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# STUDY OF THERMO-MICROFLUIDIC PHENOMENA IN MICROCHANNELS

J. KOVCHAR, A. BLIDIA, M. BARTHES, F. LANZETTA, M. DE LABACHELERIE



## CONTEXT AND OBJECTIVES OF THE STUDY

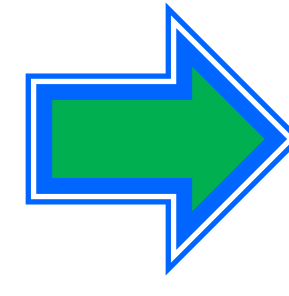
### Context of the study

Miniaturization of a Stirling engine for low temperature recovery and energy conversion → Energy losses higher than predicted by the theory

Effect of roughness and 90° angle bends on flow in channel with  $D_h < 1\text{mm}$  ?

### In the literature

- Alternate flow at sub-millimetric scale → Almost nothing
- Permanent flow at sub-millimetric scale → Conflicting results

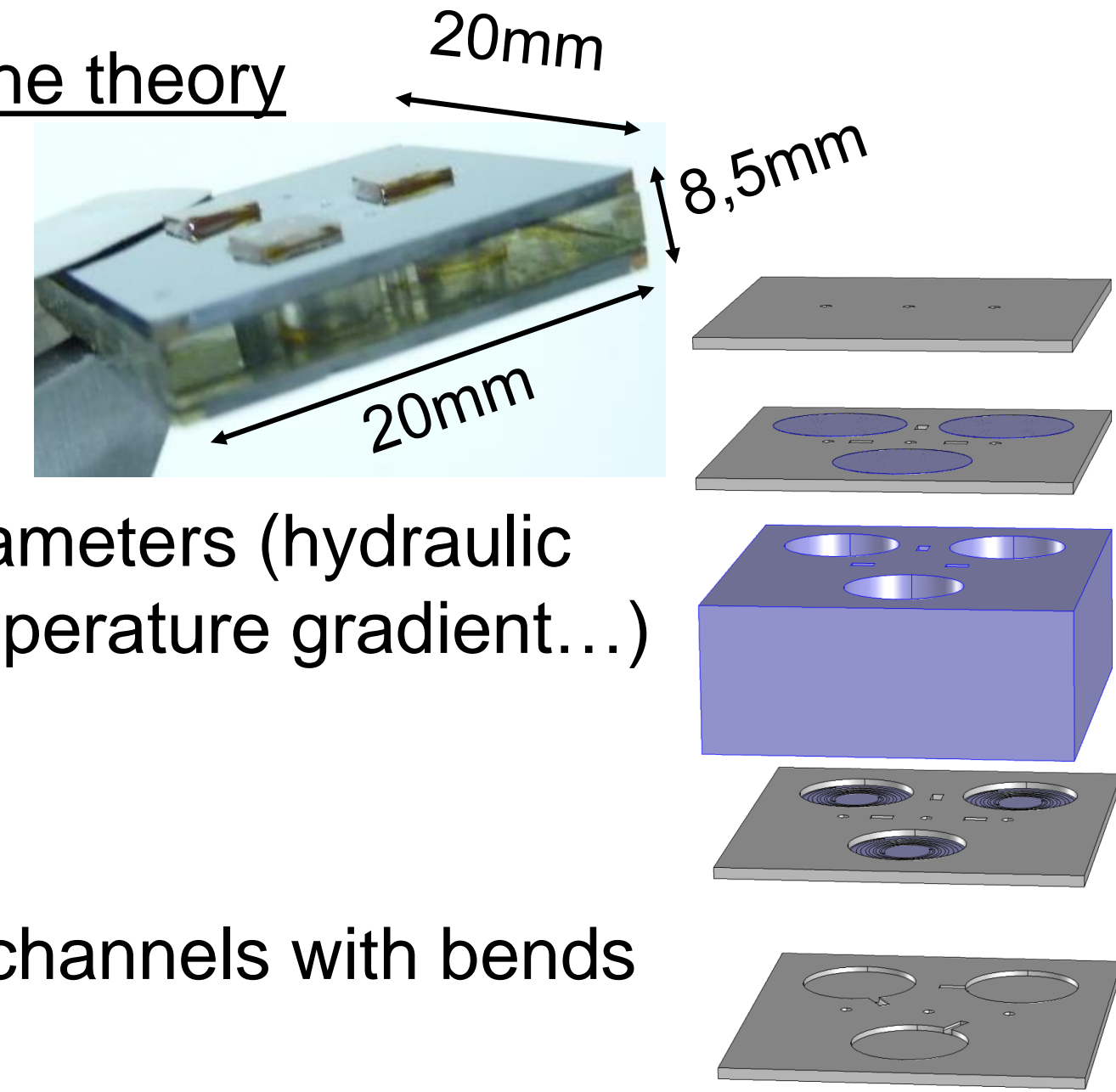


### Objectives:

Influence of geometrical and thermo-fluidic parameters (hydraulic diameter ( $D_h$ ), aspect ratio, compressibility, temperature gradient...)

