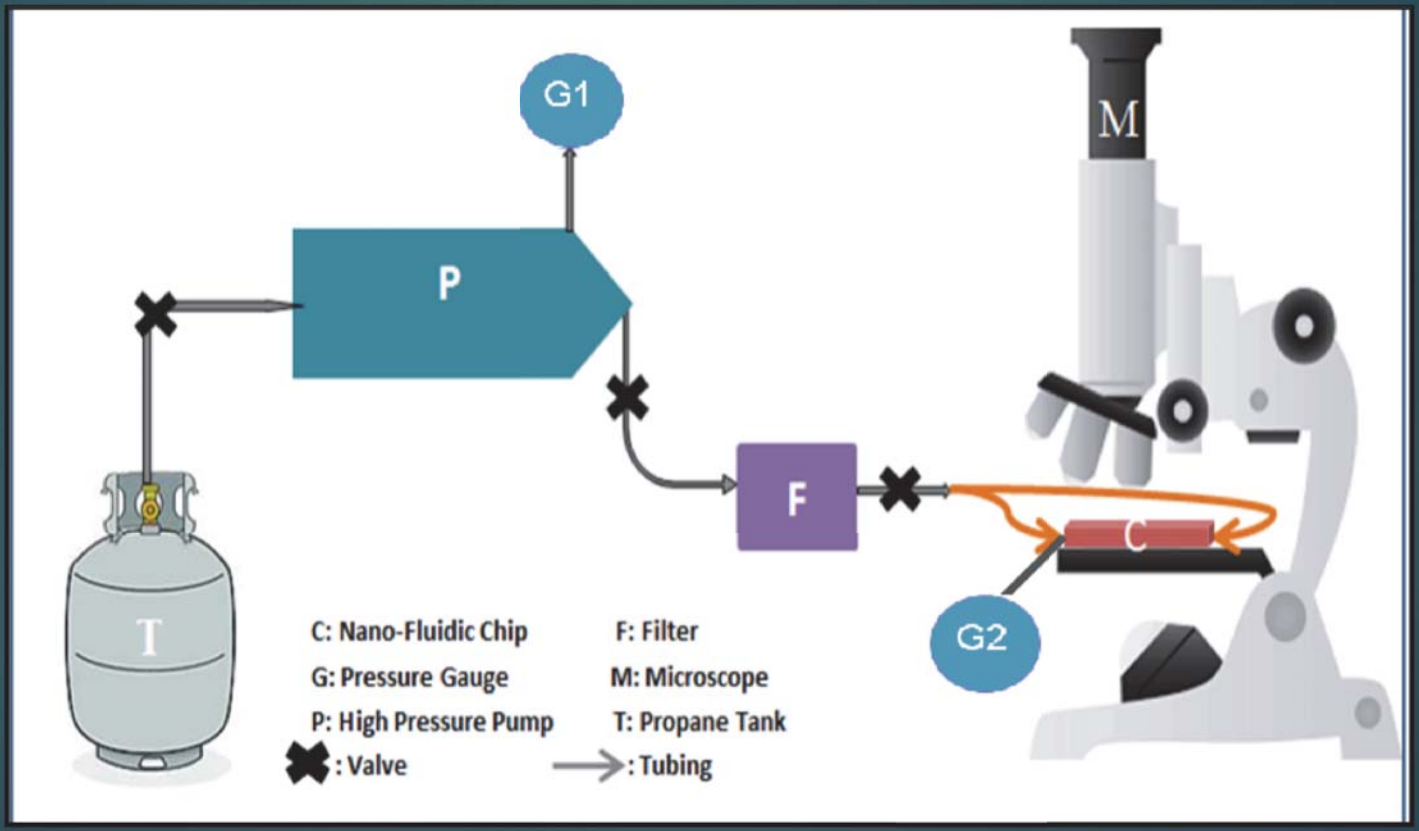
Optically Measuring Pressure in Micro-Fractures

- Project Summary
- Approach
- Tests
- Calculations
- Results
- Next Steps

PROJECT SUMMARY

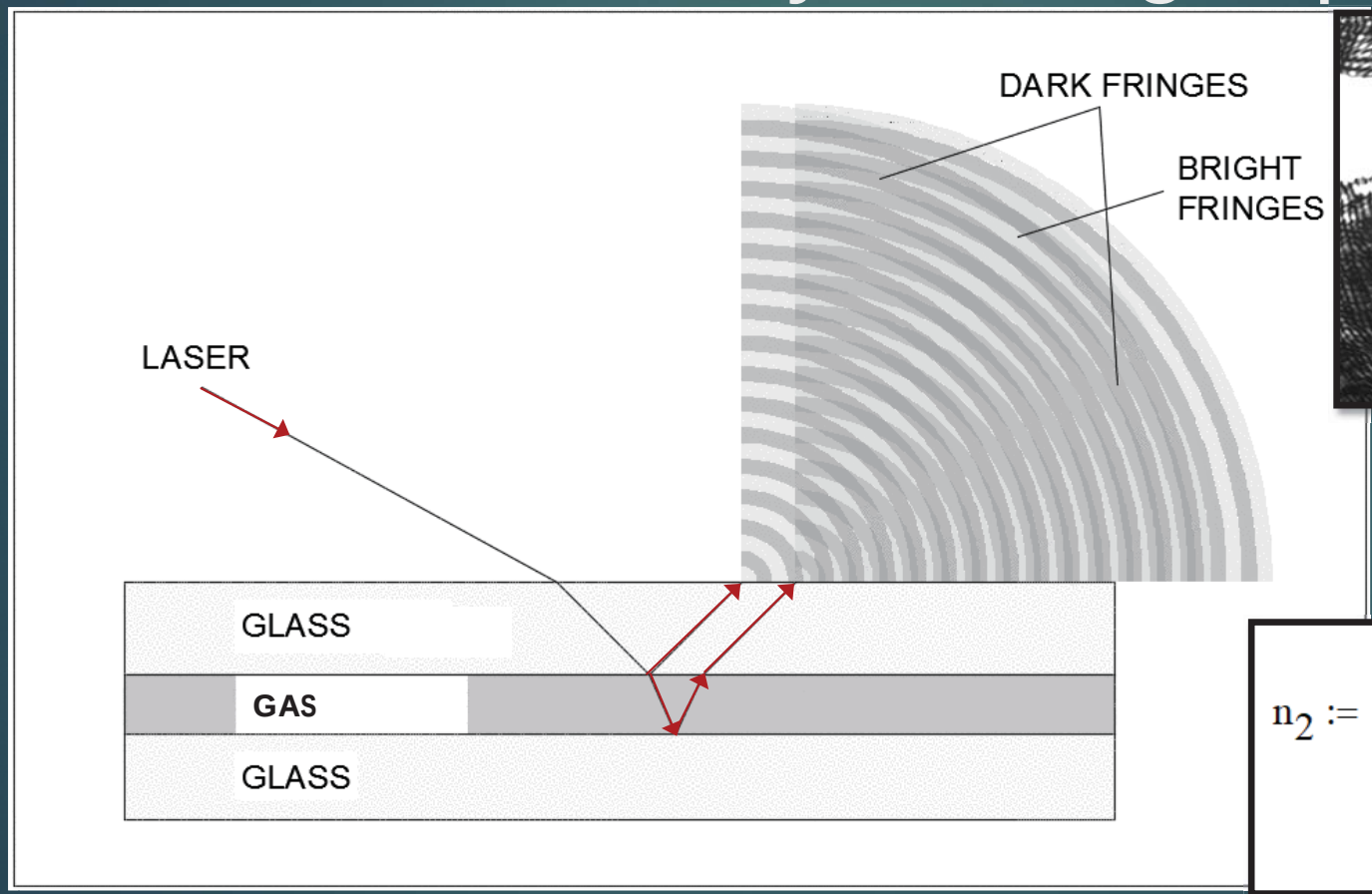
“Phase Behavior in Nanopores”

