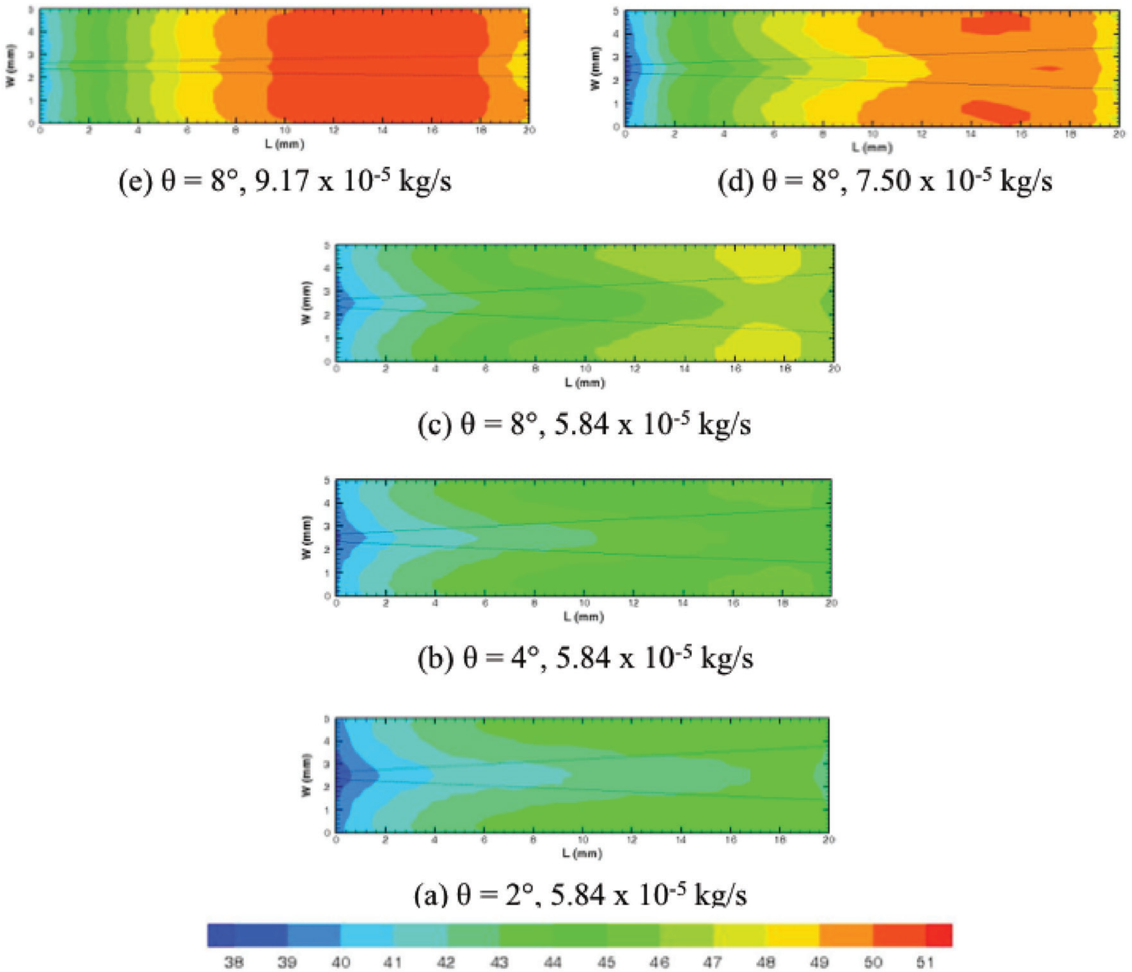
Development of constant temperature microdevice

In several biological applications, it is required to maintain the cells above / below the room temperature implying the need for heating / cooling the microdevice. For instance, in polymerase chain reaction (PCR) a particular DNA sequence is amplified and used in applications such as pathogen detection and hereditary disorder diagnosis. The entire process takes place in 3 steps: denaturation, annealing and extension for which the different stations are required to be maintained at constant temperatures of 95°C, 55°C and 72°C, respectively. When the temperature of the sample is to be raised, one can either supply a uniform heat flux at the boundaries, or maintain the boundaries at a higher temperature. As is well known, for hydrodynamically and thermally fully-developed flow in simple geometries, a uniform heat flux leads to a linear increase in surface temperature, and a constant difference between the bulk fluid and wall temperatures.



(e) $\theta = 8°$, 9.17×10^{-5} kg/s

(d) $\theta = 8°$, 7.50×10^{-5} kg/s

(c) $\theta = 8°$, 5.84×10^{-5} kg/s

(b) $\theta = 4°$, 5.84×10^{-5} kg/s

(a) $\theta = 2°$, 5.84×10^{-5} kg/s

Experimentally measured temperature contours using an IR camera in the proposed microdevice. The figure shows that the uniformity in temperature improves with tuning of the parameters (divergence angle and flow rate).

The presence of a lateral temperature gradient in the fluid however implies that the local fluid temperature can exceed the safe operating temperature limit. Maintaining the boundaries at a constant temperature is therefore the safer alternative where the local fluid temperature will necessarily be less than the wall temperature in the wall heated case. At the conventional scale, the constant wall temperature condition is typically maintained by employing phase change. Maintaining constant temperature is however not simple, more so when extended to microscale. Moreover, only certain temperatures and not any desired temperature can be achieved with the phase change technique due to the limitations in the material that can be employed for this purpose.

In this context, we have developed a *Constant wall temperature microdevice*. A diverging microchannel along with conjugate effect is utilised towards this end. The design was proved through both measurements and three dimensional numerical simulations. The investigation was carried out over a large parameter range and input conditions which helped in establishing the finding. It was confirmed that a nearly constant wall temperature condition can be achieved over a large parameter range investigated using the proposed approach. A model to arrive at the design parameter values was also obtained. The method was further demonstrated for a series of microchannels where each station was maintained at a different temperature and within ±1°C of the desired value. The finding is therefore significant and can be employed in both single and multi-stage processes such as PCR requiring different constant wall temperature with a fine resolution. A novel, microscale-PCR is being built using this technology.

Prof. Amit Agrawal, Department of Mechanical Engineering, amit.agrawal@iitb.ac.in