- Permanent flow
- Alternate flow

→ Investigation for straight channels and channels with bends



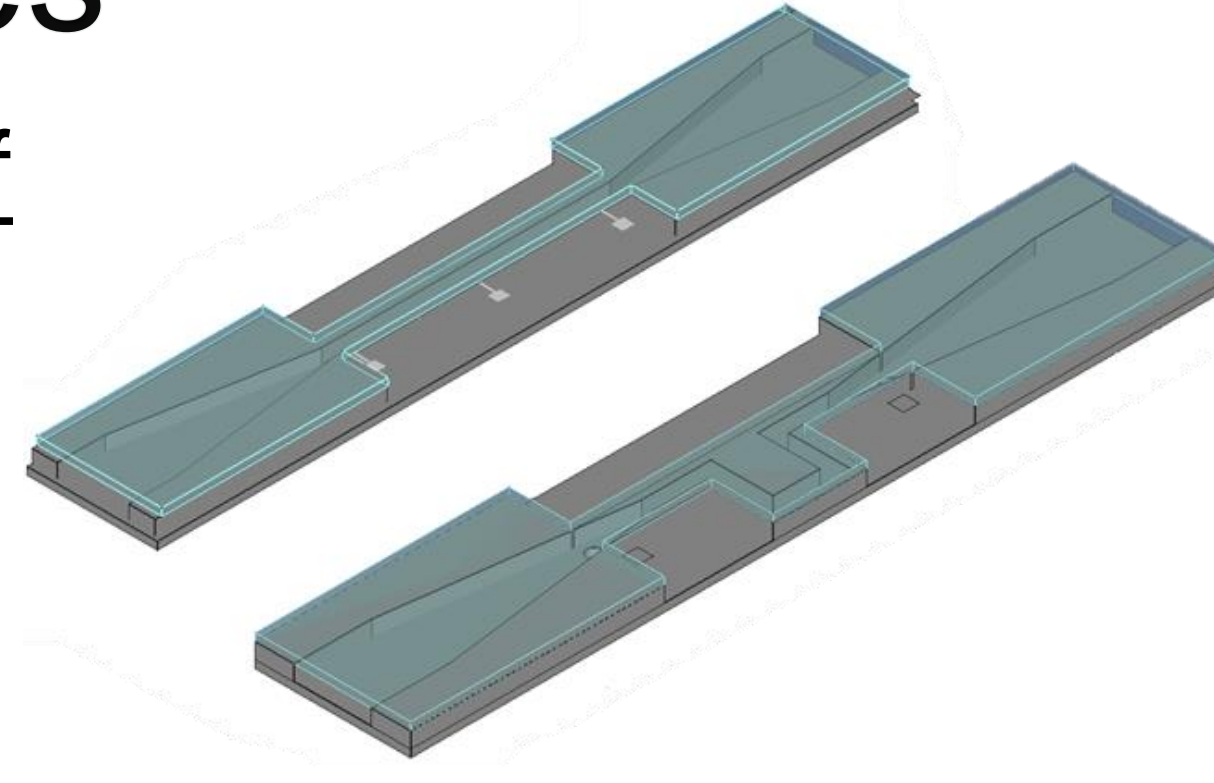
Roughness	Compressibility
Wu <i>et al.</i> 1983, Cryogenics.	Ying-Tao <i>et al.</i> 2002, Chinese Physics.
Turner <i>et al.</i> 2004, Journal of Heat Transfer.	
Yuan <i>et al.</i> 2016, Chinese Journal of Aeronautics.	Morini <i>et al.</i> 2009, Microfluid and Nanofluid.
Shen <i>et al.</i> 2006, Energy conversion and management.	Yang <i>et al.</i> 2012, Experimental Thermal and fluid science.