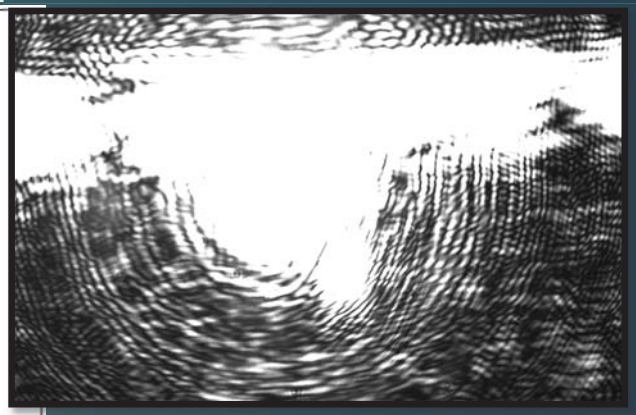
Elham Parsa Ph.D.



APPROACH

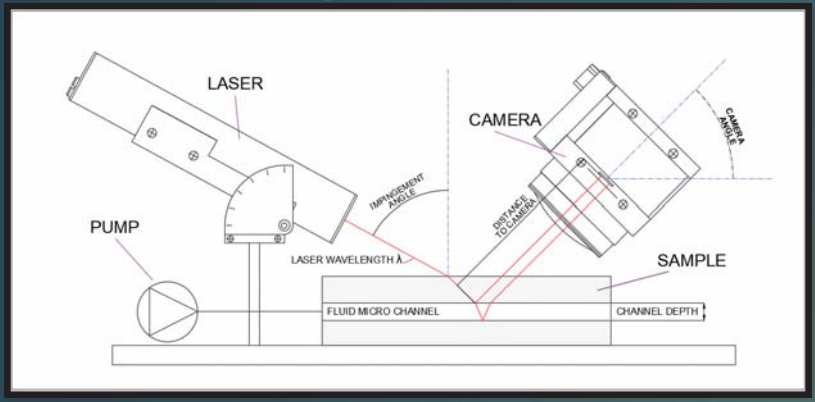
Measuring Pressure Non-Intrusively Using Laser Interferometry for single-phase



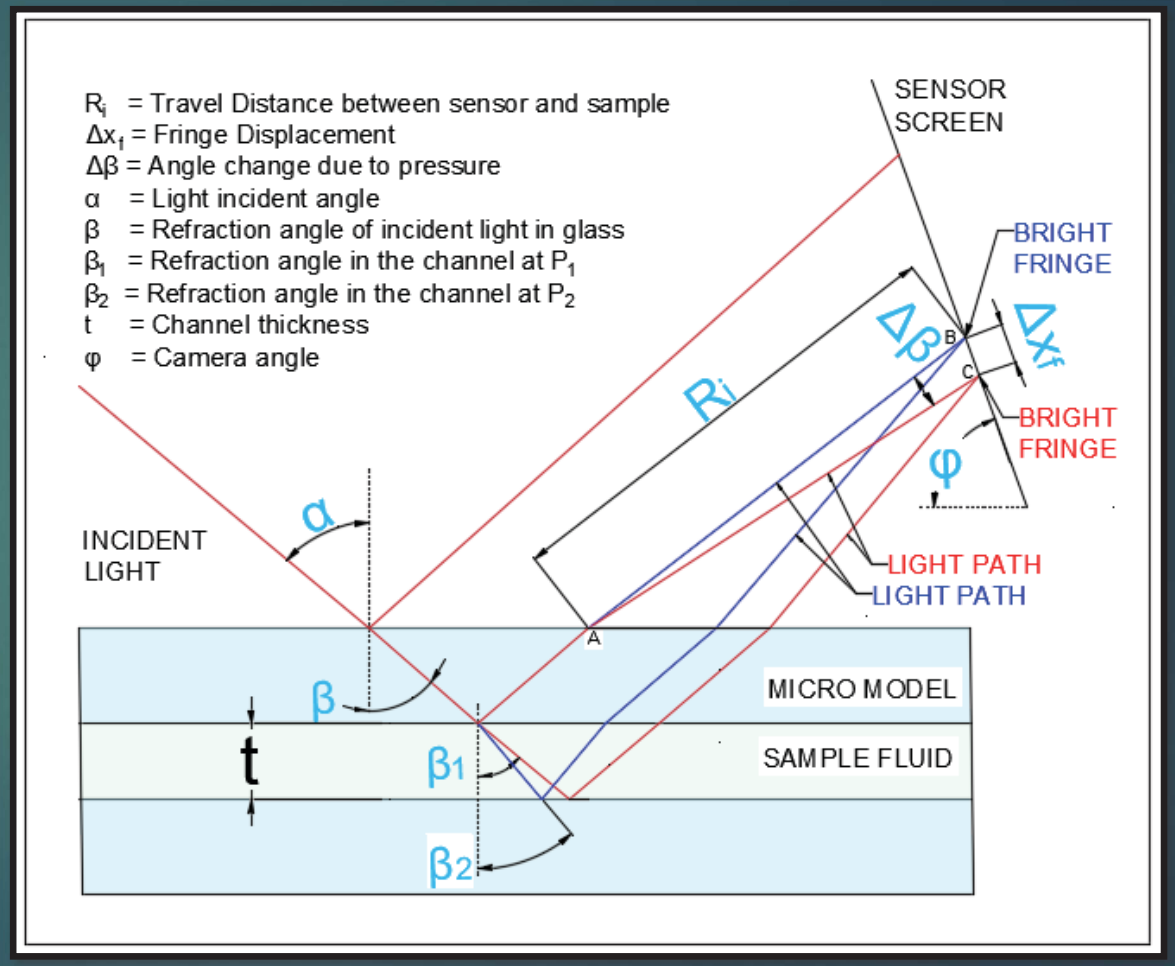


$$n_2 := \frac{n_1 \cdot \sin(\beta_1)}{\sin\left(\beta_1 - \operatorname{asin}\left(\frac{\sin(\phi) \cdot \Delta x_f}{R_i}\right)\right)}$$

