Probabilistic Representation and Inverse Design of Photonic Metamaterials Based on a Deep Generative Model

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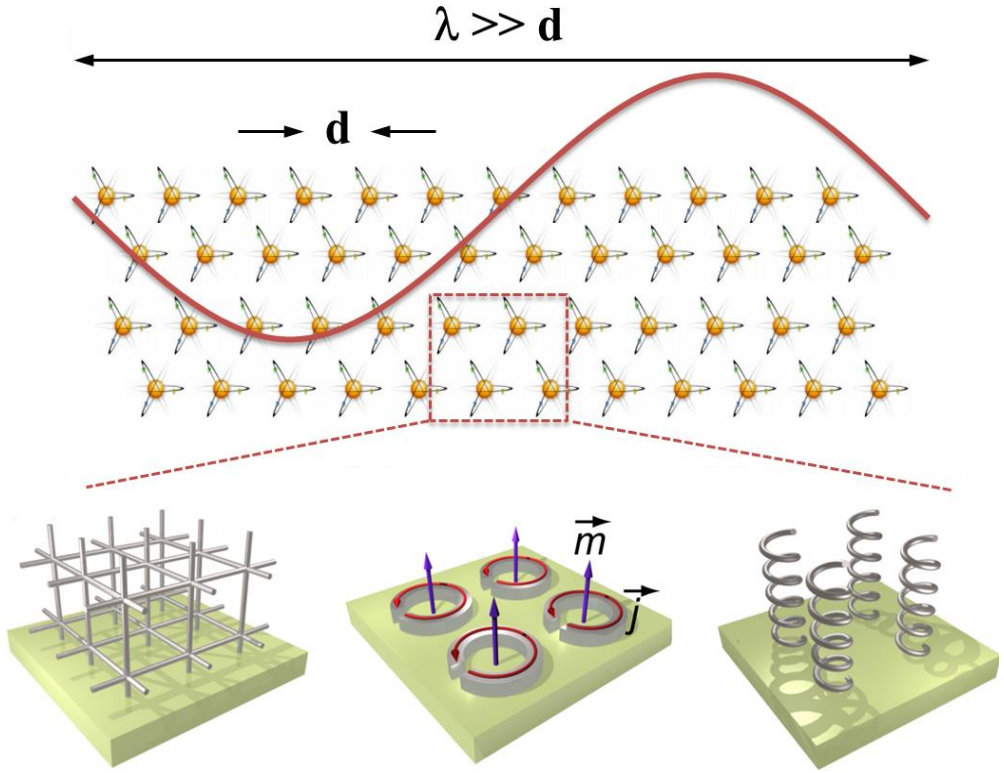
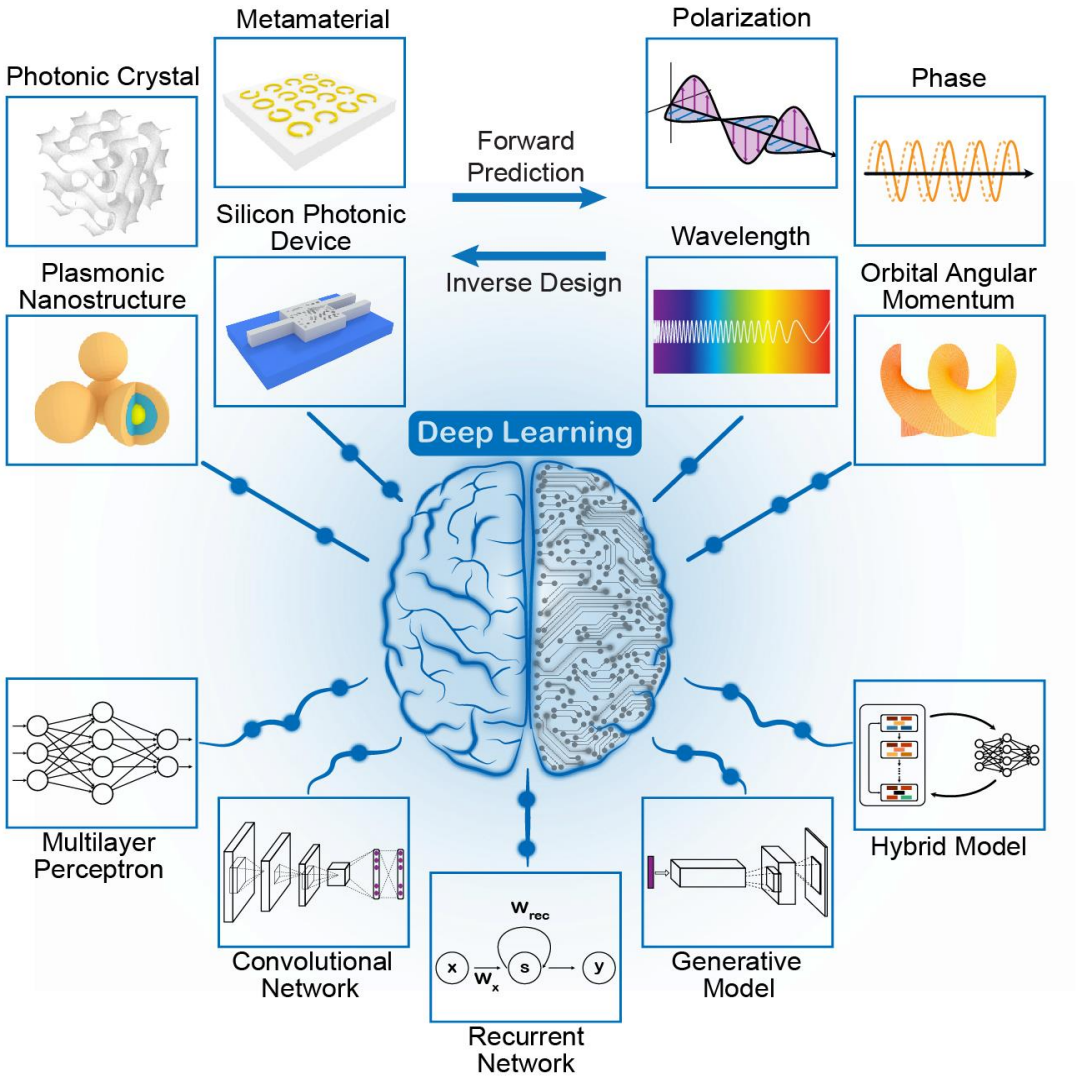
Metamaterials: beyond Natural Materials by Structural Design