## EXPERIMENTAL SETUP AND NUMERICAL SIMULATIONS

### Experimental setup and microfabrication of the devices

Design of the samples for the study of major and minor losses:

Straight channels / Channels with bends

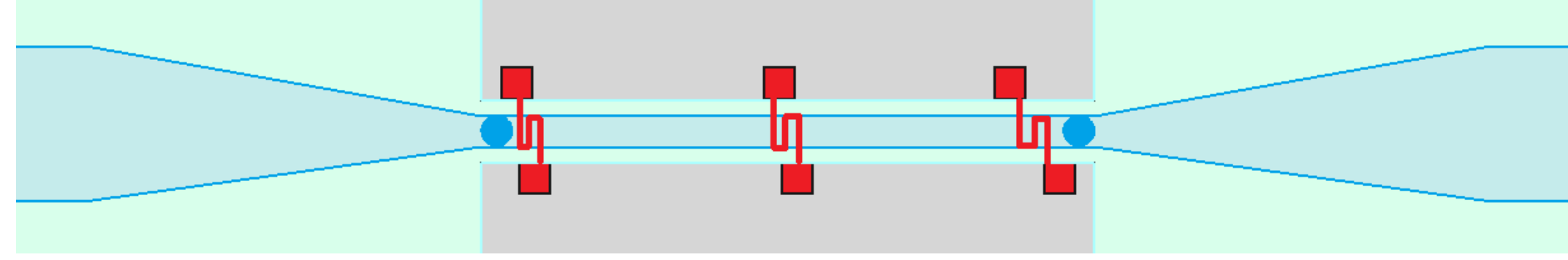


### Measurements:

- Pressure (inlet / outlet / inside the channel)
- Temperature (inlet / outlet / inside the channel)

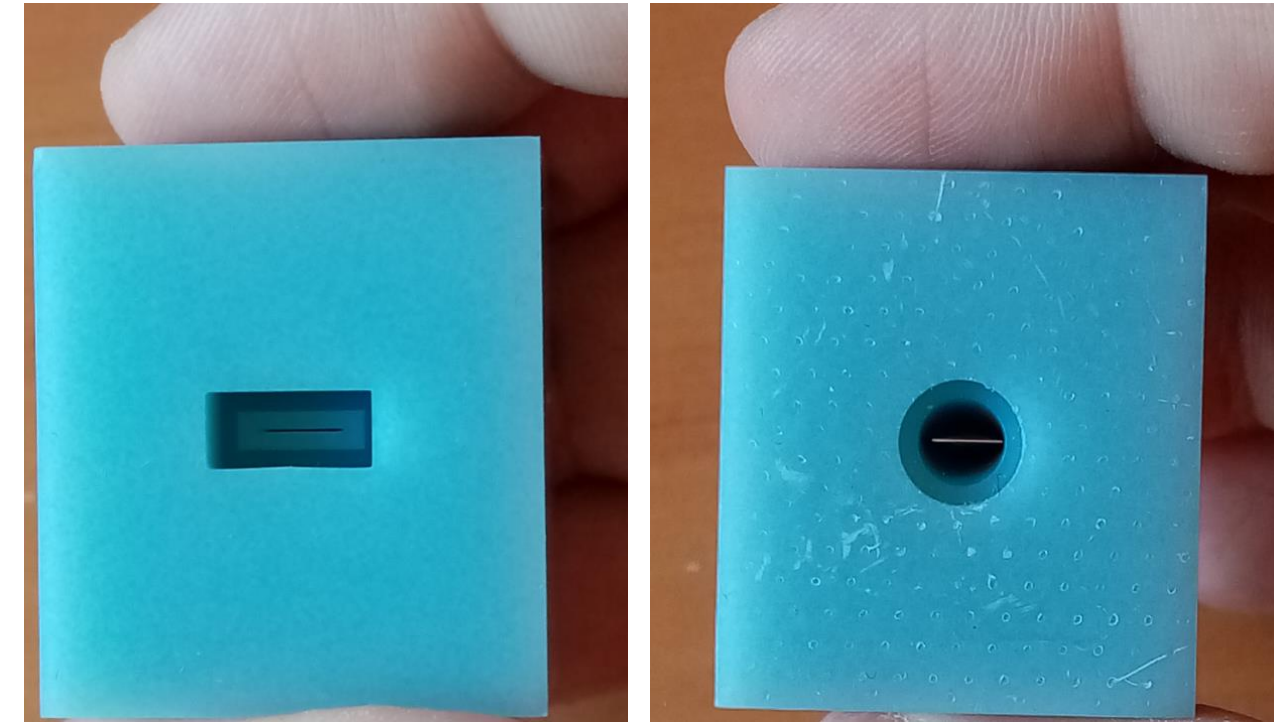
➢ Mass flow sensor

➢ Velocity



### Adaptation section part ①:

- Devices connected to microchannels
- Adapt square/rectangular cross-section to circular cross-section



