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NON-CONTACT HEATING SYSTEM FOR A CENTRIFUGAL MICROLFUIDIC PLATFORM

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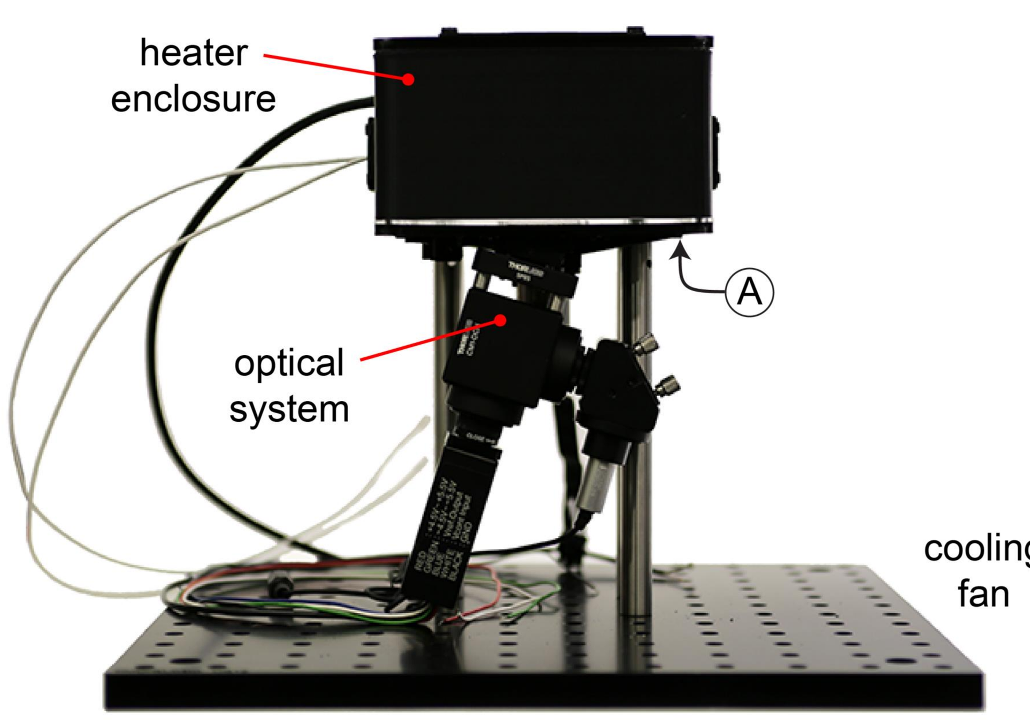
LABORATORY DIRECTED RESEARCH & DEVELOPMENT

INTRODUCTION

In an effort to expand the versatility of a centrifugal microfluidic platform known as SpinDx [1] by enabling nucleic acid tests with techniques such as loop-mediated isothermal amplification (LAMP), a non-contact heating system was integrated into the platform. An infrared emitter is used to heat aqueous samples and maintain a stable, uniform temperature, e.g. 65°C to conduct the LAMP reaction. This approach avoids the complexity and cost of incorporating both auxiliary on-disc hardware and a slip-ring for electrically interfacing with the rotating disc [2,3]. Established heating methods for centrifugal platforms include induction heating [4], which offers a non-contact solution but requires complex circuitry and on-disc electrodes. Infrared laser heating has been used successfully but suffers from inefficiency and added disc complexity by requiring an embedded metal plate to achieve indirect heating of the sample [5]. Thermoelectric heating, commonly used for PCR thermocyclers, has been implemented but requires additional moving parts, such as a linear actuator [6] or vacuum pressure system [7], to bring the disc into contact with the heating element. In addition, this must be performed on a stationary disc, making real-time detection more difficult.

