MATLAB-BASED GUI FOR LIQUID FLAT-JET CHARACTERISATION IN FEL EXPERIMENTS.

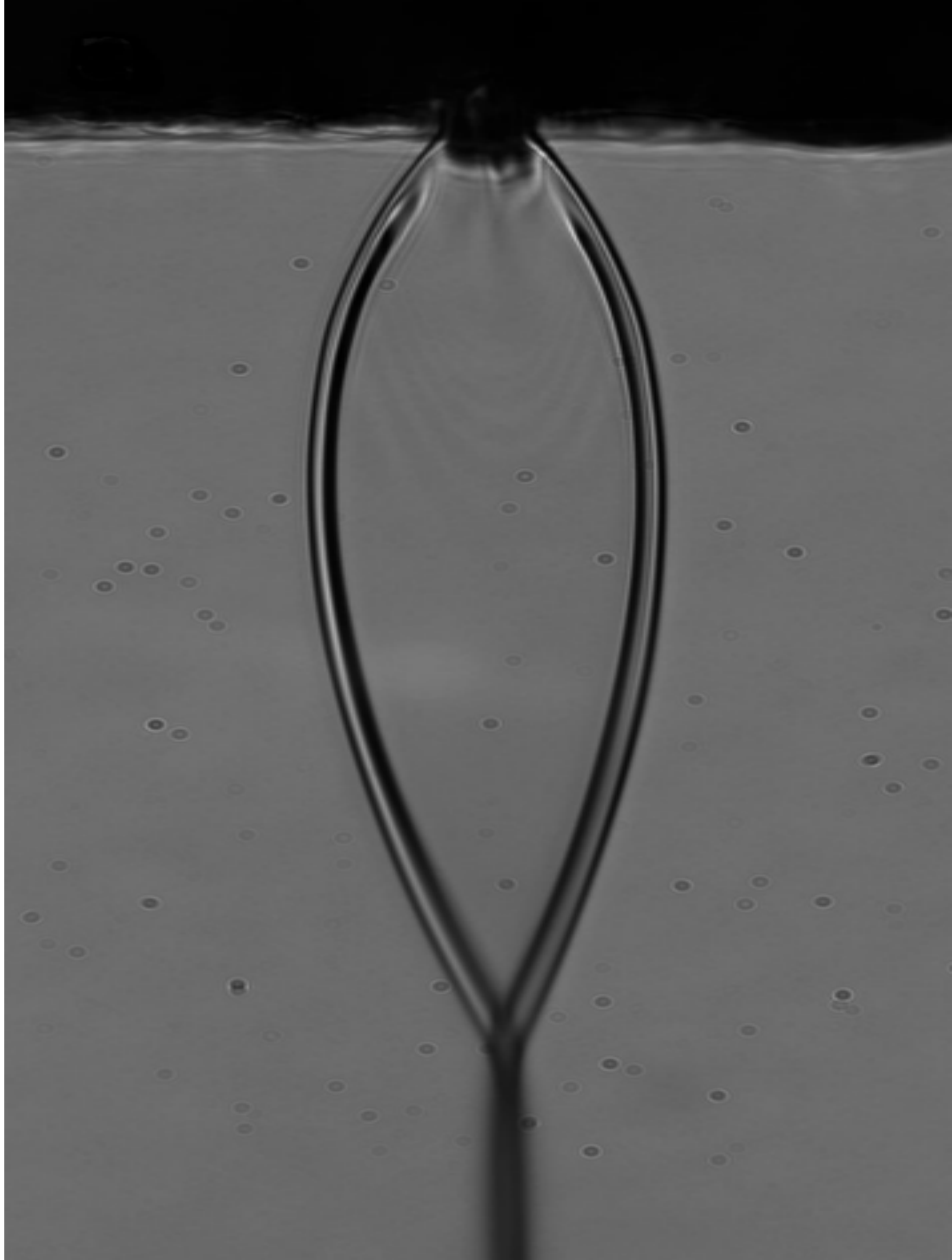
Summer Student Programme 2025

Éabha Murphy

X-Ray Femtochemistry and Cluster Physics Group, DESY.

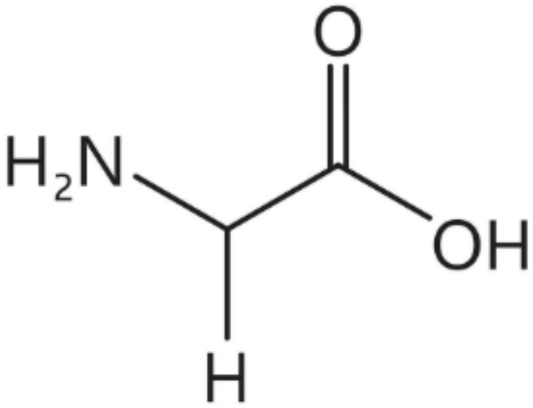
10.09.2025

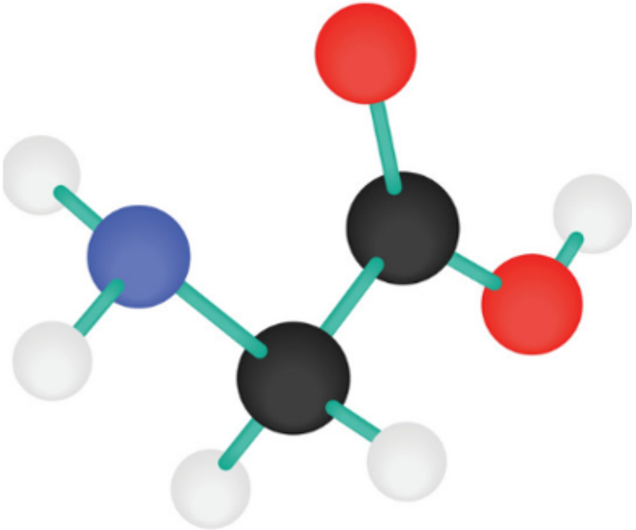
HELMHOLTZ



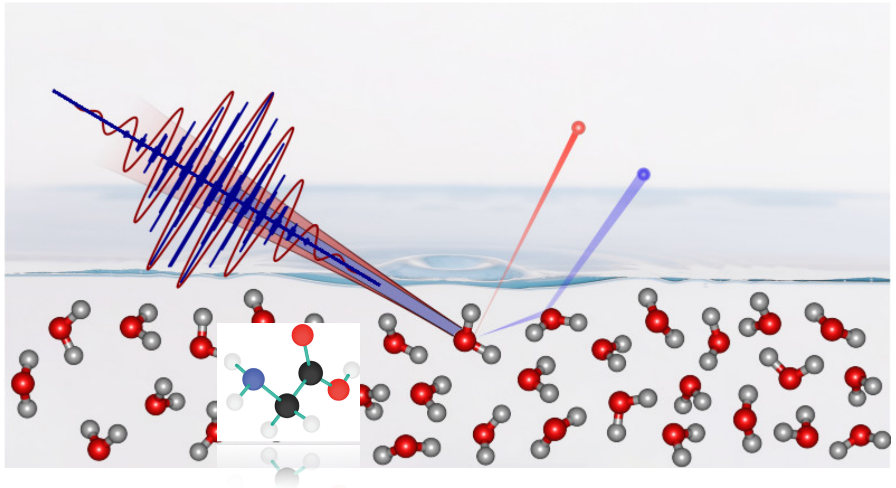
Liquid-Phase Spectroscopy

Technique to study biomolecules in water





Glycine (amino acid)

