Supplementary Information For

On Cloud Microfluidic Experiment Platform Powered by In-situ Maskless Lithography

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Experimental Setup

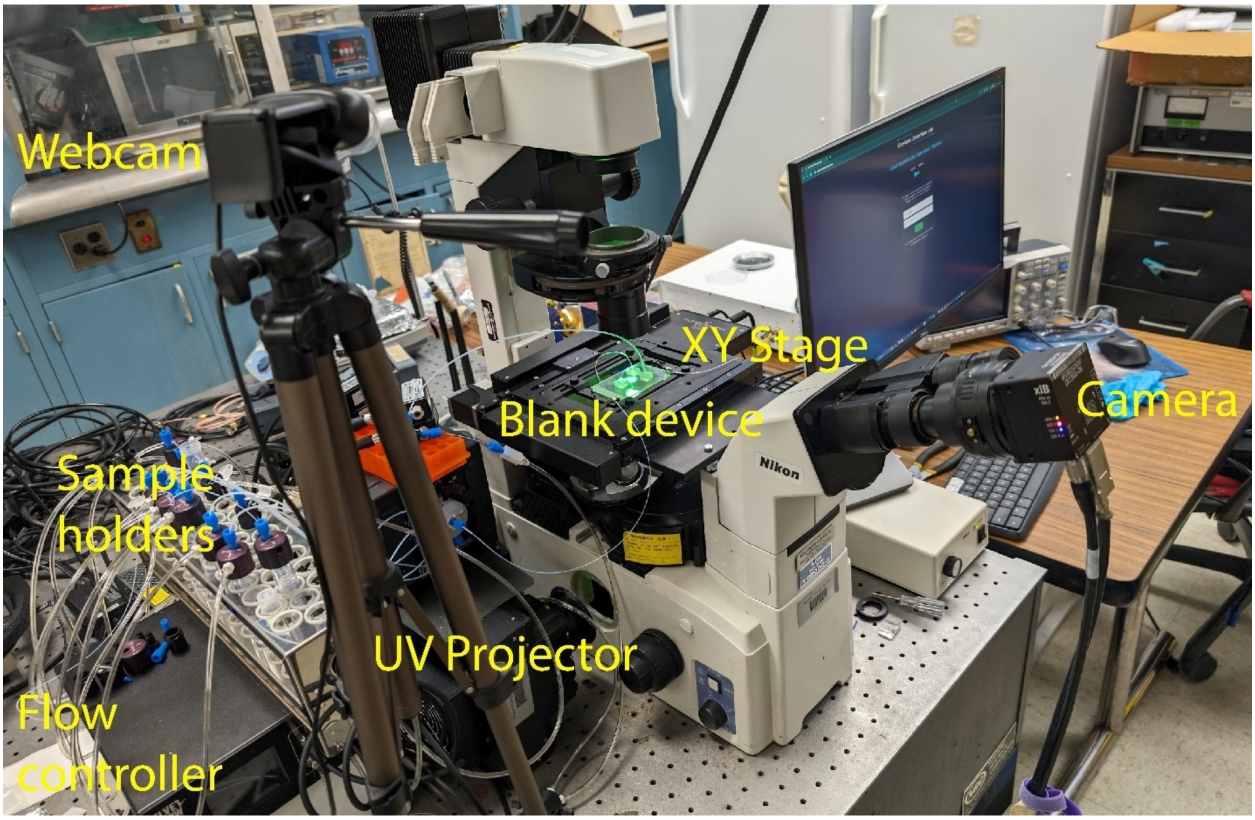

Figure S1: Experimental Setup for the online microfluidic experimental platform.