Components & Parameters:



$$n_2 := \frac{n_1 \cdot \sin(\beta_1)}{\sin\left(\beta_1 - \operatorname{asin}\left(\frac{\sin(\phi) \cdot \Delta x_f}{R_i}\right)\right)}$$



Refractive index calculation

$$n_2 := \frac{n_1 \cdot \sin(\beta_1)}{\sin\left(\beta_1 - \operatorname{asin}\left(\frac{\sin(\phi) \cdot \Delta x_f}{R_i}\right)\right)}$$

n : Refractive index, Pressure Dependent,
β_1 : Refraction Angle at Initial Pressure, Pressure Dependent,
ϕ : Camera Angle ,
Δx_f : Fringe Displacement,
R_i : Distance between camera sensor and sample chip,

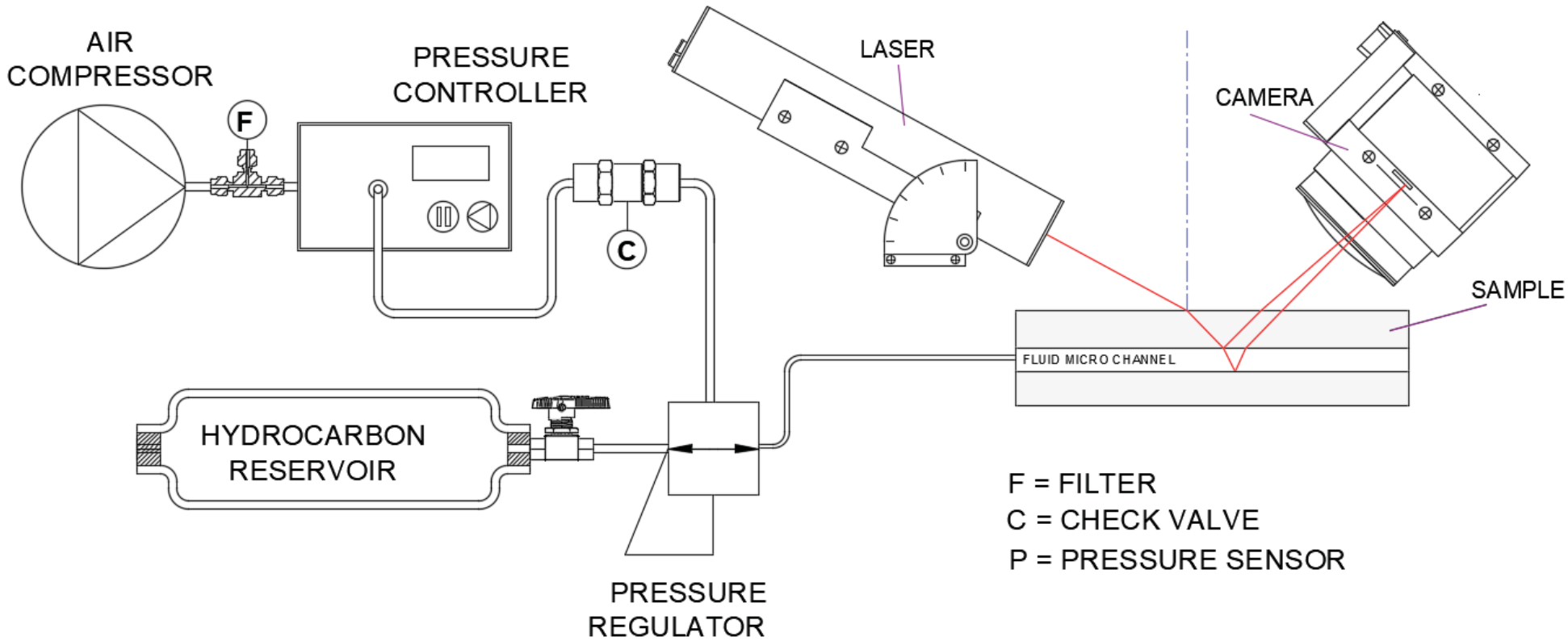
Pressure Equation

$$P = \frac{n^2 - 1}{n^2 + 2} \cdot \frac{3}{4} \cdot \frac{z \cdot R_u \cdot T}{\alpha p \cdot \pi \cdot N_A}$$

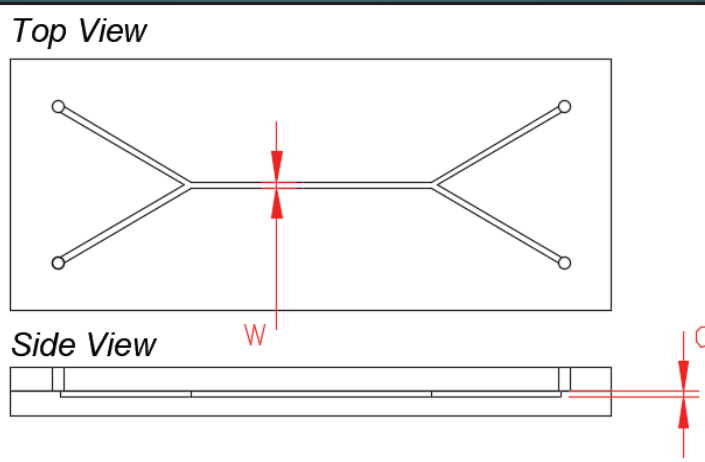
n : Refractive index,
z : Compressibility factor, Pressure Dependent
Ru : Universal gas constant,
T : Temperature,
N_A : Avogadro's number,
αp : Polarizability volume, Pressure Dependent