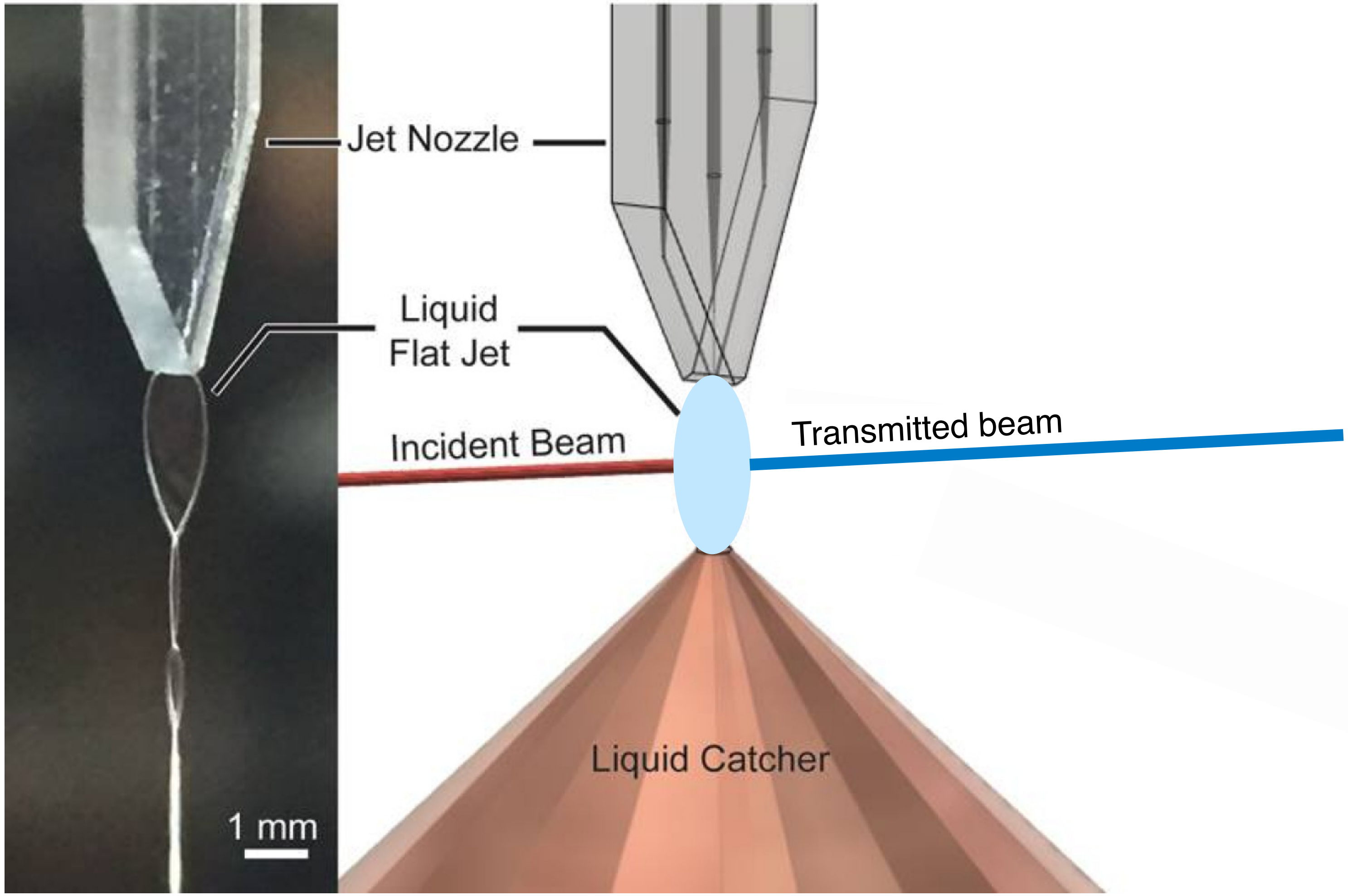


Attosecond liquid-phase spectroscopy - IRAMIS

Liquid-phase spectroscopy

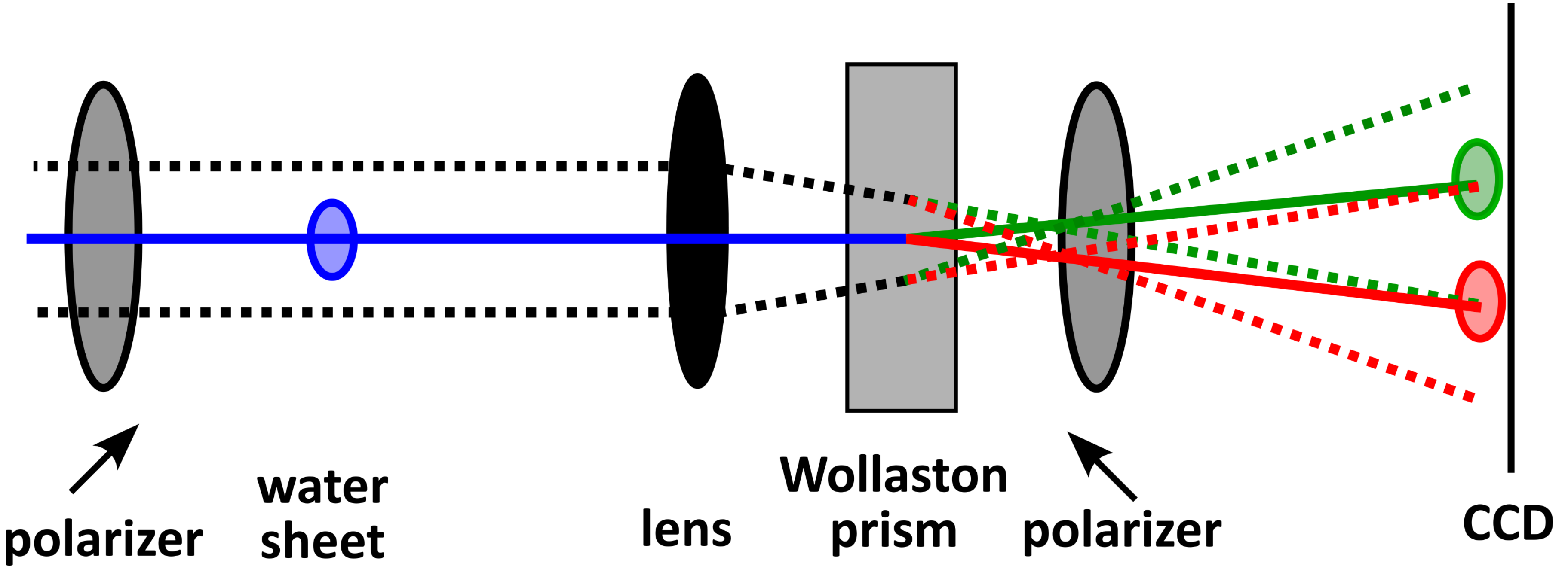
Liquid Flat-Jets

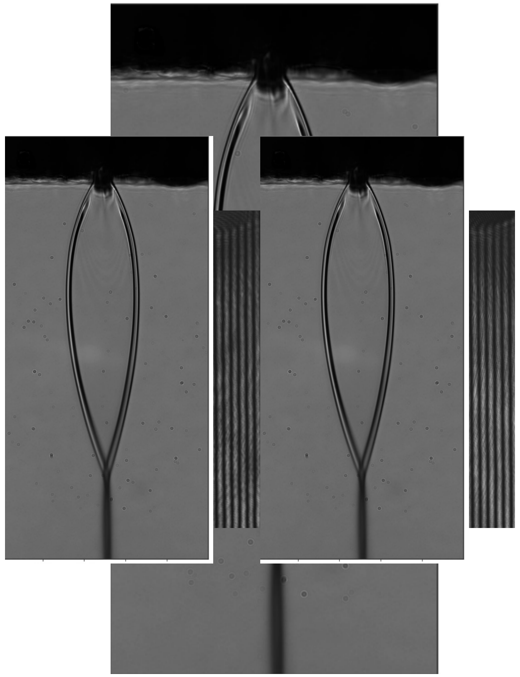
Continuous, renewable method of sample delivery