DEVICE



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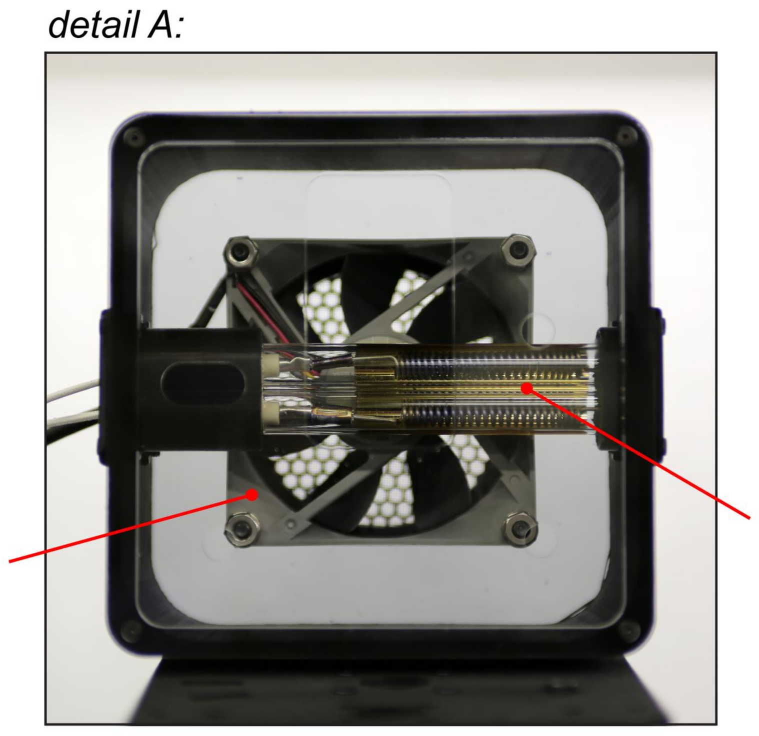
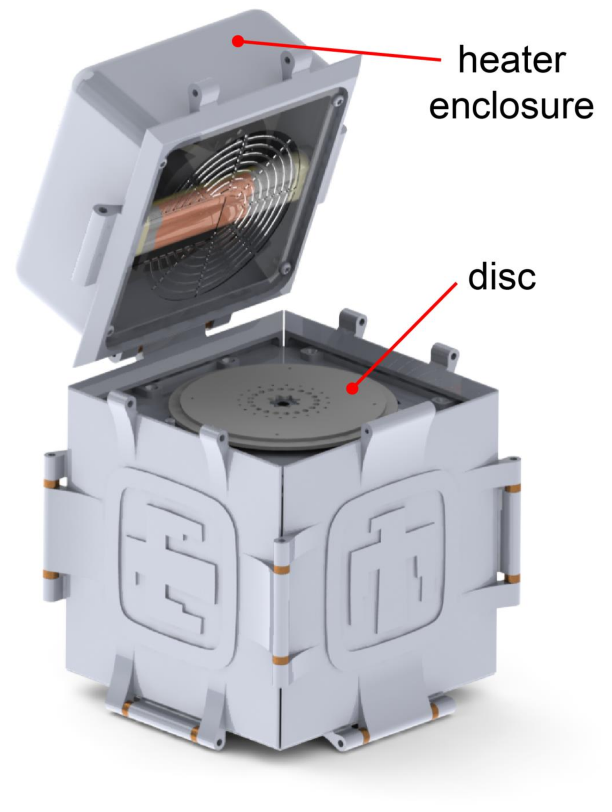
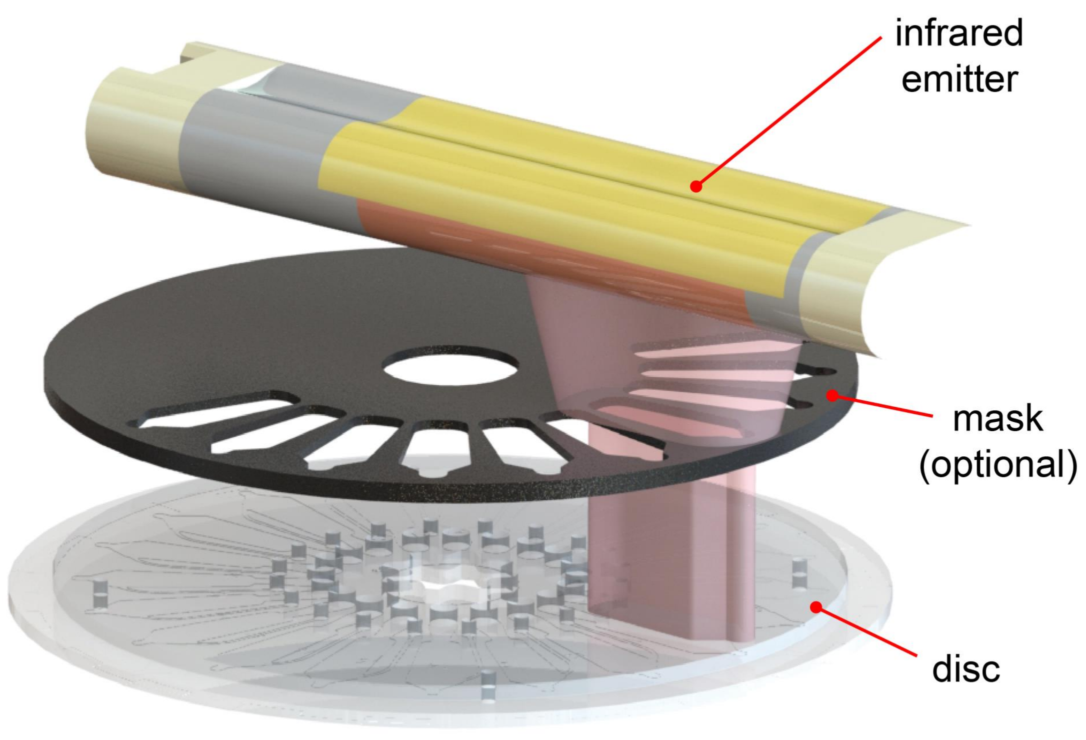


