Optimizing the Absorbance of Graphene through the use of Bragg Mirrors and Genetic Algorithms

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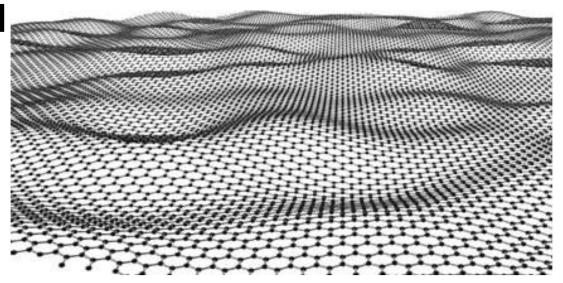
Introduction

Graphene is a monolayer of carbon atoms in a two dimensional honeycomb pattern which has been shown to possess exceptional electrical and optical properties for developing nanoelectronic and nanophotonic devices. Despite this, Graphene is a naturally weak optical absorber (around 2.6%) and as such clever concepts must be used to take full advantage of its properties.

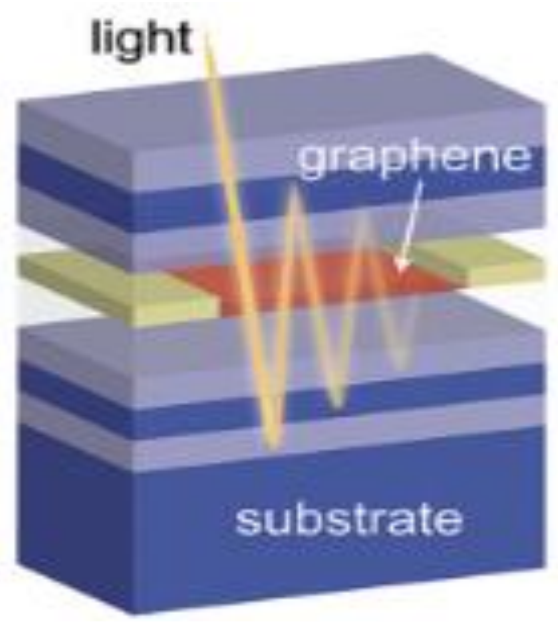
The purpose of this project was to find optimized structures so as to maximize the absorbance of graphene at several tunable wavelengths around the single mode fiber optic wavelength of 1550nm. This was done by simulating a single layer of graphene surrounded by pairs of silicon and silica which serve as Bragg mirrors that redirect incident light towards the graphene.



Model

The model simulated is composed of pairs of silicon and silica layers with varying thicknesses surrounding a one layer cavity of graphene.

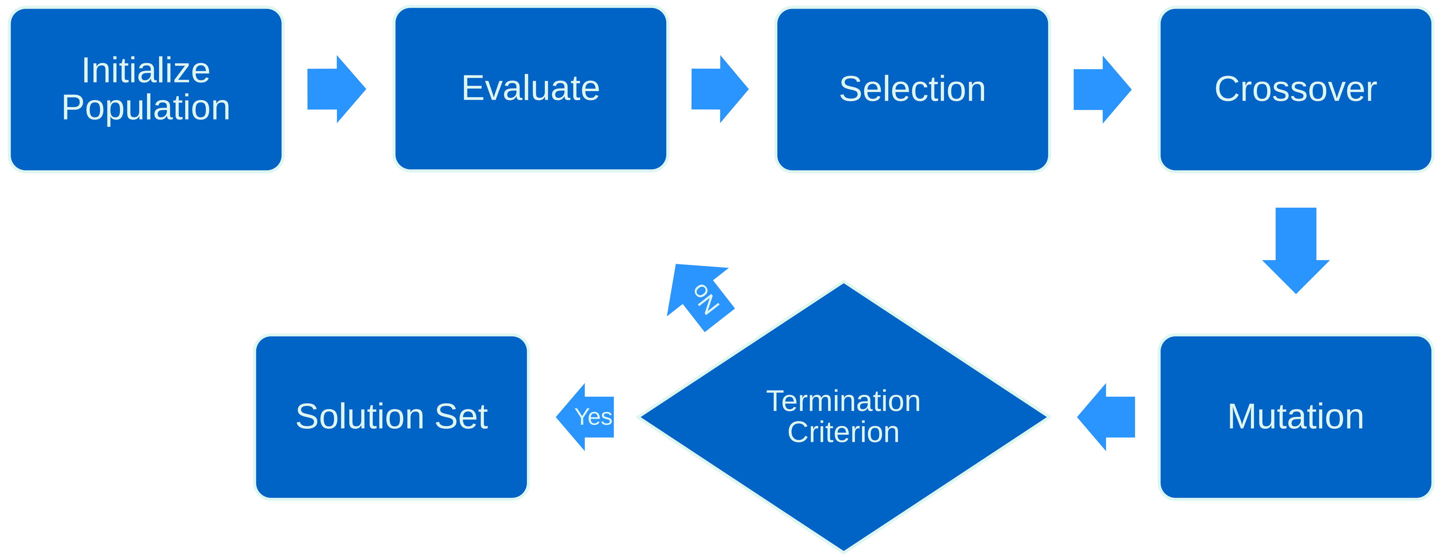
By using the silicon and silica layers as mirrors to repeatedly reflect incident light towards the layer of graphene, much larger absorption can be achieved at different wavelengths. The thicknesses of the layers must be optimized for each set of wavelengths, this is done through the use of a genetic algorithm.