- Metamaterials are artificial composite materials with subwavelength engineered structures.
- Exotic material properties can be created, which are primarily dependent on the structure rather than the chemical constituent.

Review: Y. M. Liu and X. Zhang, Chem. Soc. Rev. 40, 2494 (2011); K. Yao and Y. M. Liu, Nanotechnology Rev. 3, 177 (2014)

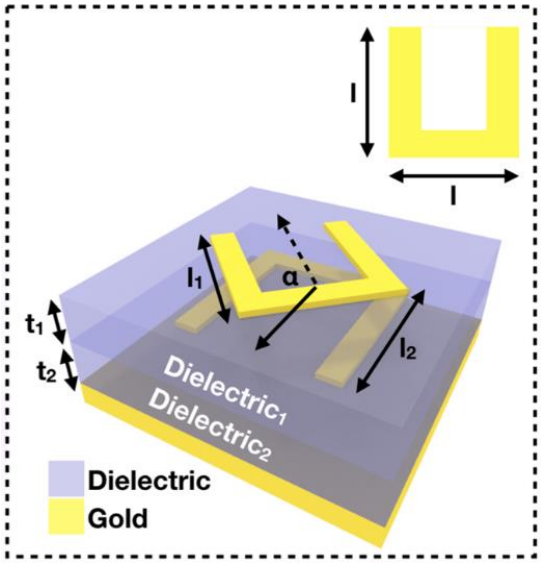
Interfacing Photonics with Artificial Intelligence



