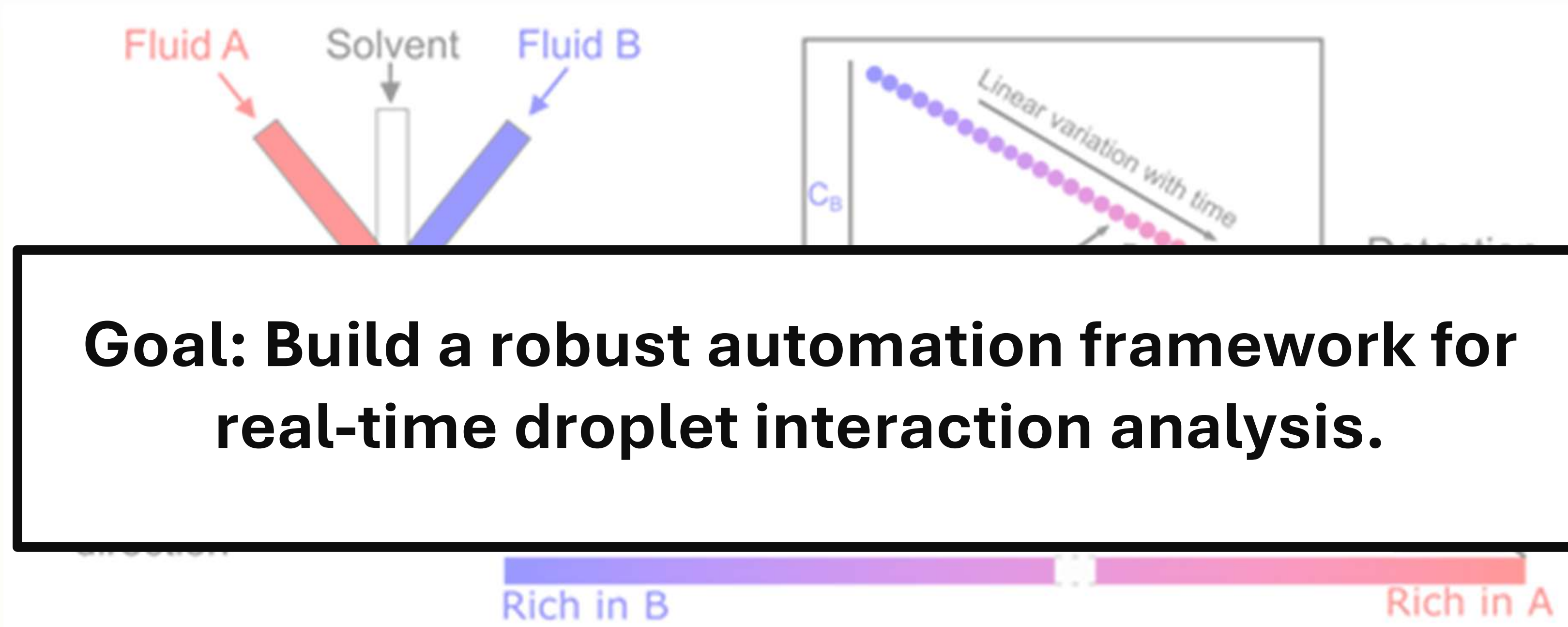
Real-time Measurement Analysis for Droplet Flow Systems

Amrik Majumdar

Westfield High School, VA

Advisors: Dr. Olivia Haider, Dr. Katie Weigandt, Dr. Jeff Kzrywon

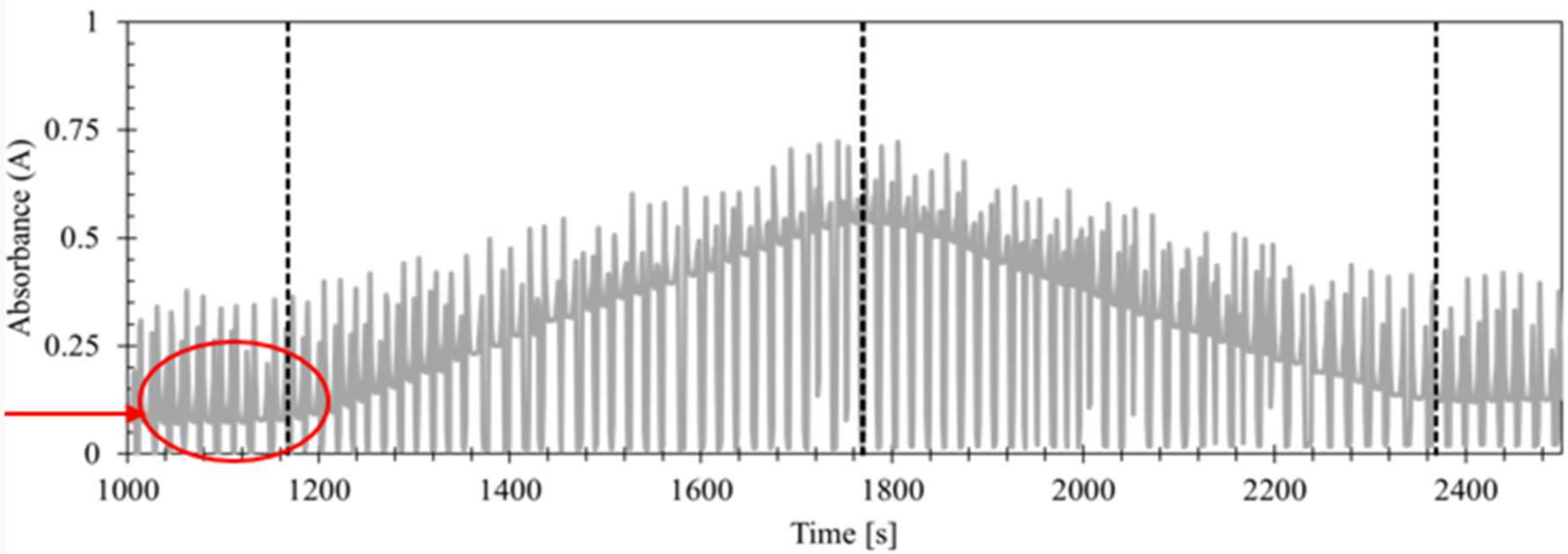
Why Droplet-Resolved Measurements Matter



Goal: Build a robust automation framework for real-time droplet interaction analysis.

- Minute composition changes can be produced efficiently and cost-effectively.
- Droplet-resolved measurements help formulation scientists compare material behavior.
- My work turns UV–Vis and image data into usable droplet-level measurements.

Why Droplet-Resolved Measurements Matter

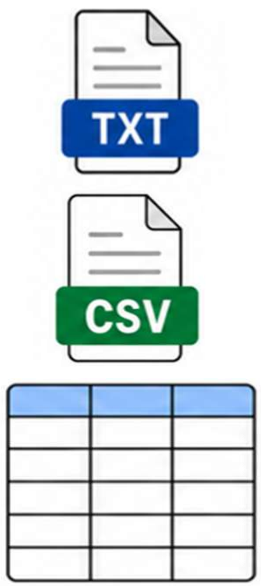


- UV–Vis peaks mark droplet entry and exit as each droplet passes the detector.
- The U-shaped interior distinguishes the droplet signal from low-absorbance oil spacers.
- Repeating these features across the trace enables reproducible droplet-level measurements.