Adapted from Chin Lee, University of California at Berkeley

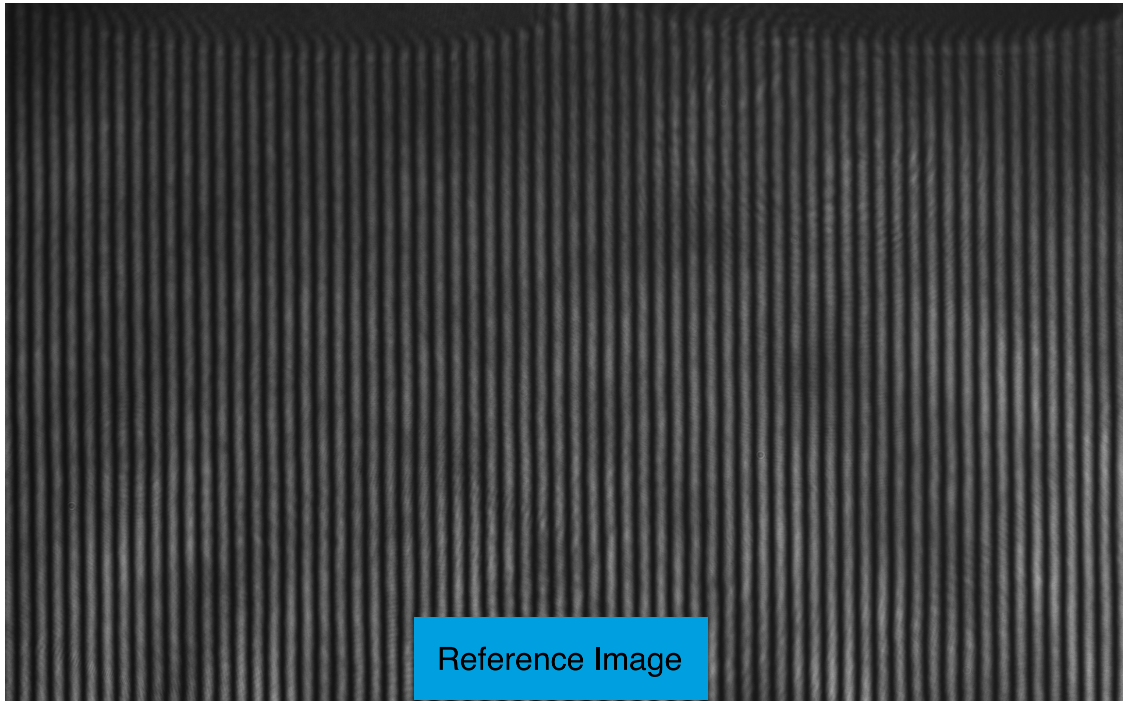
Experimental Set-up: Nomarski Interferometry

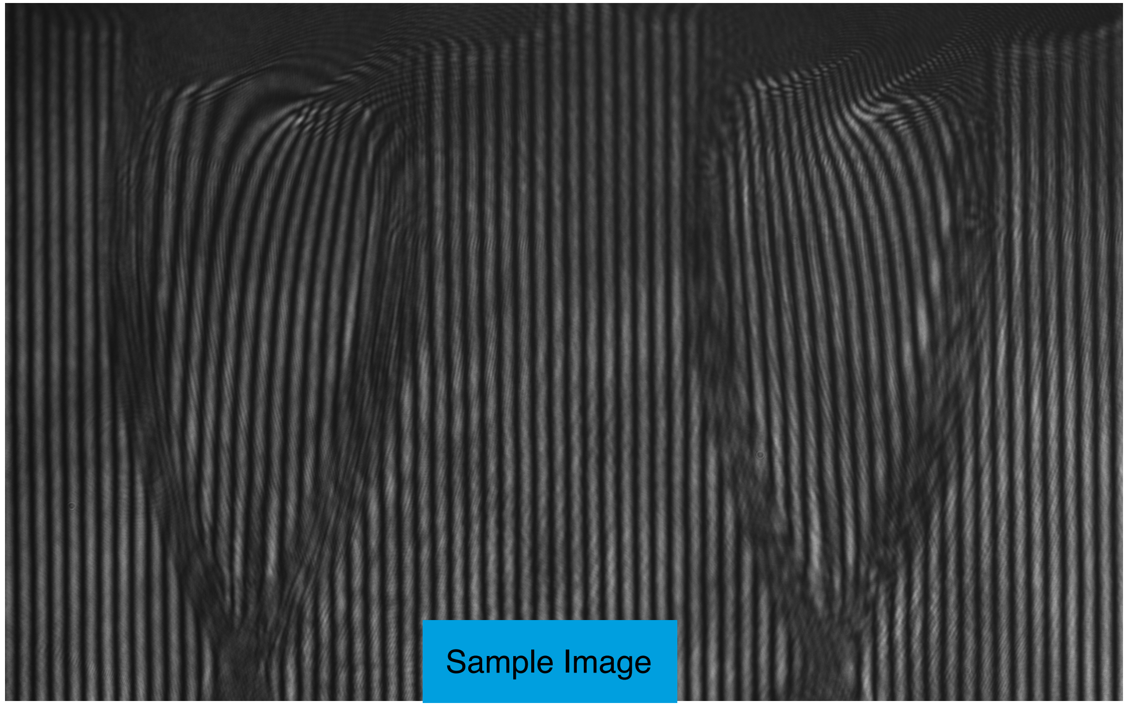




Dian Diaman, "Electron-Nuclear Coupling of Glycine in Aqueous Solution," conducted in the X-ray Femtochemistry and Cluster Physics Group at DESY

CCD Camera Images

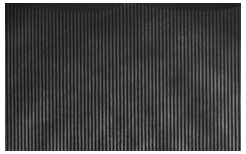


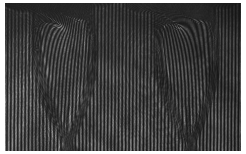


Aim of GUI: Enable us to refine the **thickness** of the liquid sheet for liquid-phase spectroscopy