Blank Device

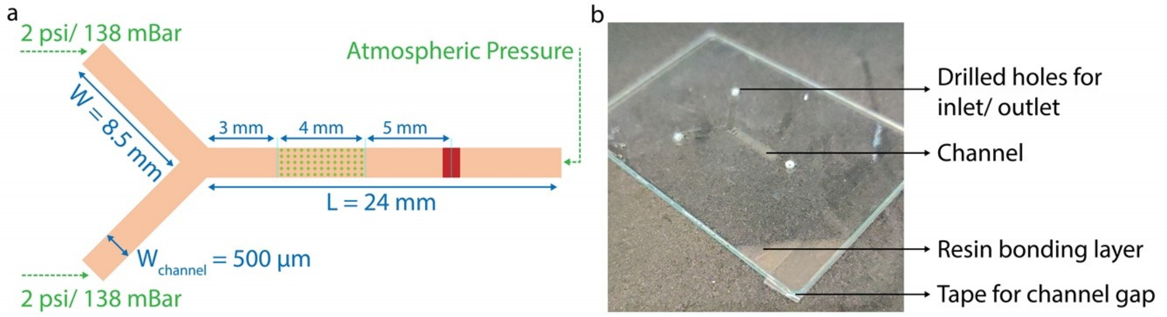

Figure S2: (a) A graphical problem statement that was presented to the students as a part of the BIOE247 course project. (b) Actual fabricated blank device as demonstration

User Interface

Supplementary Figure 3-7 demonstrates the user interface of the platform.

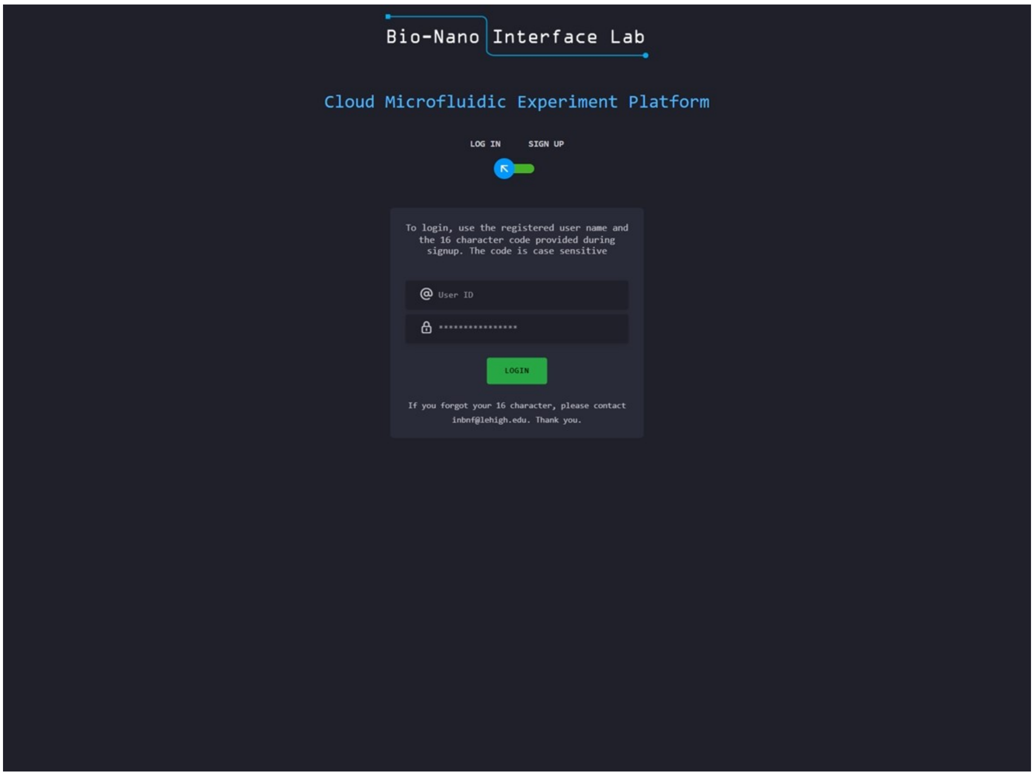

Figure S3: Signup and login page.

Figure S4: The input page contains several mode of patterning. Users can choose from standard shapes, or upload image file or upload .dxf file.