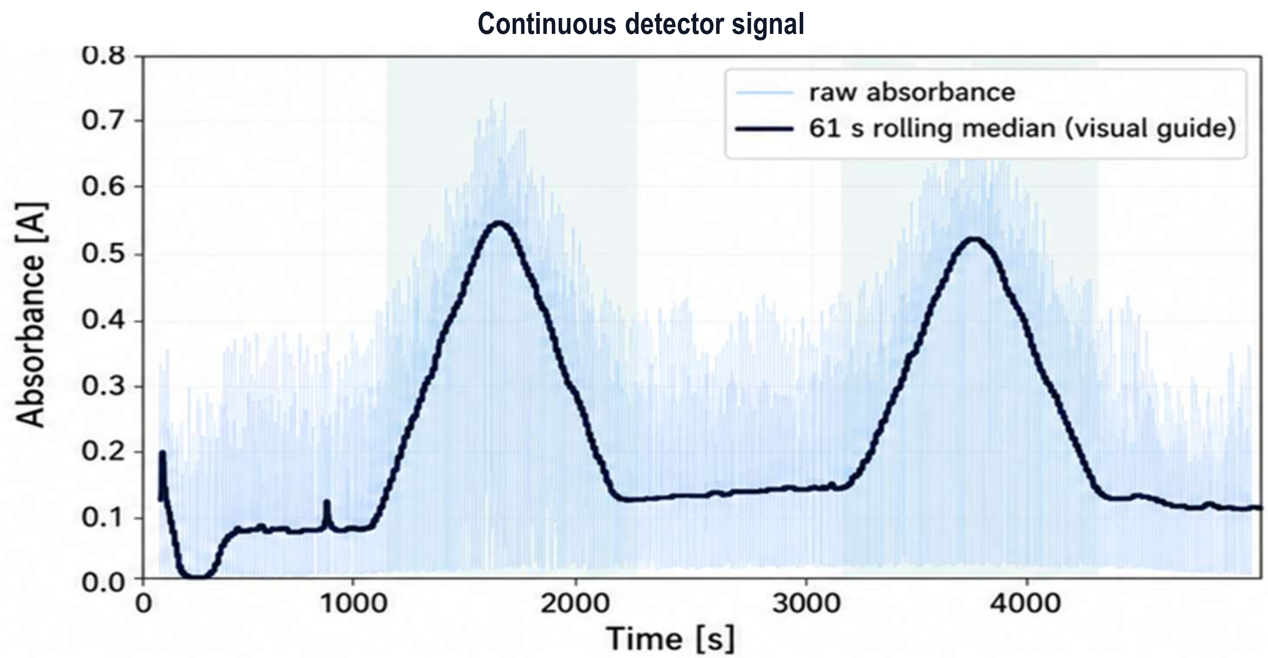
Smoothing Provides Trends, Not Droplet Information

1
DATA INPUT

Absorbance time series



2 **PREPROCESS & OVERVIEW**



- Smoothing functions remove necessary signal for absorbance data.