### Microfabrication :

#### Fabrication of the channel

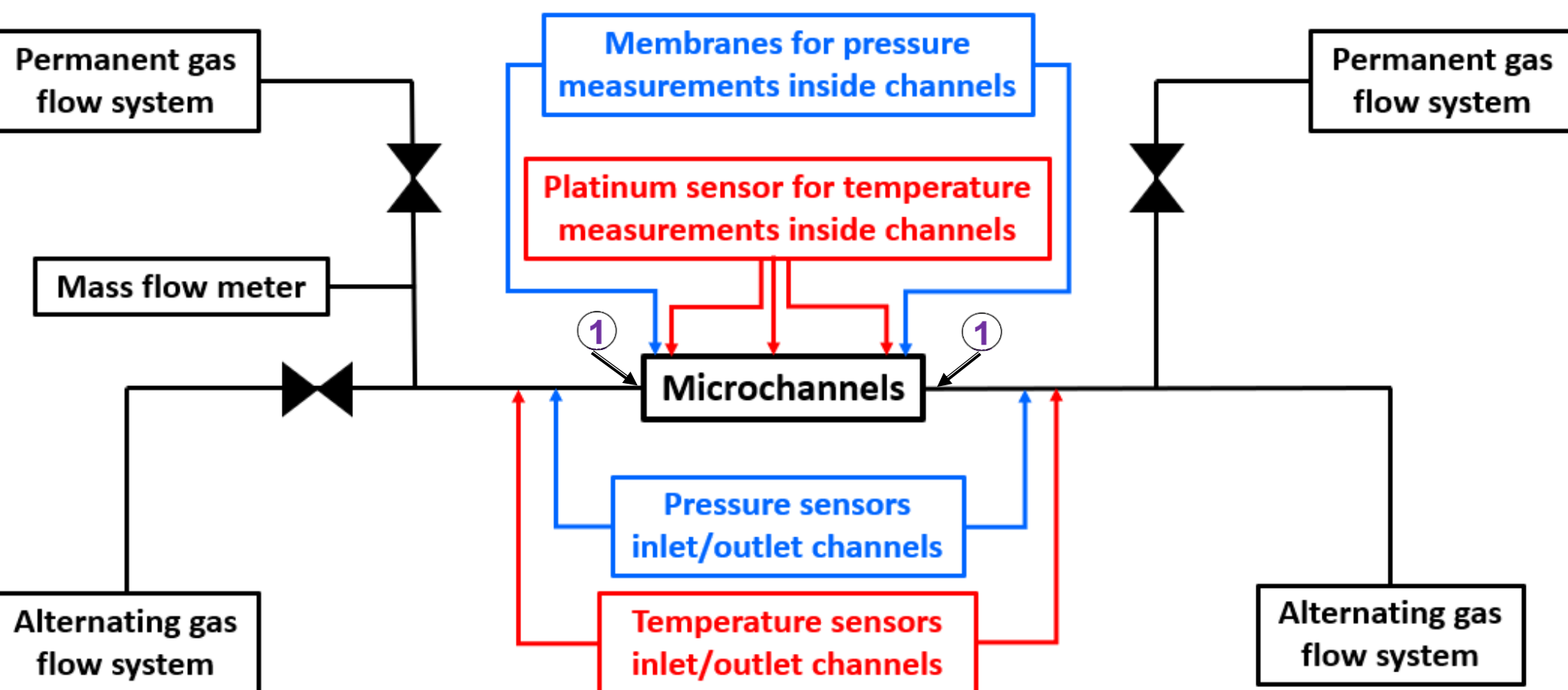
