JOULE HEATING EFFECTS ON ELECTROOSMOTIC FLOW OCCURING IN A CYLINDRICAL CONSTRICTION MICROCHANNEL

Presentation By

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Contents

Introduction

- Microfluidics deals with the precise control and manipulation of fluids and particles which are constrained to a micro scale.

- With the advent of easy micro-fabrication techniques, there has been an increasing development in the lab-on-a-chip (LOC) devices.

- A lab-on-a-chip is a device that integrates several laboratory functions into a single chip of centimeters in size

Electro kinetic Phenomenon

- Application of electric fields along the microchannel controls the movement of bulk fluid and the particles

- three important phenomenon are
  - Electro-osmosis
  - Electrophoresis.
  - Dielectrophoresis .

- These phenomena are used in the microfluidics to manipulate particles and cells like focusing, trapping and separating them.

Concept of Joule Heating

- When a wire is immersed in a mass of water and electric current is applied temperature of the water increased due to the current flowing through the wire for a considerable length of time.

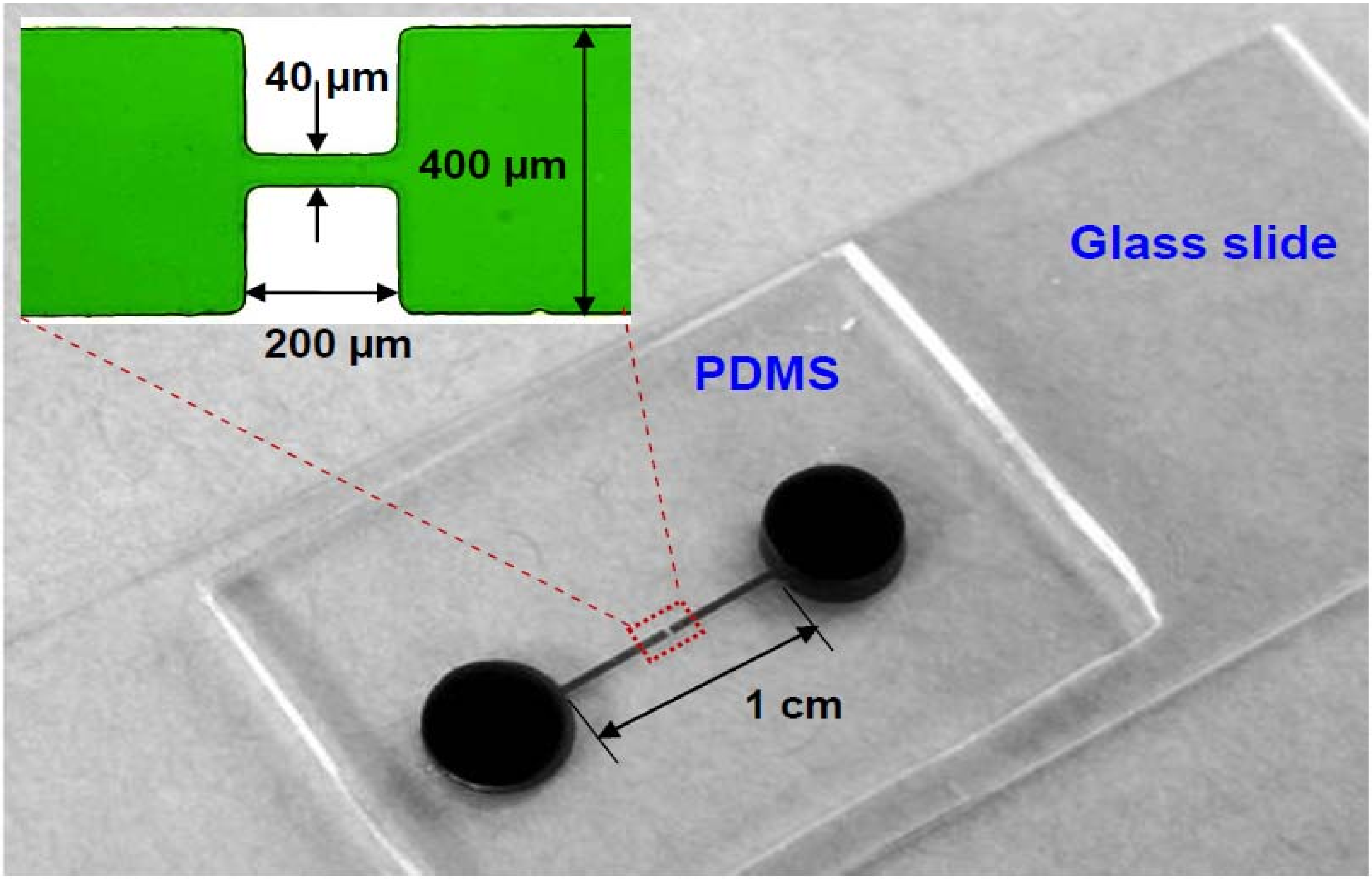
- When voltage difference is applied at the electrodes, electric energy is consumed by resistive fluid as electric current flow through and transformed into heat.