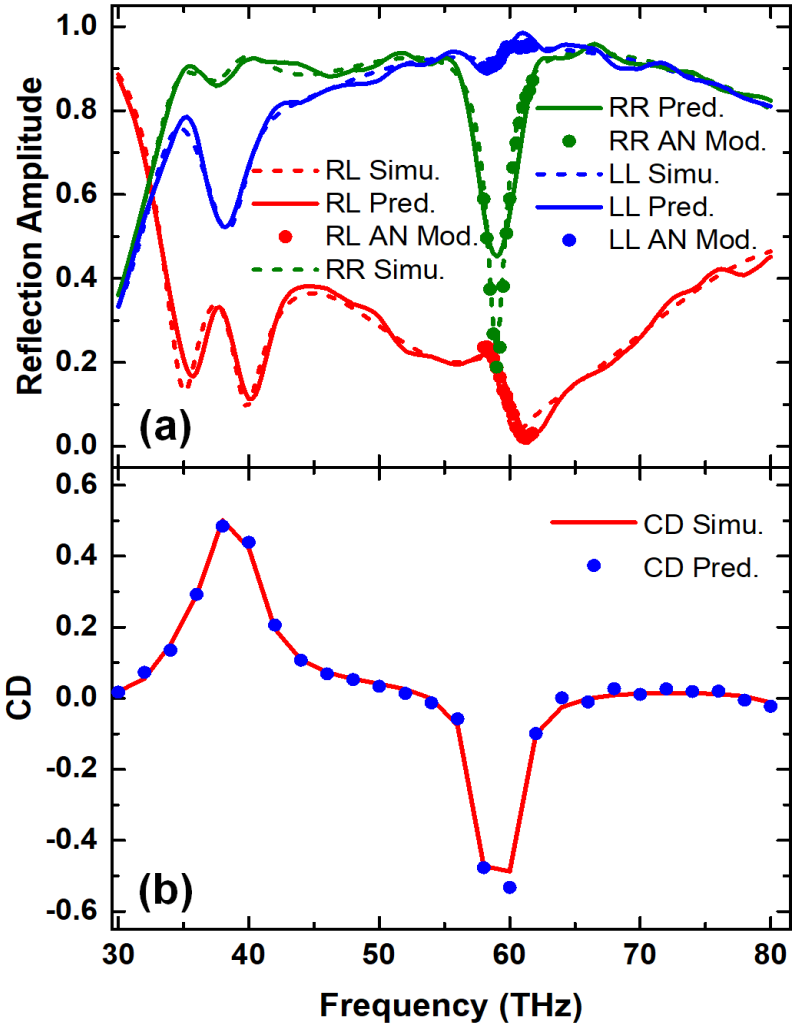
Deep learning for the design of photonic structures, Nature Photonics, online publication (2020)

Other research groups: W. Cai, M. Soljačić, J. A. Fan, J. Rho, H Suchowski, H. L. Zhang, K. Kojima, A. Boltasseva, *etc.*