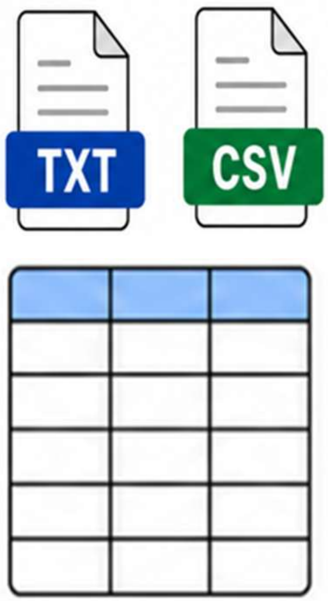
Drops detected = 10

Total drop in experiment = 260

Local Slope Preserves the Transitions That Define Each Droplet

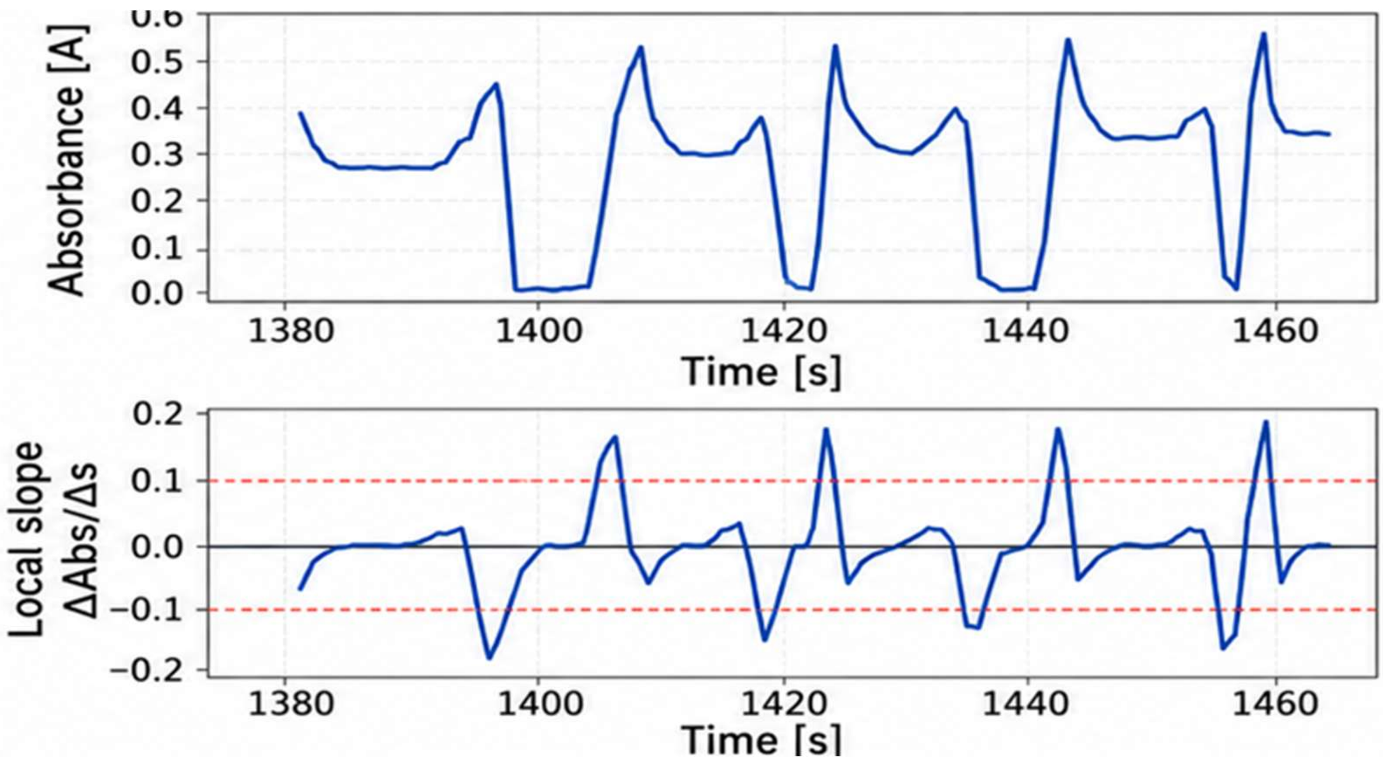
1 DATA INPUT

Absorbance time series



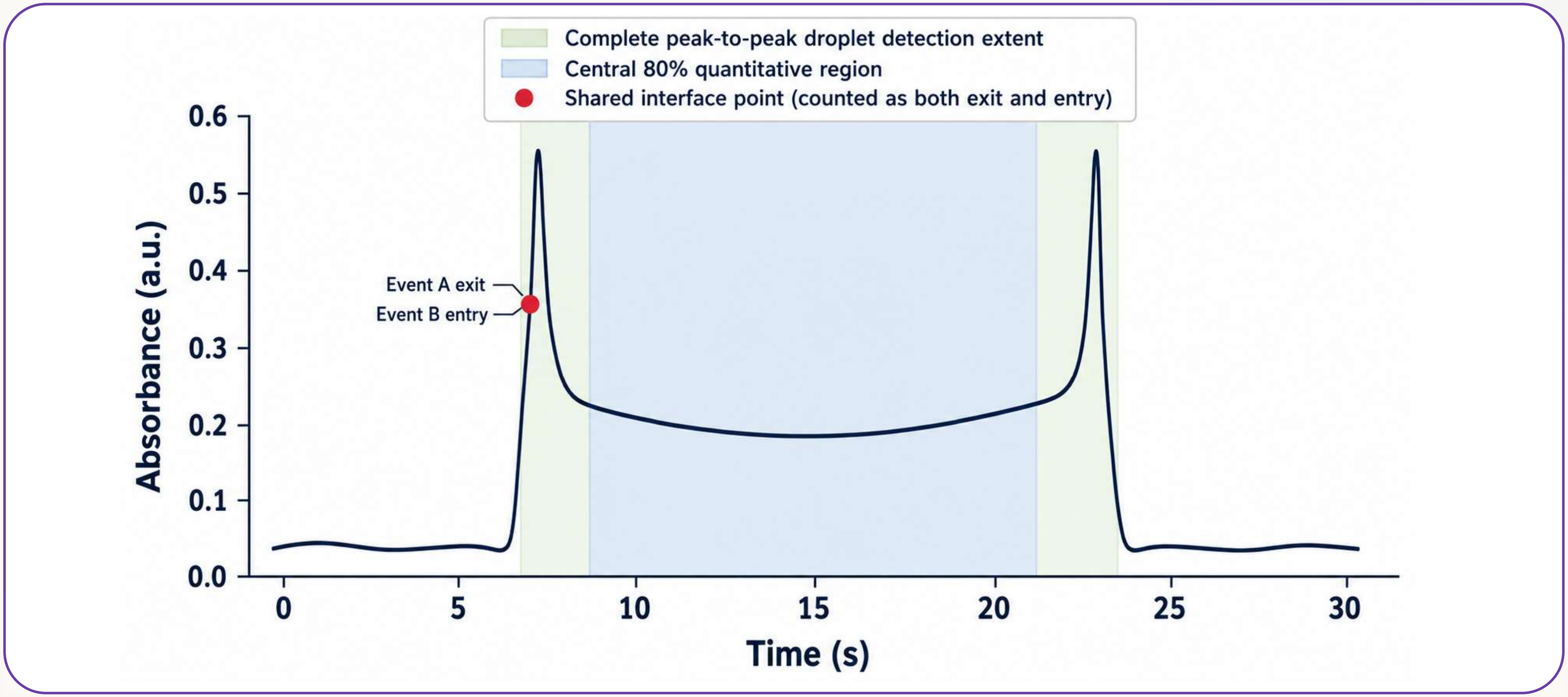
2 BOUNDARY FEATURES

Edges appear as slope changes



- Red/blue threshold crossings mark entry and exit while the raw absorbance signal remains intact.

Inner 80% Provides Droplet vs. Oil Spacer Differentiation



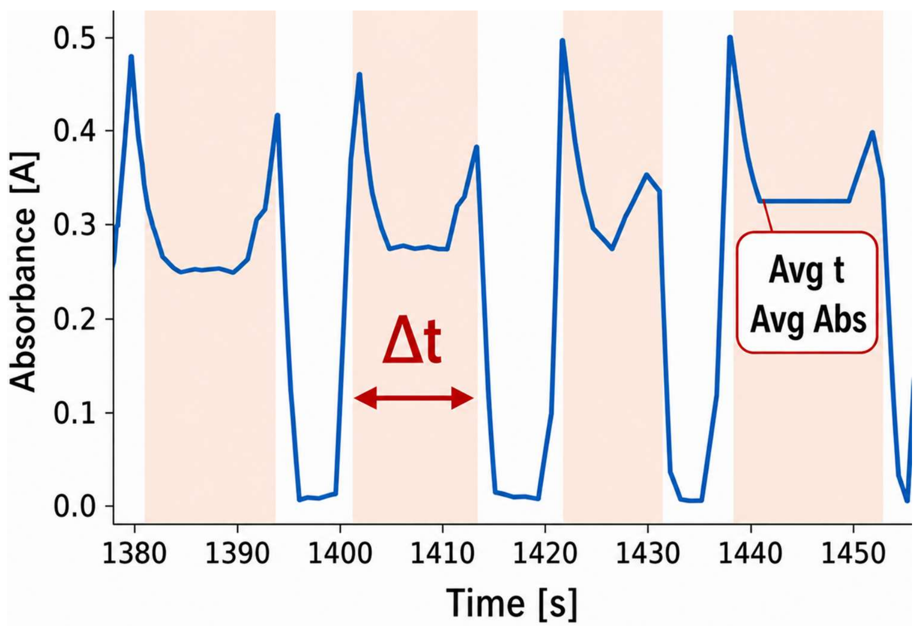
- Average absorbance of the middle 80% differentiates droplets from oil spacers.

