Numerical optimization of resonant nanophotonic devices

F. Binkowski[1], P.-I. Schneider[2], M. Hammerschmidt[2], L. Zschiedrich[2] and S. Burger[1,2]
[1] *Zuse Institute Berlin, Takustraße 7, 14195 Berlin, Germany*
[2] *JCMwave GmbH, Bolivarallee 22, 14050 Berlin, Germany*
e-mail: burger@zib.de

Advanced nanoprocessing technologies allow for the manufacturing of resonant nano-photonic structures with an increasing degree of accuracy and flexibility. In order to design structures for specific purposes, numerical optimization is an important tool. Requiring the solution of Maxwell's equations, the computation of the objective function is in general very time consuming. Therefore, optimization methods must be very efficient in the number of function evaluations required to maximize the device performance.

We have studied the performance of different optimization methods for several design problems in nanophotonics, including the optimization of light extraction from a single-photon-source and a diffractive meta-surface [1, 2]. The comparison shows that Bayesian optimization (BO) can largely accelerate to optimization. Based on the simulation results, BO builds up a stochastic model of the objective function in order to identify promising parameter values. The method, which has gained popularity in the field of machine learning, shows to be also very useful for metrology applications to reconstruct geometrical parameters from measured data.

Further, for a better understanding of the physical behavior of nanophotonic devices, an expansion of the electromagnetic field into so-called quasinormal modes (QNMs) can be instructive [3]. In presence of general dispersive media, current challenges are the derivation of orthogonality relations for QNM expansion [4] and the precise quantification of the coupling of an emitter to a background. To overcome limitations of state-of-the-art methods, we have introduced a new expansion approach [5] for analyzing light-matter interaction in dispersive nanoresonators. The theory is based on Riesz projections, which do not rely on the explicit knowledge of eigenmodes and allow for the precise quantification of the background coupling. We present the theory as well as its numerical realization and review several applications [5-8].

REFERENCES

[1] P.-I. Schneider et al., preprint arXiv:1809.06674.
[2] P.-I. Schneider et al., Opt. Express 26, 8479 (2018).
[3] C. Sauvan et al., Phys. Rev. Lett. 110, 237401 (2013).
[4] W. Yan, R. Faggiani, P. Lalanne, Phys. Rev. B 97, 205422 (2018).
[5] L. Zschiedrich et al., Phys. Rev. A 98, 043806 (2018).
[6] P. Lalanne et al., J. Opt. Soc. Am. A 36, 686 (2019).
[7] G. Kewes et al., ACS Photonics 5, 4089 (2018).
[8] F. Binkowski et al., preprint arXiv:1906.01941