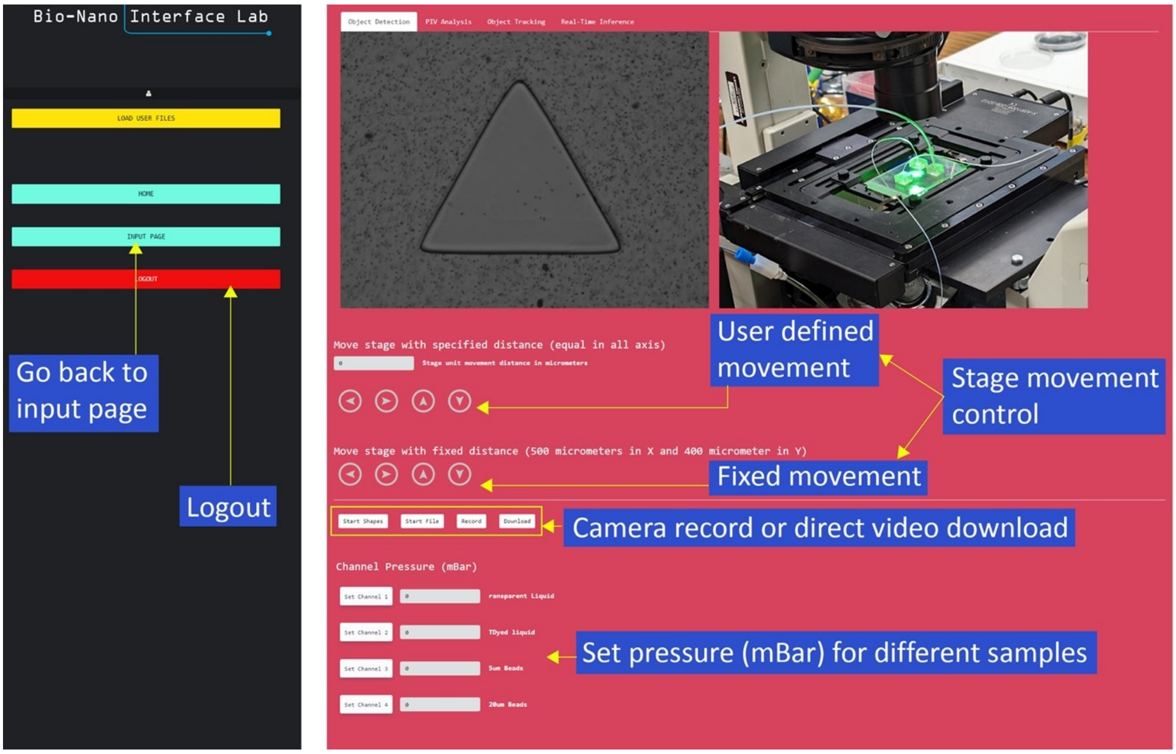

Figure S5: The fabrication and tools page contains the camera control, stage control, and sample control.

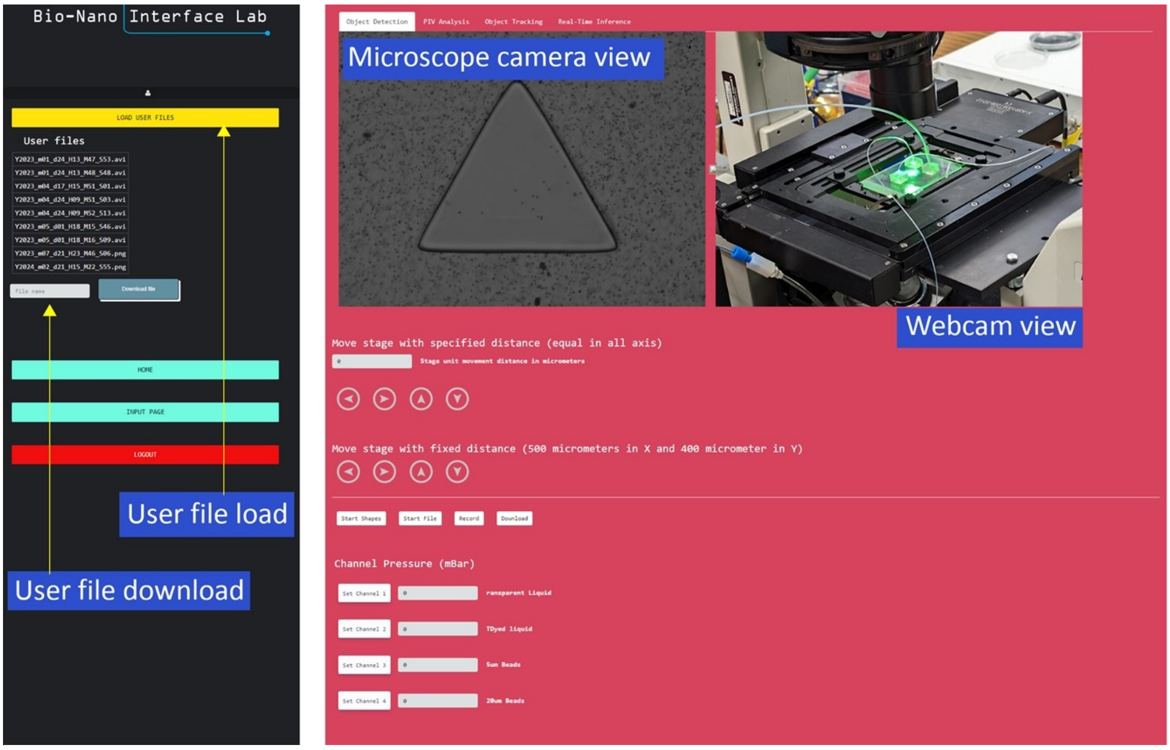

Figure S6: The user can manage files in their account from the side dashboard.