TESTS

PRESSURE CONTROL SCHEMATIC



Calibration

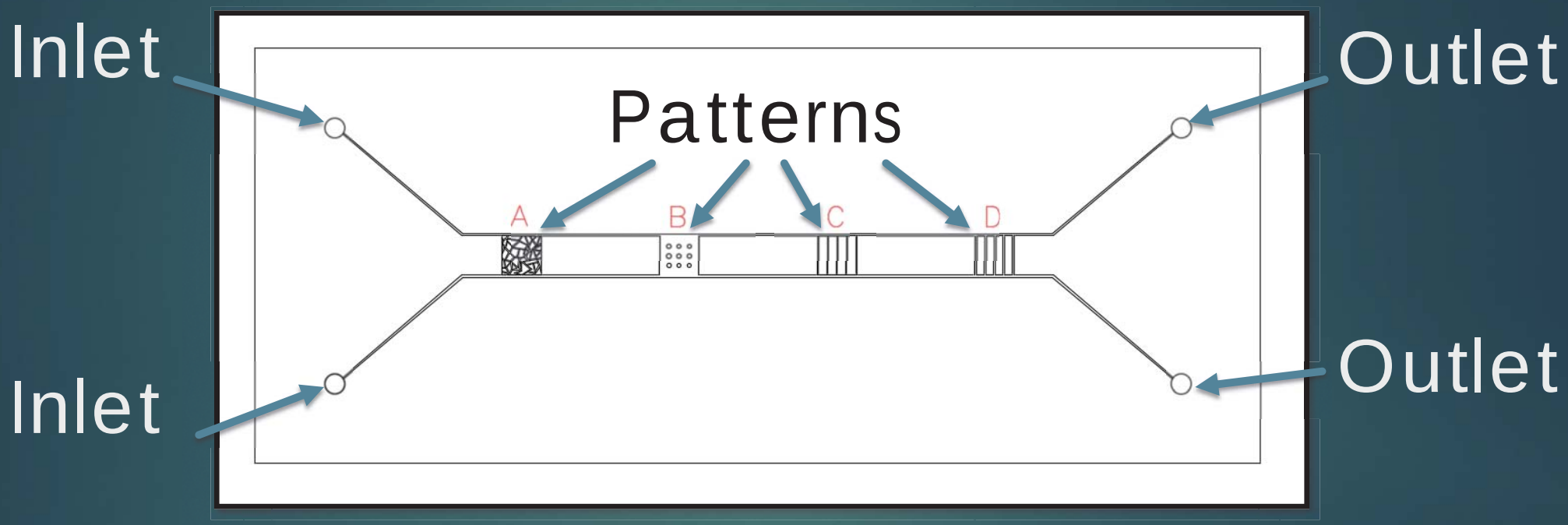


MODELS	d_1: 100um	d_2: 50um	d_3: 25um	d_4: 10um
w_1: 100um	A	B	C	
w_2: 50um		D	E	
w_3: 25um			F	G

w: channel width

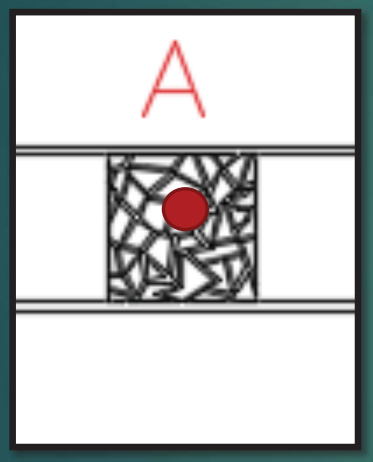
d: channel depth

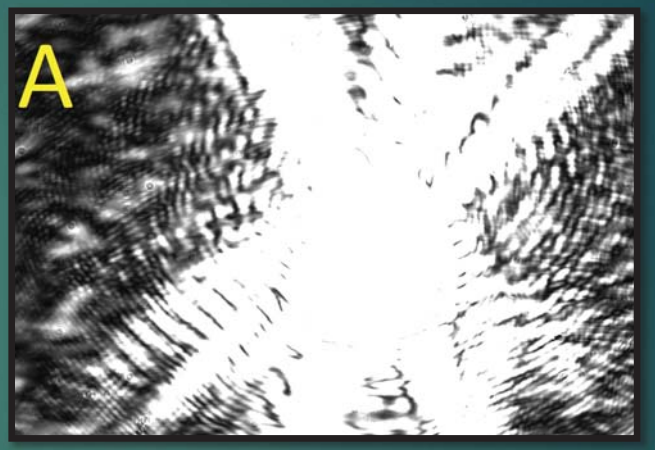
Microfluidic Chip with Geometric Variations



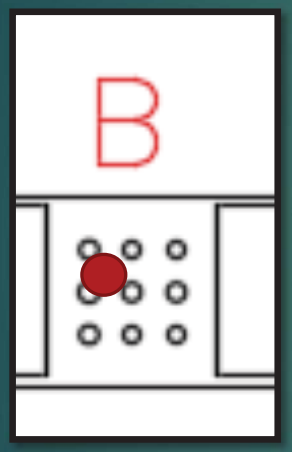
Depth 100 micron
Width 5-100 micron

Reflections from Pattern A:

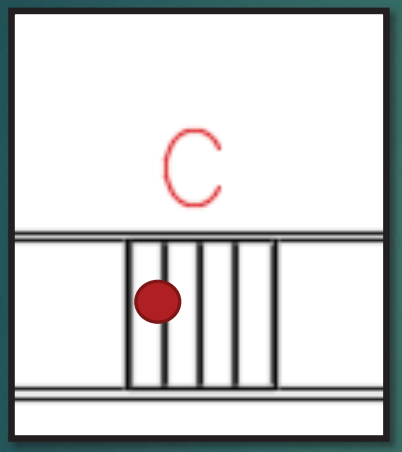


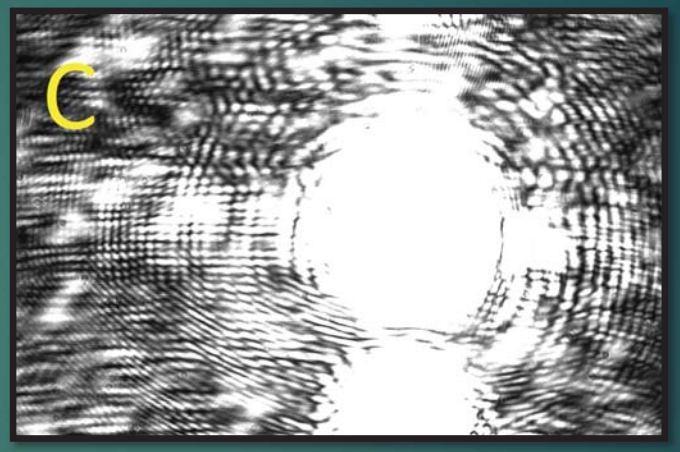


Reflections from Pattern B:

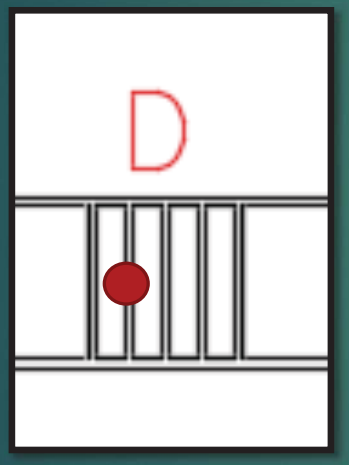


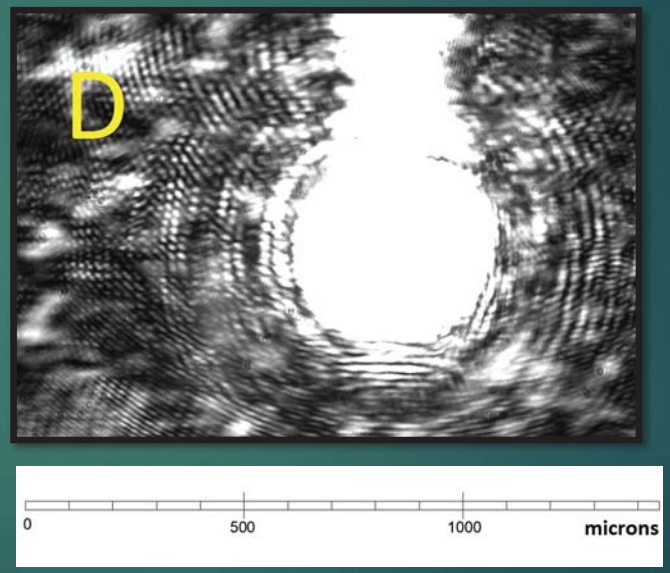
Reflections from Pattern C:



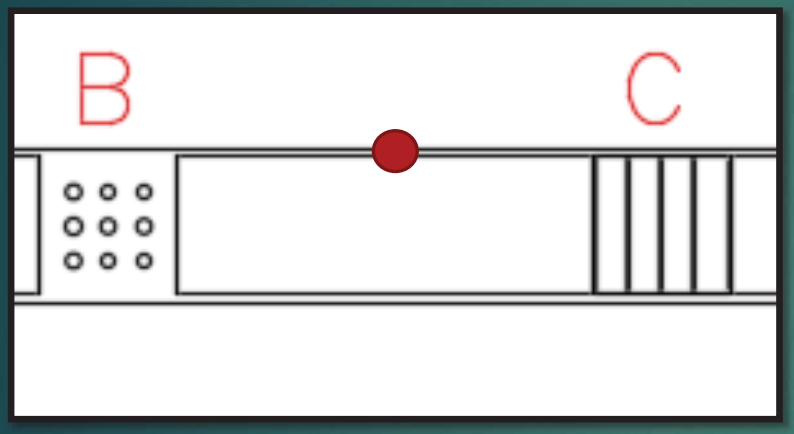


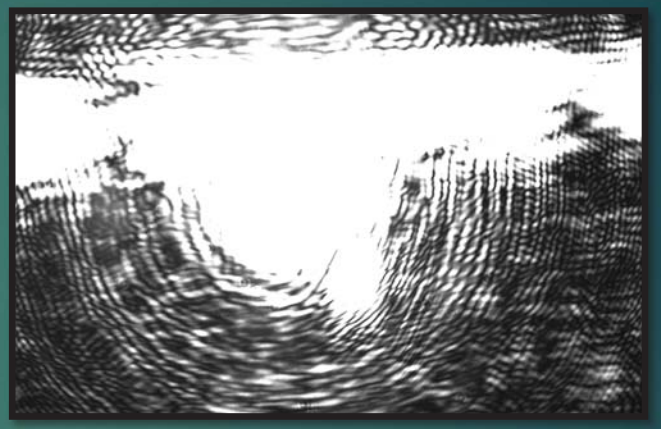
Reflections from Pattern D:

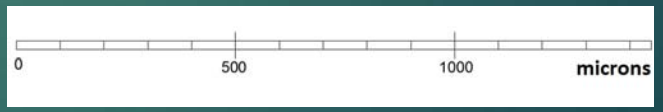




Reflections from Channel B-C:

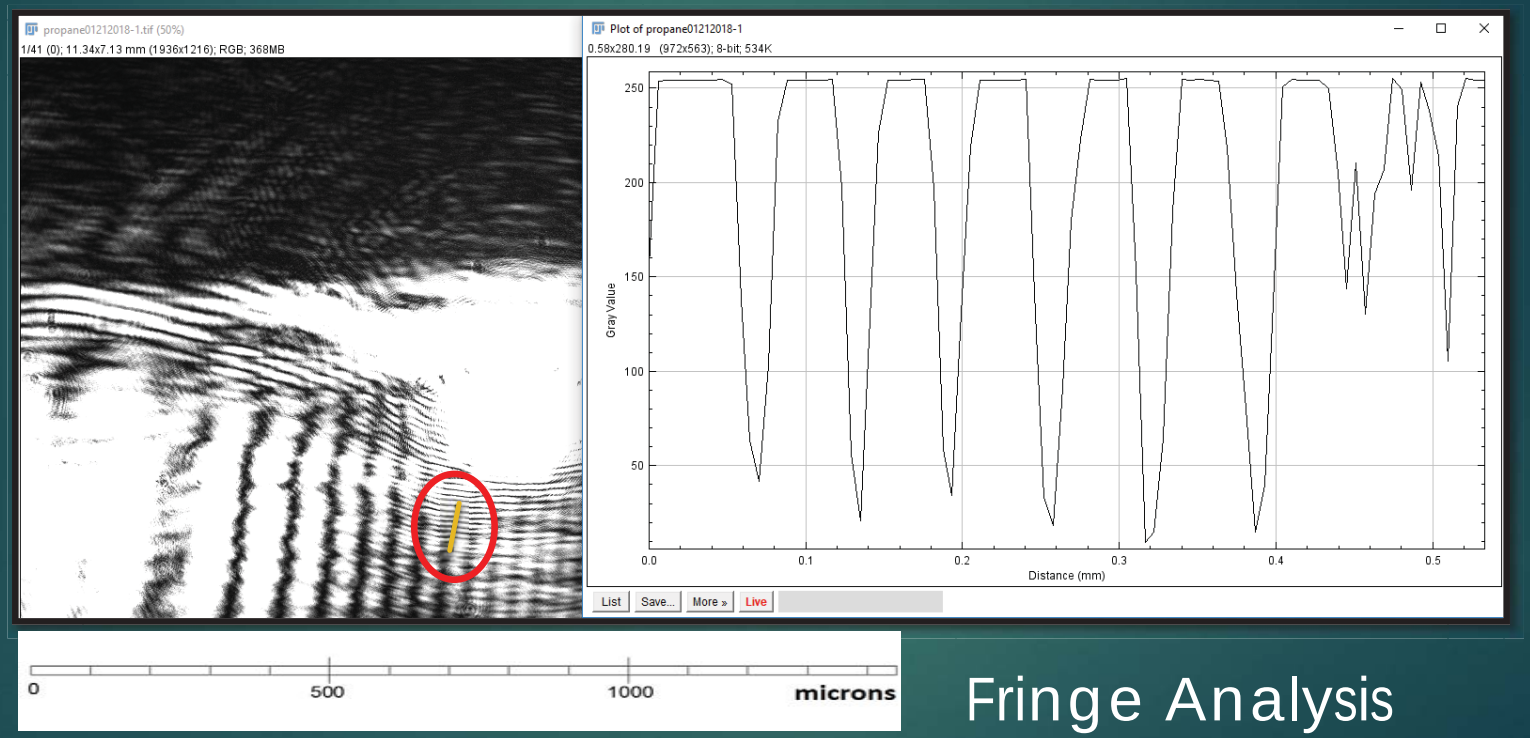






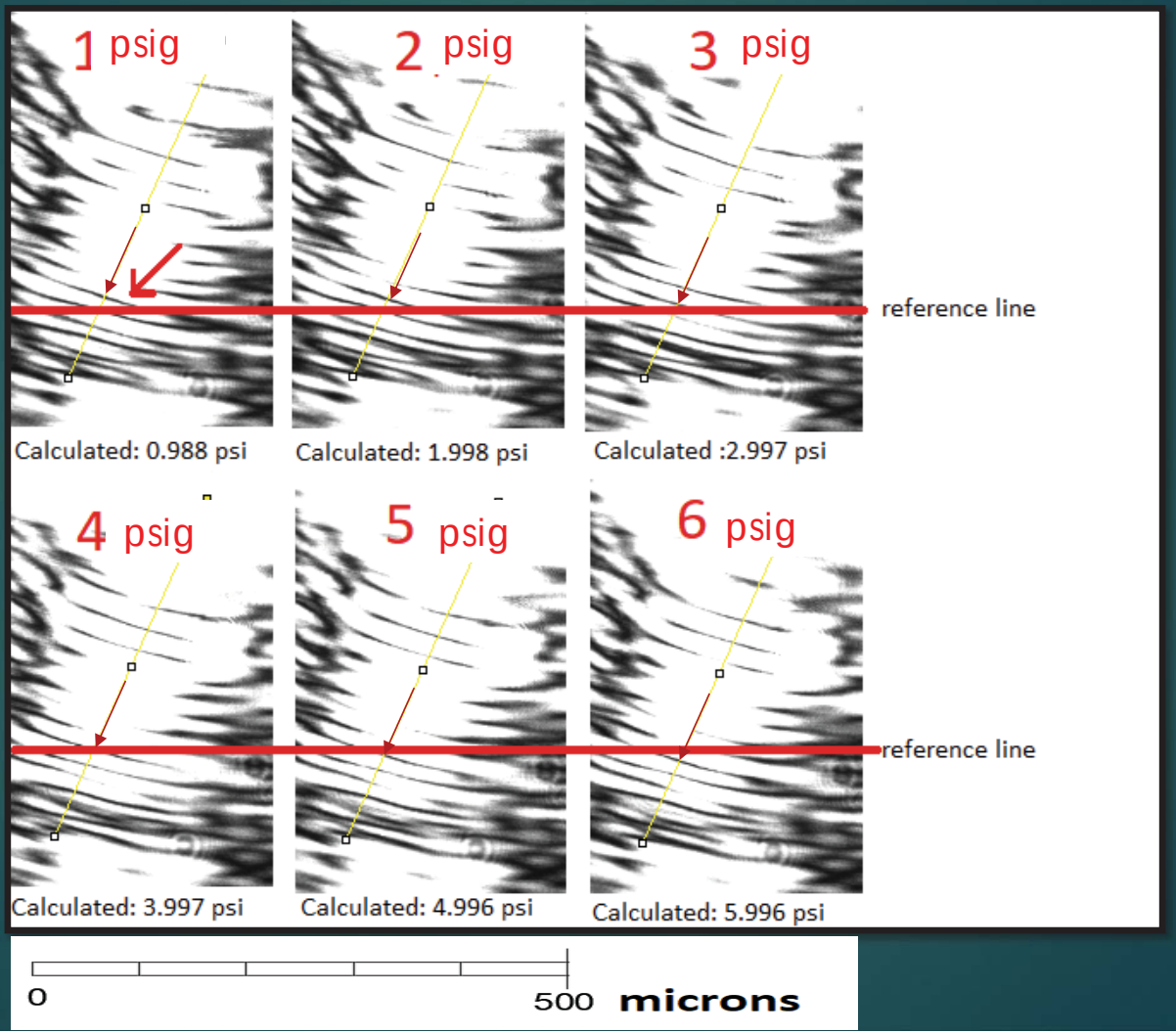
CALCULATIONS

Calculations for Propane:



Fringe Analysis

Pressure Calculations with Matlab:



RESULTS

Calculations for Propane:

Read Pressure at Inlet and Outlet, Psig	Calculated Z Factor	Measured Pressure, Psig	% Error
11.00	0.9879	11.0000	0.0002
21.00	0.9758	21.0011	0.0051
31.00	0.9639	31.0014	0.0045
41.00	0.9520	41.0005	0.0012
51.00	0.9401	51.0005	0.0009
61.00	0.9284	61.0004	0.0007
71.00	0.9167	71.0049	0.0069
81.00	0.9051	81.0005	0.0006
91.00	0.8935	91.0011	0.0012
100.00	0.8832	100.0004	0.0004

T : 19.0 °C, P_{atm} : 0.87 atm

Calculations for Butane:

Read Pressure at Inlet and Outlet, Psig	Calculated Z Factor	Calculated Pressure, Psig	% Error
2.00	0.9978	1.9998	-0.0081
4.00	0.9935	3.9998	-0.0054
6.00	0.9891	5.9998	-0.0028
8.00	0.9848	8.0000	0.0003
10.00	0.9804	10.0001	0.0011
12.00	0.9740	11.9997	-0.0028
14.00	0.9718	14.0001	0.0008
16.00	0.9675	15.9998	-0.0011
18.00	0.9632	18.0000	-0.0001
20.00	0.9589	20.0001	0.0005

T : 19.2 °C, P_{atm} : 0.87 atm

NEXT STEPS

Next Steps

- Publication
- Prototype Development
- DOE Phase II
- New Team Members
- Commercialization Partners

PROTOTYPE DEVELOPMENT

Prototype Objectives

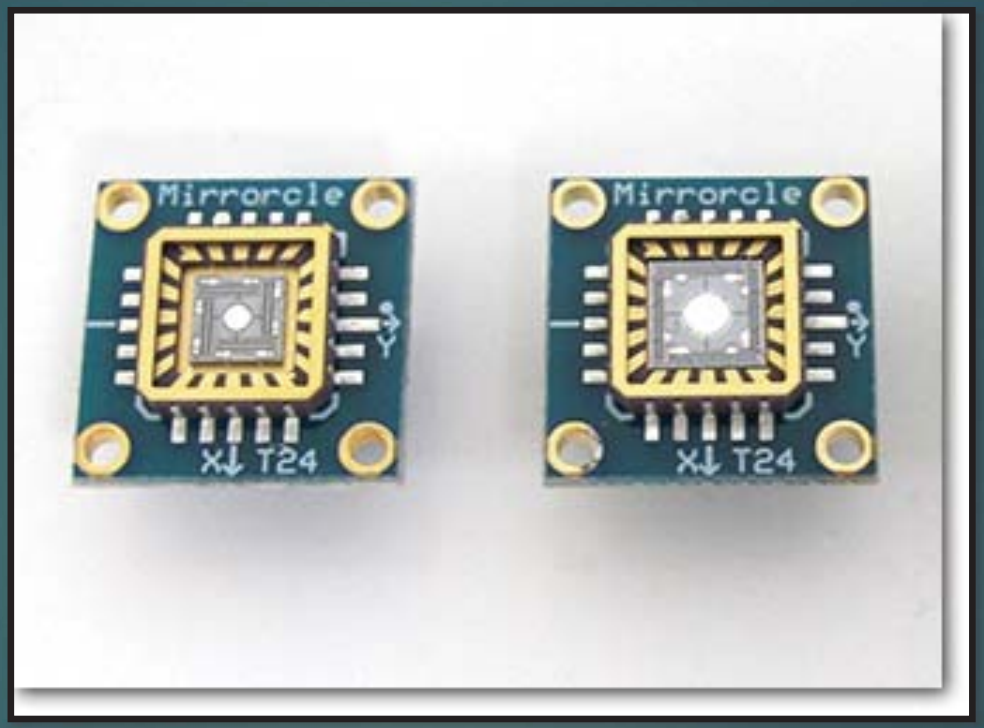
Phase-Change Research:

- Measure Pressure at Point of Phase Change
- Employ Rock on a chip with pore size distribution and map the location and sequence of phase change

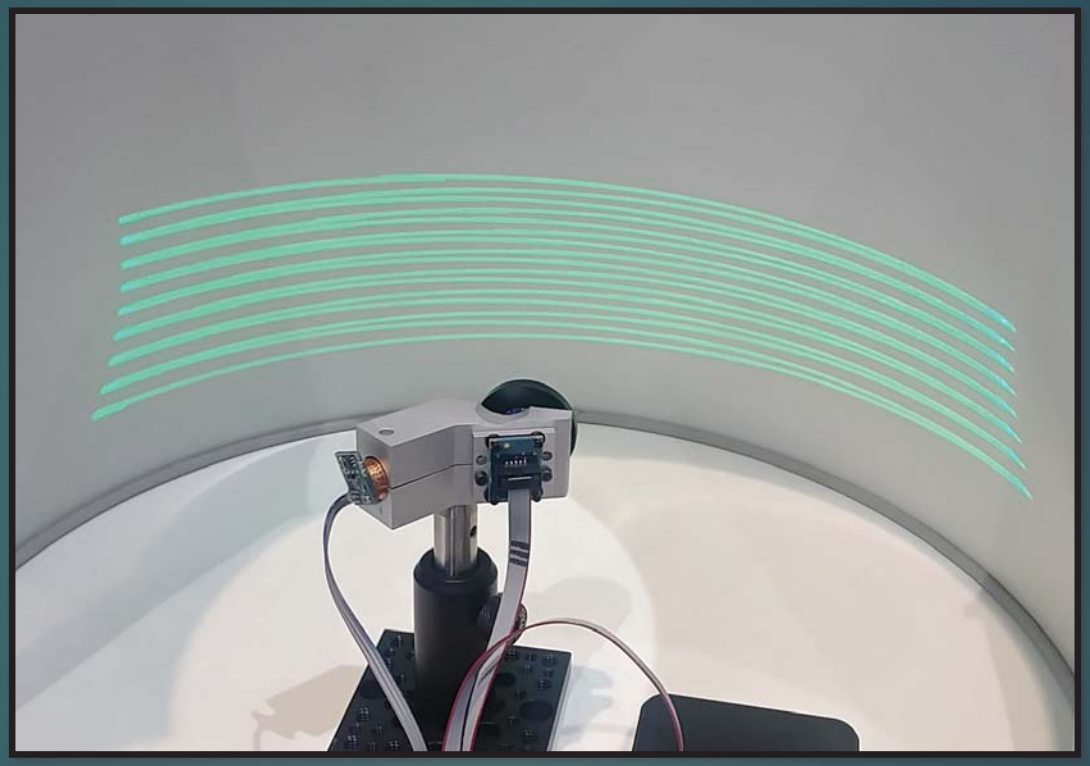
Adaptable Technologies From Photonics

- Scanning Mirrors A Method for Pressure Mapping
- Micro Temperature Control and Measurement

