Development of Digital Holographic Microscope for Three-Dimensional (3D) Microfluidics Application

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Presentation Overview

- Research Background
- Problem Statement
- Research Objectives
- Methodology
- Expected Results/ Benefits
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Research Background

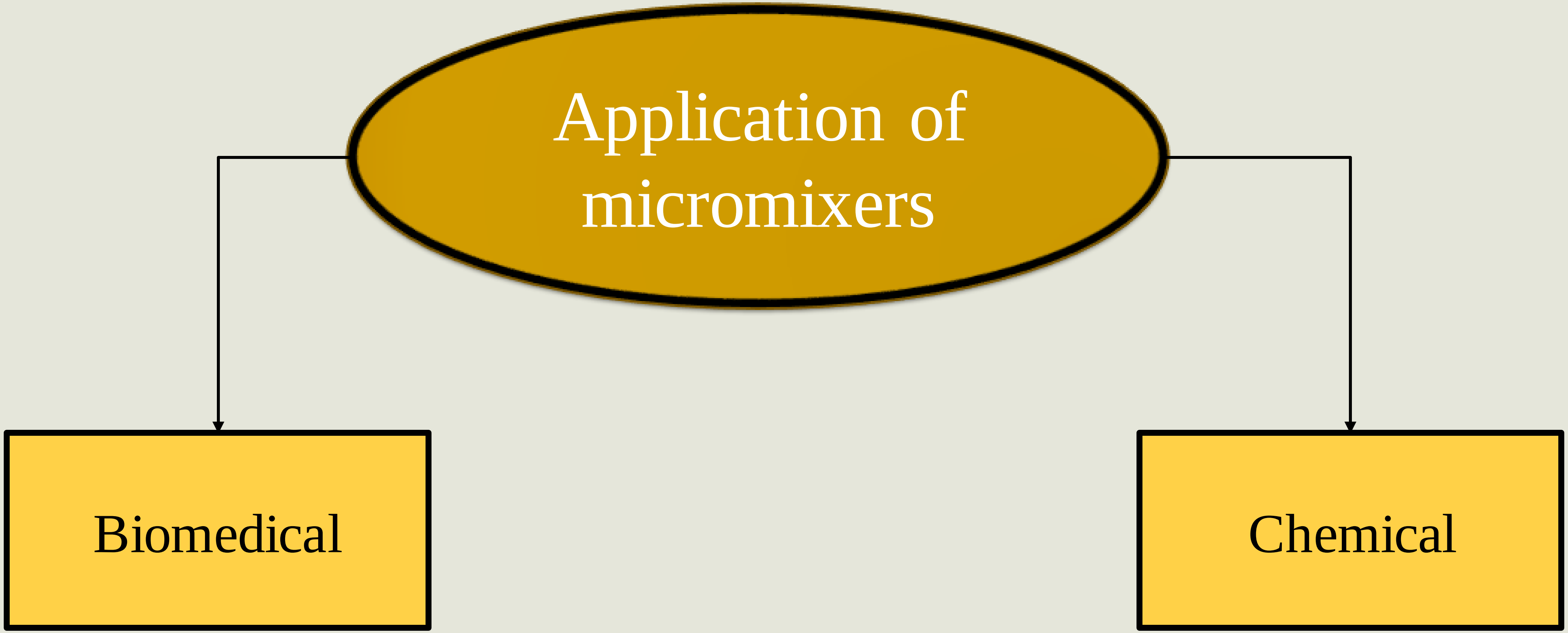

***Figure 1**: Microfluidics applications*

Research Background

Biomedical application – Diabetes monitoring

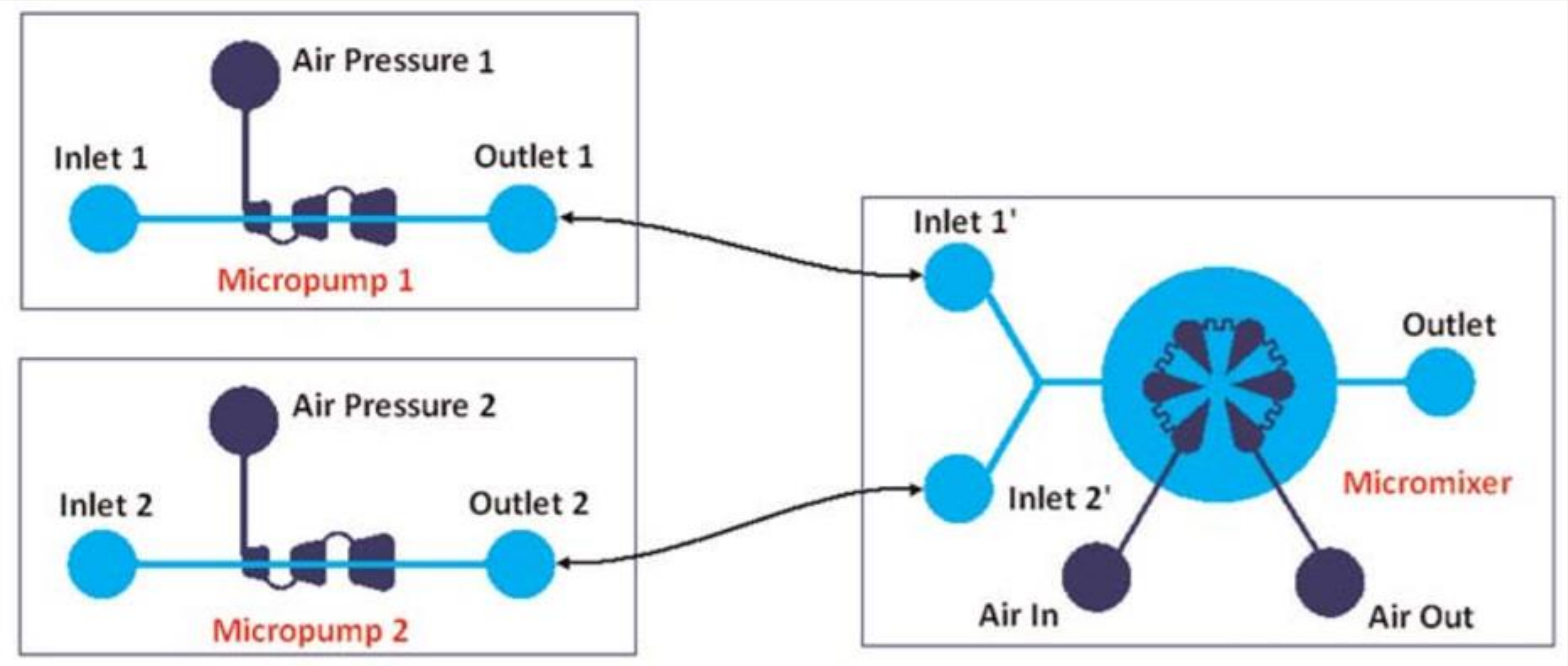

***Figure 2**: Micromixer for glucose biosensors (Yao et al., 2013)*

Research Background

Chemical application – Detection of pollutants

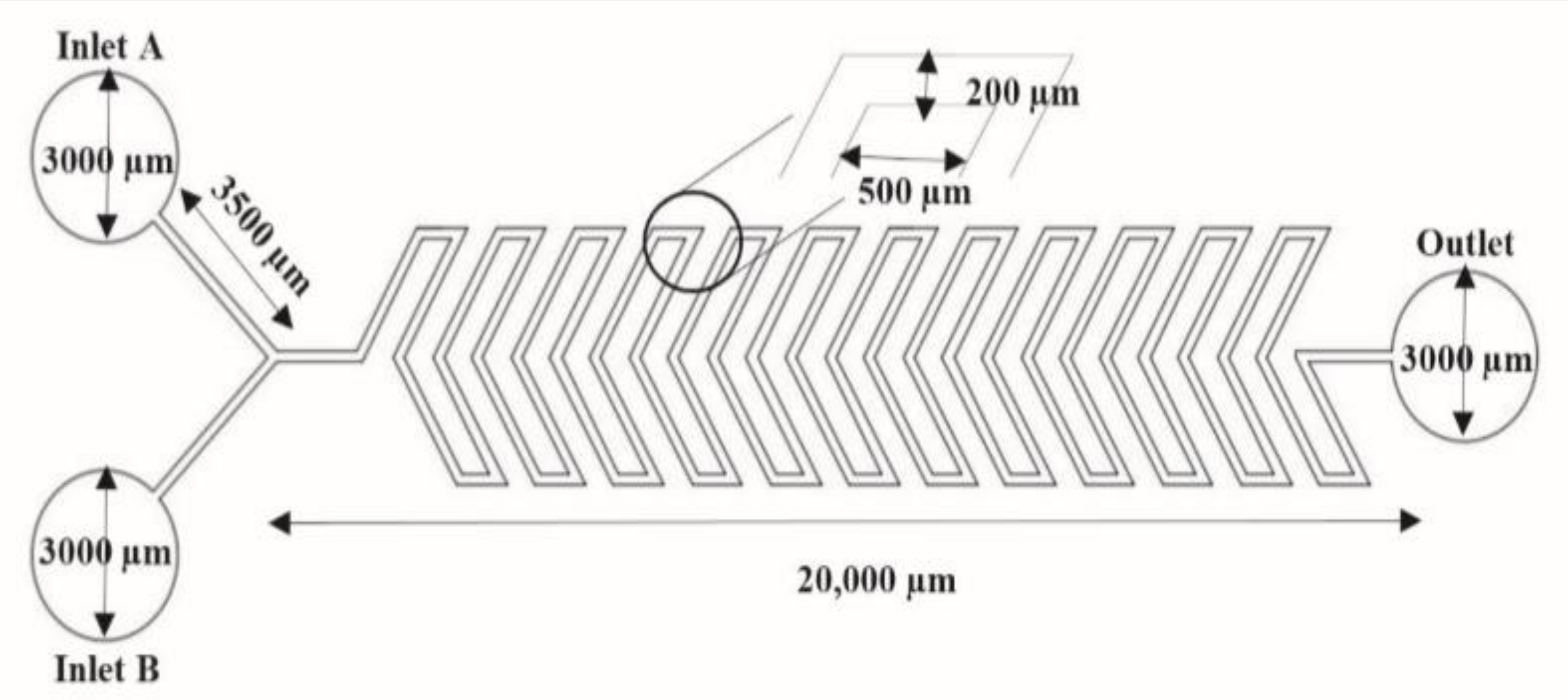

***Figure 3**: Micromixer for mercury ions detection in groundwater (Karthikeyan & Sujatha, 2017)*

Problem statement

Limitation:

It needs extremely thin sections of specimens, usually about 100 nm.

Figure 4: *Transmission electron microscopy (Othman et al., 2015)*

Problem statement

Limitation:

It has a low magnification and makes it difficult to distinguish individual cells.

***Figure 5**: Stereoscopic microscope (Chen et al., 2016)*

Problem statement

Limitation:

It is not a truly three-dimensional measurement technique.

Figure 6*: Confocal laser scanning microscope (Maeki et al., 2017)*

Problem statement

Disadvantage:

Expensive, strictly limited to fluid moving in horizontal direction.