Each Detected Window Becomes an Auditable Droplet Record

Absorbance measurements from UV-Vis

TXT file → Python workflow

SELECT PLATEAU WINDOWS



EXPORT SUMMARY

Droplet	Start [s]	End [s]	Mean time [s]	Δt [s]	Mean Abs
1	1380	1393	1386.5	13	0.283
2	1400	1414	1407.0	14	0.309
3	1421	1430	1425.5	9	0.343
4	1436	1452	1444.0	16	0.347

$$L_{\mathrm{drop}} = \left(\frac{Q}{A}\right)\Delta t$$

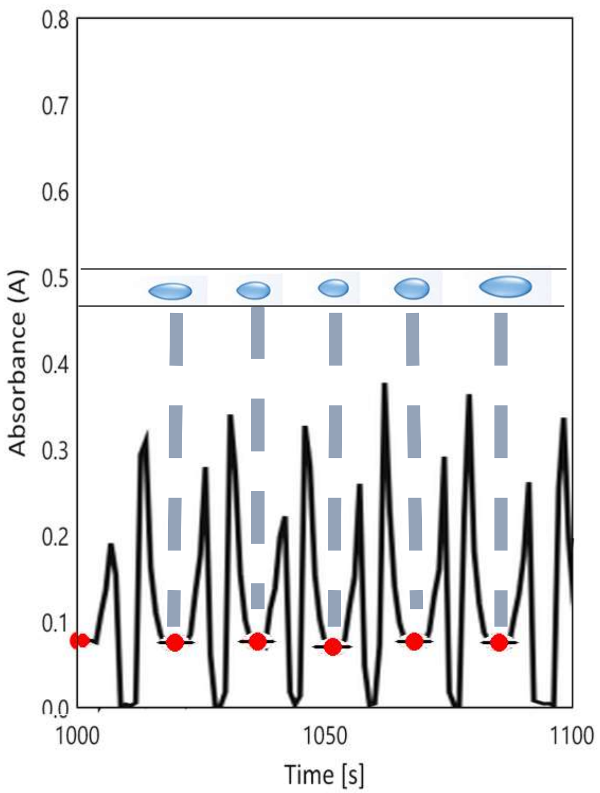
Q = volumetric flow rate

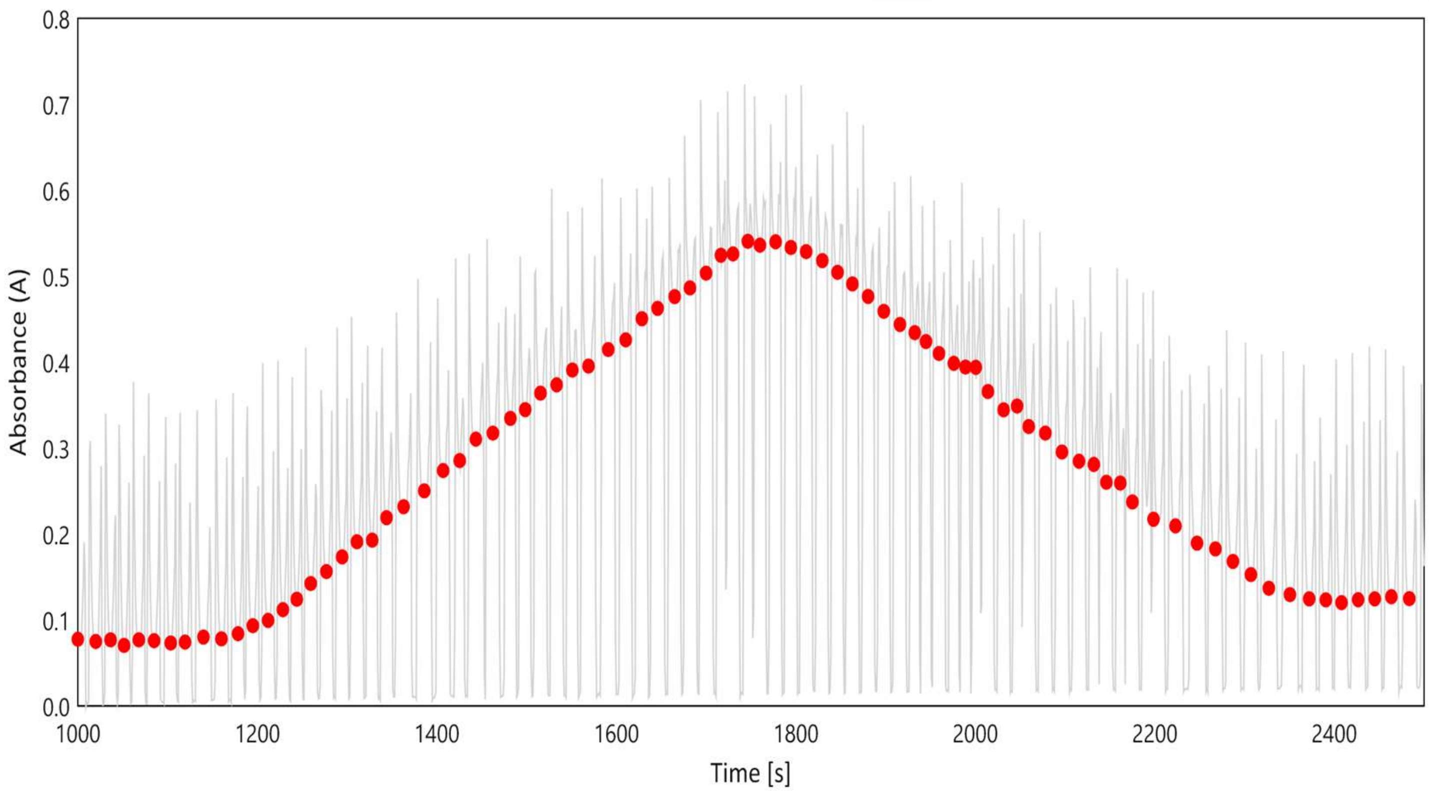
A = tubing cross-sectional area

Δt = droplet transit time

L_{drop} = droplet length

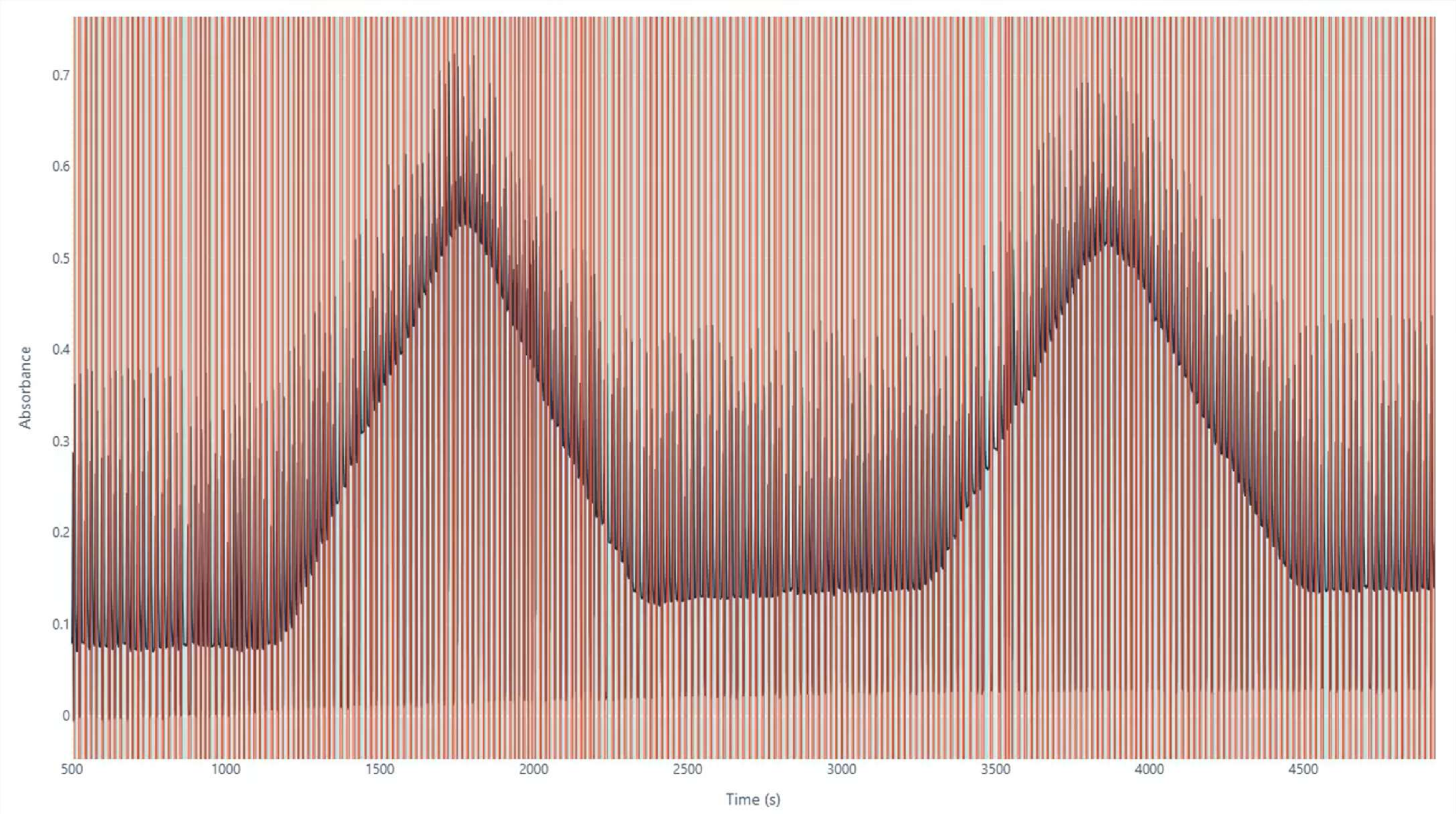
Calculated Values Agree With the Raw Instrument Signal





- Identified droplets and extracted UV-Vis absorbance data.
- Built a user-friendly script to review and export results.