Deep-Learning-Enabled Design of Chiral Metamaterials

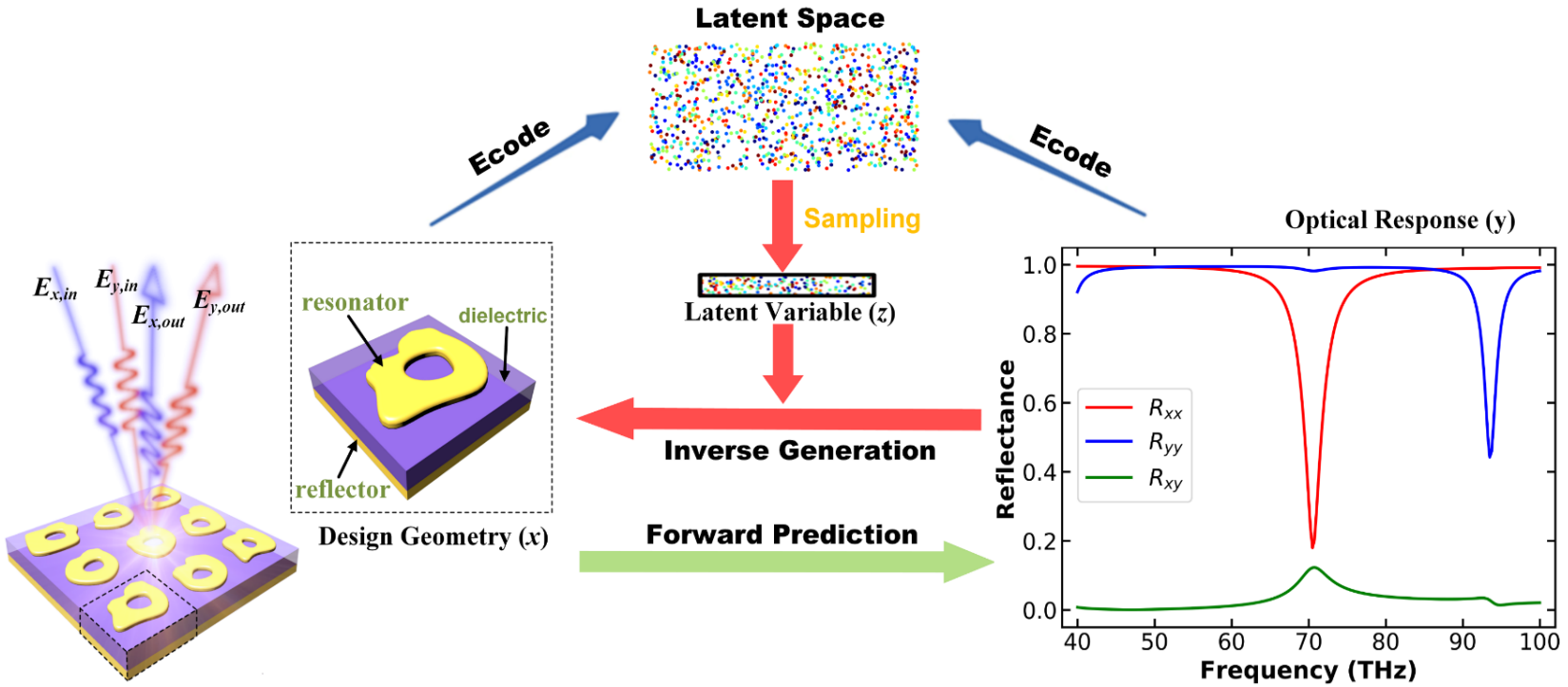


- Five geometric parameters
- 25,000 training data are equivalent to sparsely sample 7.6 points for each of the 5 continuous design parameters.