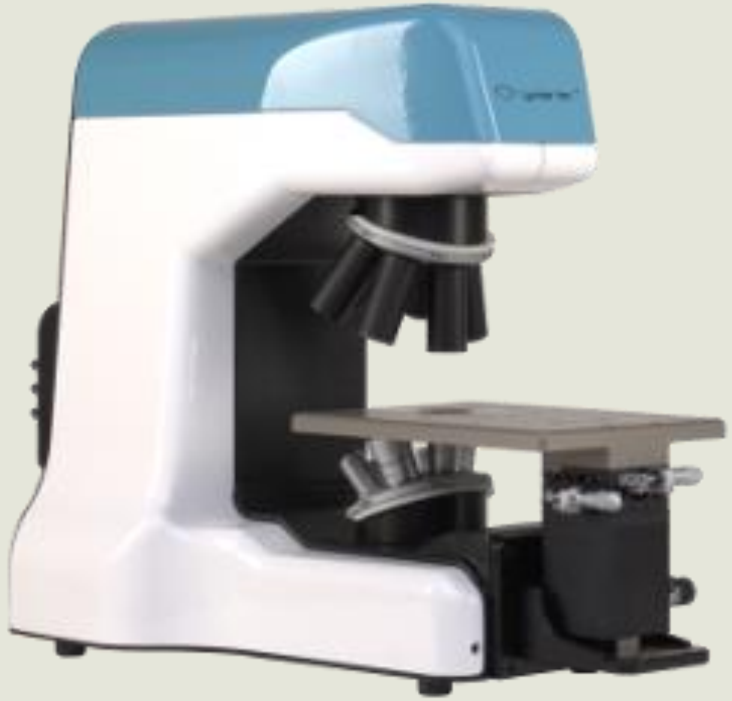

***Figure 7**: Commercially available digital holographic microscope (Campos et al., 2018)*

Research objectives

1. To design, manufacture, assemble and calibrate digital holographic microscope.
2. To design and fabricate Y-junction microfluidic mixer by laser micromachining.
3. To experimentally investigate flow mixing of three miscible fluids.

Methodology

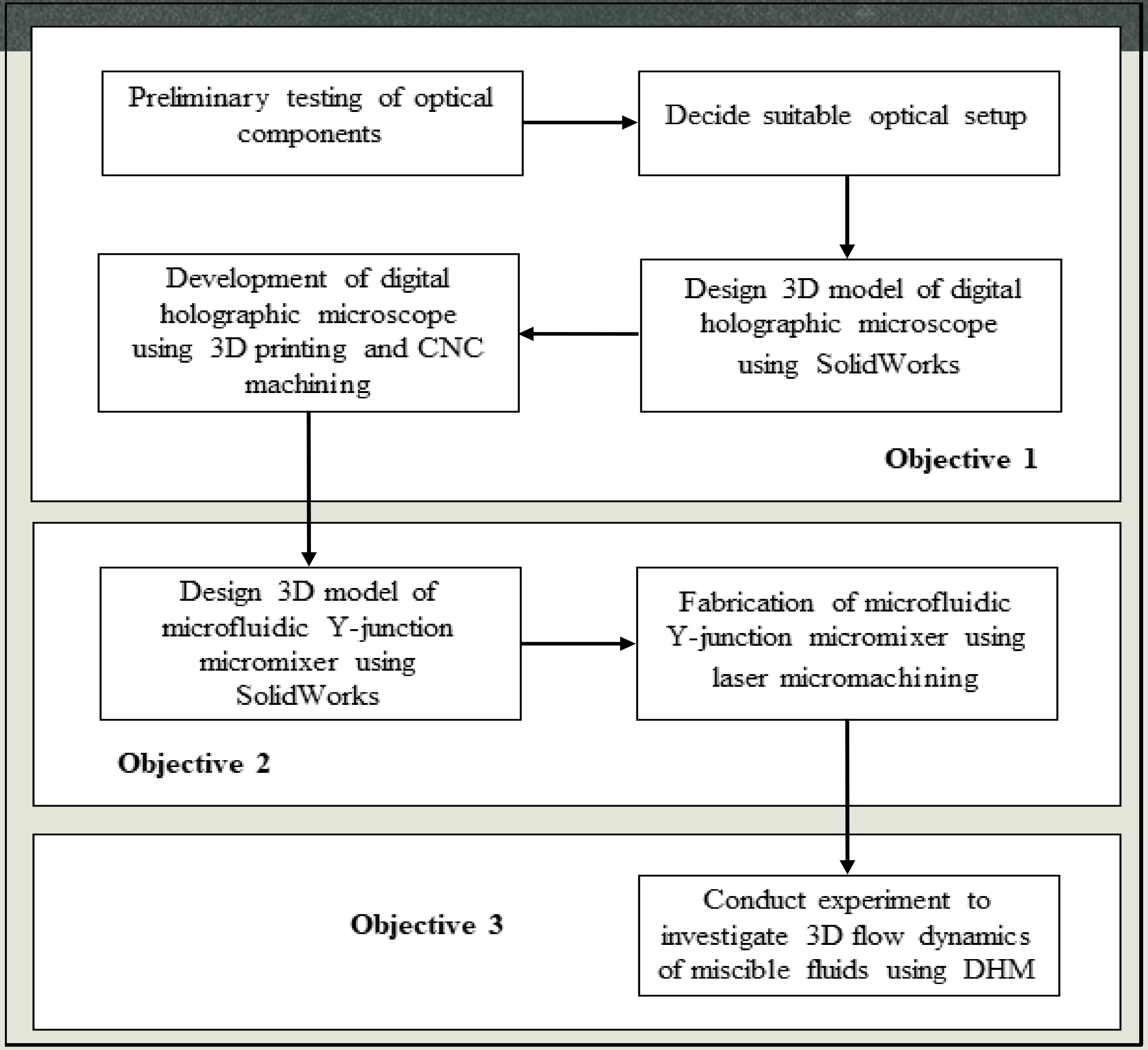

***Figure 8**:Methodology for developing digital holographic microscope*

Methodology – Objective (1)