Genetic Algorithm

Given that going through each possible configuration of thicknesses would take many years even for the fastest supercomputer, a genetic algorithm is used to find the optimal thicknesses for each particular set of wavelengths.

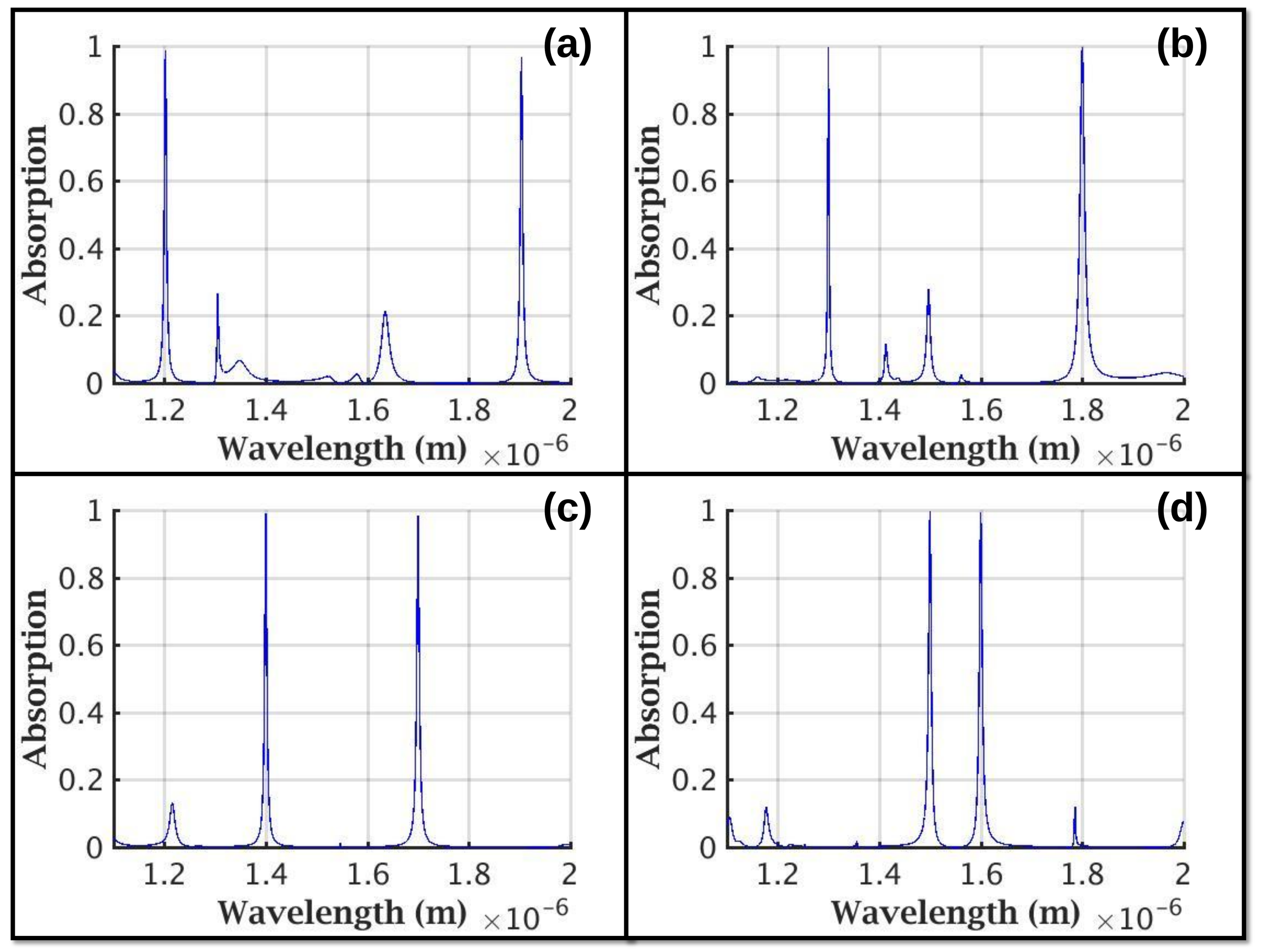
A genetic algorithm is named such because it is based on the principles of natural selection. It works by generating a "chromosome" that stores a value for the parameter that is being optimized. The "fitness" of these chromosomes is determined by calculating the absorption that can be achieved using their values, after which the fittest chromosomes are used to create offspring off of which the next generation is based. This process is repeated until the difference between generations is negligible.