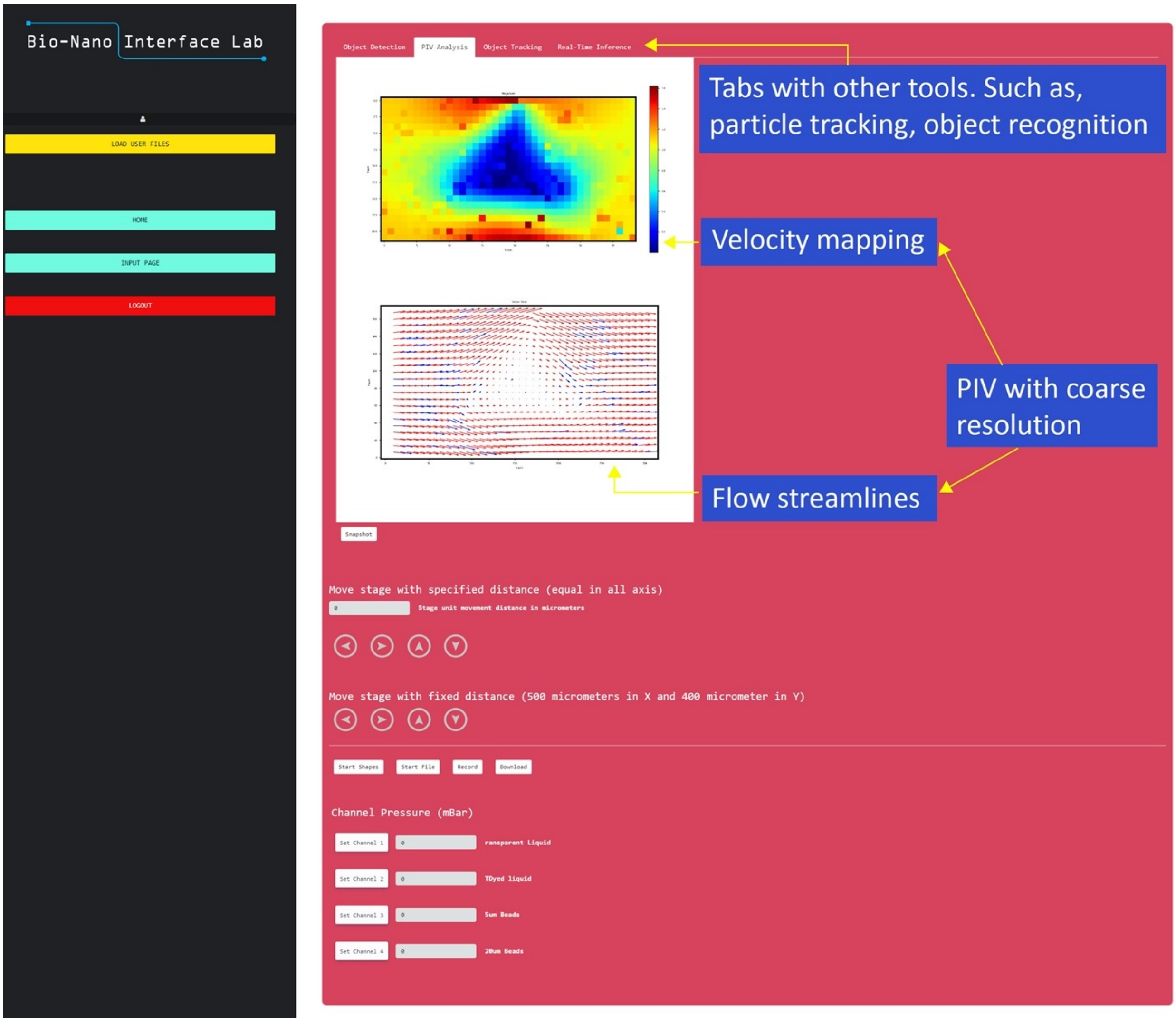

Figure S7: Users can choose from different built-in tools in this page.