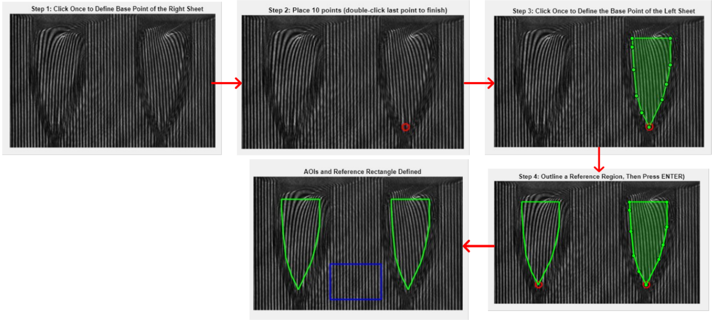
Image Processing Pipeline

Upload Reference & Sample Images

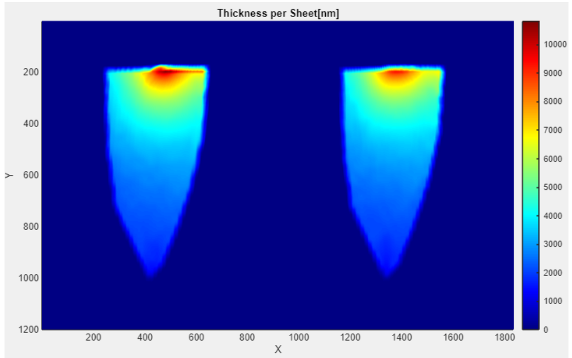




Select AOI



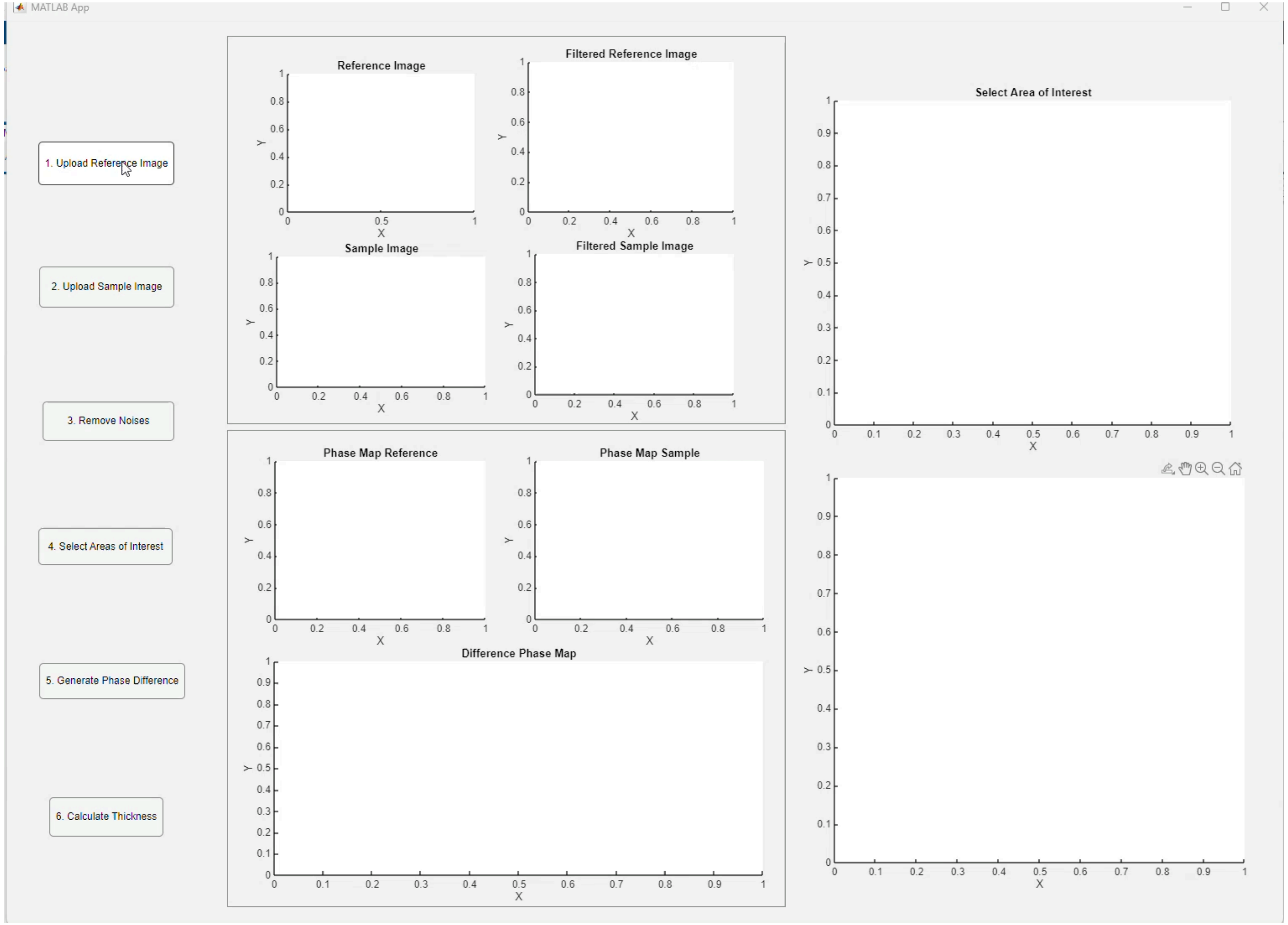
Calculate Thickness



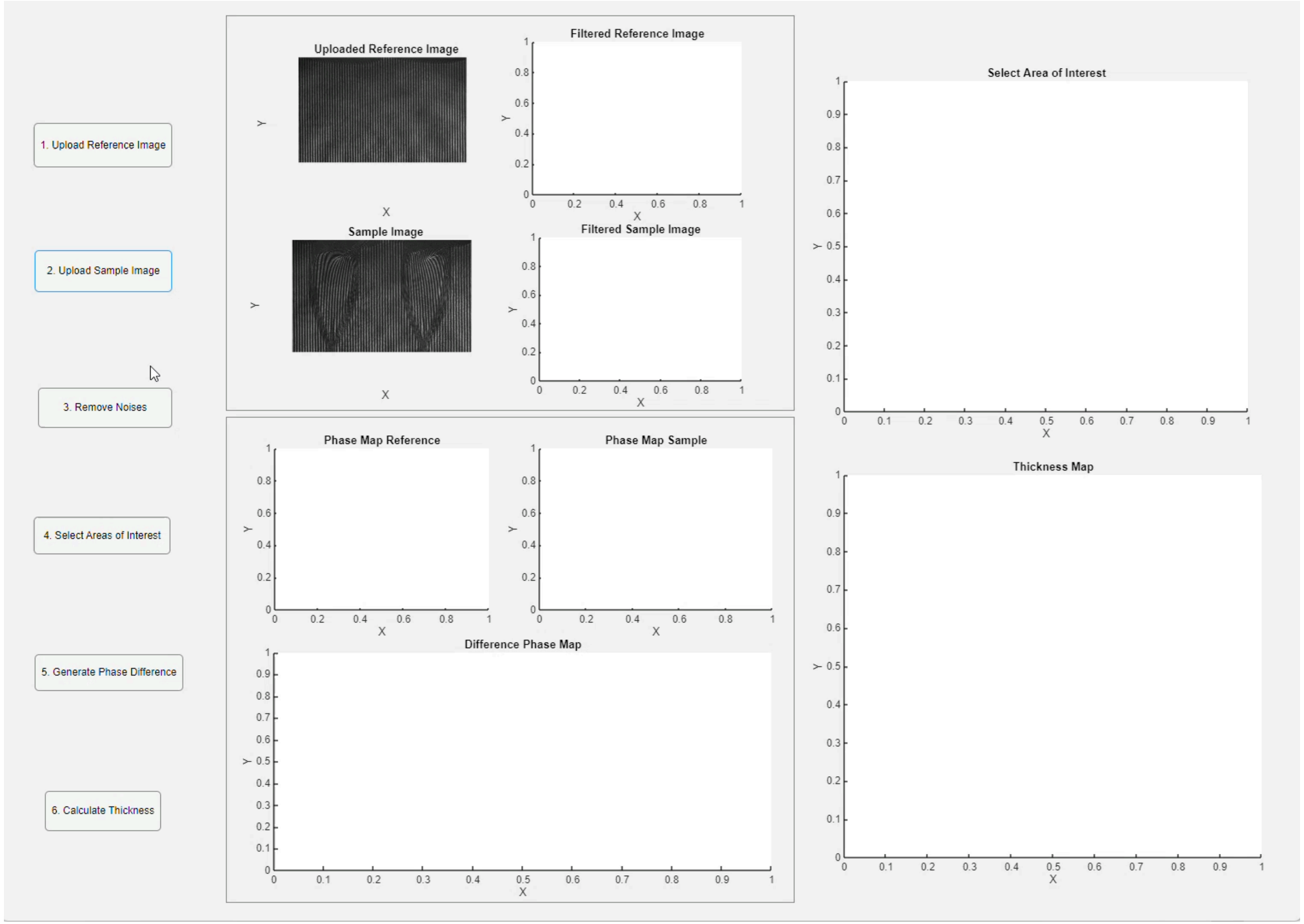
Remove Noise