- Heat generated due to joule heating is proportional to the square of electric field

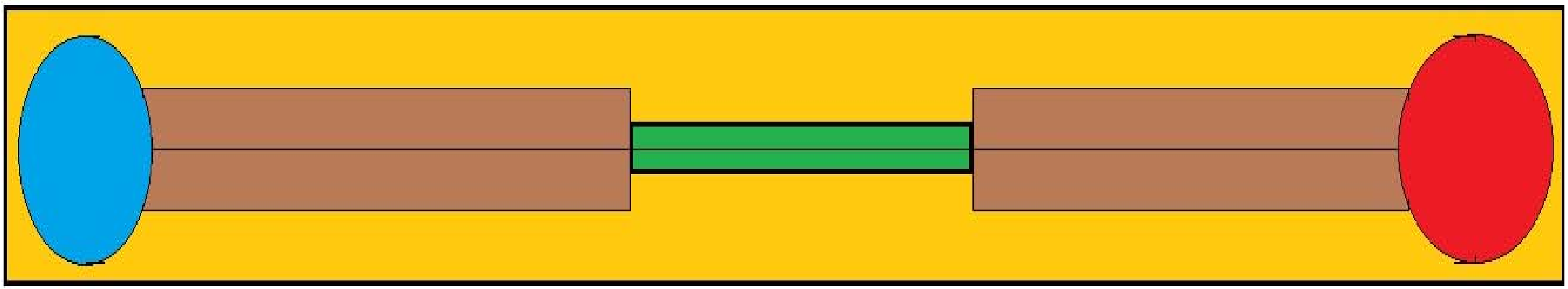
$$Q = \sigma(\mathbf{E} \bullet \mathbf{E})$$

- Where Q is the heat generated in W/m^3, σ is the electrical conductivity in S/m and E is the electric field in V/m.

Problem Setup (Sriram Sridharan)