Automation Framework Successfully Maps Droplet Information

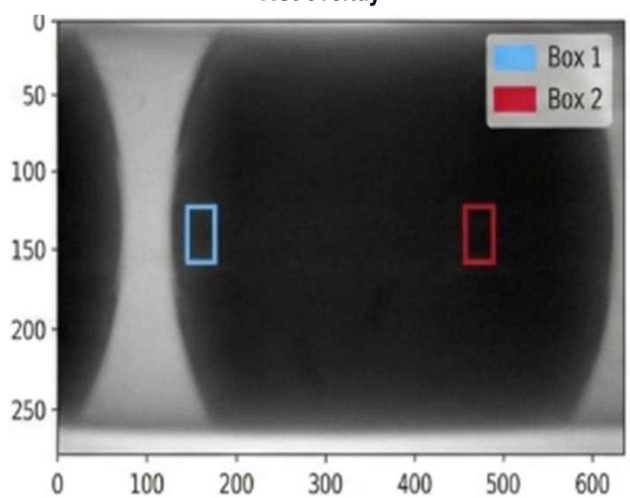


Identifying Drop Length and Velocity with Image Analysis

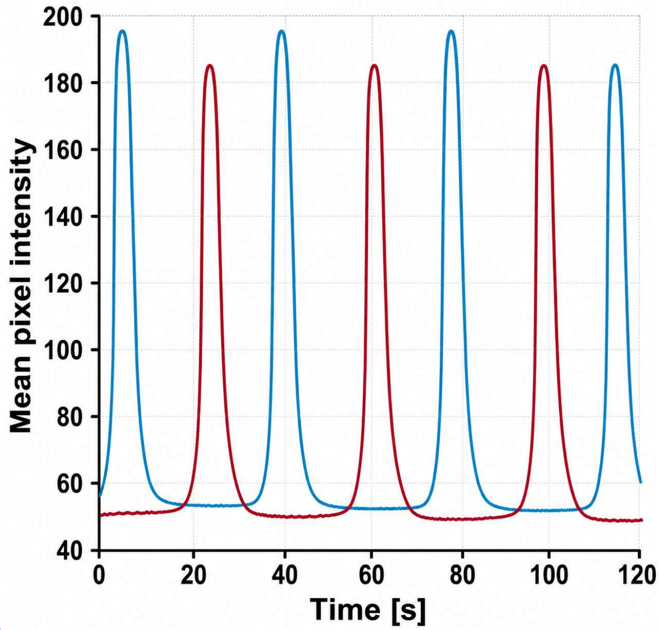
MATLAB Script → **Jupyter Notebook**

IDENTIFY ROI POSITIONS

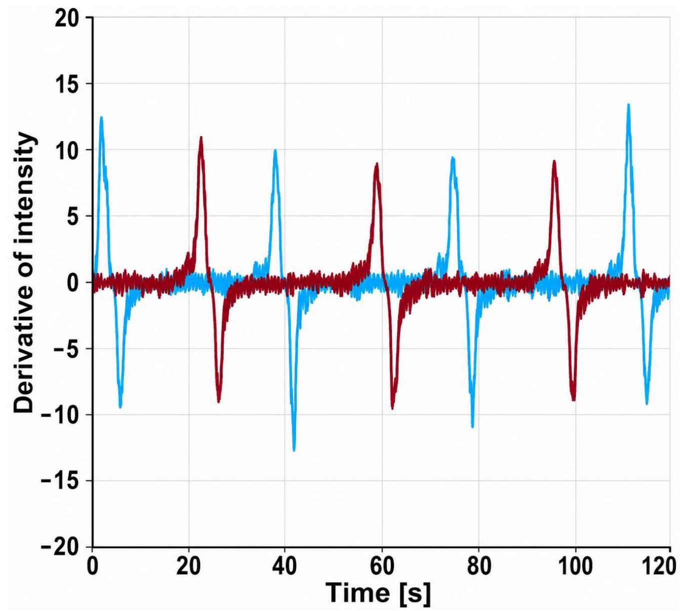
ROI overlay