PRESSURE MAP PROBING



MEMS Mirror



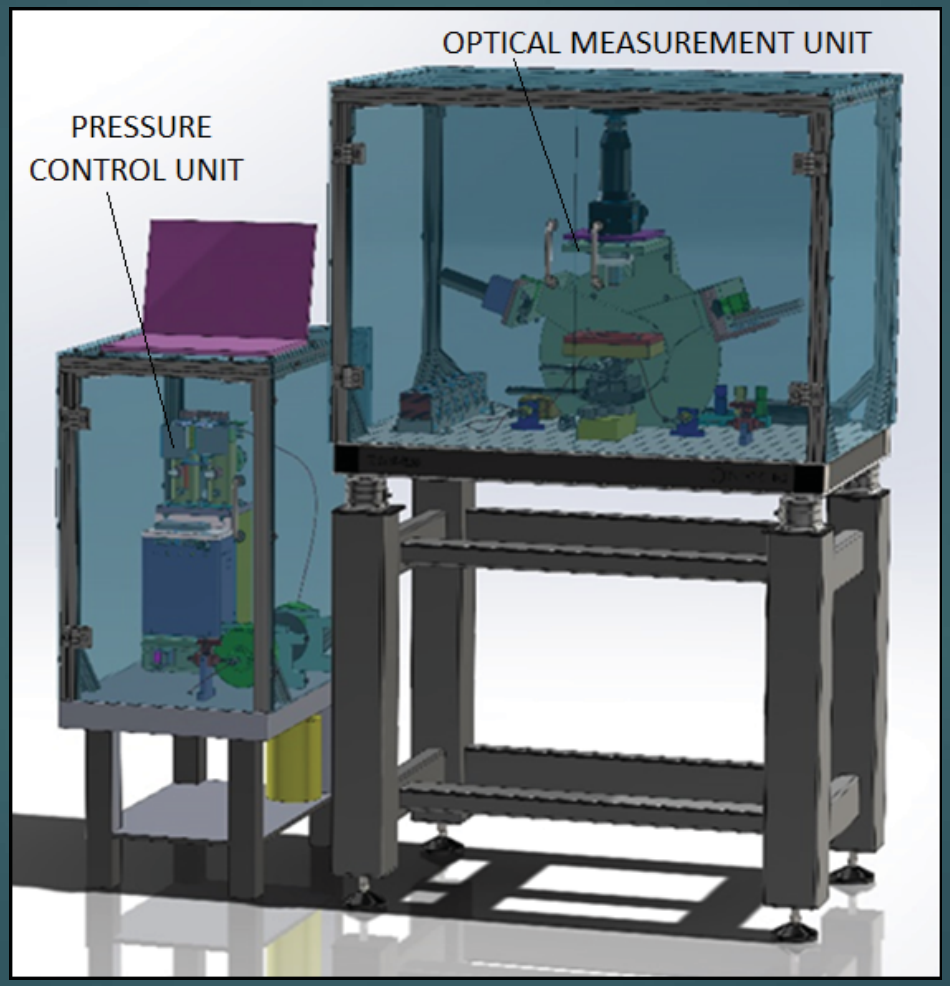
Programmable Area Scanner

Prototype Objectives

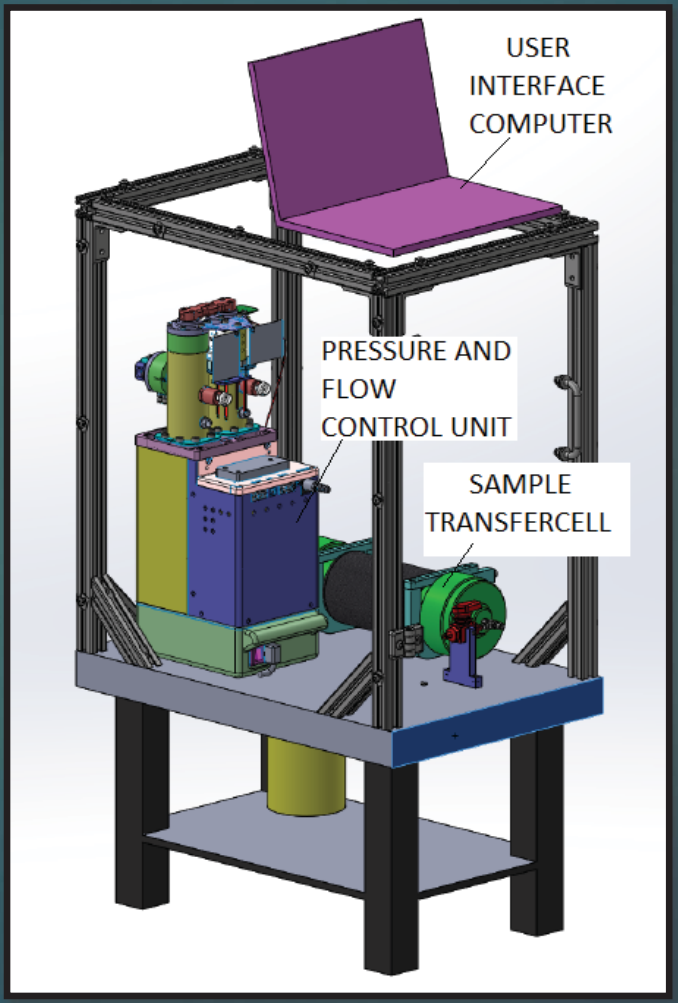
Improving the Equipment

- High Pressure Control & Measurement
- High Temperature Control & Measurement
- Alignment Automation

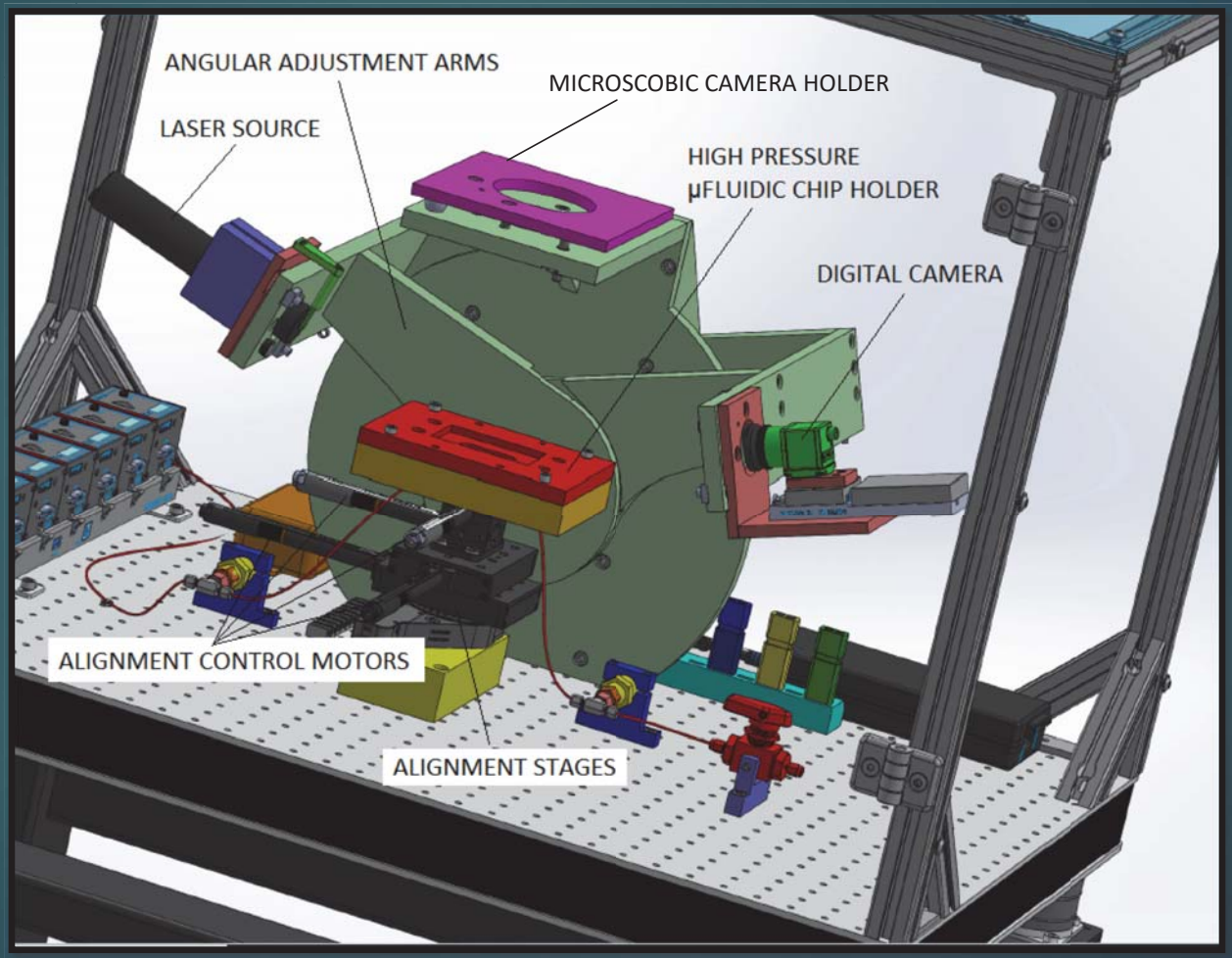
Prototype



Prototype


USER
INTERFACE
COMPUTER
PRESSURE AND
FLOW
CONTROL UNIT
SAMPLE
TRANSFERCELL

Prototype


ANGULAR ADJUSTMENT ARMS
MICROSCOBIC CAMERA HOLDER
LASER SOURCE
HIGH PRESSURE
μFLUIDIC CHIP HOLDER
DIGITAL CAMERA
ALIGNMENT CONTROL MOTORS
ALIGNMENT STAGES

Thank You

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