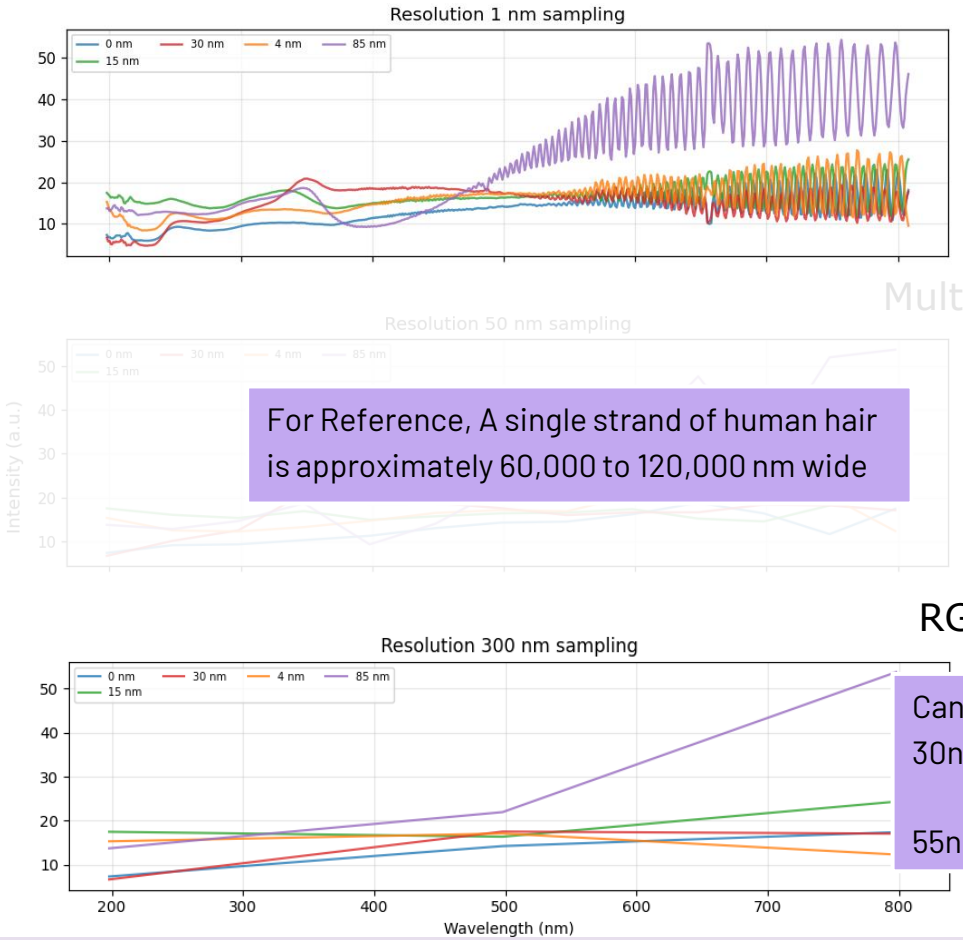
- Simultaneously capture full spectrum and 3-channel spectrum
- Can analyze spectra to extract thickness

PRELIMINARY ANALYSIS



IMAGES OF SAMPLE ON STAGE

Spectrometer



Multispectral

For Reference, A single strand of human hair is approximately 60,000 to 120,000 nm wide

RGB

Can see 85nm vs 30nm !

55nm difference!

SPECTRAL RESOLUTION REDUCED BY BINNING AND AVERAGING

FUTURE WORK

- Improve UI and Camera rig
- Test on more samples (from partners)
- Increase metrology accuracy
- Integrate into real system

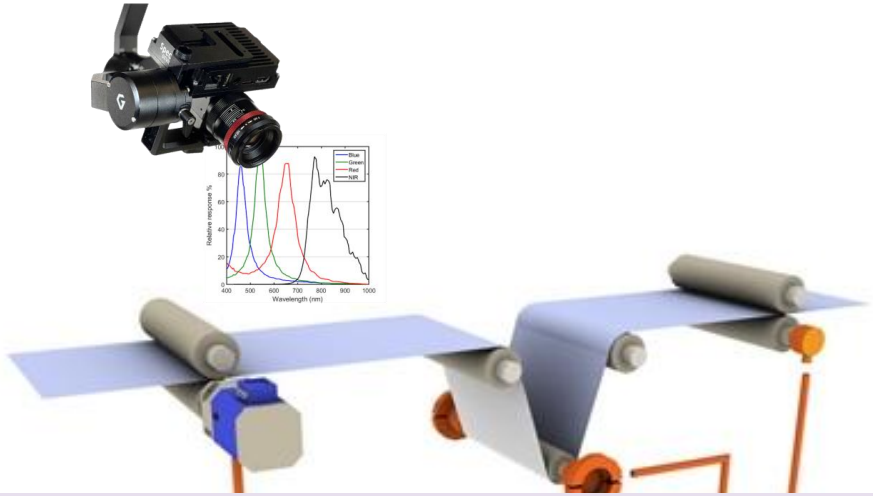


ILLUSTRATION OF INDUSTRIAL THIN-FILM INSPECTION

THANK YOU!

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Questions?