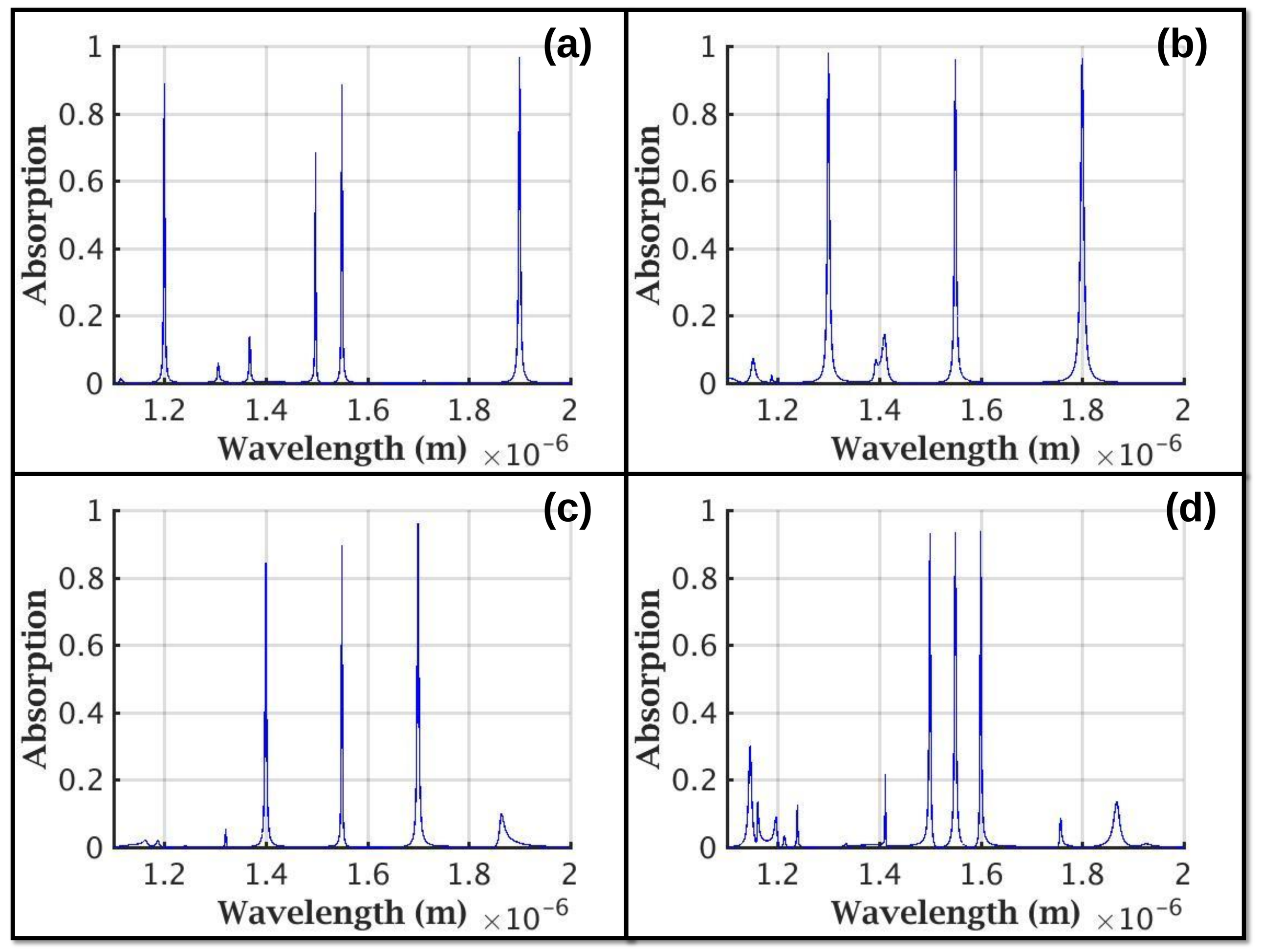
Results

These are the results for the Graphene's absorption in cases which two and three wavelengths are optimized. Both sets are centered around the 1550nm wavelength, which is also optimized for the three wavelength cases. The margin of error in the thicknesses necessary to obtain these results was ~1nm for the two wavelength set and ~.1nm for the three wavelength set.

