Global design optimization in photonics: from high performance to fabrication robustness

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Abstract — **Modern photonic devices are characterized by a large number of parameters and the need for an "holistic" optimization of their behavior taking into account multiple figures of merit, noteworthy tolerance to fabrication uncertainty. We present here a set of tools based on dimensionality reduction capable of handling such multi-parameter, multi-objectives design problems.**

Keywords*— *Photonic devices, machine learning, fabrication tolerances, optimization.

Design of photonic devices is steadily departing from classical geometries and focusing a growing interest on complex structures exploiting non-trivial shapes and metamaterials with the goal to either increase the integration scale or introduce novel functionalities. As a consequence, the number of parameters that must be handled during the design vastly increase and often a strong correlation is also introduced. Sequential optimizations or independent parameter sweeps are prone to return sub-optimal solutions and more advanced optimization tools become essential. Besides the complexity of the design space generated by the input parameters, an effective design must also deal with a number of figures of merit that contribute to the final quality of the device, e.g., losses, bandwidth, or generated back-reflections [1]. Among these figures of merit, tolerance to fabrication uncertainty is among the most important ones since it determines the likelihood for the realized device to behave according to the design intent [2]. This complex scenario requires the development of a novel set of tools.

In this invited talk we will present our recent work on the application of machine learning tools to multi-parameter, multi-objective optimization problems in photonic design. In particular, we will discuss the potentiality of dimensionality reduction and surrogate models for the analysis of the complex design spaces characterized by a large number of correlated parameters [3,4]. By reducing the number of parameters without a significant loss of information, the designer is able to explore the design space efficiently and compute any required figure of merit criteria, including fabrication tolerances. As an example, Fig. 1 shows a set of Pareto-optimal designs of the profile of a power splitter/combiner for the mid IR described by 16 variables. Each solution (marked by a dot) represents a different optimal compromise between efficiency, roll-off and back-reflection. Their analysis allows the designer to identify structural limits and bottlenecks of the geometry and to take informed decisions based on the relative priorities of all figures-of-merits in view of a particular application.

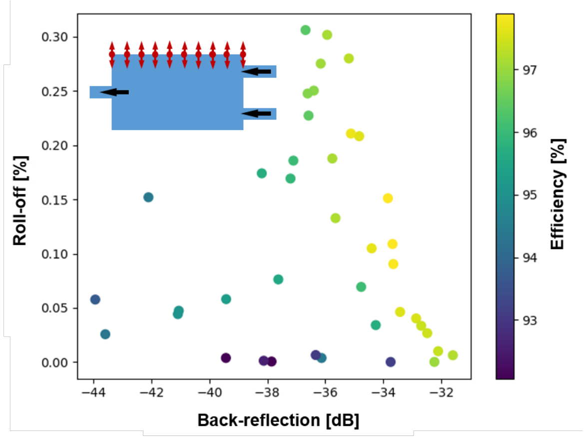

Figure 1: Example of multi-objective optimization of a power splitter/combiner for the the mid-IR (λ = 5.5 µm). The use of dimensionality reduction allows to compress the design space and discover a set of Pareto-optimized designs (dots) offering different compromises between efficiency, roll-off, and back-reflection.

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