User Feedback

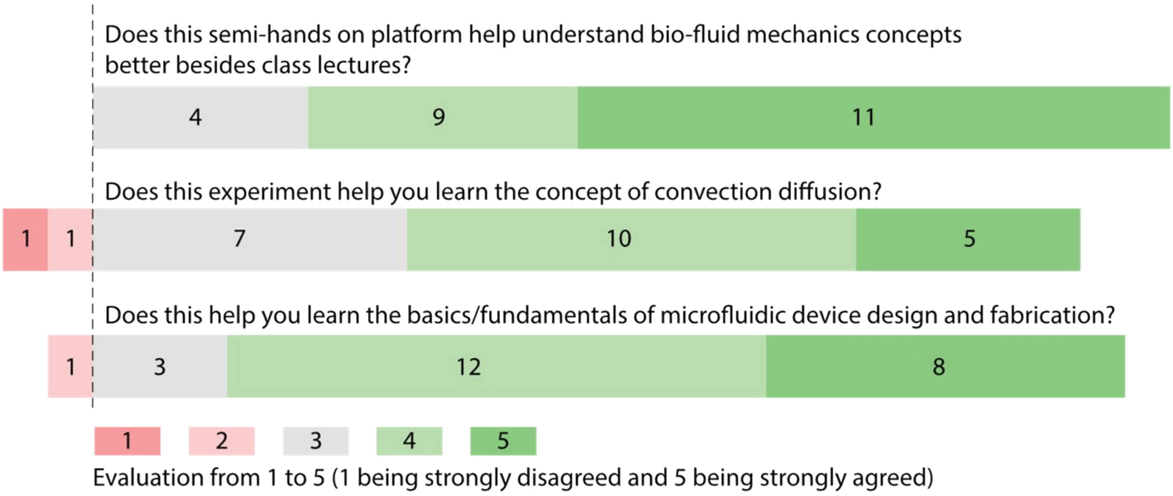

Figure S8: Feedback on the cloud microfluidic experiment platform from the students in the BIOE247 course.

Table S1: Student comments and suggestions after using the cloud microfluidic experiment platform for the course project.

Positive comments	Suggestions	Category
I would've liked to create more designs in real life to see which ones had the best mixing. I thought it was relatively simple to work with, maybe a bit more instruction directly on the platform could be helpful. I really liked this portion of the project and would have like more time to try different patterns.	Continue making the user interface as friendly as possible. The procedure can be modified to be easier to follow. Maybe on the arrows to move the camera, put coordinates. (i.e., +X, -X, +Y, -Y). I think there should be x and y axis markers so that you know which way you are moving with the arrows at the bottom.	Improving the interface
I thought the project was a fun and interesting one. It was a great way to gain a better understanding of fluid mechanics. In order to make it more impactful, make groups smaller as not everyone in group was able to work on it, and it seemed really fun.	The platform is a little confusing for students that have never worked with microfluidics. It would be nice to get a little practice with it before starting the project. Maybe we could have been given a bit more time to complete the project.	More time to get accustomed
This was a very good project. No further suggestions needed.	Maybe do something like this in lab. More interactive experiment.	Prefers a more in-lab experience
	Make the students aware of design considerations so that they have a better idea of if the machine will be able to correctly fabricate their design.	Needs more emphasis on the theory

Table S2: Student understanding on what else this platform can be used for microfluidic experiments.

- I think we can run tests that are more geared towards turbulent flow with this platform.
- Changing other properties and seeing how mixing is affected.
- Tests for larger mixing devices potentially.
- Maybe this kind of platform could also be used to look at how changing flow rates can impact different fluid properties.
- The mixing of multiple fluids instead of just two
- It would be interesting to test flow through a porous membrane.
- To see if certain fluid properties affect mixing under the same conditions.
- I think you could do diffusion tests and more tests on the flow of different materials.
- The diffusion of more than two fluids
- To be honest I have no idea.
- Cell mixing and diffusion.
- Any simulation of fluidic properties can be run on COMSOL.
- Possibly other types of mixing (like the membrane diffusion mixing)
- You could test scaled down models using microfluidics or tests for fluid dynamics around objects.
- I am unsure.
- Another suggestion might be to include running a test that includes further statistical analysis to accept or reject the hypothesis that effective mixing has occurred.