Generate Phase Difference

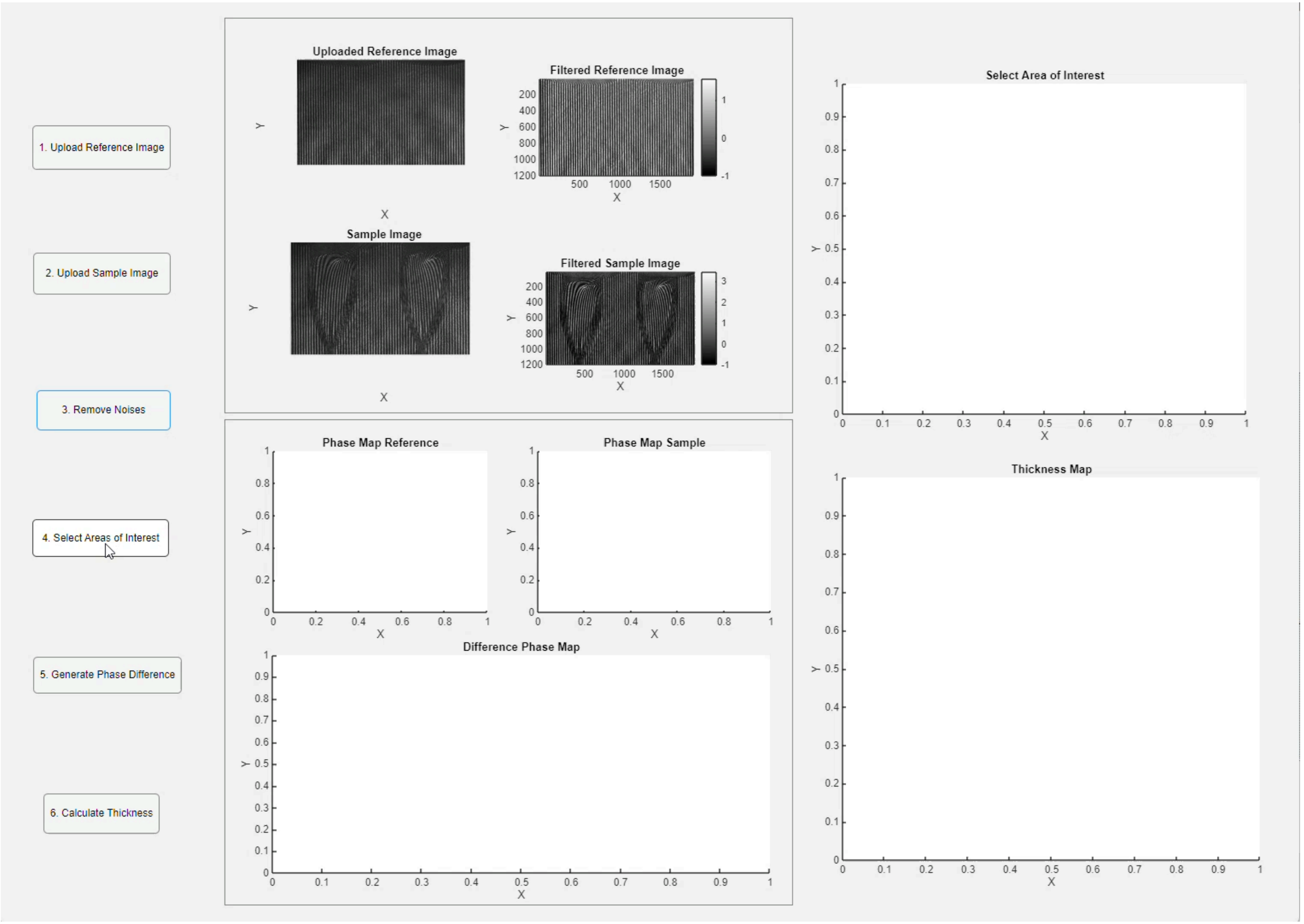
Upload Reference & Sample Image



Remove Noises

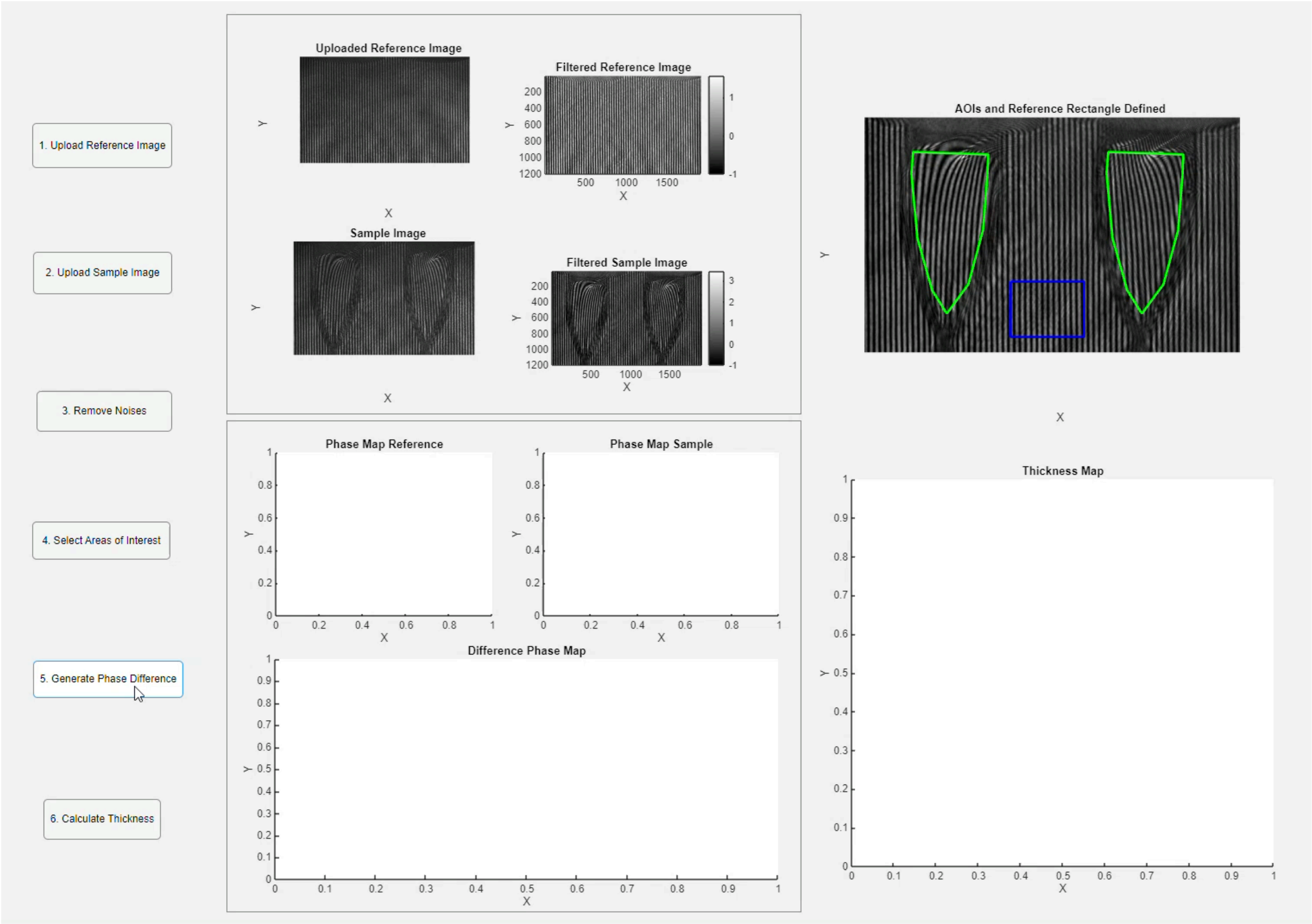


Select AOI

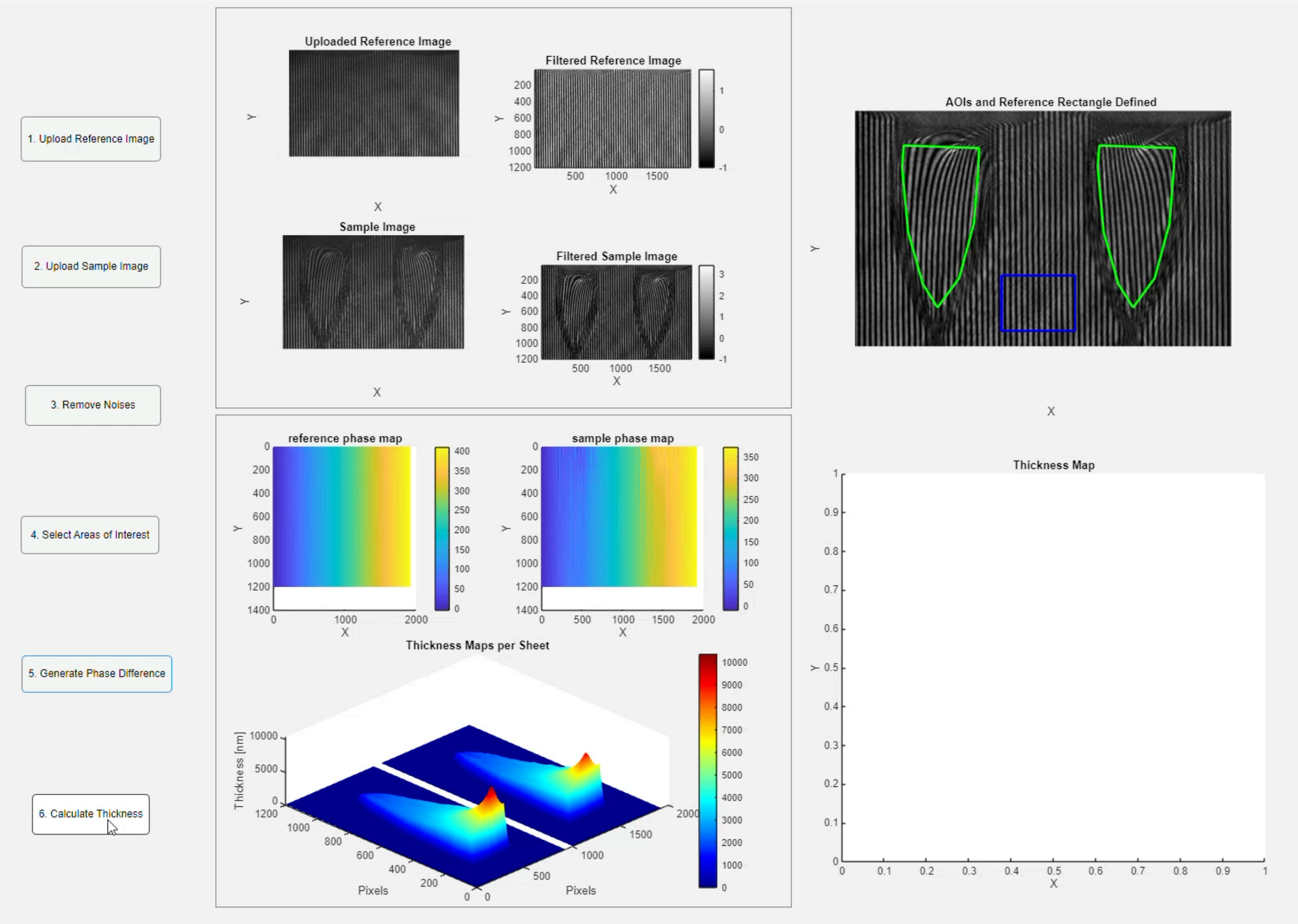


1. Upload Reference Image
2. Upload Sample Image
3. Remove Noises
4. Select Areas of Interest
5. Generate Phase Difference
6. Calculate Thickness
Uploaded Reference Image
Filtered Reference Image
Sample Image
Filtered Sample Image
Phase Map Reference
Phase Map Sample
Difference Phase Map
Select Area of Interest
Thickness Map