W. Ma et al., ACS Nano 12, 6326 (2018); Highlight in Nature Photon. 12, 443 (2018)

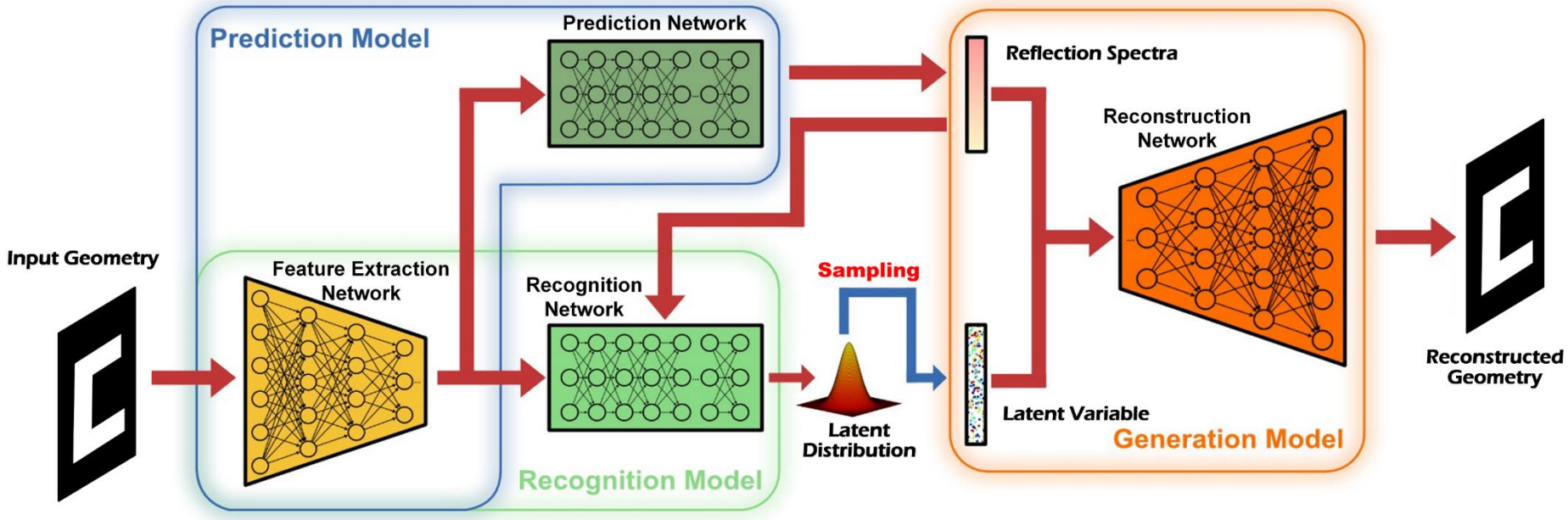
Designing Metamaterials Based on a Deep Generative Model



- Arbitrary shape represented by a 64×64 pixelized image
- Encoder-decoder configuration with latent variables to represent the metamaterial design
- Generative model to solve the one-to-many mapping issue in the inverse design

W. Ma et al., Adv. Mater. 31, 1901111 (2019)

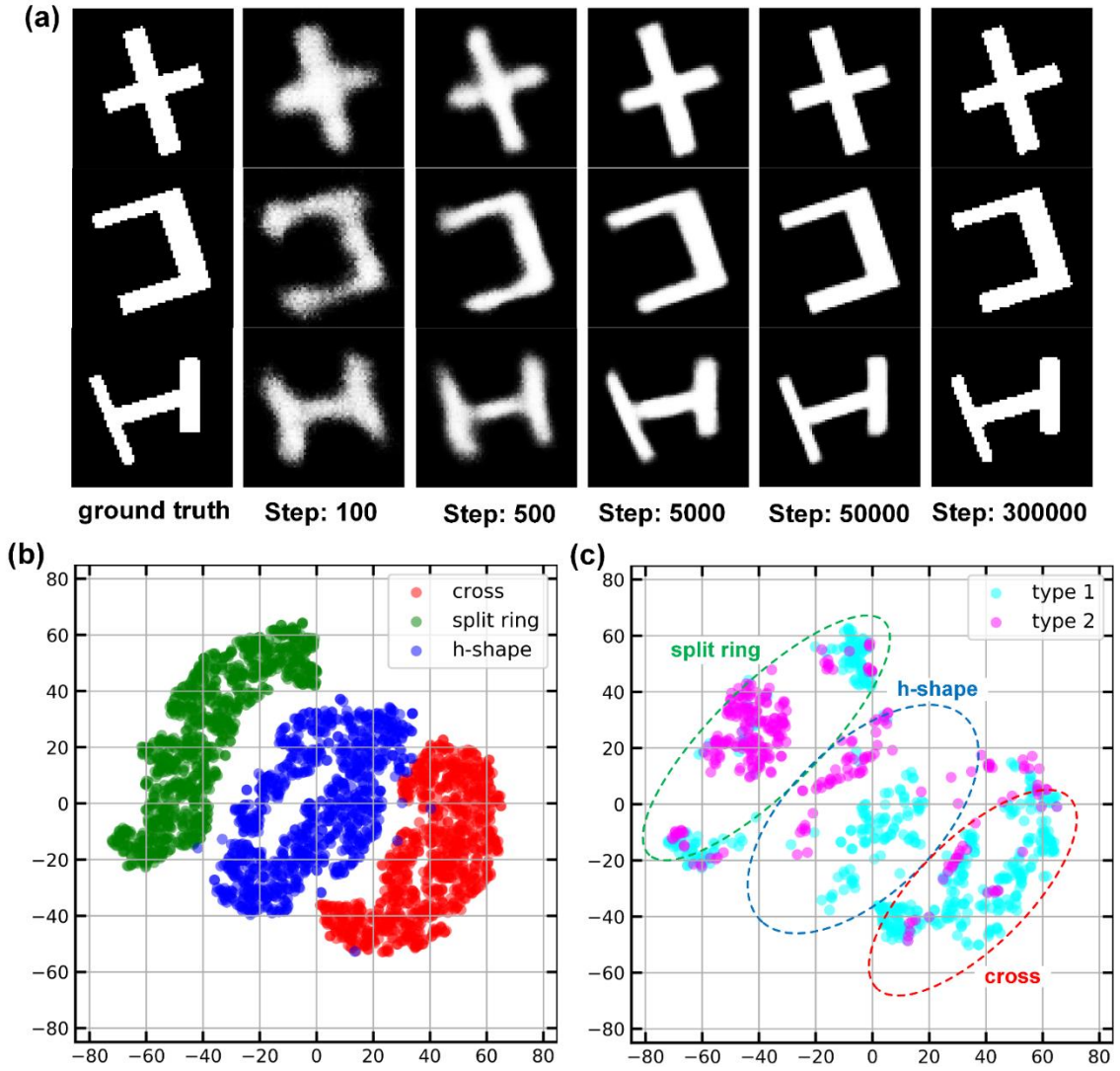
Architecture of the Deep Generative Model



