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# Evolutionary optimization of nanophotonic multilayered structures

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## Summary

We apply optimization algorithms inspired by evolution photonic structures. Trying to maximize the reflection coefficient of a multilayered structure systematically leads to the famous Bragg mirror. This shows it is an optimal structure and explains why it is often found in nature.

## Genetic algorithm

Genetic/evolutionary algorithms are optimization algorithms directly inspired by evolution. They use a process of selecting structures (here each structure will be called an "individual") best suited to what is desired. A *cost function* is defined for this purpose. The lower it is, the more the structure/individual is considered adapted, and the higher are its chance to "survive".

- We take a starting population that is randomly generated.
- The next generation is produced using different ways
  - A part of the previous generation is selected and kept - the more fit the individuals, the higher their chances to be kept.
  - The rest of the next generation is obtained combining two parents that have been selected in the previous generation because they are adapted to our criteria.
  - The best individual is always kept, as a reference.
- We monitor how the cost function of the best individual evolves. After a certain number of generations, we stop the process. The individual with the lowest cost function is the result (see Fig. 1).

## Bragg Mirror

A Bragg mirror is a structure that can often be found in nature[2], and that is commonly used because of its ability to reflect light very efficiently. However, it has never been proven that it is an optimal structure.

The structure we considered is composed of a given number of layers of any thickness and any index between 1.4 and 1.7. We use Moosh[1] to compute the reflection coefficient  $r(\lambda)$  at the operation wavelength  $\lambda = 600nm$ . The cost function we have chosen is  $1 - r(\lambda)$ . We thus asked the algorithms to maximize the reflection coefficient.

For a few layers, as well as for any number up to twenty, the algorithm converge towards a Bragg mirror (see Fig. 2). Sometimes and for a very high number of layers the algorithm "fails" but the structure always closely resembles a Bragg mirror. This makes us confident that the Bragg mirror is the optimal solution to the problem of reflecting light with transparent materials.

## Conclusion

We have used evolutionary algorithms to optimize multilayered structures and we have found that, using a simple objective function, the algorithms are actually able to retrieve Bragg mirrors as the best structure to reflect light at a given wavelength. Bragg mirrors can be considered as a valid test-case to assess the efficiency of a given optimization algorithm. We thus expect this fundamental work to be useful to the community and we are planning to optimize more complex structures in the future, as some kind of regularity seems to easily emerge during the optimization process.

## References

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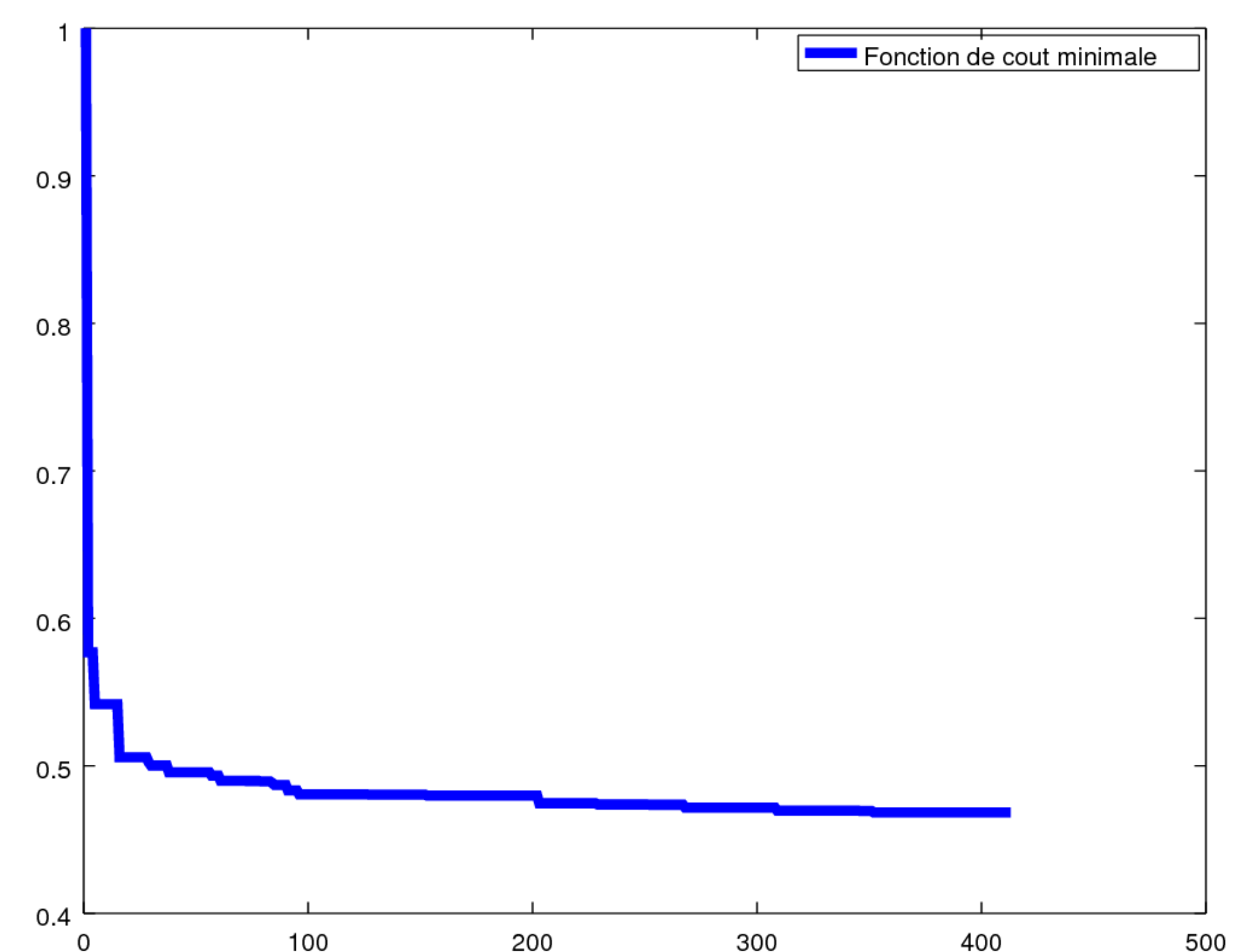