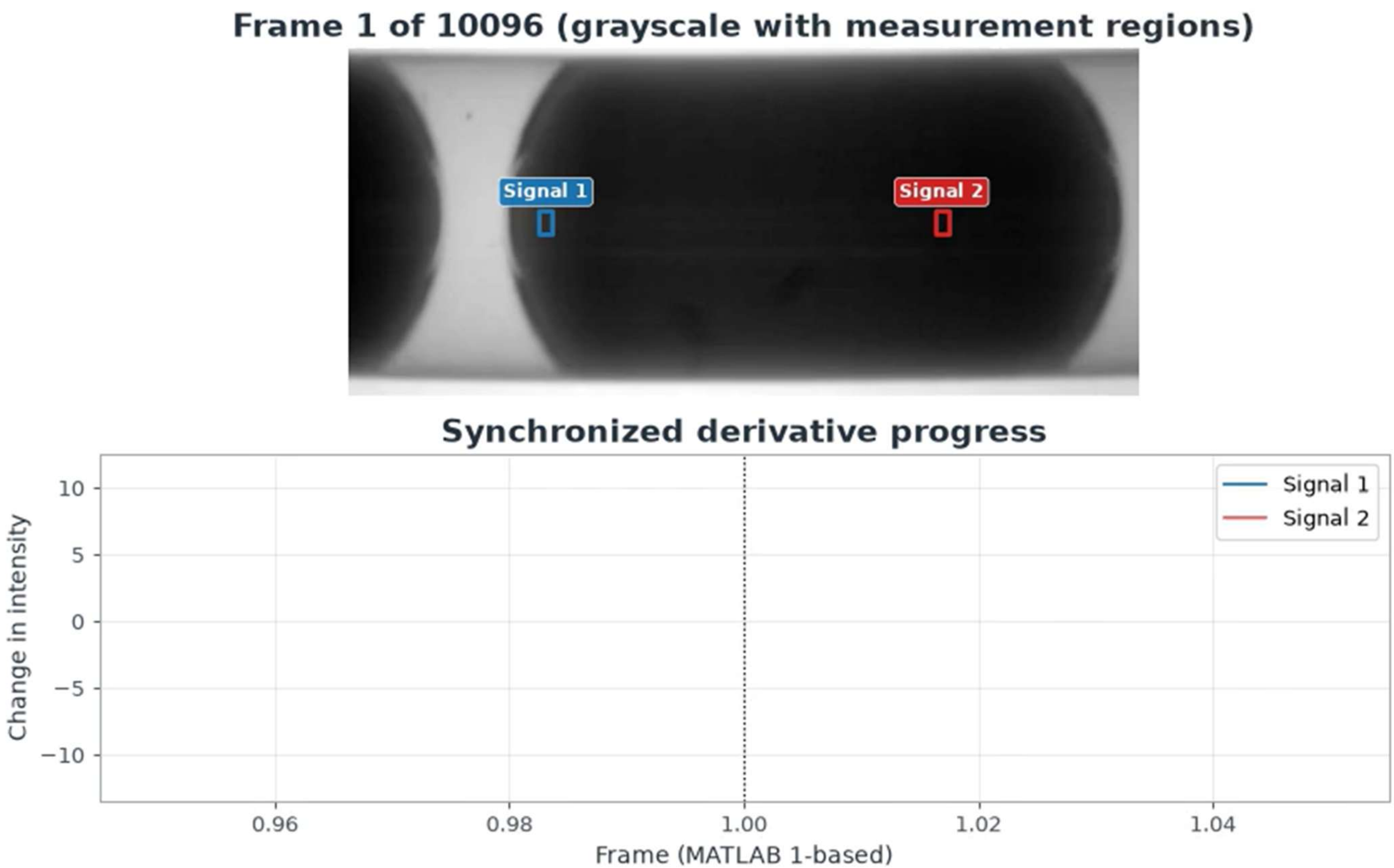


EXTRACT INTENSITY SIGNALS



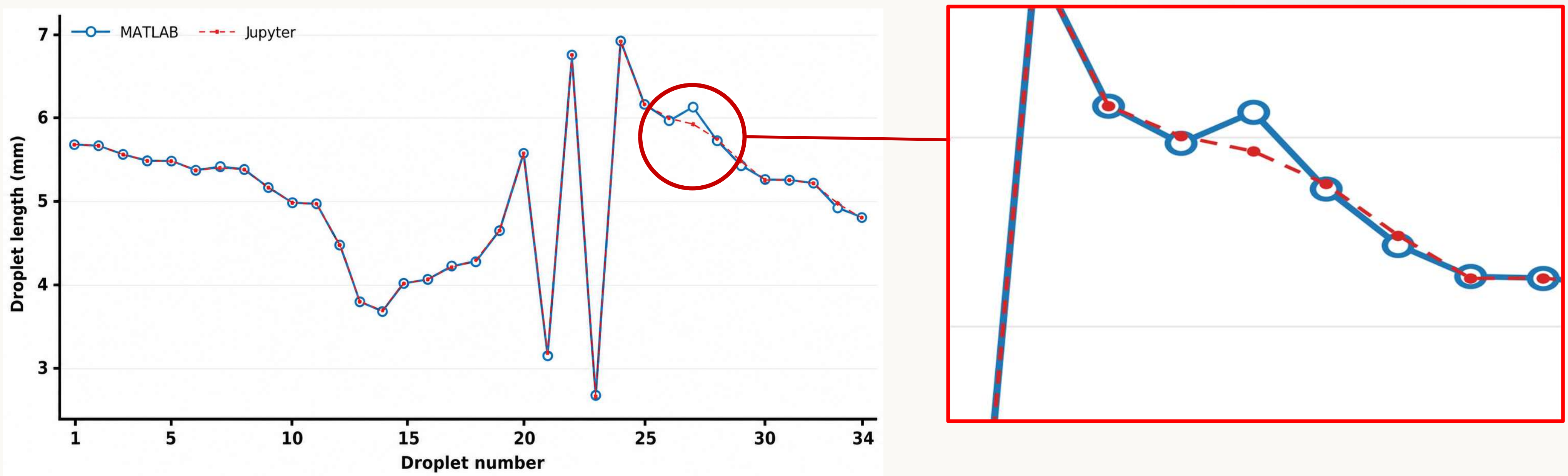
CALCULATE LENGTH, VELOCITY & EXPORT




Frame 1 of 10096 (grayscale with measurement regions)
Signal 1
Signal 2
Synchronized derivative progress
Signal 1
Signal 2
10
5
0
−5
−10
Change in intensity
0.96
0.98
1.00
1.02
1.04
Frame (MATLAB 1-based)

