Secure Cyber-Physical DNA Manufacturing for Life Science Applications and Ultra-Long-Term Data Storage

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Objectives

This project will research a new process for high-throughput, large-scale synthesis of synthetic DNA oligonucleotides.

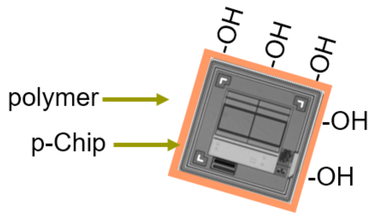
Objectives:

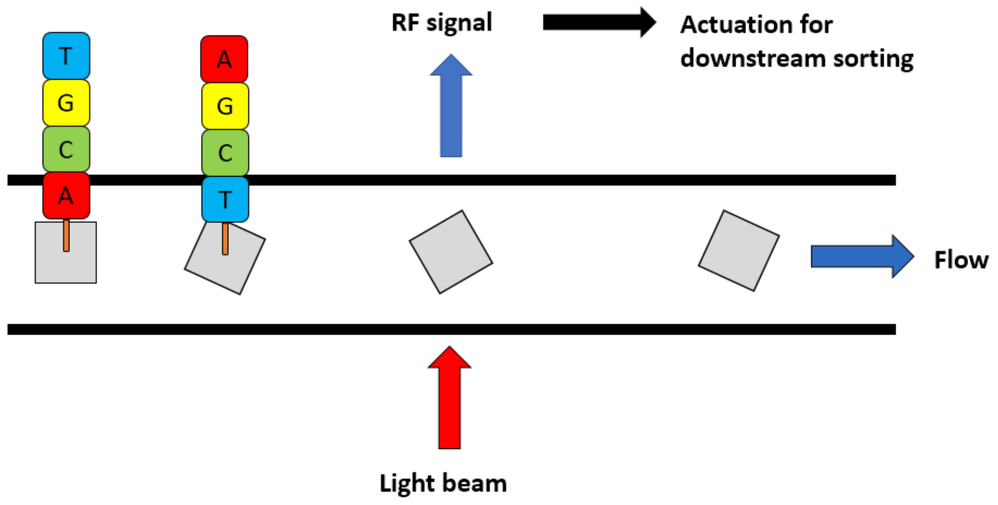
- Adapt modified computational fluid dynamic models to predict trajectories of p-Chips in fluid flow.
- Design an integrated microfluidic manifold with capabilities for real-time p-Chip sorting and encrypted DNA synthesis.
- Assess vulnerabilities of system to side-channel attacks and implement defense mechanisms for secure synthesis of DNA oligonucleotides.

Background and Motivation

Synthetic production of DNA has enabled broad, cross-sectional applications within molecular biology including the reconstruction of genomes and engineering of metabolic pathways. Synthetic DNA has also been explored as a platform for digital data storage. Current microarray-based technologies for large-scale *de novo* DNA synthesis, however, are limited by their low-throughput, substantial error rates, and significant costs [1].

- **P-Chip** silicon-based microtransponders present a **superior solid phase support for DNA oligonucleotide synthesis**
  - Capable of transmitting a **unique serial number via radio frequency signals** when illuminated with a modulated laser.
  - Allows for **differentiation of large number of unique, synthesized sequences** for binning and multiplexing.

