Characterization of a touchless heating system for microfluidic applications

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Introduction

In microfluidics, precise control of the temperature during procedures may be paramount. Especially for studies that may utilize blood, it is essential to have precise control of the temperature to be at physiological temperature in order to obtain relevant data. However, temperature control is further complicated at the micro-scale since heat dissipation is very quick. To achieve temperature control in the microfluidic lab, a simple touchless heating system was developed that utilizes a heating lamp that is controlled by a thermocouple feedback loop. In this study, the touchless heating system's performance is validated and calibrated for applications in microfluidics. The performance of the system is characterized by the ability for the fluid to reach the desired temperature, the amount of time it takes and how the temperature is distributed on the chip. These characteristics were tested for three different types of bulbs, at two bulb height, and with two feedback controller locations.

Methodology

- The fabrication of microfluidic chip is completed in a clean room. PDMS is prepared by mixing the polymer and curing agent component, degassing of the mixture, pouring of the mixture on a microfluidic wafers and curing the mixture on a hotplate. A 100µm*50µm*2cm channel was chosen.
- Several configurations were tested to observe the effect on the overall ability of the heating system.
  - The system was tested using a 40W infrared (**IR**) bulb, 50W IR bulb and 50W ceramic (**CER**) heater bulb.
  - The height of the lamp was tested 5 cm and 15 cm above the PDMS chip.
  - The location of the thermocouple feedback controller (**FBC**) was tested at the inlet (position 2) and outlet (position 5).
- For each test, a syringe pump was used to push water through the channel of the chip until it filled up.
- Four thermocouple are placed in predetermined locations on the chip or at the tip of the syringe to measure temperature over time. (reference Figure 2)
- With the lamp in position the touchless heating system is switched on by turning on the lamp and is set to heat up the chip to 37ºC.

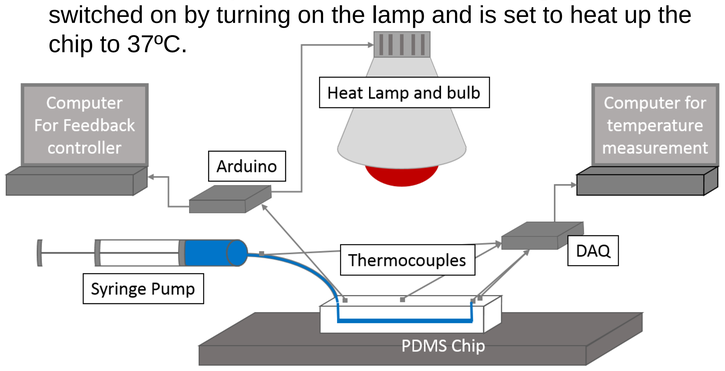

Figure 1. Overview of touchless heating system

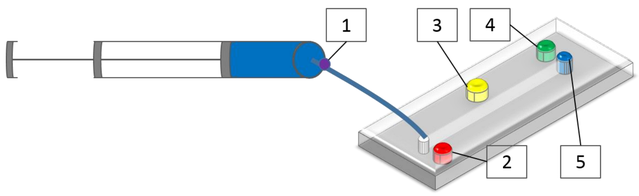

Figure 2. Location of the thermocouples position and corresponds to the colors on the graph. Position 5 is immersed in the fluid.

Results

Comparing bulb type

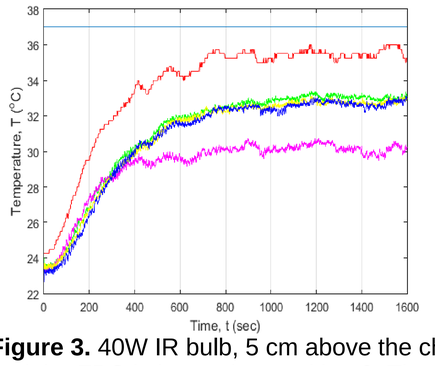

Figure 3. 40W IR bulb, 5 cm above the chip and the FBC is located at position 2. The desired temperature is not reached for the average chip temperature.

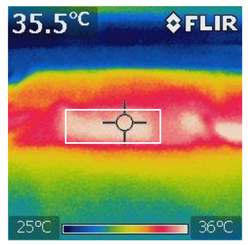

Figure 4. IR image of heat signature of 40W IR bulb on PDMS chip set 5 cm above

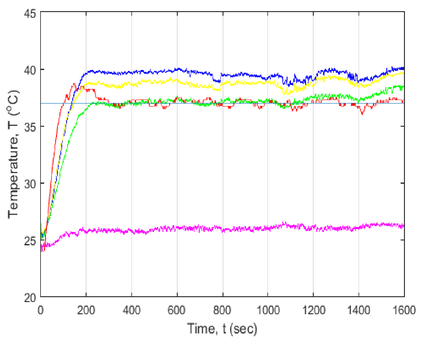

Figure 5. 50W IR bulb, 5 cm above the chip and the FBC is located at position 2. Overshooting is observed for the controller.

