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Topology Optimization of Photonic Devices Using Function Expansion Method and Evolutionary Approach

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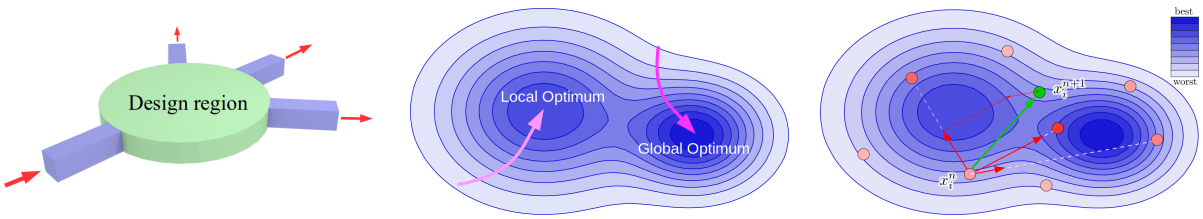
In recent increase of communication traffic, further high capacity photonic network is desired and many kinds of high-performance and compact photonic devices have to be developed. Recent advance in numerical simulation technique of photonic devices enables us to estimate transmission property of waveguide devices in reasonable computational time and to design photonic devices on personal computer.

In this study, we develop a topology optimization method which can automatically generate innovative device structure with desired transmission property beyond our past knowledge. In order to optimize device structure, in general, the structure in the design region is expressed by a lot of numerical design variables and those design variables are optimized by some optimization technique. In this study, we employ function expansion method to express device structure and optimize the design variables utilizing hybrid method of gradient method and evolutionary algorithm. An image of problem setting and optimization methods are illustrated in Fig. 1.

In the function expansion method, a structure in design region is expressed as follows [1]:

$$n^2(r) = n_a^2 + (n_b^2 - n_a^2)H(w(r)), \qquad w(r) = \sum_{i=1}^{N} c_i f_i(r) \tag{1}$$

where $H(\xi)$ is a modified Heaviside function, $f_i(r)$ $(i = 1, 2, \cdots)$ are basis function, and c_i are amplitudes of the basis functions. c_i are the design variables in our optimization approach and are optimized to obtain an optimum structure with desired transmission property. In our past study, we employ gradient method to optimize design variables and adjoint variable method (AVM) to efficiently calculate sensitivity with respect to design variables. However, we sometimes encounter a problem of being trapped in local optima. On the other hand, although evolutionary approach, such as firefly algorithm, is possible to find out more global optima, higher computational cost is required[2]. In this study, in order to improve the optimization approach and efficiently search more global optima, we develop hybrid evolutionary approach with gradient method.



(a) Design momdel (b) Gradient Method (c) Firefly Algorithm

Figure 1. Topology optimal design of photonic device

References

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