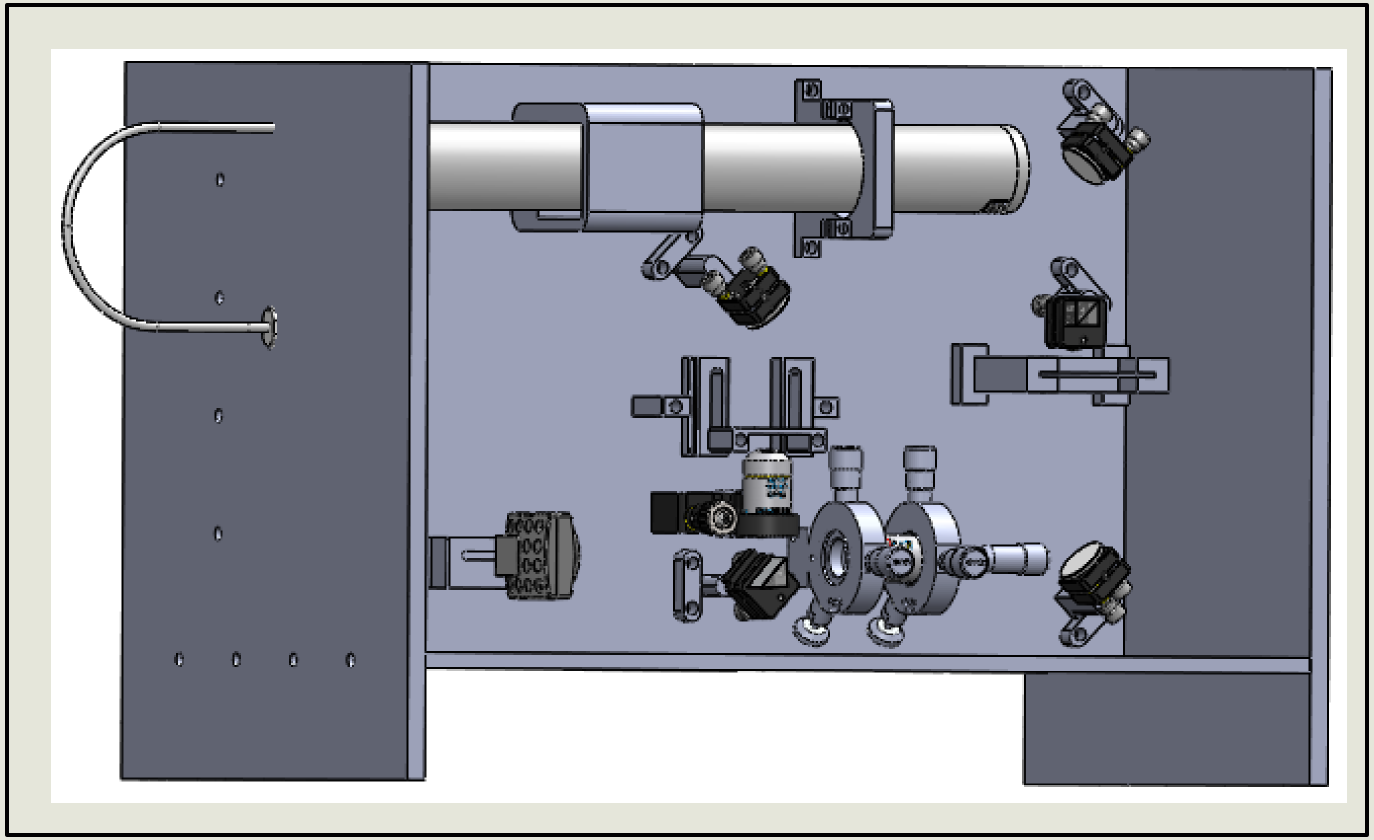

Figure 9*: 3D model of digital holographic microscope*

Methodology – Objective (1)