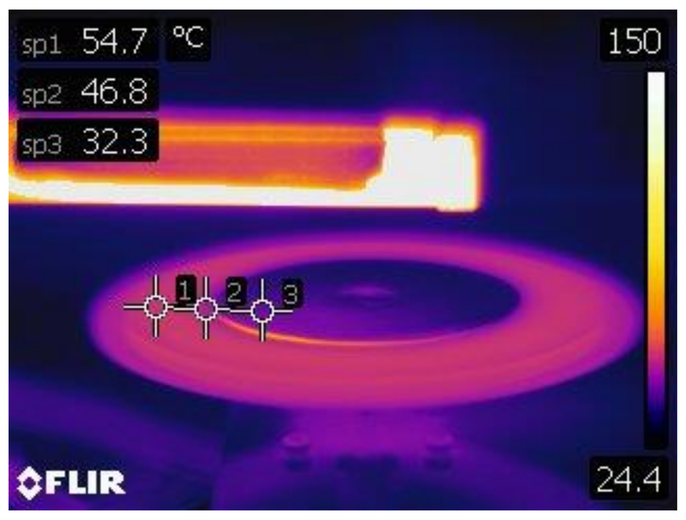
The temperature control system is integrated into the lid of the instrument in order to heat the disc from above, which avoids exposing sensitive optical and electrical components in the base of the platform to waste heat. A prototype was built around a 3d-printed shell that houses an axial cooling fan and a custom 100W medium wave, carbon filament infrared emitter (Heraeus Noblelight), which is powered by a 12VDC source. The emitter has peak wavelengths at 2.4-2.7 µm and features a dual-filament design with a gold retro-reflector to focus radiation into a roughly 50 mm by 20 mm region. This focal spot is aligned along a radial section of the microfluidic disc, centered with the reaction chambers. The medium wave radiation band emitted by the heater closely matches peak absorption wavelengths of water, enabling efficient heating of the low-volume (e.g. 10 µL) aqueous samples contained in the disc.