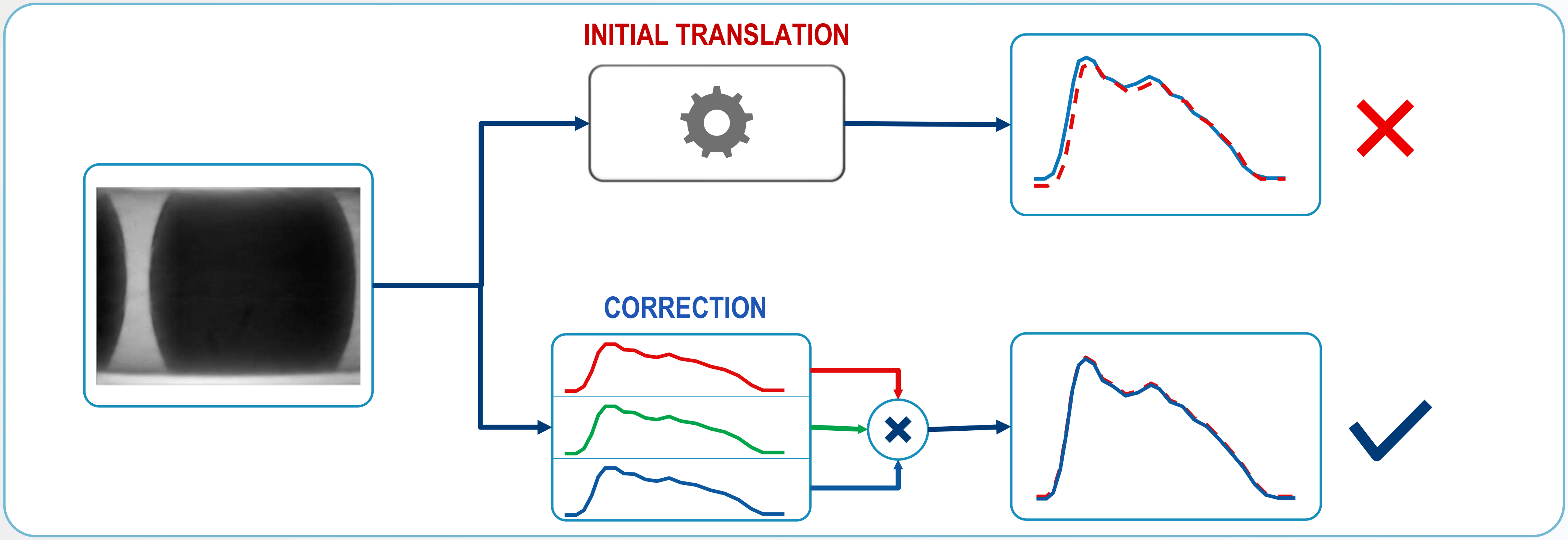
Conversion Analysis Proves Improper Translation

Initial conversion



- Fundamental tests showed the translated Jupyter results were not fully accurate.
- Small differences appeared across many points, with one droplet showing a major error.
- The next slides isolate the cause, apply the correction, and verify the result.

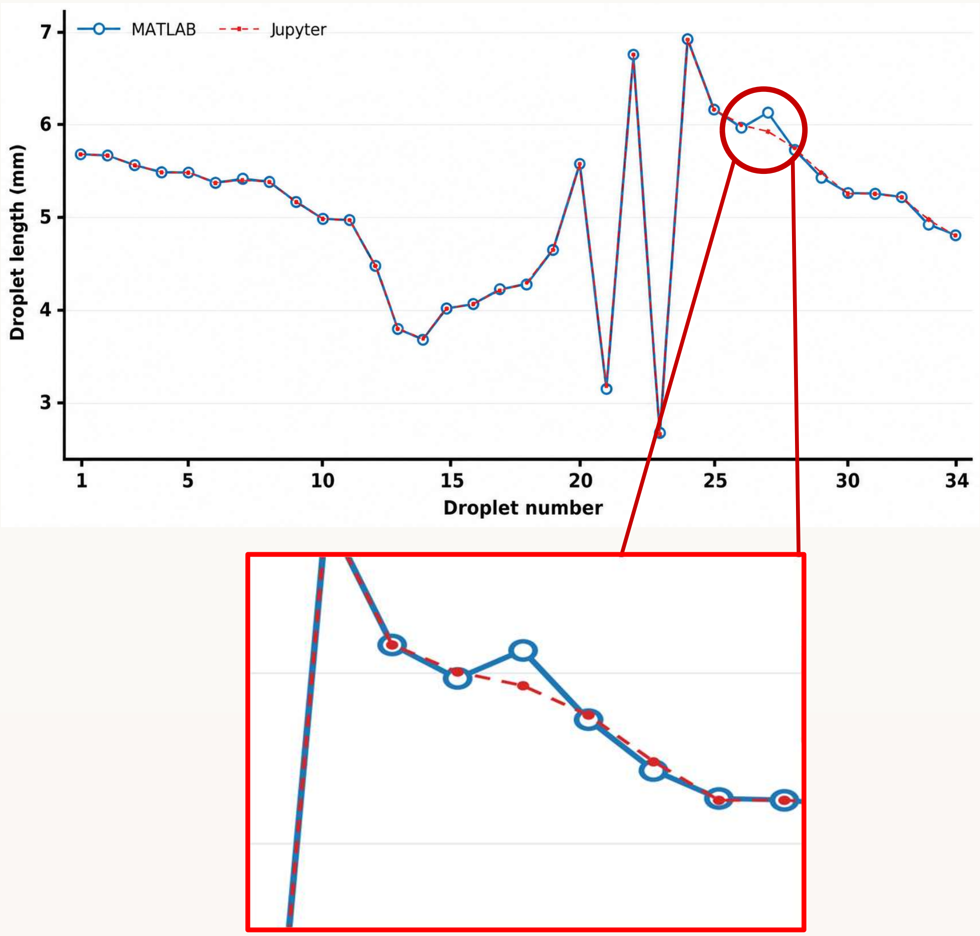
Identifying Drop Length and Velocity with Image Analysis