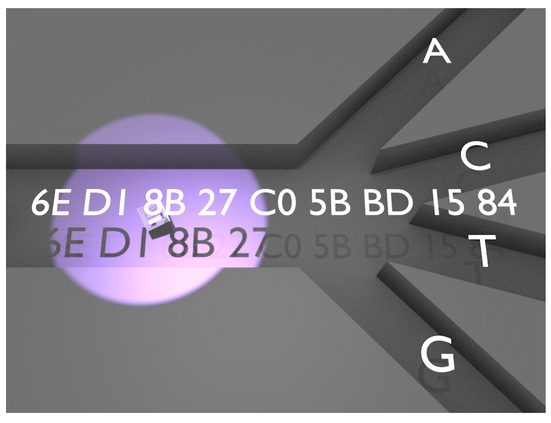




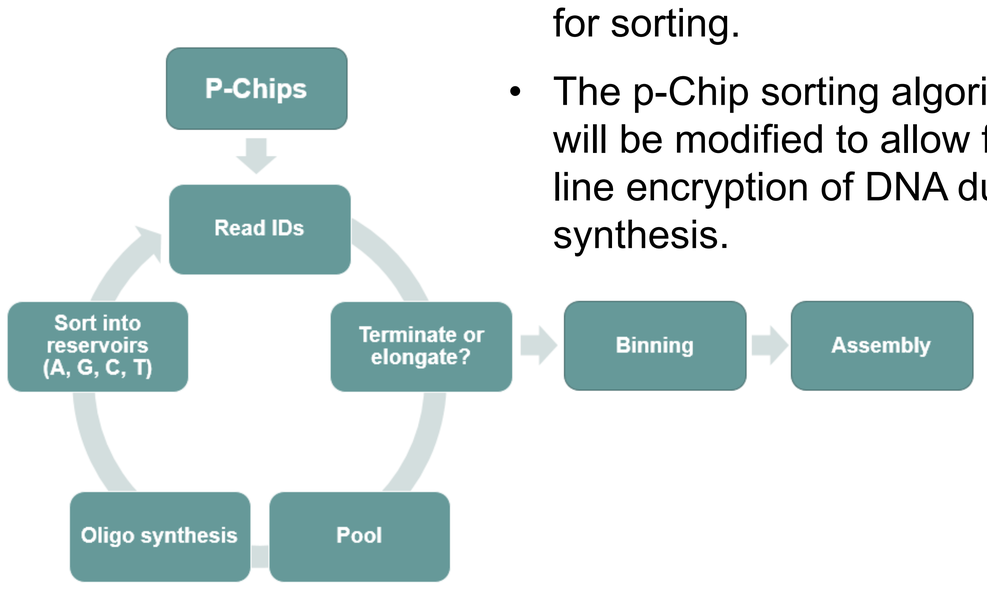
Modeling p-Chips in Fluid Flow

- Wang et al. identified shortcomings in current computational fluid dynamics software in modeling particle trajectories in fluid flow and introduced a microfluidics-optimized particle simulation algorithm (MOPSA) to correct the errors [2].
- The MOPSA algorithm will be extended to 3-D and adapted to account for the lift, drag, and torque of the rectangular p-Chip units.

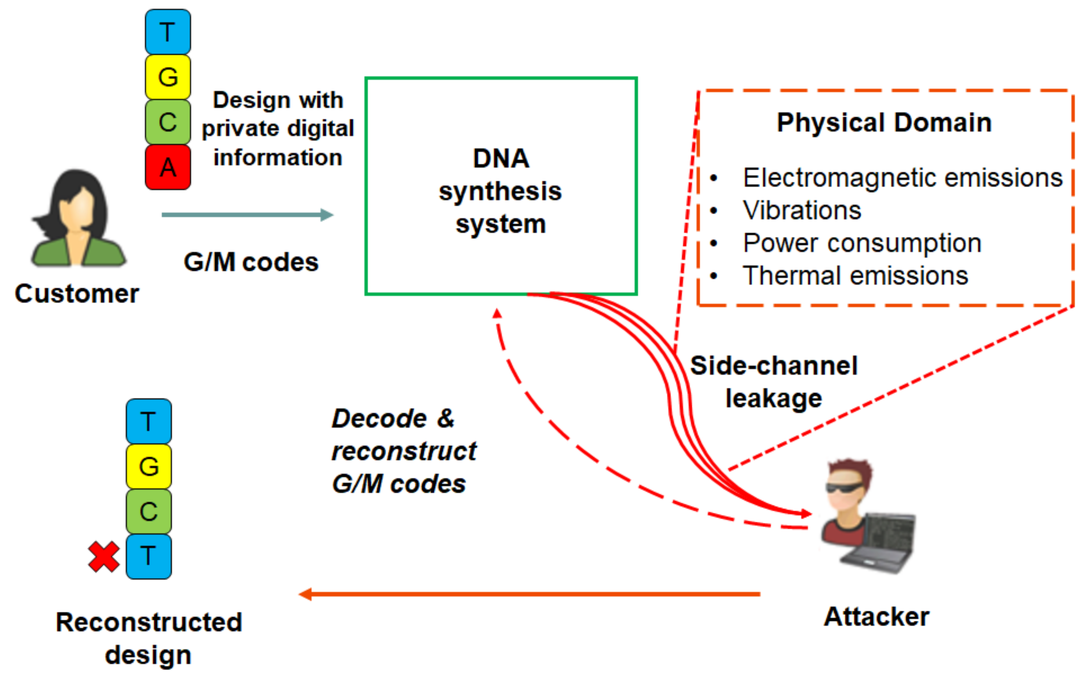
Real-Time p-Chip Sorter for DNA Synthesis



- A sorting microfluidic manifold will be developed for real-time sorting and massively parallel DNA oligonucleotide synthesis.
- A p-Chip sorting algorithm will be developed to extract information about p-Chip identity and location and perform downstream actuation for sorting.
- The p-Chip sorting algorithm will be modified to allow for on-line encryption of DNA during synthesis.



Side-Channel Attacks



- Potential side-channel leakage will be evaluated.
- Defense mechanisms will be implemented to increase the robustness of the microfluidic DNA synthesis system against side-channel attacks.

References

1) Kosuri, S. and Church, G.M., 2014. Large-scale de novo DNA synthesis: technologies and applications. *Nature methods*, *11*(5), pp.499-507.
2) Wang, J., Rodgers, V.G., Brisk, P. and Grover, W.H., 2017. MOPSA: A microfluidics-optimized particle simulation algorithm. *Biomicrofluidics*, *11*(3), p.034121.
3) Faruque, A., Abdullah, M., Chhetri, S.R., Canedo, A. and Wan, J., 2016, April. Acoustic side-channel attacks on additive manufacturing systems. In *Proceedings of the 7th International Conference on Cyber-Physical Systems* (p. 19). IEEE Press.

Acknowledgment

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