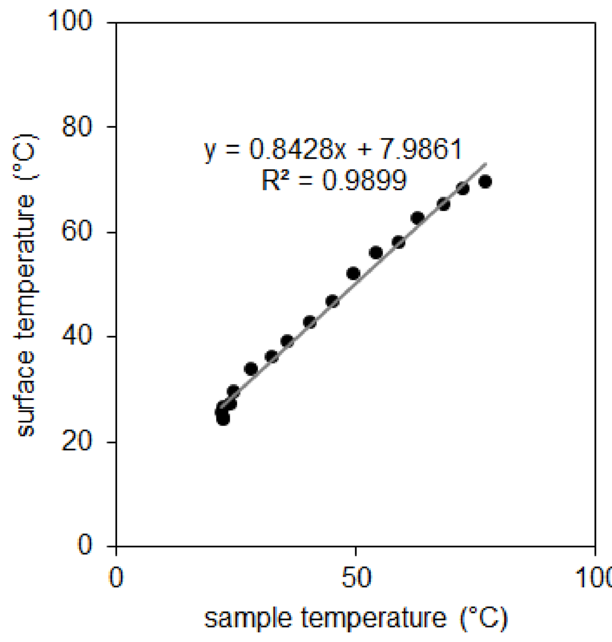




CALIBRATION

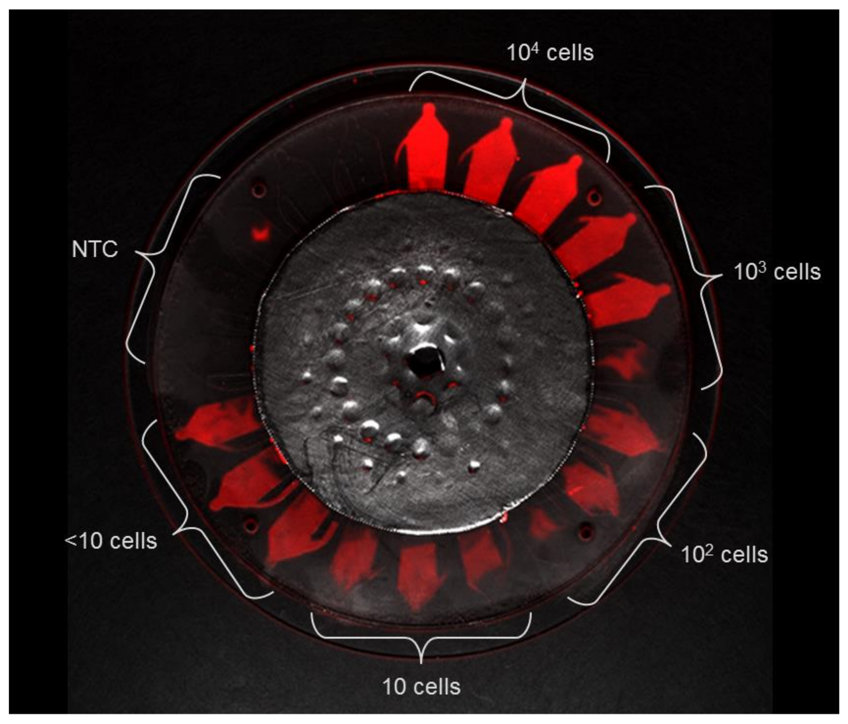
Calibration of the heating system was performed by first fabricating a disc with a T-type micro-thermocouple embedded in one of the reaction chambers. This thermocouple was connected to a custom hub with a built-in slip ring, allowing the thermocouple to rotate with the disc during heating while the output wiring remained stationary. In parallel with the thermocouple measurement, an infrared camera was positioned above the disc to measure the top surface temperature of the disc. Temperatures collected from the top surface of the disc were correlated with true sample temperatures measured using the embedded thermocouple. This correlation was then used for open loop operation of the disc in all future experiments, requiring only a simple infrared camera measurement to confirm setpoints.





E COLI AMPLIFICATION

The calibrated heating system was tested by amplifying a heat-killed E. coli O157:H7 target (KPL, Cat. No. 50-95-90) using a LAMP reaction with Cy5-labeled primers targeting the stx1 gene. With a 10x serial dilution of the target DNA from 10^4 cells/µL to ~1 cell/µL, sets of 10 µL reaction were run in triplicate for each template concentration along with a negative template control (NTC). The disc was heated to 65°C, incubated for 45 min, then cooled on ice. Fluorescence was then measured using a gel imager. Successful detection over the range of dilutions was observed.



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