Figure 1: Cost function for the best individual as a function of the number of generations, showing the convergence of the algorithm.

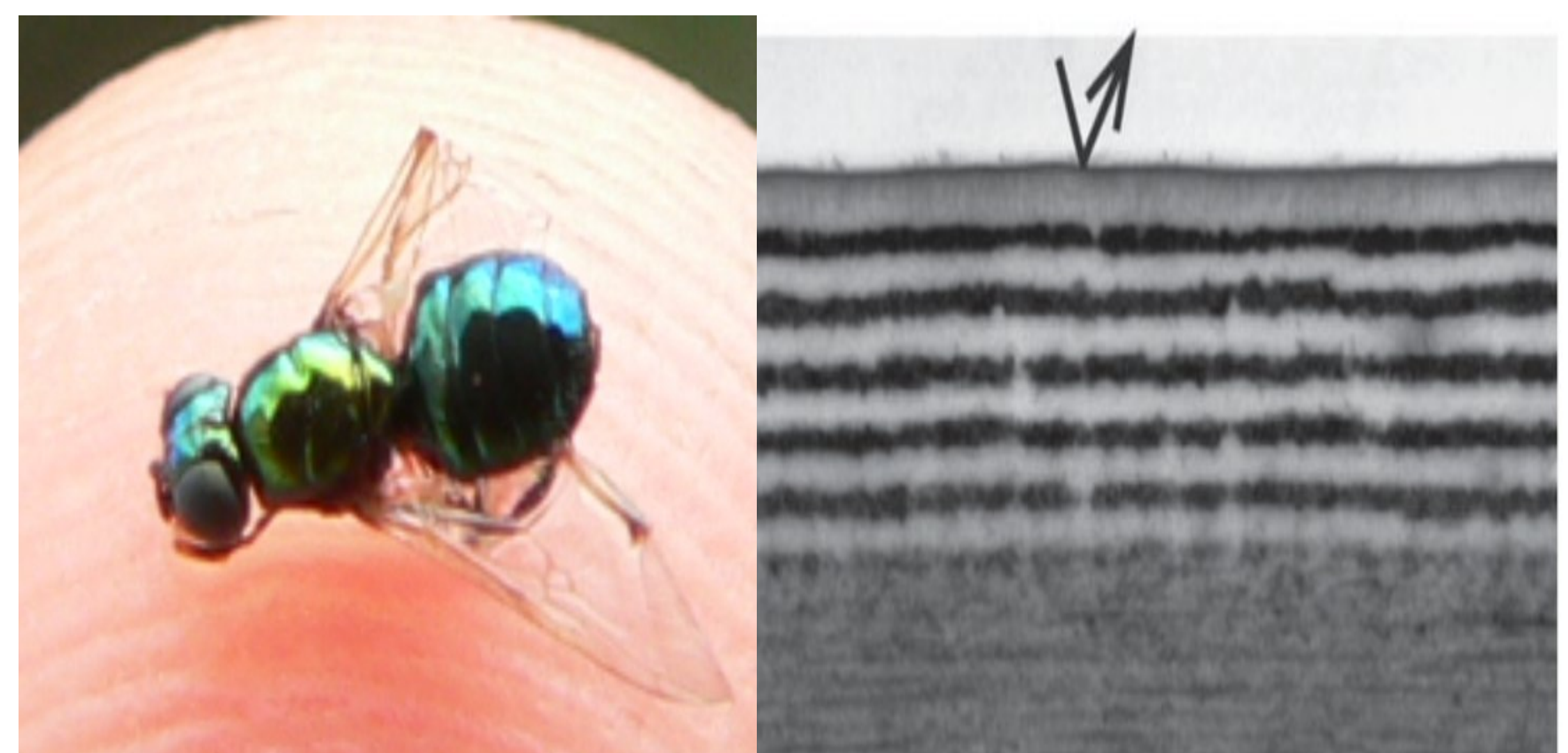


Figure 2: Left: An insect bearing a typical Bragg mirror resulting in a bright green specular reflection. Right: Actual structure on the elytra of an insect[3].