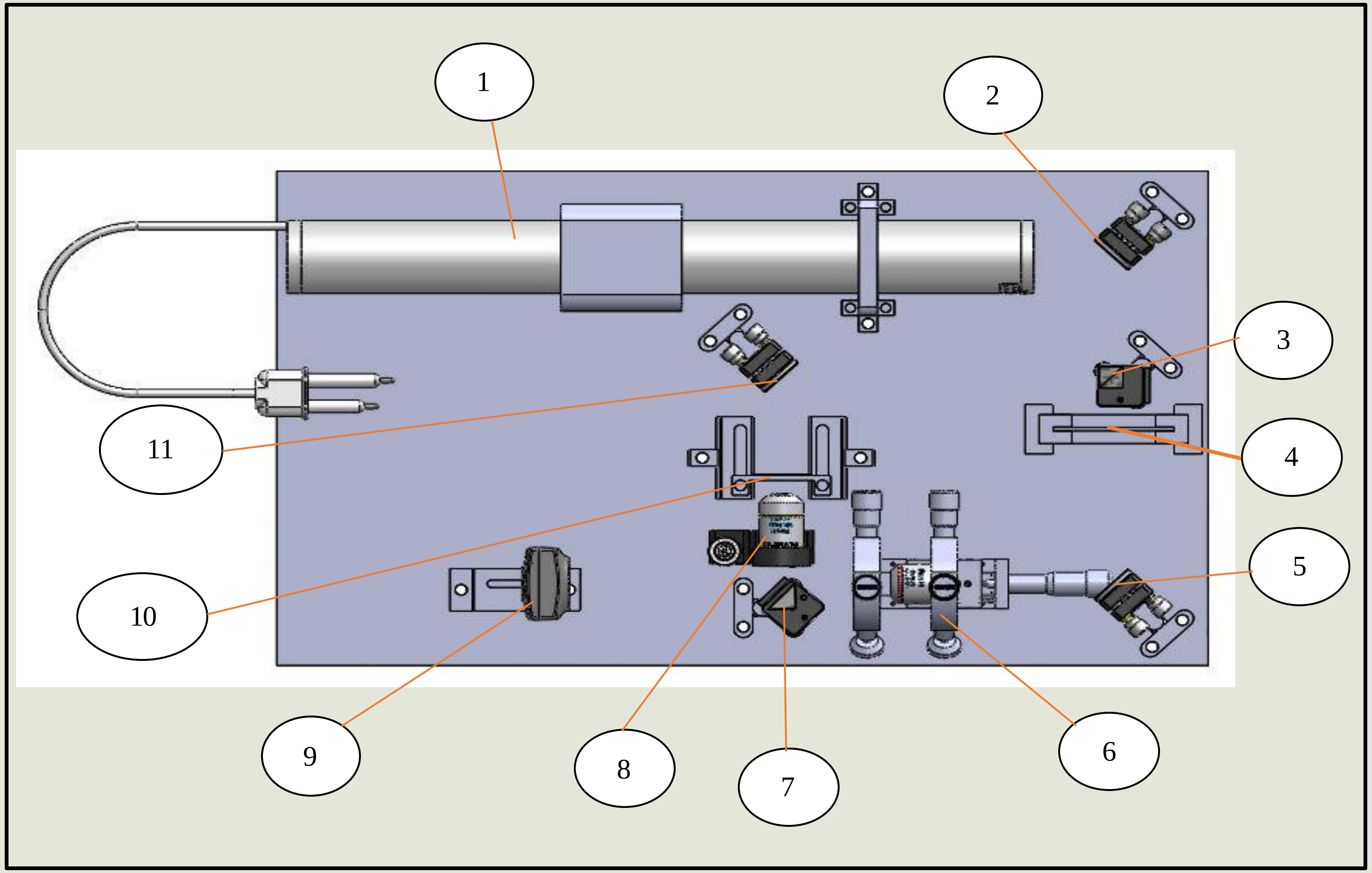

***Figure 10**: Optical set-up*

***Table 1**: List of components*

No.	Optical component
1	He-Ne laser
2, 5, 11	Round mirrors
3	Beam splitter
4	Linear step ND filter
6	Spatial filter
7	Right angle prism mirror
8	10× microscope objective
9	CMOS camera
10	Sample

Methodology – Objective (1)

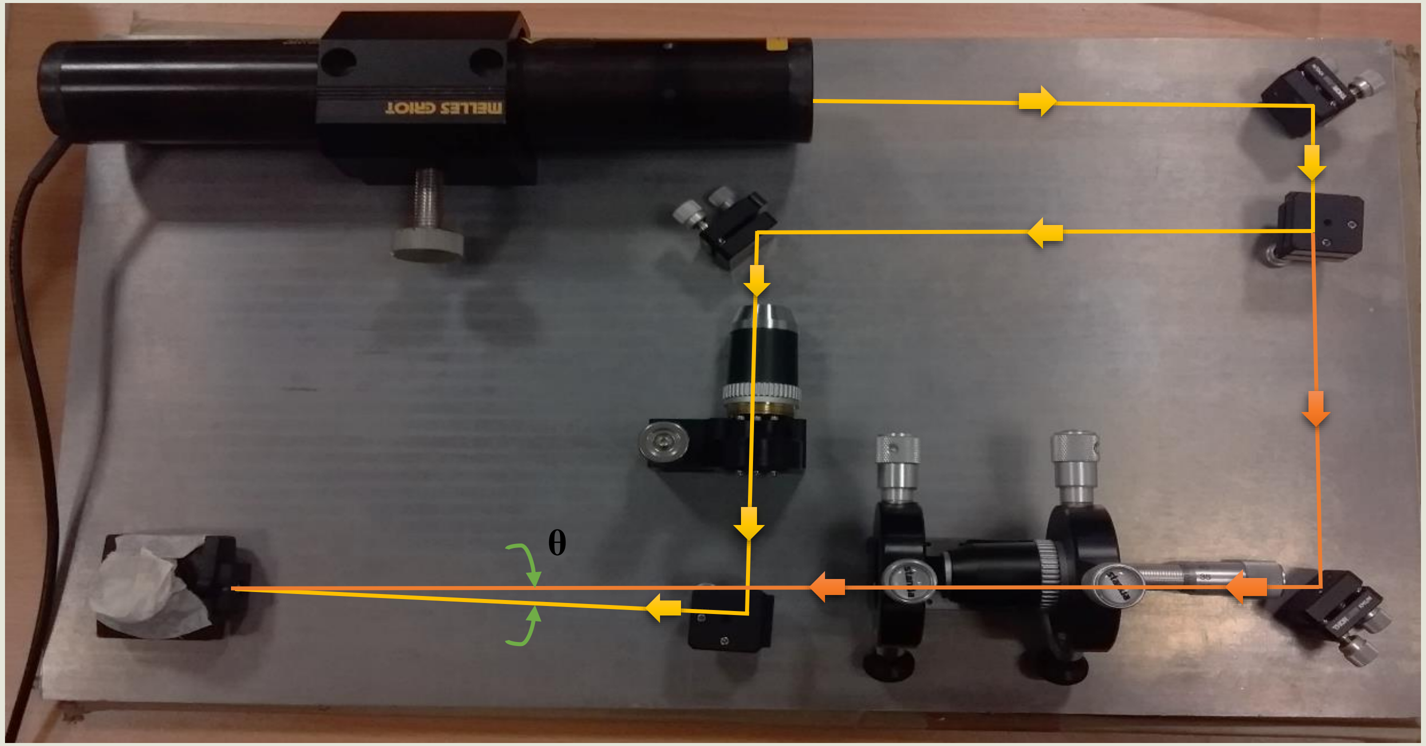

***Figure 11**: Actual optical set-up*

Methodology – Objective (1)