Problem definition

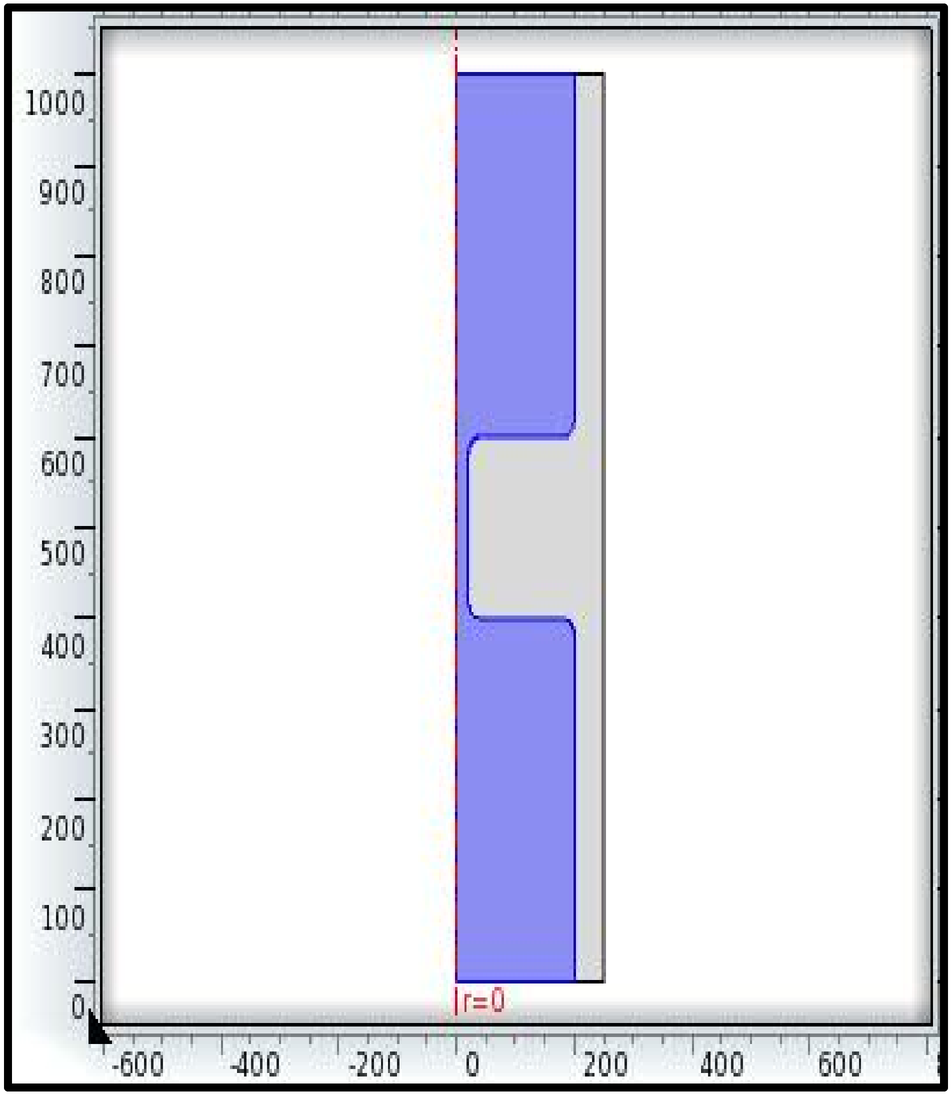


Geometry

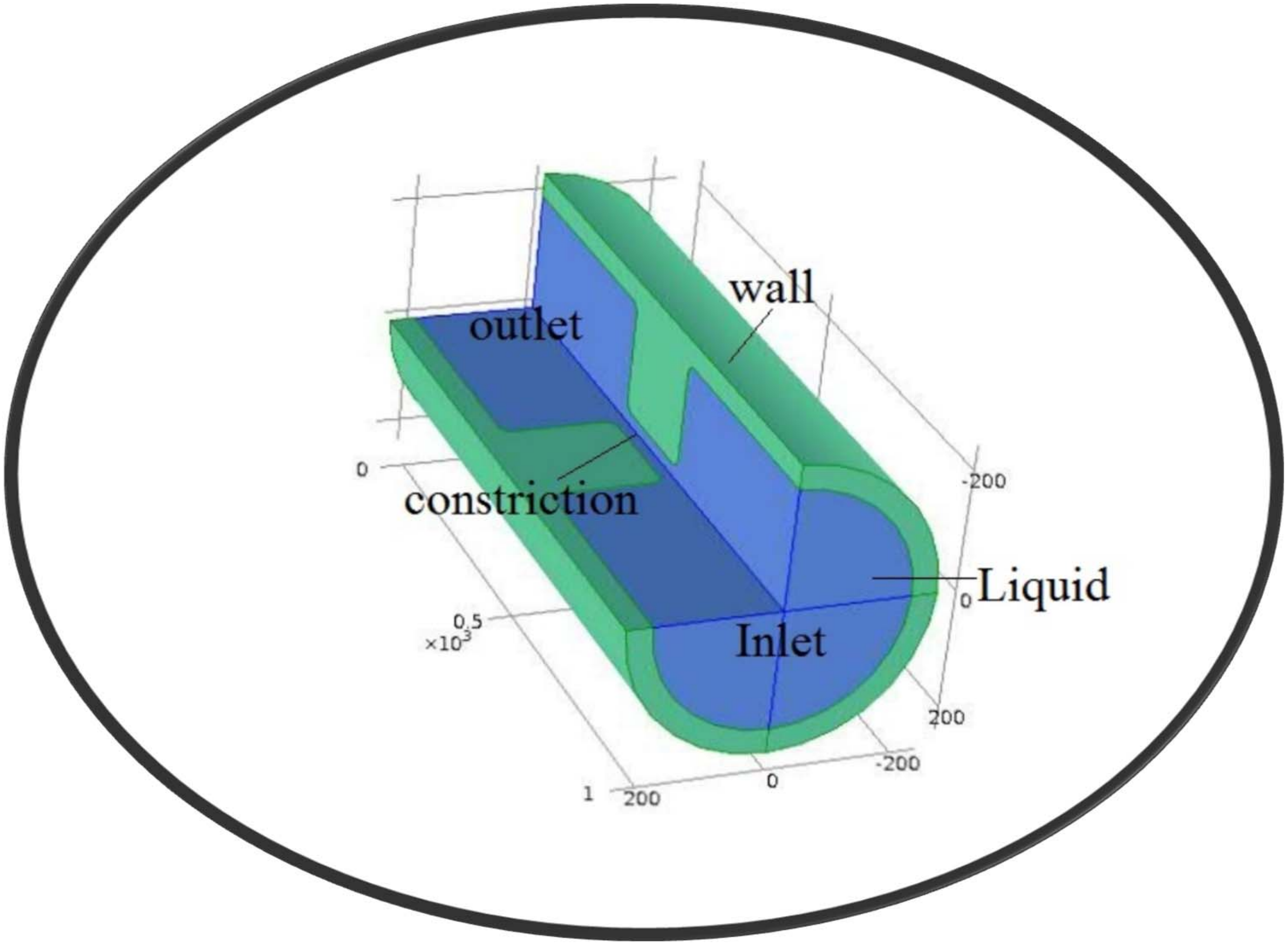
Top View

Zoomed in View

- Axisymmetry
- Length 1000 µm.
- Outer radius 250 µm.
- Inner radius 200 µm.
- Constriction length 200 µm.
- Constriction radius 20 µm.