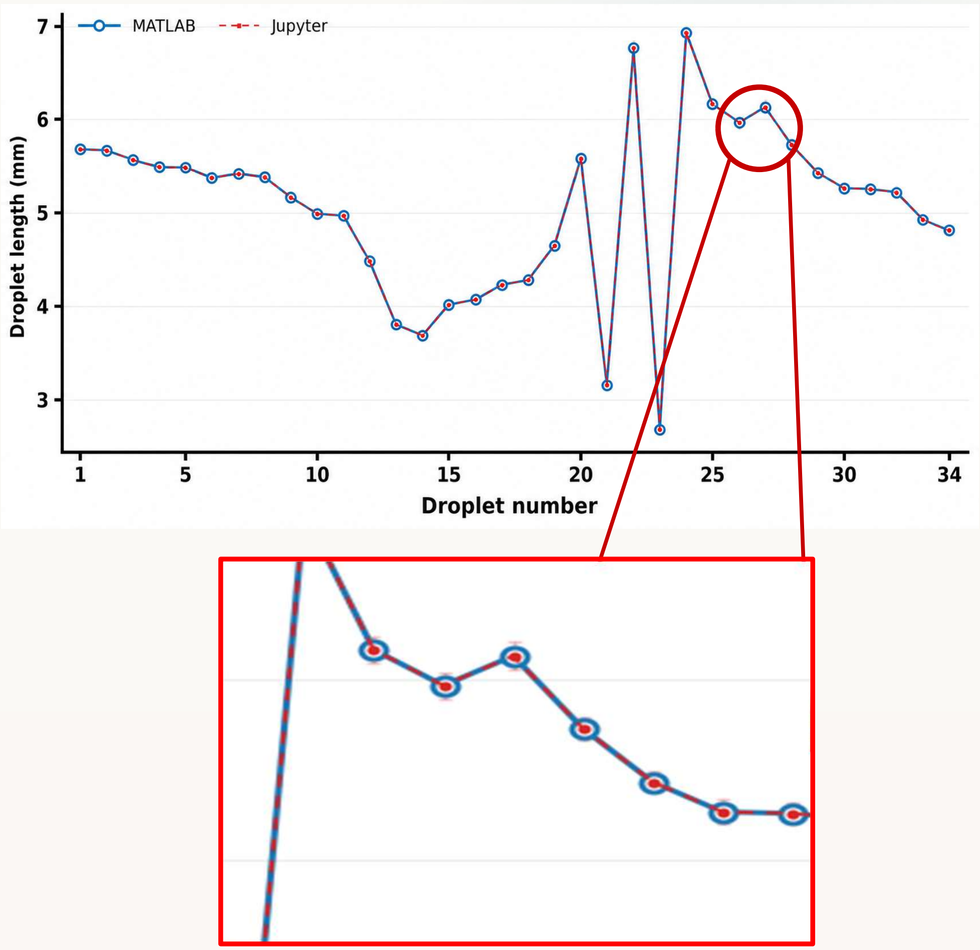
- The initial grayscale shortcut was efficient but did not match MATLAB's numerical processing, causing differences in the measured outputs.
- The corrected notebook now uses MATLAB-compatible weighted greyscaling, half-up rounding, clipping, and integer preservation before averaging.

A Targeted Correction Closes the MATLAB–Jupyter Gap

Initial conversion



After correction



One record connects image and absorbance measurements

- Convert continuous droplet streams into reliable droplet-level measurements.
- Characterize droplets through complementary UV–Vis and image-based analysis.
- Integrate these workflows toward real-time analysis and automated experiments.

LONG-TERM GOAL

Combine image-derived and signal-derived measurements for each droplet.

Acknowledgments

Thank You!

- Mentors: Dr. Olivia Haider, Dr. Katie Weigandt, Jeffery Krzywon

❖ Special Thanks: Paul Kienzle

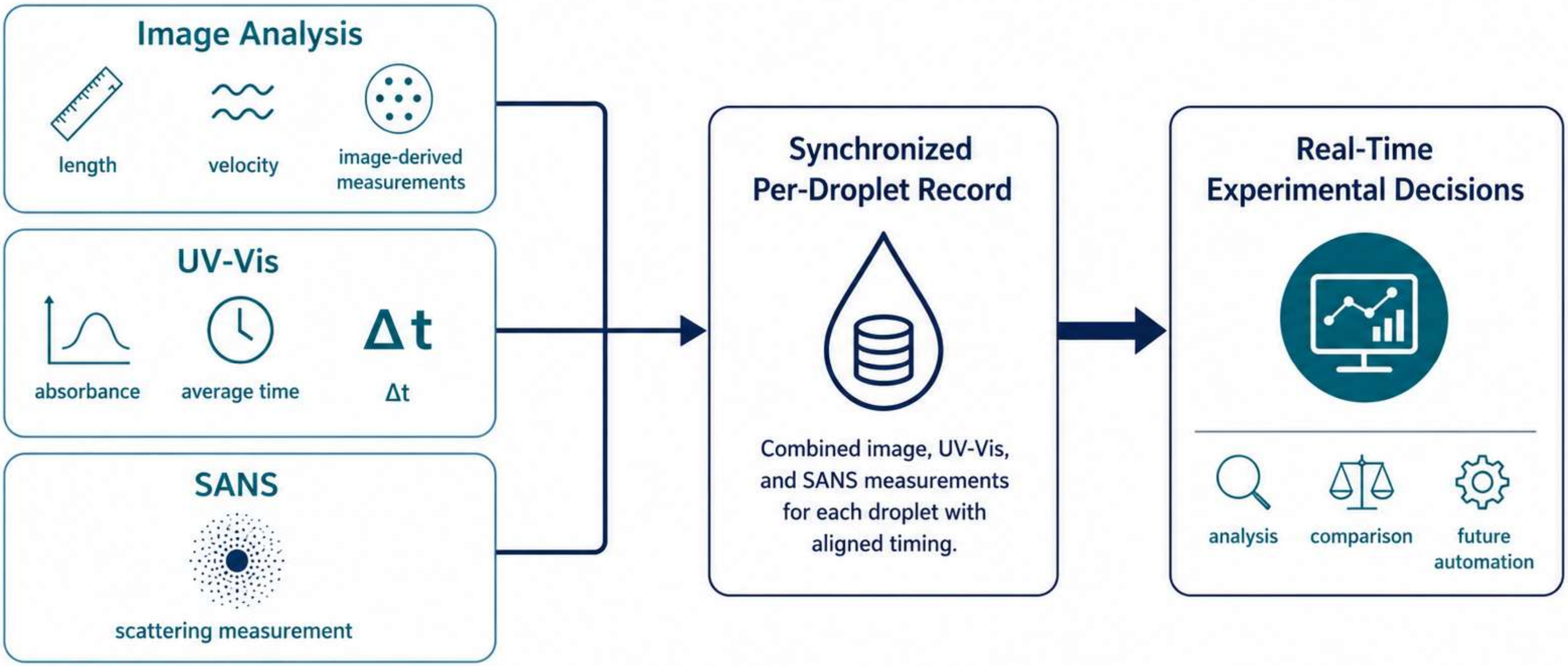
- SHIP Directors: Cara O'Malley, Dr. Julie Borchers, Dr. Leland Harriger, Dr. Kelsi Rehmann, Dr. Susana Marujo Teixeira
- CHRNS, NCNR Staff, and the NIST SHIP Program

CHRNS CENTER FOR HIGH RESOLUTION NEUTRON SCATTERING NIST

NIST National Institute of Standards and Technology U.S. Department of Commerce

NIST Center for Neutron Research

Future NCNR Detector Integration



- The long-term goal is to connect complementary measurements for the same droplet so experiments can eventually be interpreted and adjusted in real time.

How the Workflow Evolved Over the Internship

1. **Week 1**
   Project framing
   Define the droplet-level outputs and understand the NCNR workflow

2. **Week 2**
   Signal parsing
   Inspect continuous UV-Vis traces and build import / preprocessing tools

3. **Week 3**
   UV-Vis workflow
   Detect boundaries and extract droplet-level absorbance measurements

4. **Week 4**
   Image translation
   Convert the MATLAB image-analysis workflow into Jupyter

5. **Week 5**
   Validation / correction
   Diagnose MATLAB–Jupyter differences and apply the grayscale fix

6. **Week 6**
   Integration / wrap-up
   Validate outputs, standardize exports, and outline future combined analysis

- This timeline is useful backup context if someone asks how the project progressed over the summer.