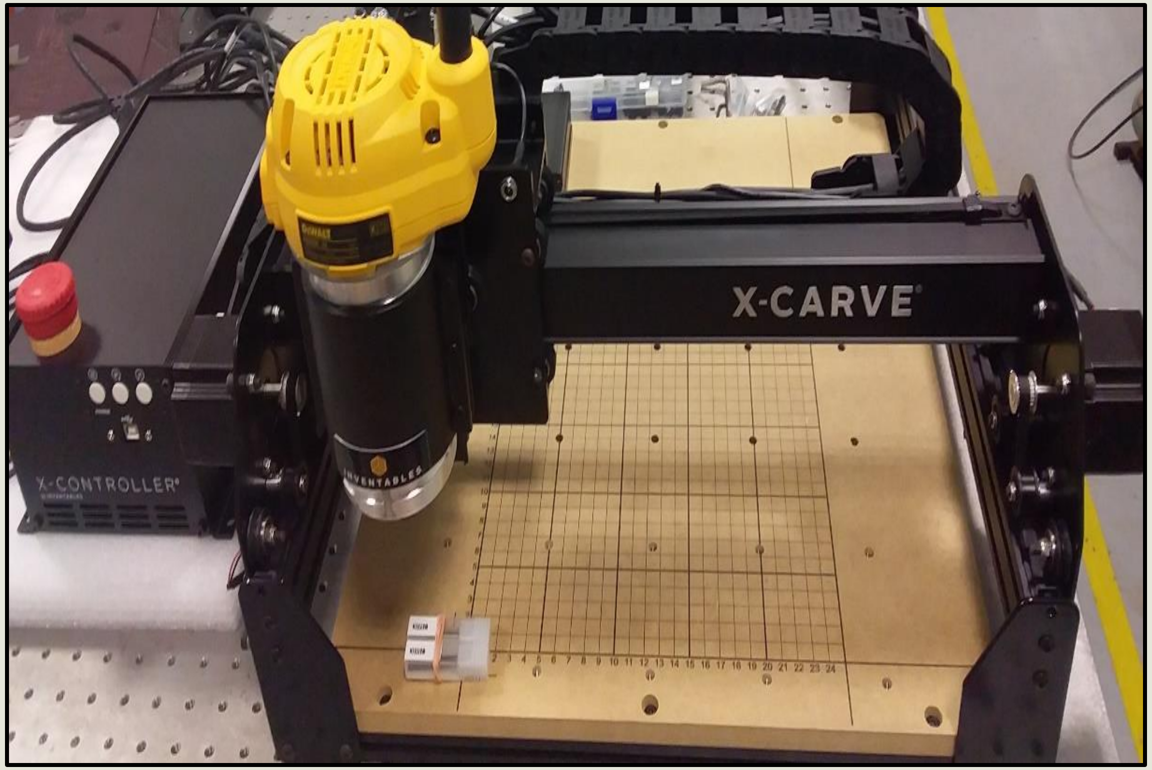

***Figure 12**: Components fabrication by 3D printing and CNC machining*

Methodology – Objective (2)

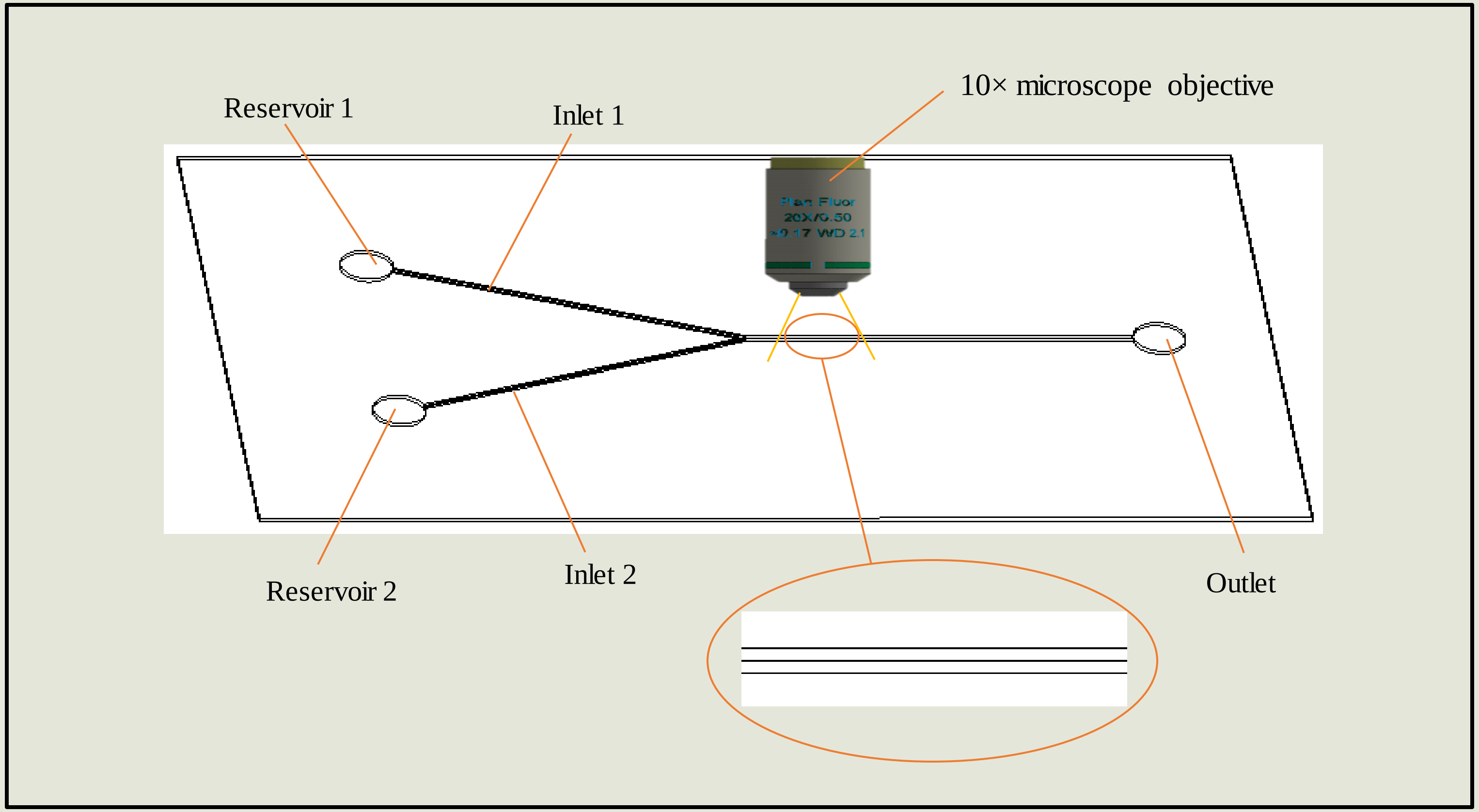

***Figure 13**: 3D model of microfluidic Y-junction micromixer*

<u>Microchannel dimension:</u>

Length = 80 mm

Width = 50 mm

<u>Y-junction micromixer dimension:</u>

Reservoir's diameter = 4 mm

Depth = 400 microns

Total length = 63.5 mm

Degree of Y = 40°

Methodology – Objective (2)

