Benchmarking different optimization algorithms for maximizing the extraction efficiency of a single-photon source

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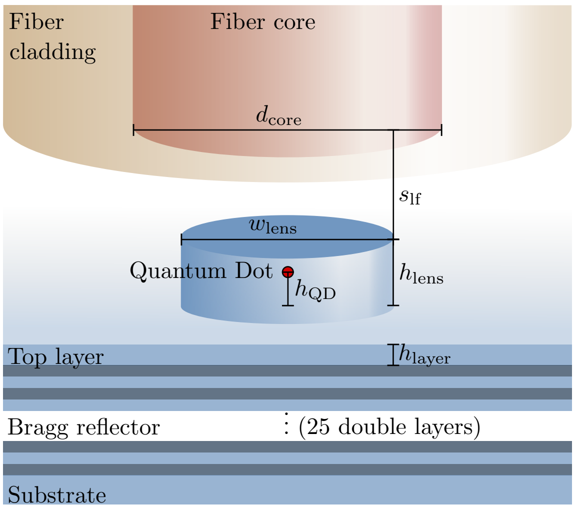
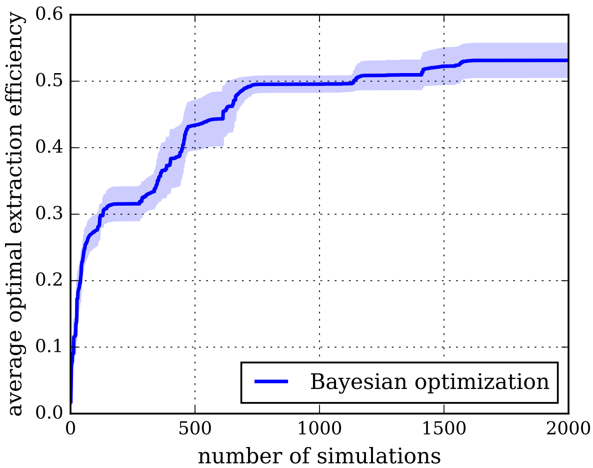
Advanced nanoprocessing technologies such as 3D in-situ electron-beam lithography allow for the manufacturing of micro and nano optical structures with an increasing degree of accuracy and flexibility.[2] In order to design structures that are optimized for specific purposes, numerical optimizations based on the solutions of Maxwell's equations are an important tool.

We consider the numerical optimization of a single-photon emitter (SPE) utilizing a quantum-dot (QD) emitting photons at a vacuum wavelength of $\lambda = 1,300\,\mathrm{nm}$ in the telecom O-band. The QD is embedded into a resonant mesa structure made from gallium arsenide (GaAs). An underlying Bragg multilayer structure reflects the light emitted by the QD back into the upper hemisphere. The light is coupled into an optical fiber above the QD consisting of a homogeneous fiber core and fiber cladding. The system is parametrized by six parameters, the width and height of the mesa, the elevation of the QD within the mesa, and the thickness of the GaAs layer above the Bragg reflector, the fiber-core diameter and the distance between mesa and fiber tip (see Figure).

The goal of the parameter optimization is to maximize the photon extraction efficiency of the SPE into the optical fiber. The extraction efficiency is determined using a finite-element method.[4] We compare the performance of different optimization approaches, i. e. Bayesian optimization, particle-swarm optimization, the Nelder-Mead simplex algorithm, and random sampling. We show that Bayesian optimization,[1,3] an approach known from machine learning, can offer superior performance.





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