Two Wavelengths:



Three Wavelengths:



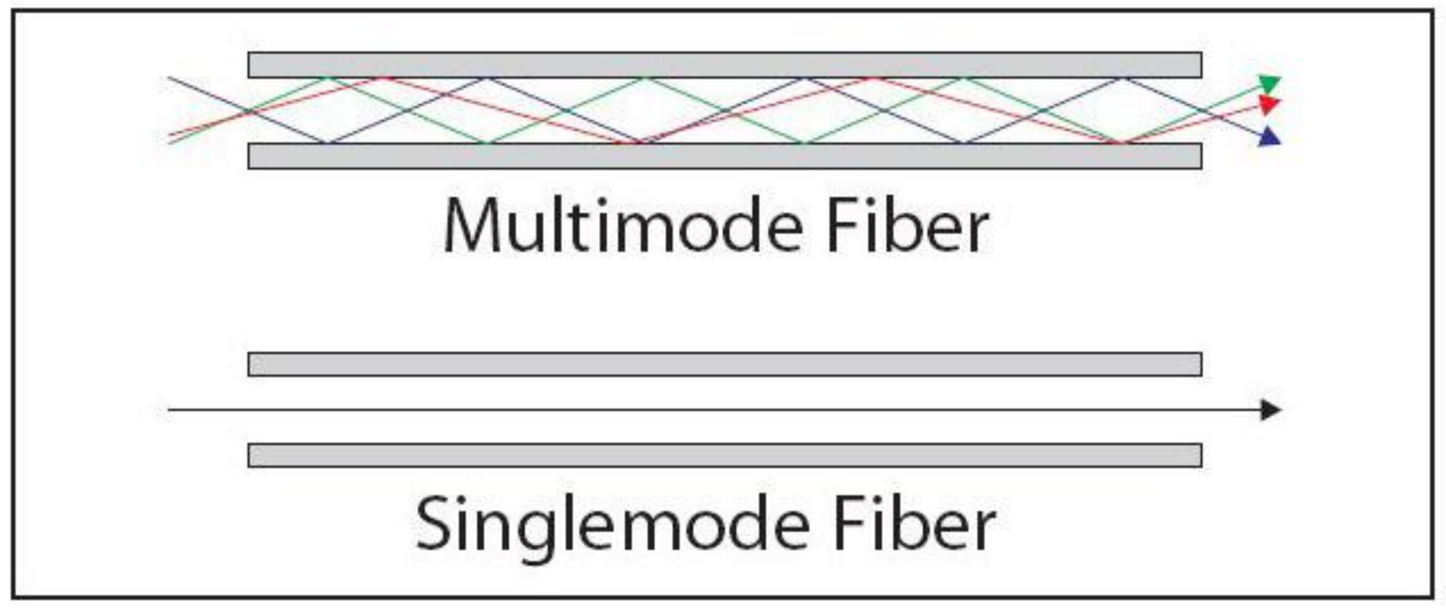
(a) 1200/1900nm, (b) 1300/1800nm, (c) 1400/1700nm, (d) 1500/1600nm
These are the wavelengths pairs for all the cases, given that 1550nm is the third wavelength in all the three wavelength cases.

Conclusions

This project makes it clear that there are suitable Fabry-Perot cavity structures for optimizing the absorbance of graphene at different tunable wavelengths in the range of 1200-1900nm, including the fiber optic wavelength of 1550nm. Despite this it is important to note that the quality of the optimizations drops as the amount of wavelengths to be optimized increases. To replicate these results in an experimental environment, one would need a fabrication method with around a 1nm margin of error for the two wavelength cases and .1nm for the three wavelength cases.

Future Work

Possible next steps for the project would be to create new structures to optimize the absorption of graphene around 850nm, another wavelength commonly used in multimode fiber optics transmissions. This can be done using different reflective materials such as alternating layers of AlAs and Al(0.10)Ga(0.90)As.



Acknowledgements

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References

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