Exploded View



Physics Used for simulation

- Ac/Dc Module - Electric currents (dc)

- Heat transfer Module – Conjugate heat transfer (Laminar flow)

Basic Equations used

1. $\nabla.(\sigma\nabla\phi) = 0$

2. $\rho C_p u\nabla T = \nabla.(K\nabla T) + Q$

   $Q = \sigma E^2$ (W/m^3)

   $\nabla.(K_P\nabla T) = 0$

3. $\nabla . V = 0$

$$\rho(V.\nabla)V = -\nabla p + \nabla.(\mu \nabla V) + \rho_e E$$

Electro osmotic velocity

$u_{eo} = \mu_{eo} E$ (m/s) (Helmholtz-Smoluchowski Eqn)

$\mu_{eo} = \varepsilon_0 \varepsilon_r \frac{\zeta}{\mu}$ (m^2/V.s)

COMSOL Implementation

- 2D Axisymmetry
- Physics
- Geometry Building
- Material Selection
- Boundary Condition
- Meshing
- Post Processing

Boundary Conditions

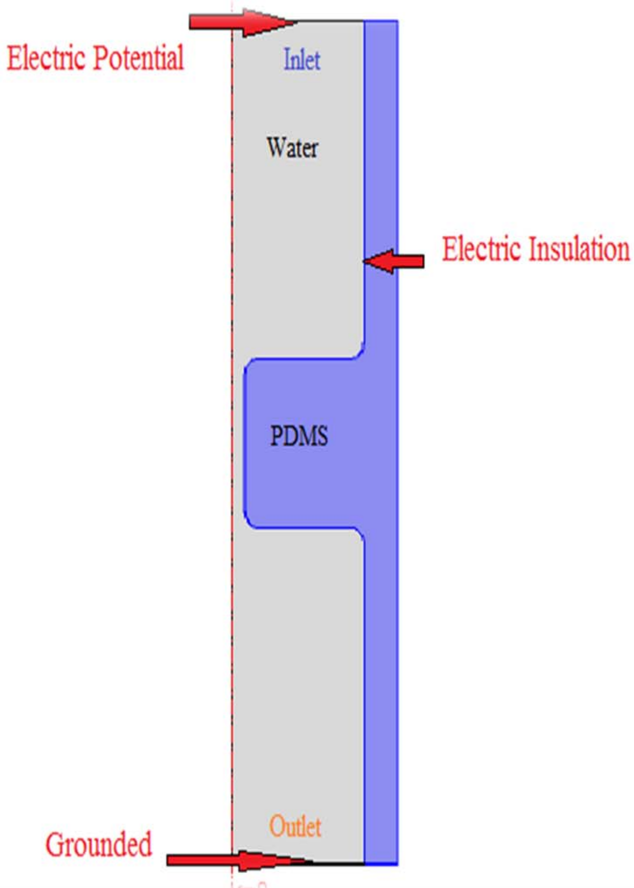


Figure Electric Boundary Condition

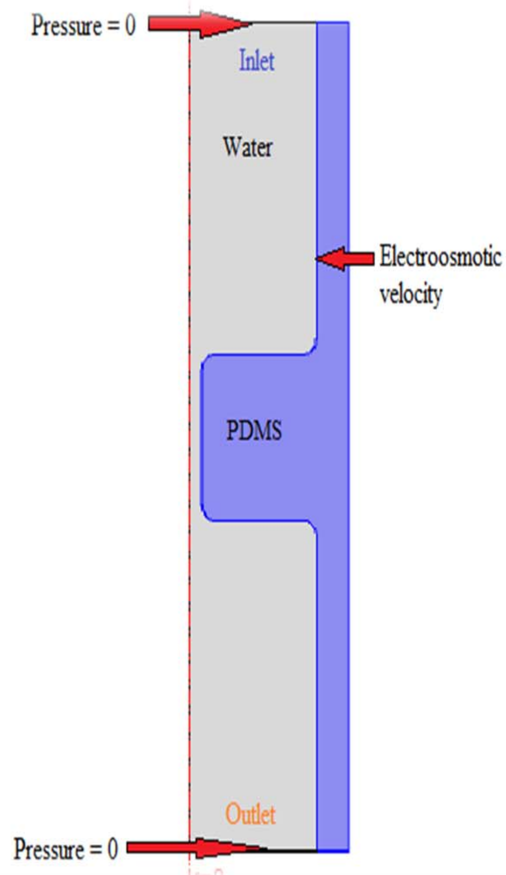
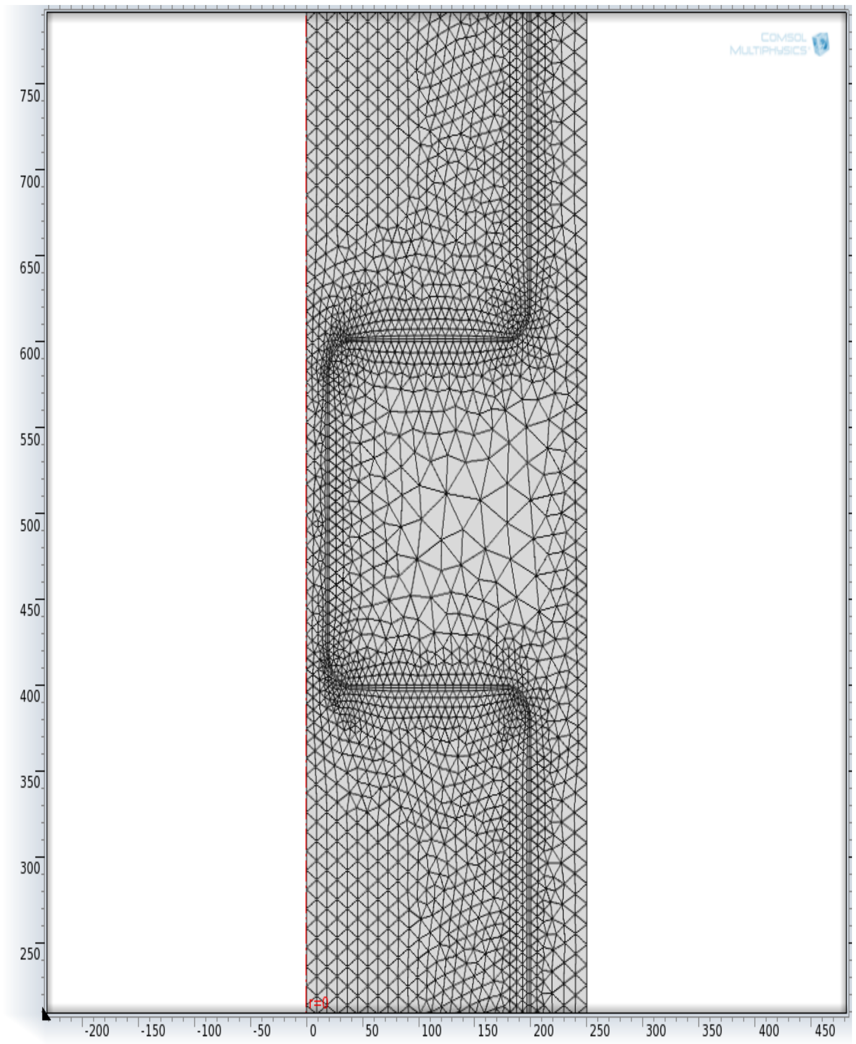


Figure: Flow Boundary Condition

Meshing

- The mesh consists of around 7109 triangular elements and about 418 quadrilateral elements
- Average mesh quality of 0.94.



Results

- How Joule heating effects the velocity profile?
- How velocity profile was altered due to Joule heating?
- Comparison of velocity profile with and without Joule heating.