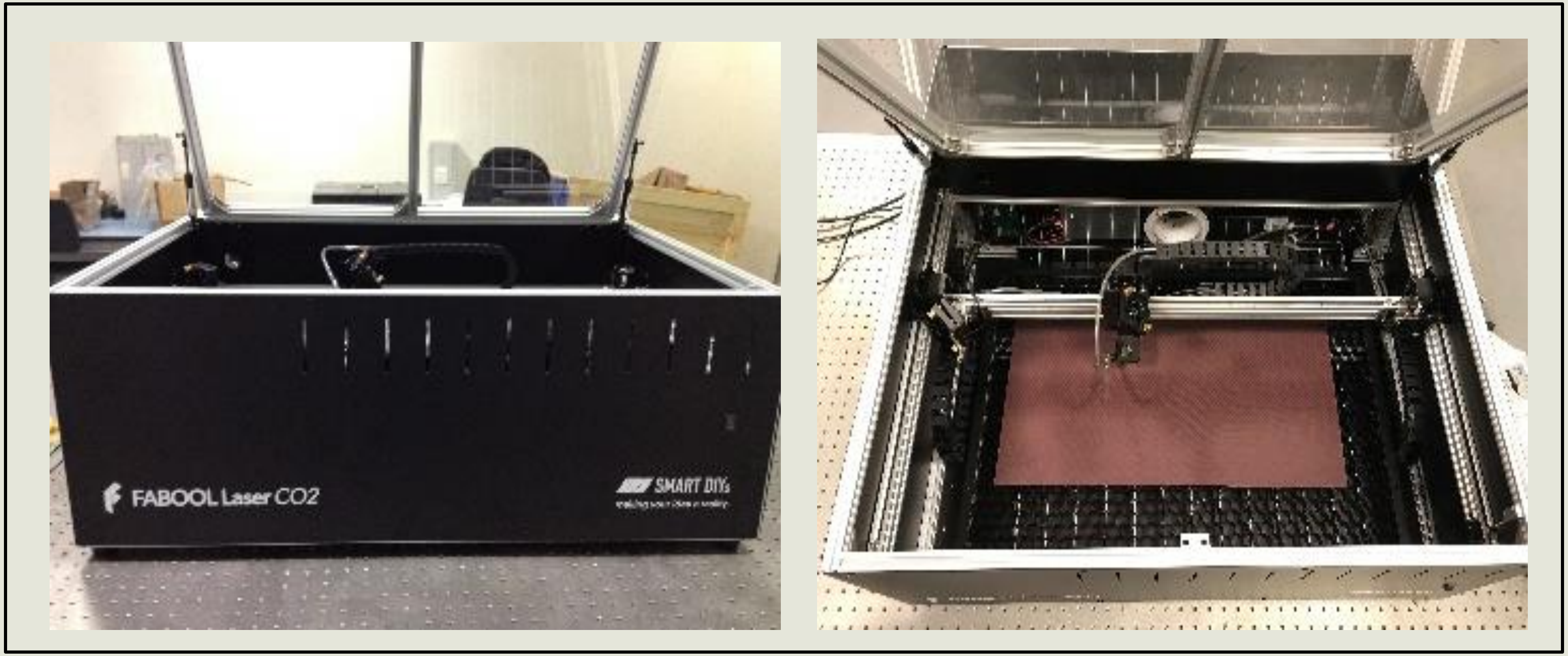

***Figure 14**: CO_2 laser cutter (front view, top view)*

Methodology – Objective (3)

***Table 2**: Three miscible fluids*

	Inlet 1	Inlet 2	Application
Mixing (1)	Distilled water	Alcohol	Inexpensive solvent - Cosmetics - Drugs
Mixing (2)	Distilled water	Brine	Saline solution - Sinus/ eyes rinse - Cleaning wounds
Mixing (3)	Alcohol	Brine	Dehydrating alcohol - Oil extraction - Biodiesel production - Human wound antiseptic

Expected Results/ Benefits

1. A functional low-cost digital holographic microscope will be manufactured and calibrated. This process will involve programming work to synchronize CMOS camera and illumination source.
2. The developed microscope will be able to distinguish individual particles and measure micrometer thin sections of specimens.
3. Custom-made digital holographic microscope can be used to observe and visualize miscible fluids that move either in horizontal or vertical direction under the influence of gravitational force.

Project Significance

- ✓ Reasonable cost when compared to the commercially available DHM.
- ✓ Custom-made DHM can be used by most research institutions.
- ✓ Developed DHM can measure and characterize fluid under the influence of gravitational force i.e., in vertical direction.

References (1)

Campos, V., Rappaz, B., Kuttler, F., Turcatti, G., & Naveiras, O. (2018). High-throughput, non-perturbing quantification of lipid droplets with Digital Holographic Microscopy. *Journal of lipid research*, jlr. D085217.

Chen, X., Li, T., Zeng, H., Hu, Z., & Fu, B. (2016). Numerical and experimental investigation on micromixers with serpentine microchannels. *International Journal of Heat and Mass Transfer, 98*, 131-140.