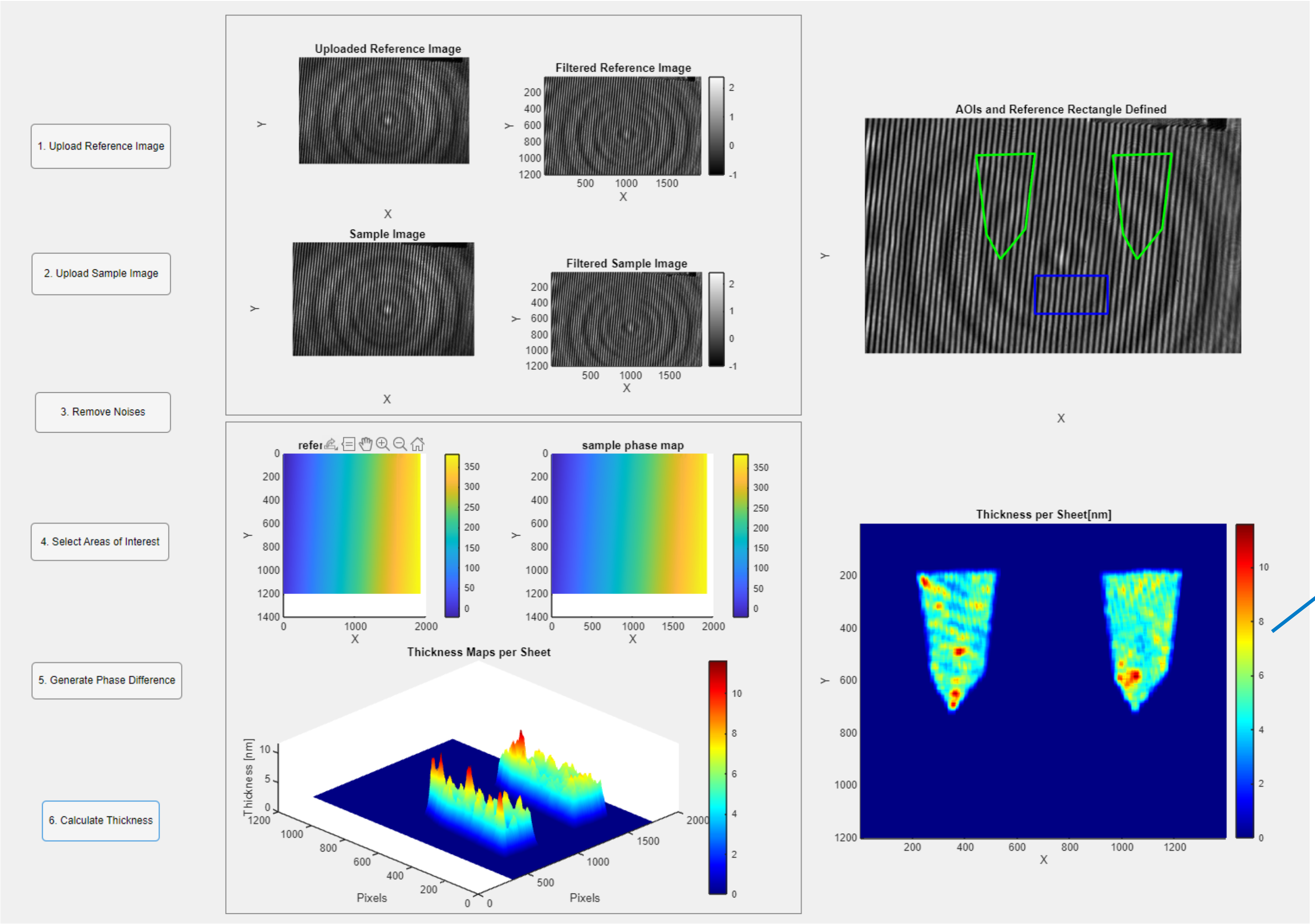
Generate Phase Difference

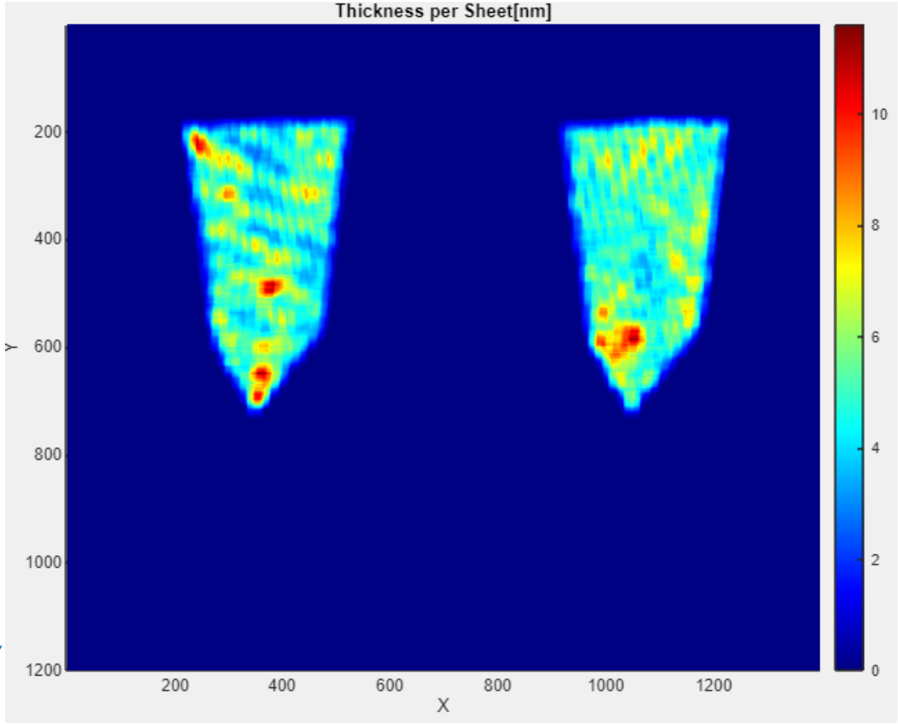


Calculate Thickness



Resolution of GUI



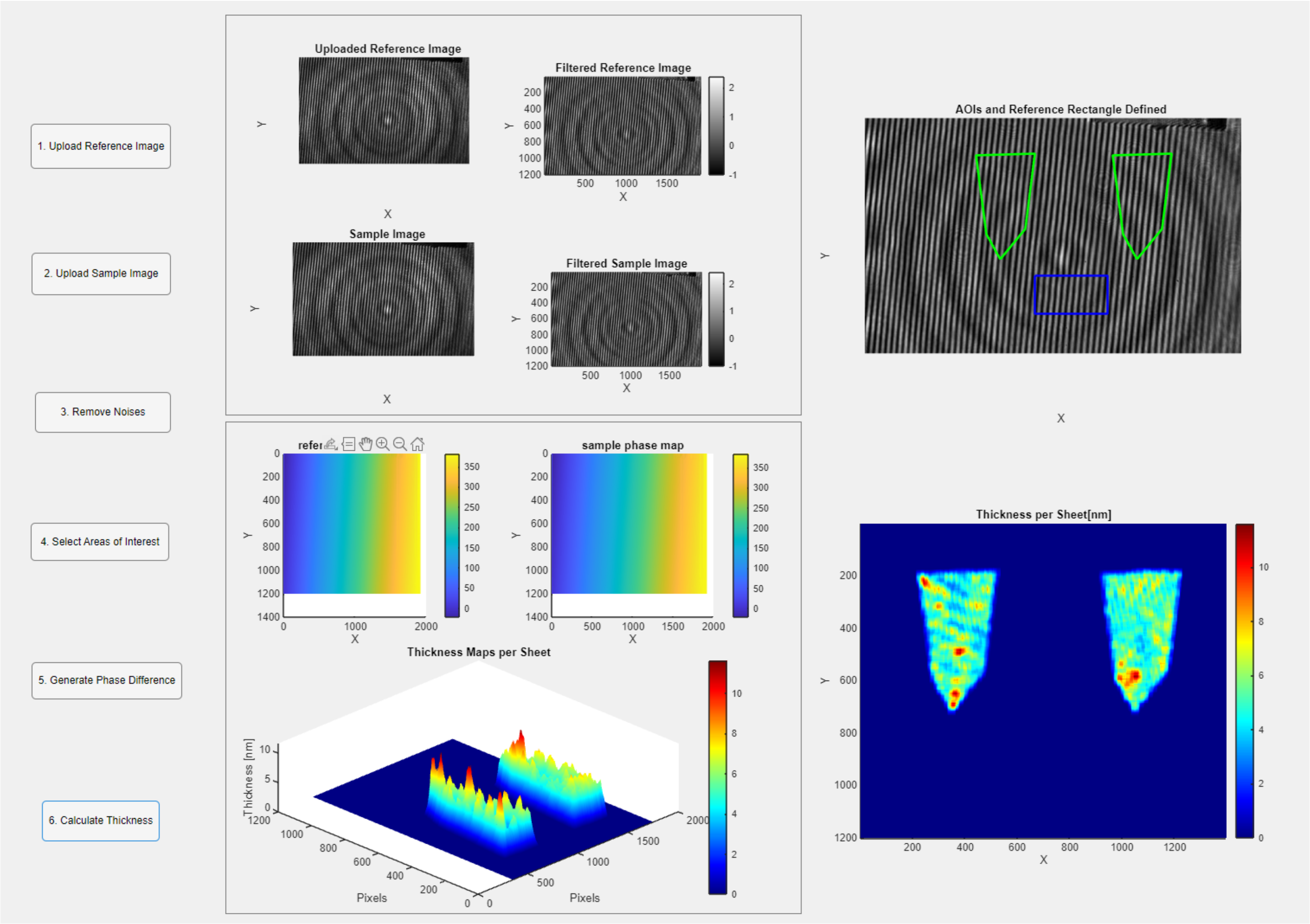


- Our tool: **sub 10nm** precision
- Literature for interferometric methods: sub 100nm precision

- Water molecule ≈ 0.3nm
- Thickness resolution ≈ 30 water molecules

Conclusion

- MATLAB based GUI that successfully allows for refining of the **thickness** of the liquid sheet for liquid-phase spectroscopy
- Sub 10nm precision and potential for further improvement
- **Future direction:** expandable for online monitoring of thicknesses