Table S3: A summary and comparison of similar research.

Study	Main focus	Design on web/cloud	Remote experiment execution	Remote fabrication	Real experimental data collection	Main educational/research scope	Key distinction from the present work
Zhang et al., [1]	Open-source interactive design platform for 3D-printed microfluidic devices	Yes	No	No	No	Design automation for 3D-printed microfluidics	Enables browser-based design and DFM, but not remote physical experiments.
Wietsma et al., [2]	Classroom lab-on-a-chip kit and student-fabricated devices	No	No	No	Yes, in the classroom	Hands-on school/university microfluidics education	Strong in-class learning, but experiments are local classroom practicals, not cloud-accessed.
De Micheli et al., [3]	Mixed reality for enhanced microfluidics laboratory course	No	No	No	Supports existing lab course	Visualization and conceptual learning	Enhances understanding of microfluidic phenomena, but does not provide remote fabrication or online experimentation.
Delgado et al., [4]	Economical in-class sticker microfluidic activity	No	No	No	Yes, in class	Low-cost hands-on device manufacturing and microscale physics	Affordable and portable in-class activity, but not internet-enabled or remotely operated.
Sano et al., [5]	Internet-enabled LoC technology for education	Yes	Yes	No	Yes	Remote programming education using cloud-integrated LoCs	Closest prior work in remote access, but centered on open-loop educational assay execution rather than a general platform for remote fabrication, experimentation, imaging/analysis.
This study	Cloud microfluidic experiment platform	Yes	Yes	Yes	Yes	Education and research	Integrates remote in-situ fabrication, experiment control, imaging, and server-side analysis in one platform.

Table S4: Step-by-Step Implementation Guide for a Cloud-Accessible Microfluidic Experiment Platform

Objective	**Instruments / Tools Used in This Study**	**Notes**
Establish an experimental imaging system	Inverted microscope (Nikon Ti-series) and Ximea high-speed color camera	Any microscope-camera system capable of imaging microfluidic channels can be used. In this case, the camera port was used for the UV maskless lithography, and one of the eyepieces was used for imaging through a camera adapter.
Integrate the flow control system	Elveflow OB1 pressure controller with MUX distribution valve	Syringe pumps or other programmable pressure controllers may also be used. But it will require a changeable reservoir. As there was only one inlet for the resin and sample, the distributor was used to control the reservoir.
Enable device positioning	Zaber X-ASR motorized X-Y translation stage	Any programmable motorized stage with API support can be integrated.
Connect the hardware to the central control computer	Local workstation/server running Python-based control software	Device communication is performed through manufacturer APIs.
Implement central control software	Python scripts integrating stage control, camera acquisition, and pressure control APIs	Other environments, such as MATLAB or LabVIEW, could also be used
Develop a user interface for experiment control	Web interface built using HTML/CSS with backend Python scripts. Flask was used to integrate both.	Interface design can vary depending on the facility.
Implement user and data management	Local server storage and user account management system. Python based excel management was used as a database in this study.	Can be implemented using database systems such as SQL
Enable remote access to the platform	Ngrok-based secure tunnel connecting the local server to the internet	Other server hosting or VPN-based access systems can be used
Prepare a blank microfluidic device	Glass–glass microfluidic chamber fabricated using spacer tape and UV-curable resin	Optical transparency and gas impermeability are important for in-situ photopolymerization
Upload device designs and initiate fabrication	Design files (e.g., PNG or CAD-based patterns) uploaded through the web interface	Designs are projected for in-situ photopolymerization inside the device
Capture experimental data	Camera-based video acquisition through Python control scripts	Data stored locally for later processing
Perform experimental data analysis	OpenPIV for particle image velocimetry and OpenCV-based particle tracking executed on the local server	Other analysis software may be integrated, depending on the experiment
Run remote experiments	Experiments are controlled through the web interface while hardware executes commands locally	Some preparatory steps (device loading and sample preparation) currently require in-lab assistance

Supplementary movies

Supplementary movies can be found at the following link. 10.6084/m9.figshare.29144891.

References

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3 A. J. De Micheli, T. Valentin, F. Grillo, M. Kapur and S. Schuerle, *J. Chem. Educ.*, 2022, **99**, 1272–1279.

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