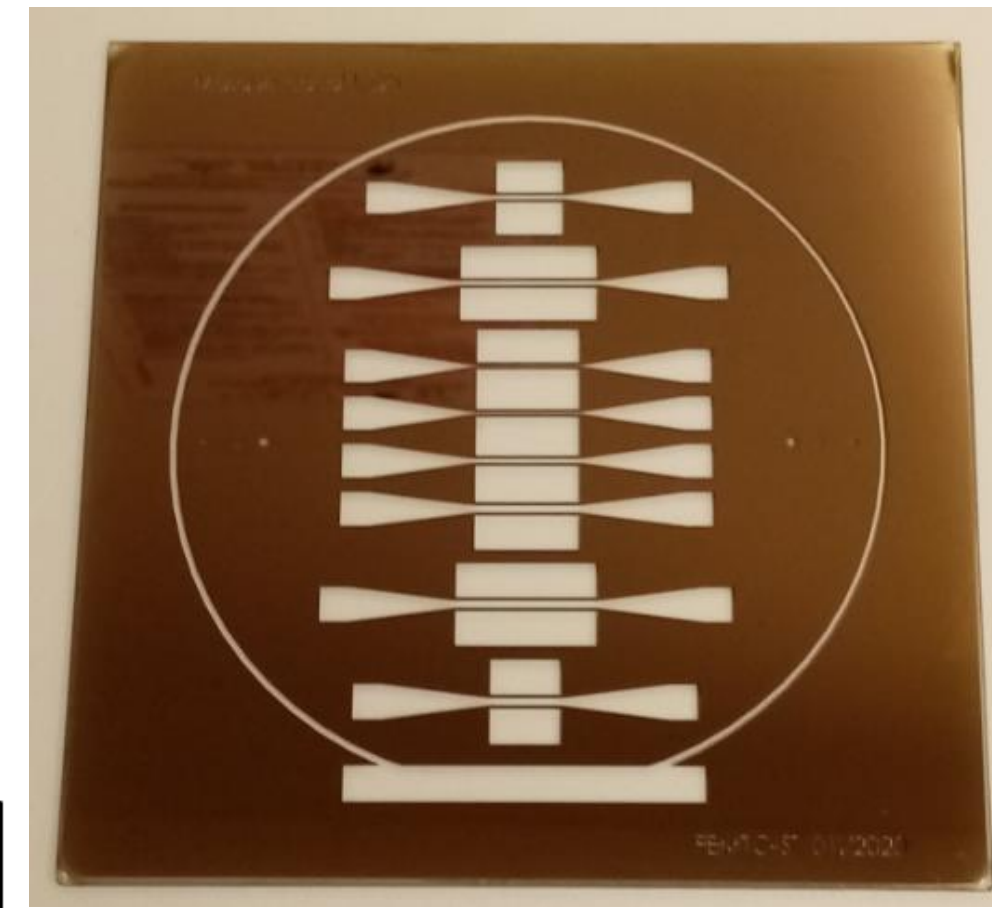
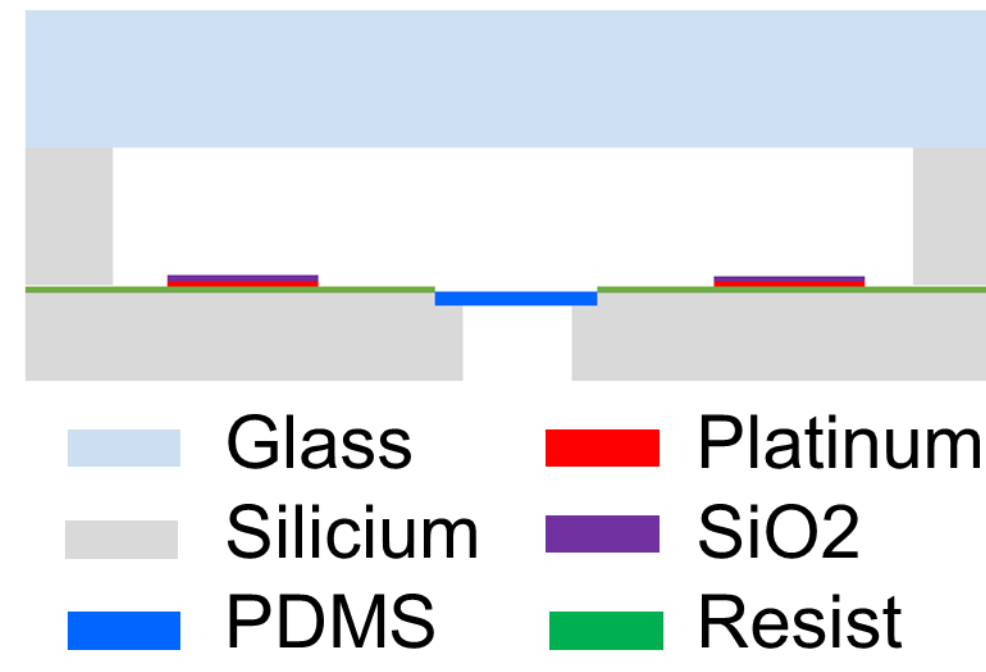
→ Etching on the whole wafer