Vielen Dank

Acknowledgements

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Hsuan-Chun Yao

Dian Diaman

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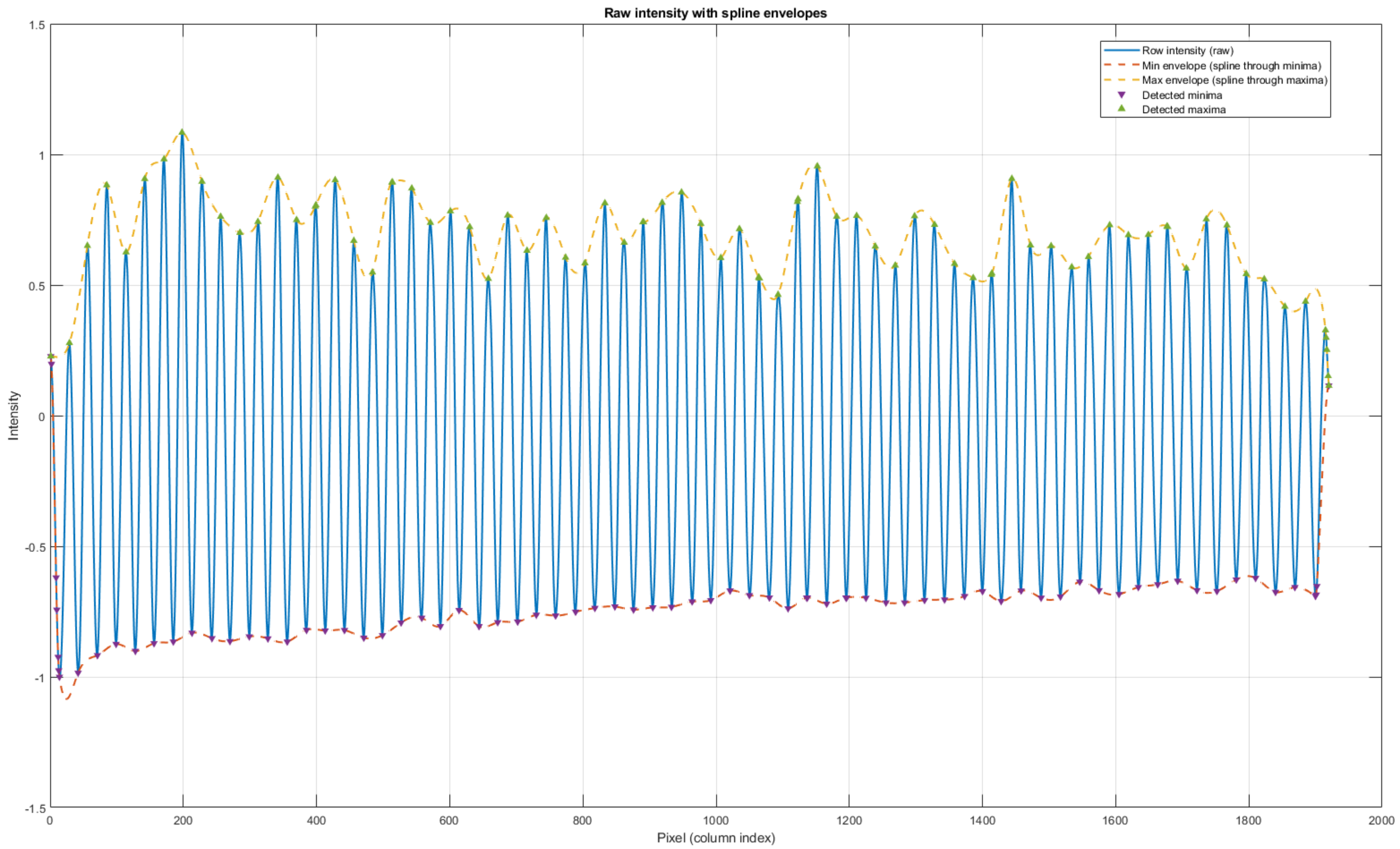
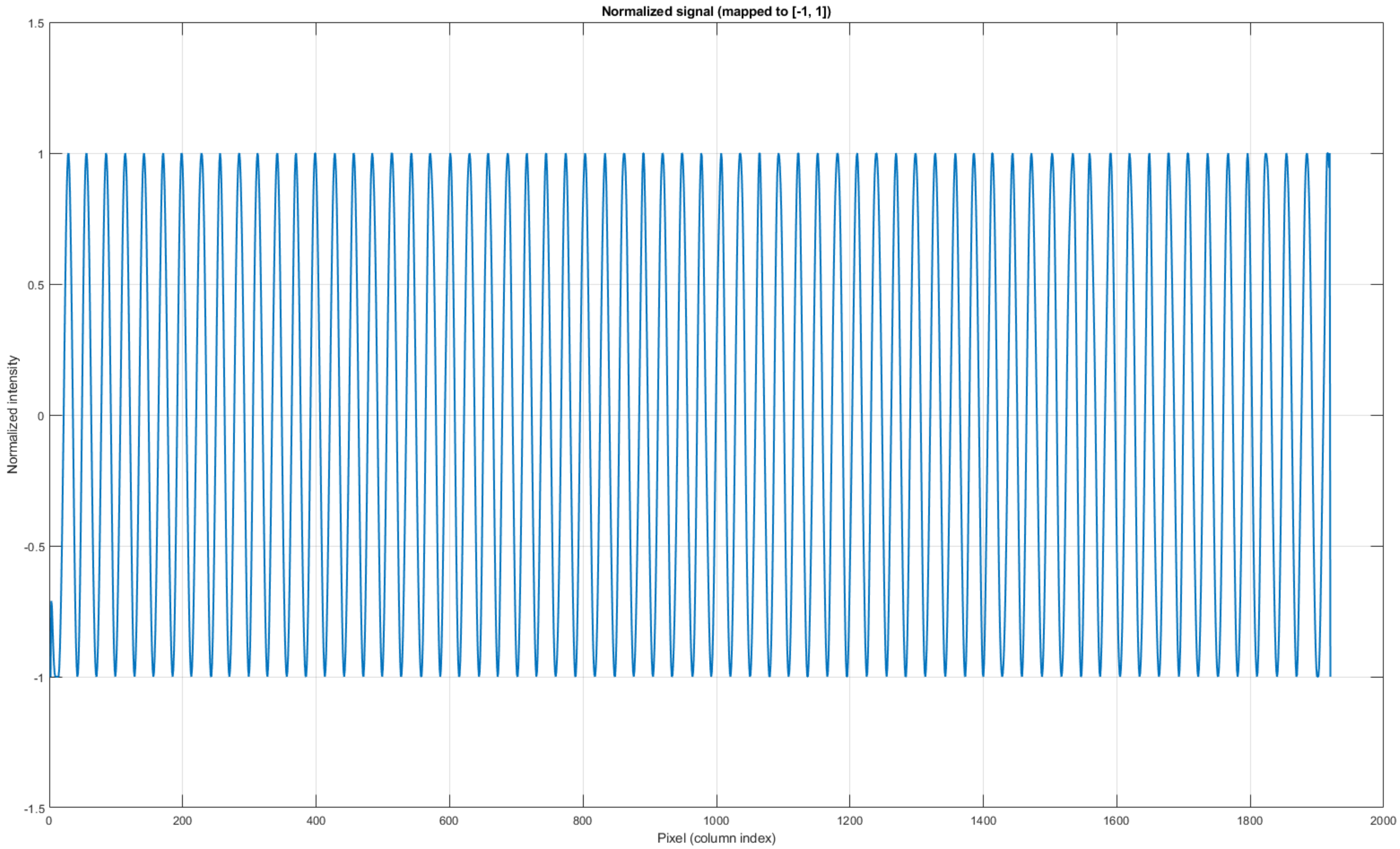
Spline



Raw intensity with spline envelopes
Row intensity (raw)
Min envelope (spline through minima)
Max envelope (spline through maxima)
Detected minima
Detected maxima
Intensity
Pixel (column index)
1.5
1
0.5
0
-0.5
-1
-1.5
0
200
400
600
800
1000
1200
1400
1600
1800
2000

Spline



Normalized signal (mapped to [-1, 1])
Normalized intensity
Pixel (column index)
1.5
1
0.5
0
-0.5
-1
-1.5
0
200
400
600
800
1000
1200
1400
1600
1800
2000

Equations

2.2 Phase Extraction

The resultant interference can be expressed by Eq. 1, where $\Delta\phi$ is the relative phase difference between the two beams, calculated from the ordinary I_o and extraordinary I_e rays produced by the Wollaston prism.

$$I = I_o + I_e + 2\sqrt{I_o I_e}\cos(\Delta\phi) \tag{1}$$

The phase difference is directly related to the optical path length difference between the two rays. For a sample of thickness d, the phase shift can be shown as in Eq. 2, where λ is the laser beam wavelength, n_{medium} is the refractive index of the sample and $n_{\text{air}} \approx 1$. The phase shift is hence directly proportional to the thickness and the contrast in refractive index between the sample and the surrounding water.

$$\Delta\phi = \frac{2\pi}{\lambda}\Delta\delta = \frac{2\pi}{\lambda}\left(n_{\text{medium}} - n_{\text{air}}\right)d \tag{2}$$

2.3 Thickness Conversion

The equation for phase can be rearranged for calculation of thickness, as shown in Eq. 3.

Wavelength = 632.8nm

$$d = \frac{\Delta\phi\,\lambda}{2\pi\left(n_{\text{water}} - 1\right)} \tag{3}$$