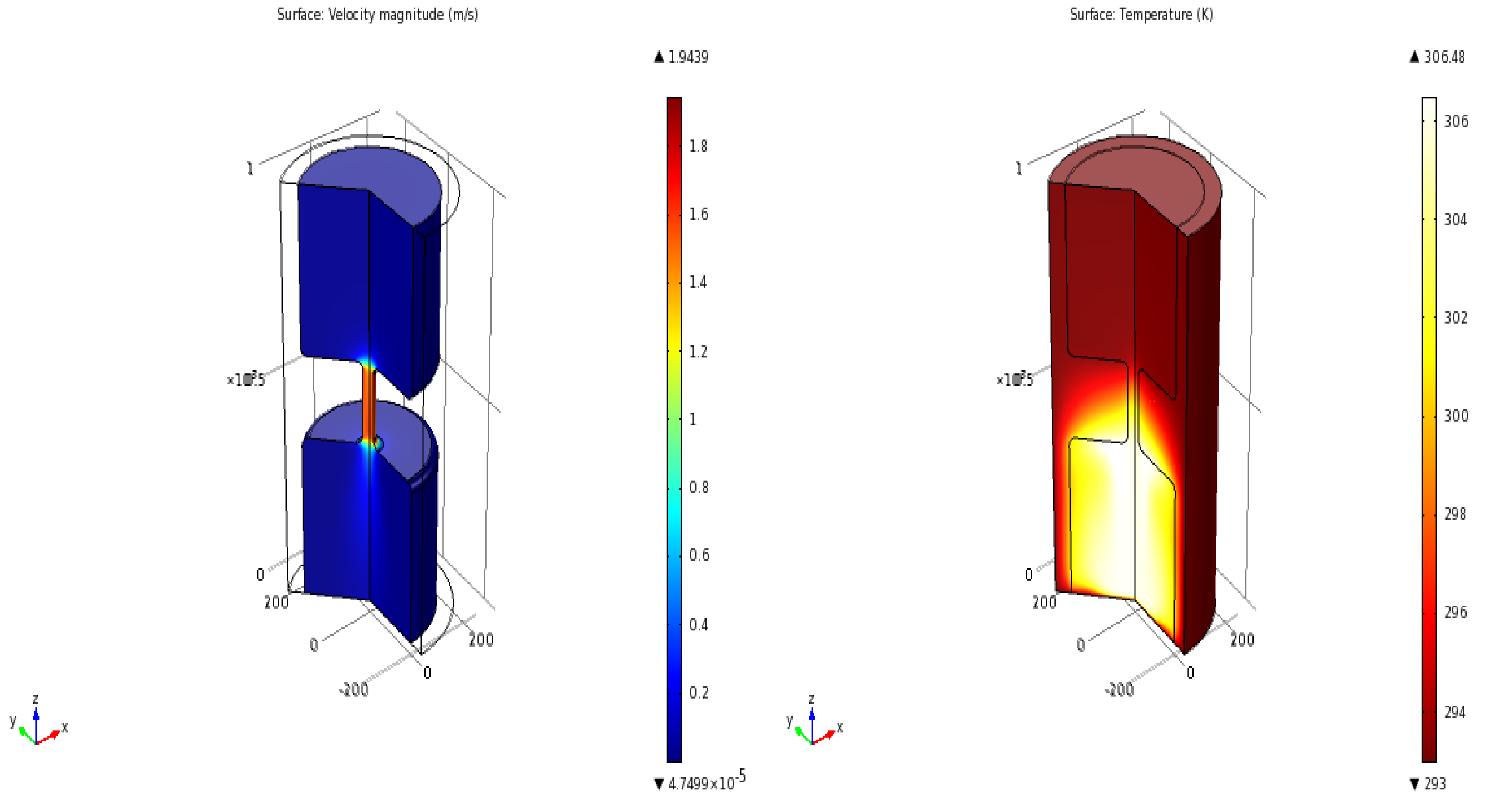


Figure : Velocity and Temperature distribution of a cylindrical microchannel with zeta potential -10 mV