Figure 3: Multilayered structure resulting from the optimization using evolutionary algorithms. The structure is exactly a Bragg mirror whose central wavelength is 600 nm.

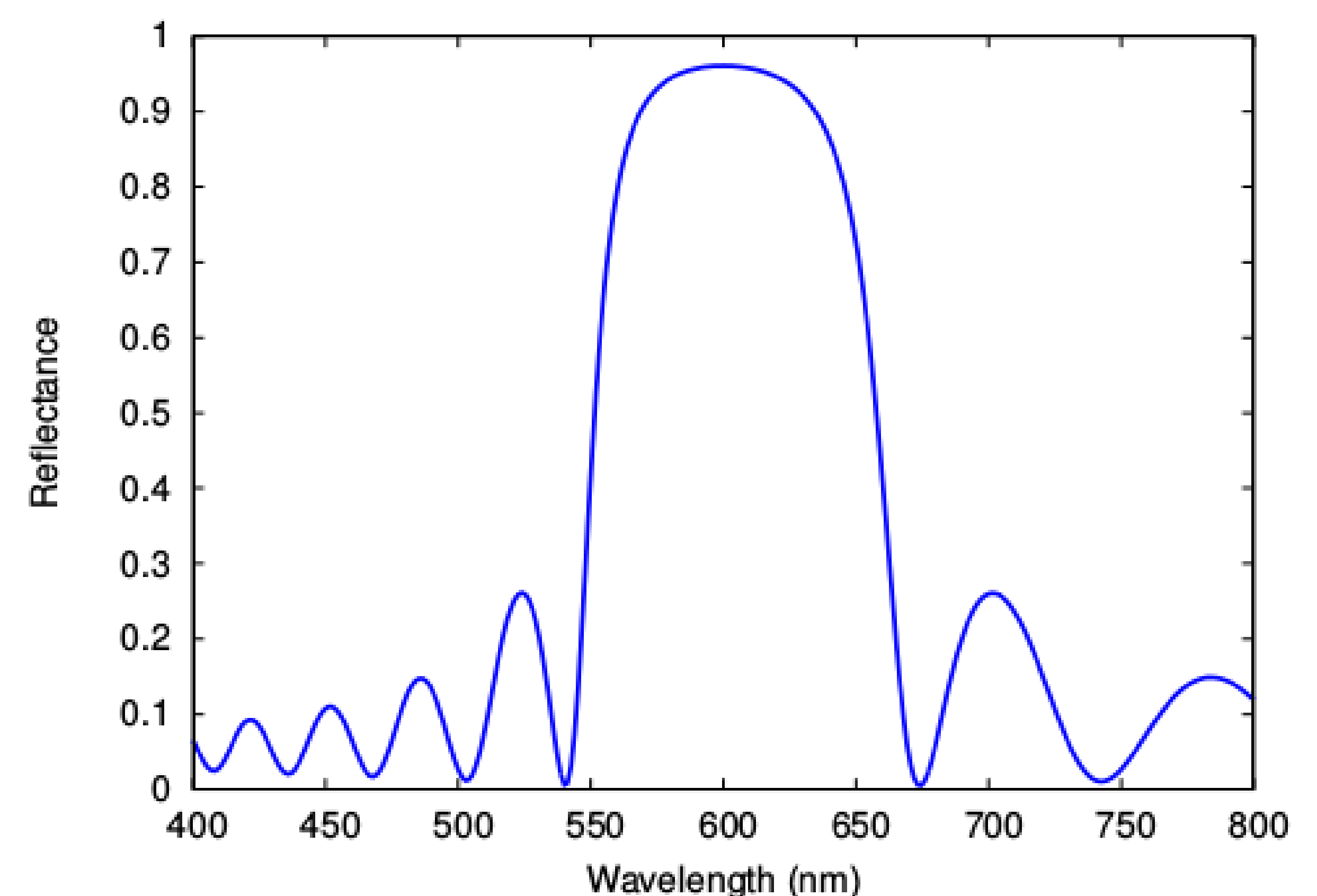


Figure 4: Reflection spectrum corresponding to the optimized structure shown Fig. 3.