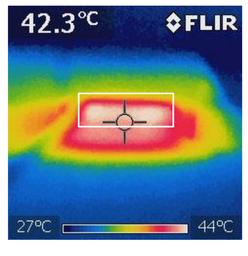

Figure 6. IR image of heat signature of 50W IR bulb on PDMS chip set 5 cm above

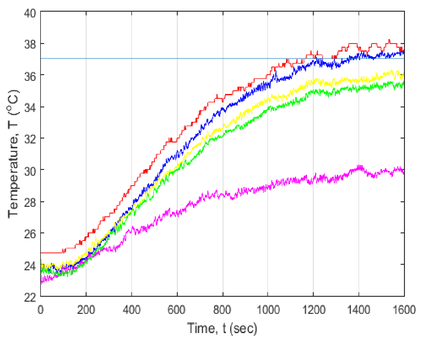

Figure 7. 50W CER bulb, 5 cm above the chip and the FBC is located at position 2.

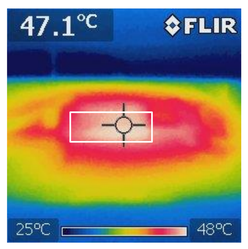

Figure 8. IR image of heat signature of 50W CER bulb on PDMS chip set 5 cm above

Comparing bulb height

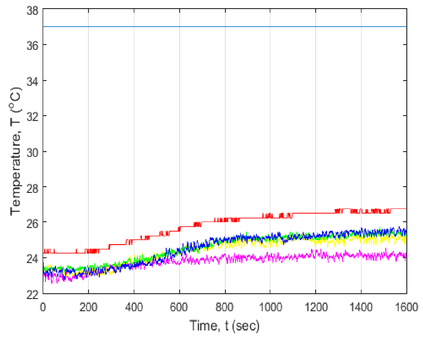

Figure 9. 50W CER bulb, 15 cm above PDMS chip and the feedback controller is located at position 2 (compare to Figure 7).

Comparing feedback controller location

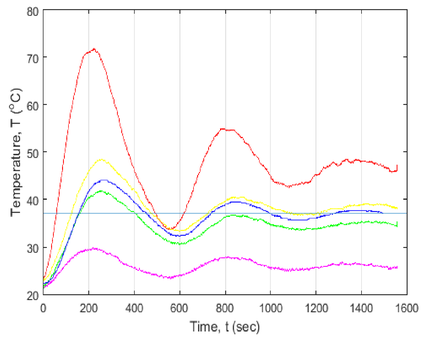

Figure 10. 50W IR bulb, 5 cm above the chip and the FBC is located at position 5 (compare to Figure 5)

Table 1. Summary of Data

Bulb Type	Lamp Height (cm)	Max Temp. (ºC)	Time to Reach Stable Temp. (min)	Stable Temp. for position 5 (ºC)	Location of Feedback Controller
40W IR	5	36.5	13.3	33.0	2
40W IR	15	27.6	13.3	27.6	2
50W IR	5	40.4	5.0	39.5	2
50W IR	15	41.0	14.1	34.5	2
50W IR	5	71.9	23.3	37.0	5
50W CER	5	38.4	26.7	37.5	2
50W CER	15	27.0	25.0	25.5	2

Conclusion

- From the results it can be concluded that the bulb type, bulb height and location of the feedback loop will affect the ability of the touchless heating system.
- For applications that may utilize blood, the 50W IR bulb would be an ideal candidate to quickly heat up the microfluidic chip when set to 5 cm above the chip.
- For applications where imaging of the microfluidic chip is required and there is sensitivity to light then the 50W CER bulb would be ideal since it does not produce light. The drawbacks however include slow heating time and sensitivity of the heating potential based on the bulb height.
- Controlling of the initial overshoot of the heating system is greatly influenced by the positioning of the FBC. From the study the ideal position appears to be close to the inlet of the chip.
- For future studies, the affect of dynamic flow should be tested under the various configurations.

Acknowledgement

I would like to thank my supervisor Dr. Marianne Fenech, and the lab members for helping me in the study.

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