#### Sensors

- Platinum sensor : Platinum deposition
- Membrane fabrication : Etching and deposition of PDMS
- Etching on back side → optical access

#### Assembly of the device

- Bonding of the Glass and top Silicium wafers
- Bonding of the top Silicium and bottom Silicium wafers

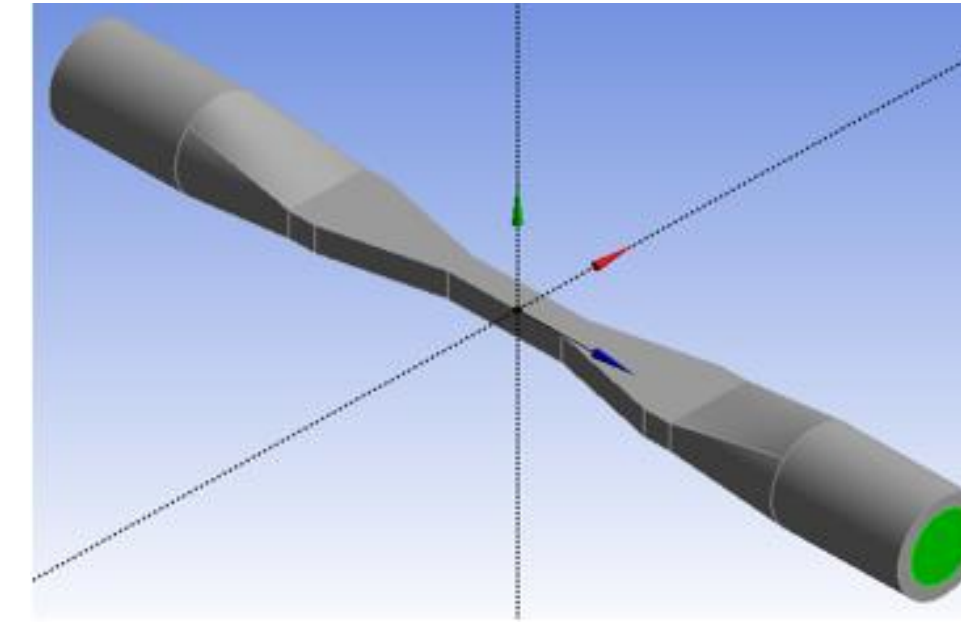


### Geometry and boundary conditions of simulation

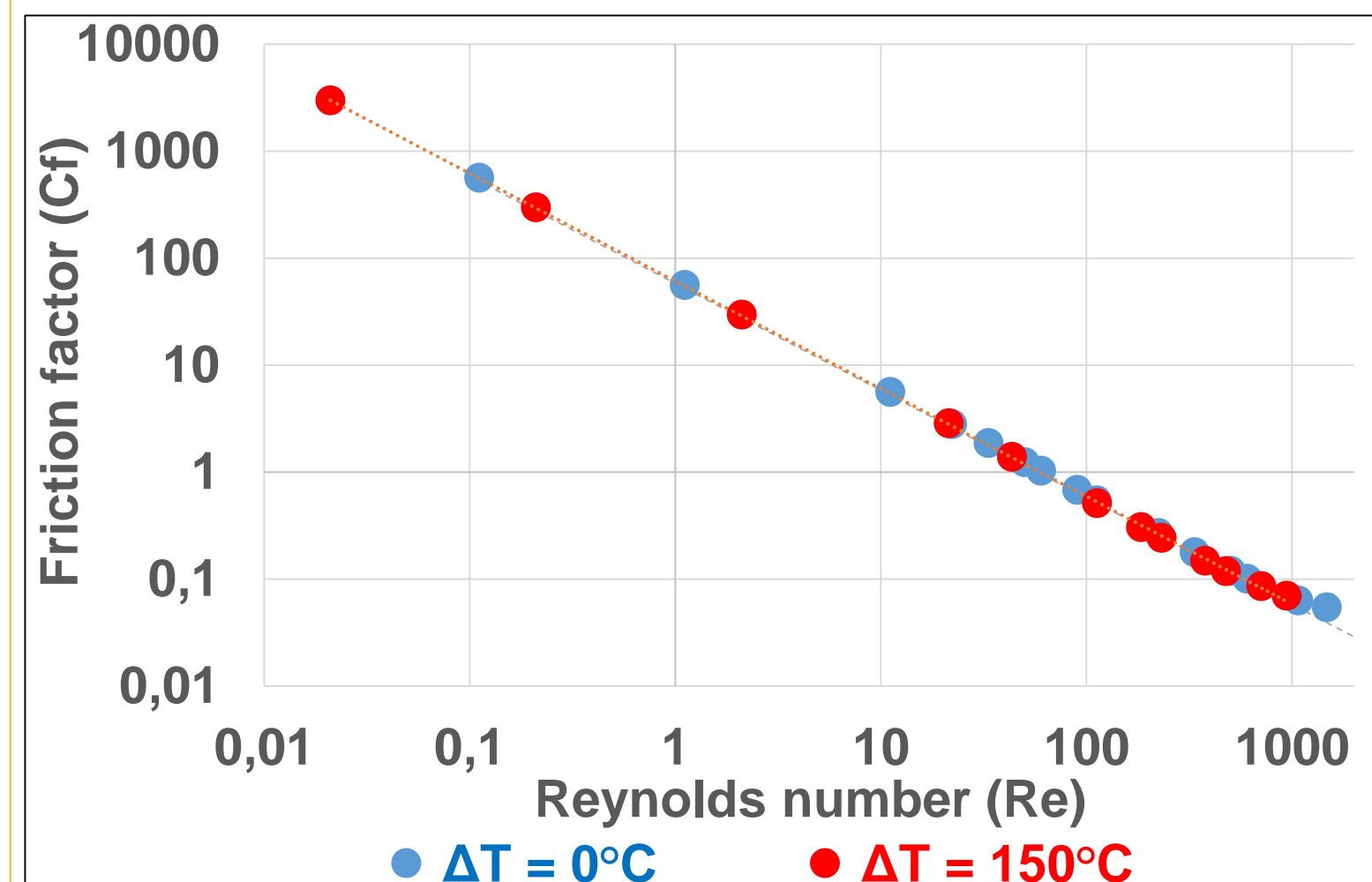
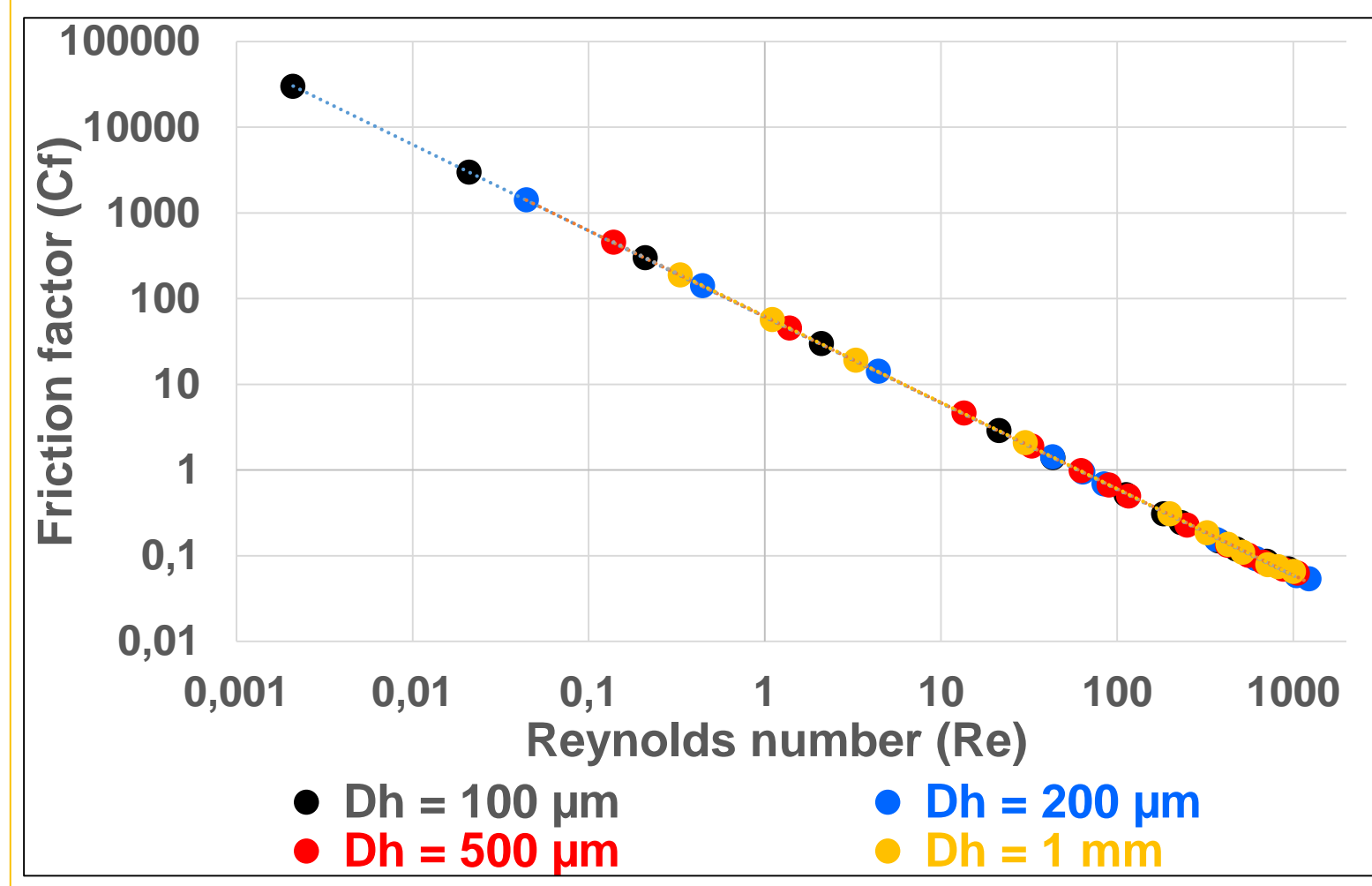
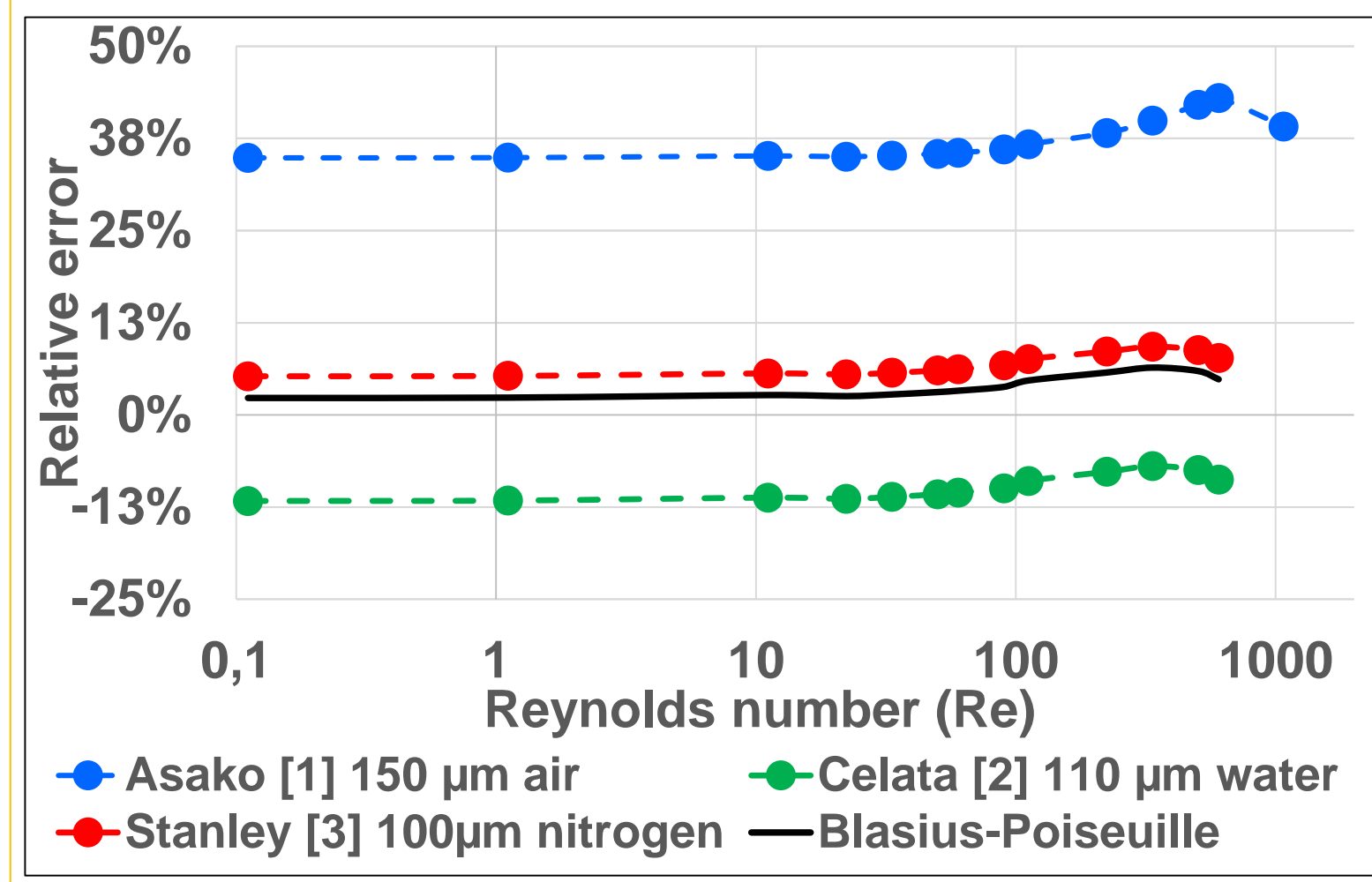
Numerical simulation for microchannels and adaptation part with different  $D_h$   
→ With / Without temperature gradient between the channel's inlet and outlet

#### Boundary conditions:

- Inlet velocity and temperature (300K – 450K)
- Outlet pressure ( $P_{atm}$ ) and temperature (300K)
- Adiabatic wall



### Numerical results



[1] Y. Asako, K. Nakayama, T. Shinozuka, 2005, International Journal of Heat and Mass Transfer.  
 [2] R.S. Stanley, 1997, Two-phase flow in microchannels, PhD, Louisiana Tech University.  
 [3] G.P. Celata, M. Lorenzini, G.L. Morini, G. Zumbo, 2009, International Journal of Heat and Fluid Flow.

## RESUME & PERSPECTIVES

### Resume

- ❑ Numerical results have been compared with experimental results from the literature:
  - Simulations results for different  $D_h$  show no significant influence of  $D_h$  on the friction factor
  - No significant influence of temperature gradient on friction factor
- ❑ Microdevices currently in fabrication

### Perspectives

- ❑ Experimental study of both permanent and alternate flows in microchannels
- ❑ Numerical investigation on the influence of bends on permanent and alternate flows
- ❑ Comparison between numerical and experimental results