Rapid Multichannel Plasmonic Thermocycling using Gold Nanorods

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Abstract

Polymerase chain reaction (PCR) is a technology that can replicate small amounts of DNA. It is used frequently in biological research as well as medical diagnoses. A PCR reaction typically involves around 30 heating and cooling cycles and takes 1-2 hours, and as such it is desirable to decrease this time in order to facilitate its use and speed up diagnosis, therefore allowing for faster treatment. Here a system is shown to achieve the rapid thermocycling that would be needed to create a PCR machine capable of completing a PCR reaction in less than one minute. This system uses the large and tunable absorbance of gold nanorods in solution to harness energy delivered by a laser to heat the samples.

Introduction

- PCR - thermocycling between 3 stages (denaturation, annealing and elongation) to amplify DNA signal in sample

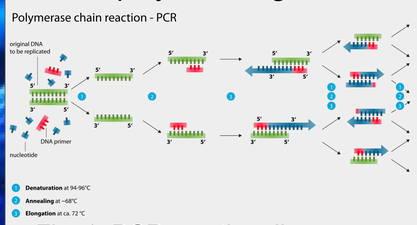

Fig. 1: PCR reaction diagram

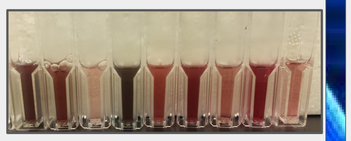

Fig. 2: GNRs with different SPR peaks

- Gold Nanorods (GNRs) can be created with a specific aspect ratio (length/width) by adjusting the concentrations (AgNO3, HCl) in their synthesis, which determines the wavelength of their surface plasmon resonance (SPR). That is used to match the SPR peak to the laser wavelength, maximizing plasmonic heating.

Results and discussion

- A procedure for the synthesis of gold nanorods was developed and GNRs with the correct aspect ratio were synthesized (LSPR peak at 808nm)

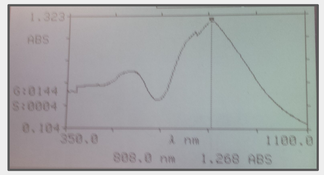

Fig. 3: Absorbance spectrum of synthesized GNRs with an absorbance peak at 808 nm

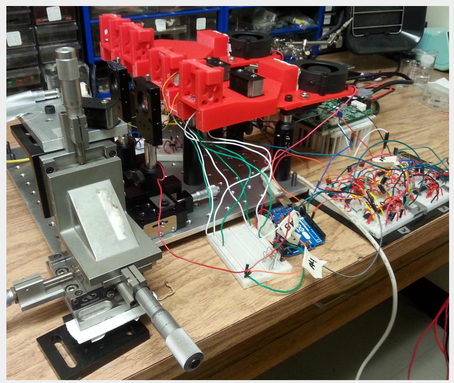

Fig. 4: Current system

Fig. 5: System diagram

- 3D models were designed to hold all components in place and aligned, with a built-in fan tunnel for the cooling system, a cage system for the detection system and samples, and a stand for the 808nm power laser (heating system) and optic components
- Display: interactive menu that gets user input and outputs readings
- Code and MCU: main Arduino code and controller that implement cycles and controls components such as lasers, diodes and fans
- Heating system: 808nm power laser and optic components that emits a collimated laser beam
- Cooling system: fans and fan tunnels that generate a cool air flow

- Detection system: a laser diode emits a beam that goes through the sample and hits a photodiode; the change in absorption of the sample will cause a difference in the photodiode reading
- The power absorbed by the sample can be calculated by measuring the beam's power after it goes through the sample

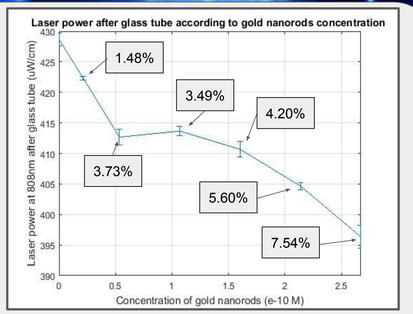

Fig. 6: Laser power being detected after the sample tube. Percentage denotes increase in power absorbed with respect to water

Conclusion

The application of plasmonic heating to PCR machines can reduce the runtime to around 1% of the original value and speed up the process of diagnosis, therefore increasing the effectiveness of treatment.
The current system can be further improved to perform thermocycling to more samples at the same time, such as an 8-tube rack model.

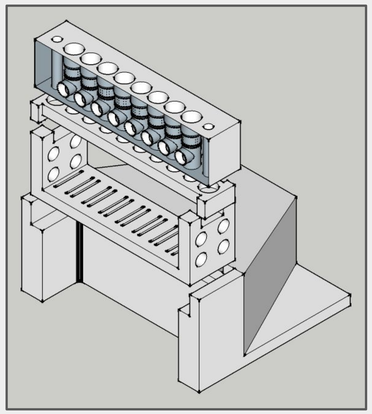

Fig. 7: An 8 eppendorf tube rack

Its performance can also be enhanced by implementing PID loops for the laser control, heating up the samples as rapidly as possible from one state to another and holding the samples at constant temperatures at each stage of the process.

Acknowledgements

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