

# **Hybrid approaches integrating machine learning and shape optimization for the design of electromagnetic structures**

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Recent impressive advances in the fabrication of nanostructures and metamaterials have enabled new classes of devices with unprecedented functionalities and performance. The large number of design parameters in such nanostructures has made the inverse design and optimization challenging due to the extensive computational requirements of the conventional design approaches. Several techniques based on topological (i.e., shape) optimization or machine learning have been proposed with successful implementation for certain classes of devices along with some shortcomings.

This talk is focused on a new approach for the inverse design of large-scale electromagnetic nanostructures through integrating topological optimization with machine-learning algorithms. This hybrid design techniques allows for systematical optimization of both structural patterns and physical parameters for efficient exploration of the entire design space. By employing dimensionality reduction techniques such as variational autoencoder, trained by topologically optimized structures, better visualization and analysis of the input-output relation in electromagnetic nanostructures are enabled. Reducing the dimensionality not only facilitates the inverse design process with less computational requirements, but also provides better insight into the physics of the device operation (i.e., knowledge discovery). By optimizing across multiple domains, this design approach systematically converges to superior local minima or maxima, uncovering high-performance device configurations.

In addition to describing the fundamental aspects of this hybrid technique, its unique features will be presented by using it for the inverse design of a few classes of passive and reconfigurable metaphotonic structures with an unprecedented performance. These results suggest that the hybrid approach presented in this talk can enable a new paradigm in the design of electromagnetic nanostructures, especially metamaterial-based devices with a large number of design parameters.