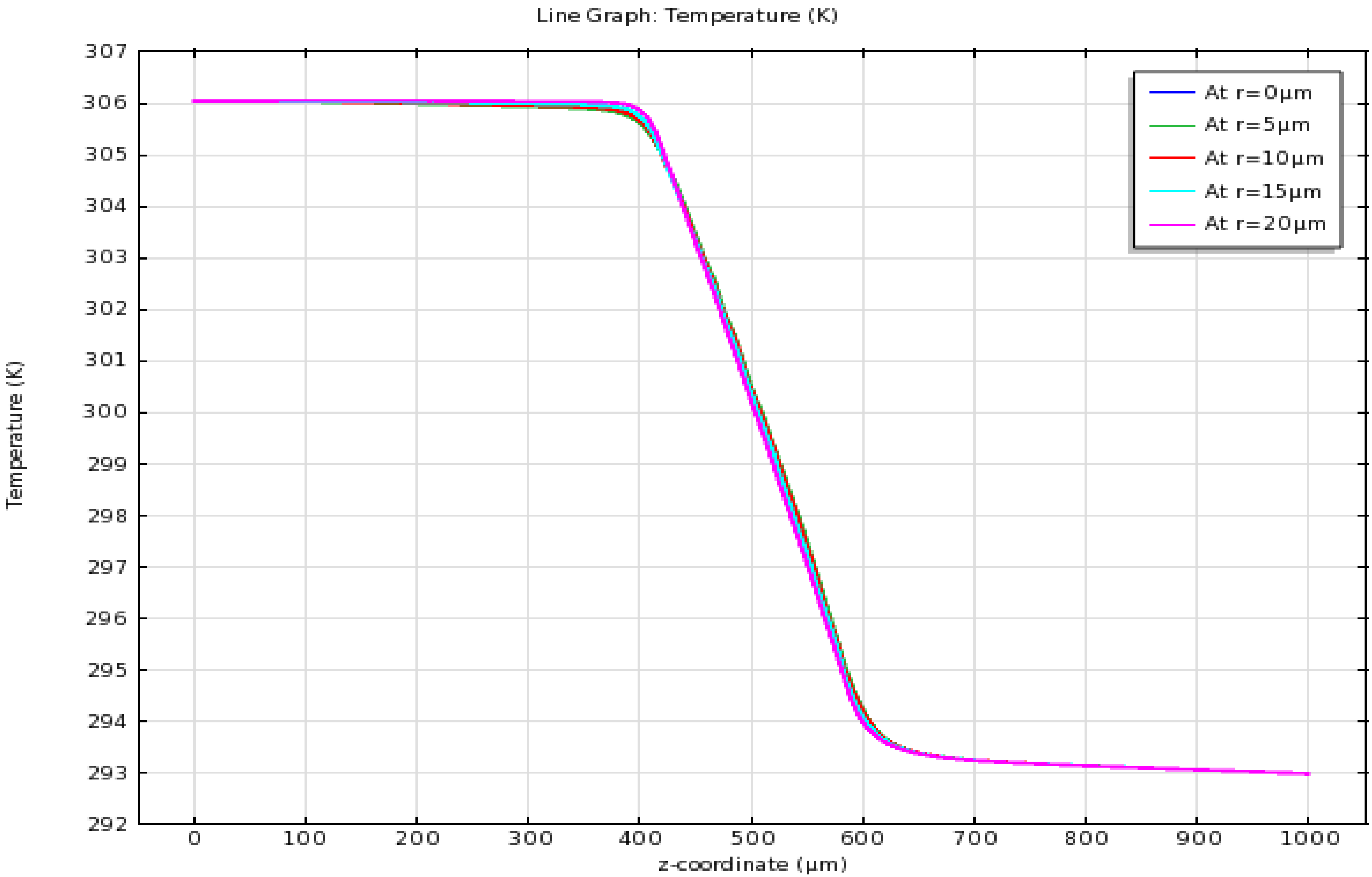


Figure : Temperature profile along a cylindrical microchannel with zeta potential of -10 mV