Karthikeyan, K., & Sujatha, L. (2017). *Design and fabrication of microfluidic device for mercury ions detection in water.* Paper presented at the Nextgen Electronic Technologies: Silicon to Software (ICNETS2), 2017 International Conference on.

Maeki, M., Fujishima, Y., Sato, Y., Yasui, T., Kaji, N., Ishida, A., . . . Tokeshi, M. (2017). Understanding the formation mechanism of lipid nanoparticles in microfluidic devices with chaotic micromixers. *PLoS One, 12*(11), e0187962.

References (2)

Othman, R., Vladisavljević, G. T., Bandulasena, H. H., & Nagy, Z. K. (2015). Production of polymeric nanoparticles by micromixing in a co-flow microfluidic glass capillary device. *Chemical Engineering Journal*, *280*, 316-329.

Wang, W., Zhao, S., Shao, T., Jin, Y., & Cheng, Y. (2012). Visualization of micro-scale mixing in miscible liquids using μ-LIF technique and drug nano-particle preparation in T-shaped micro-channels. *Chemical engineering journal*, *192*, 252-261.

Yao, P., Tung, S., Zhan, Z., Hua, J., & Dong, Z. (2013). Development of microfluidic-based telemedicine for diabetes care and screening. *Transactions of the Institute of Measurement and Control*, *35*(7), 893-900.

Zhang, J. W., Liu, S. F., Cheng, C., Li, W. F., Xu, X. L., Liu, H. F., & Wang, F. C. (2019). Investigation of three-dimensional flow regime and mixing characteristic in T-jet reactor. *Chemical Engineering Journal*, *358*, 1561-1573.

Gantt Chart

	Year	2018				2019										
	Month	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov
1	Literature study															
2	Optical alignment, calibration and code programming of DHM															
3	Experimental investigation of optimum laser micromachining parameters for fabricating microfluidic Y-junction micromixer															
4	Preliminary experiment															
5	3D trajectories of moving particles in miscible fluid assessment in Y-junction micromixer by DHM															
6	Documentation															

THANK YOU!

Problem statement

- Most mixing research in the literature are studied by numerical simulation. The simulation results of the mixing quality are qualitative and there is some difference of mixing degree among them (Zhang et al., 2018).
  - Therefore, the experimental investigations about the mixing quality are needed for verification.

Hypothesis

1. The trajectories of moving particles are inherently three-dimensional in nature.
2. The mixing efficiency of miscible fluid decreases with the increase of fluid's flow rate at $5 < Re < 100$.

Research questions

1. How digital holographic microscope can be utilized to provide accurate 3D trajectories of moving particles in miscible fluid?
2. How the design of microfluidic Y-junction micromixer affect the mixing quality of miscible fluid?
3. What is the relationship between flow rate and mixing efficiency of miscible fluid?

Methodology – Objective (2)

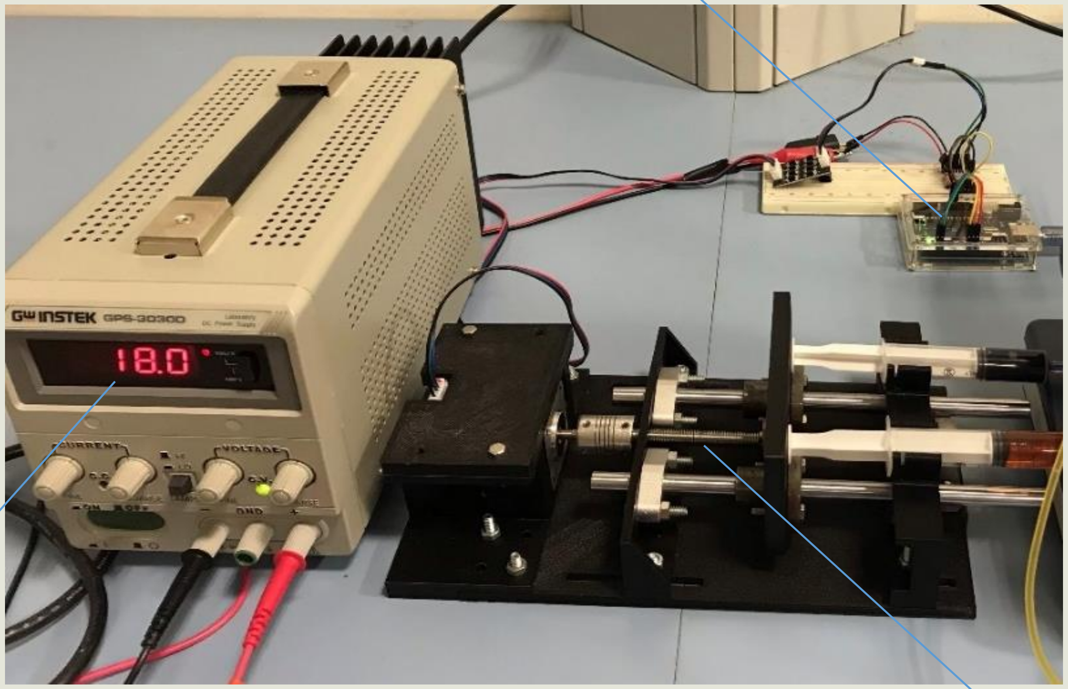

Figure 15:
Syringe pump setup

Methodology – Objective (3)

***Table 3**: Reservoirs' materials*

	Reservoir 1	Reservoir 2	Application
Particle's characteristics	**4210A Polystyrene microspheres** • Diameter = 10 μm	**Magnaflux 14A seeding particle powder** • Diameter = 6 μm	
Mixing (1)	Distilled water	Alcohol	Inexpensive solvent - Cosmetics - Drugs
Mixing (2)	Distilled water	Brine	Saline solution - Sinus/ eyes rinse - Cleaning wounds
Mixing (3)	Alcohol	Brine	Dehydrating alcohol - Oil extraction - Biodiesel production - Human wound antiseptic