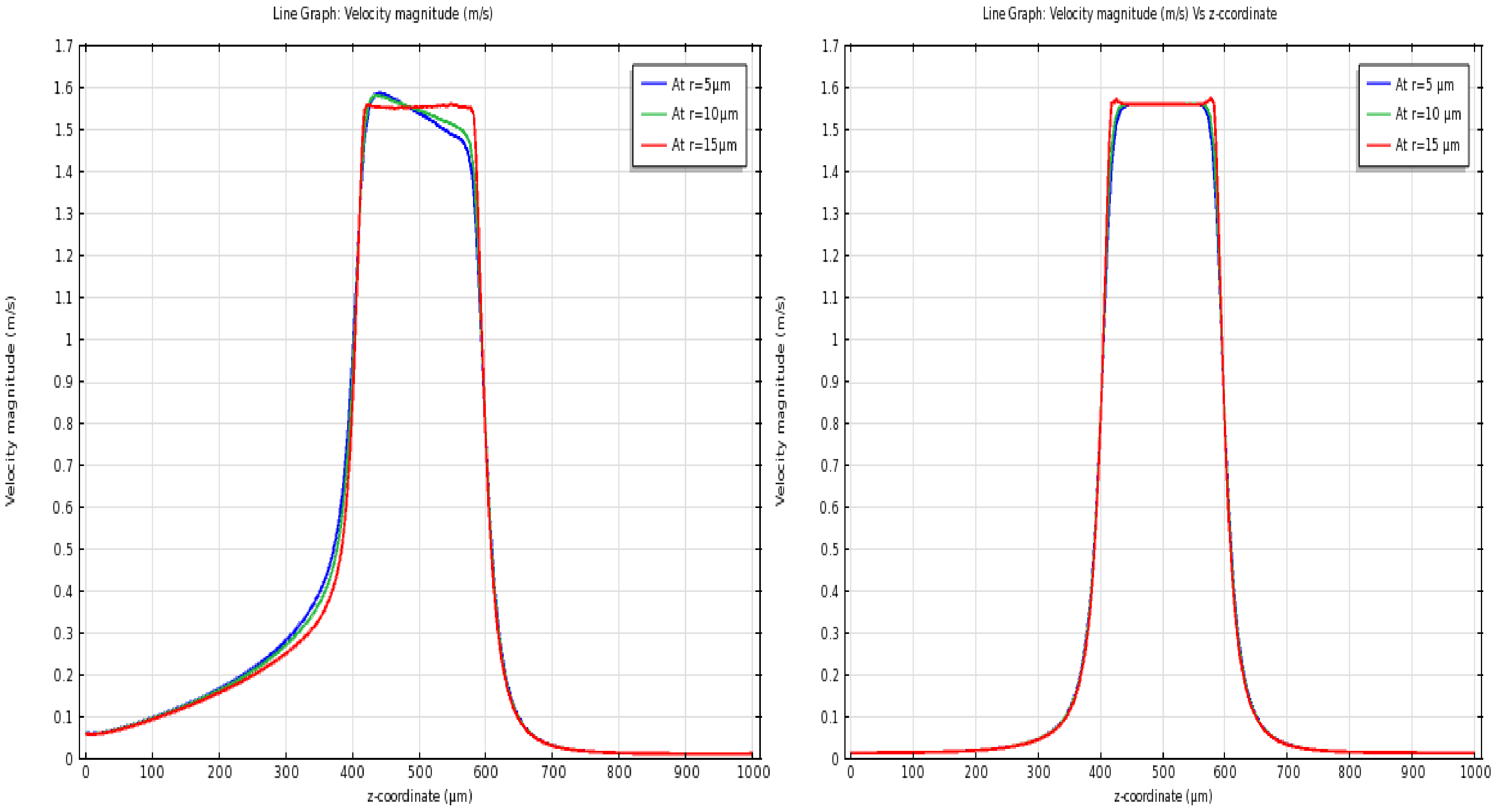


Figure : Velocity profile along a cylindrical microchannel with and without Joule heating

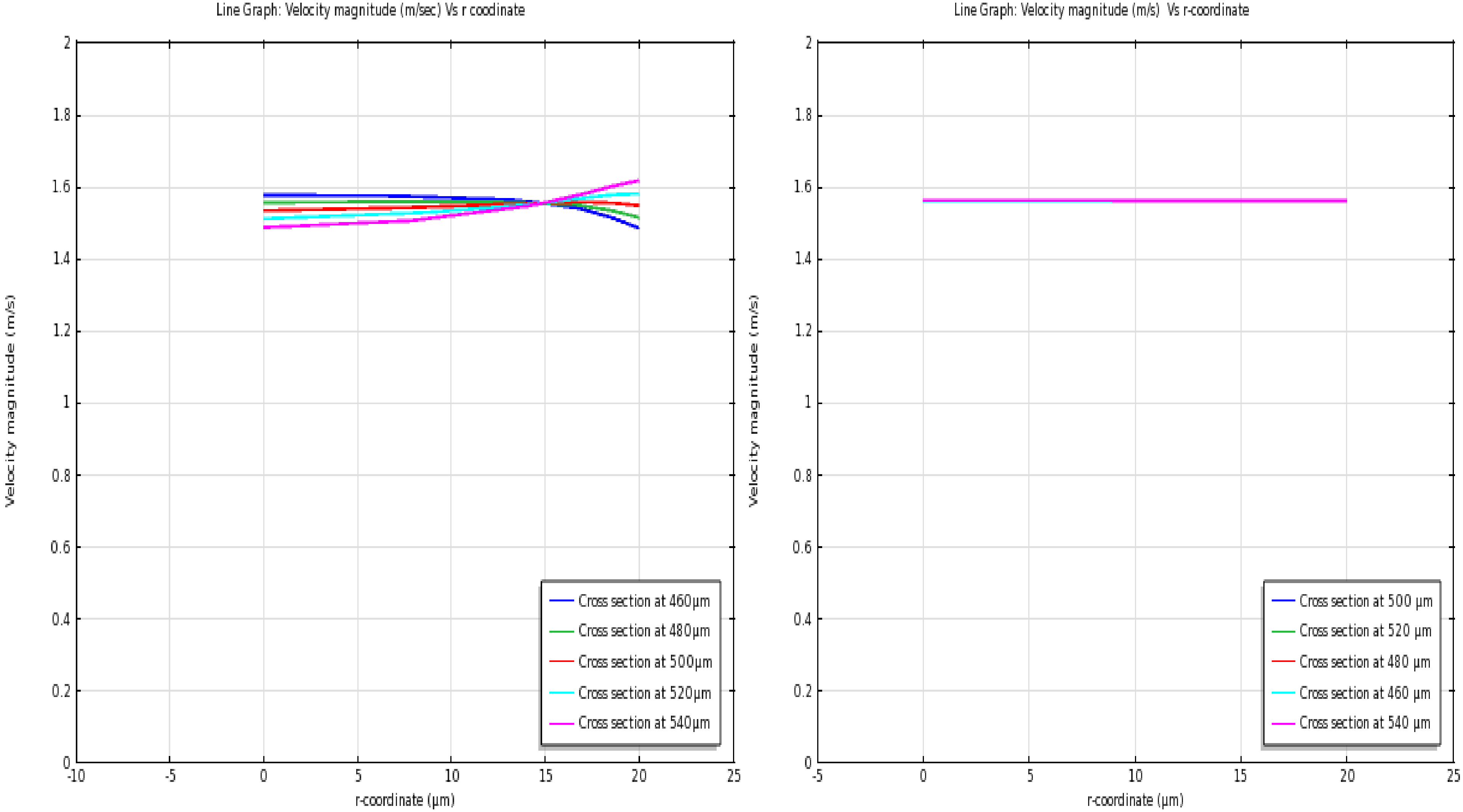


Figure : Velocity profile in a cylindrical microchannel cross section with and without Joule heating

Conclusion

- The velocity profile was significantly changed due to the presence of Joule heating and the plug like velocity profile disappeared.

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THANK YOU