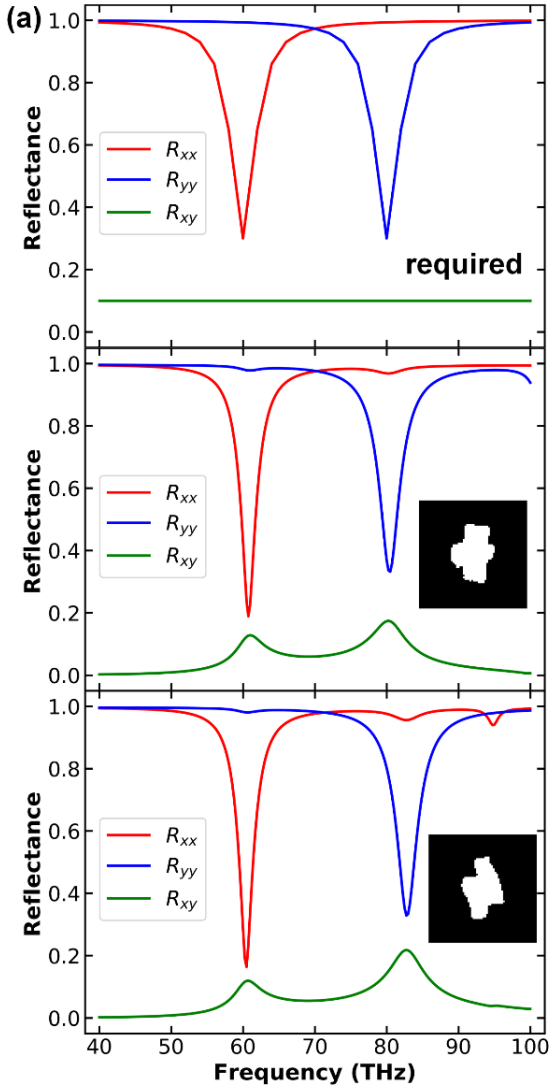
Recognition model: encodes the metamaterials with optical response into a low-dimensional latent space.
Prediction model: outputs a deterministic prediction of the optical response for a given metamaterial.
Generation model: accepts the optical response and the sampled latent variable to produce feasible metamaterial designs according to specific requirements.

W. Ma et al., Adv. Mater. 31, 1901111 (2019)

Metamaterial Construction and Representation in Latent Space

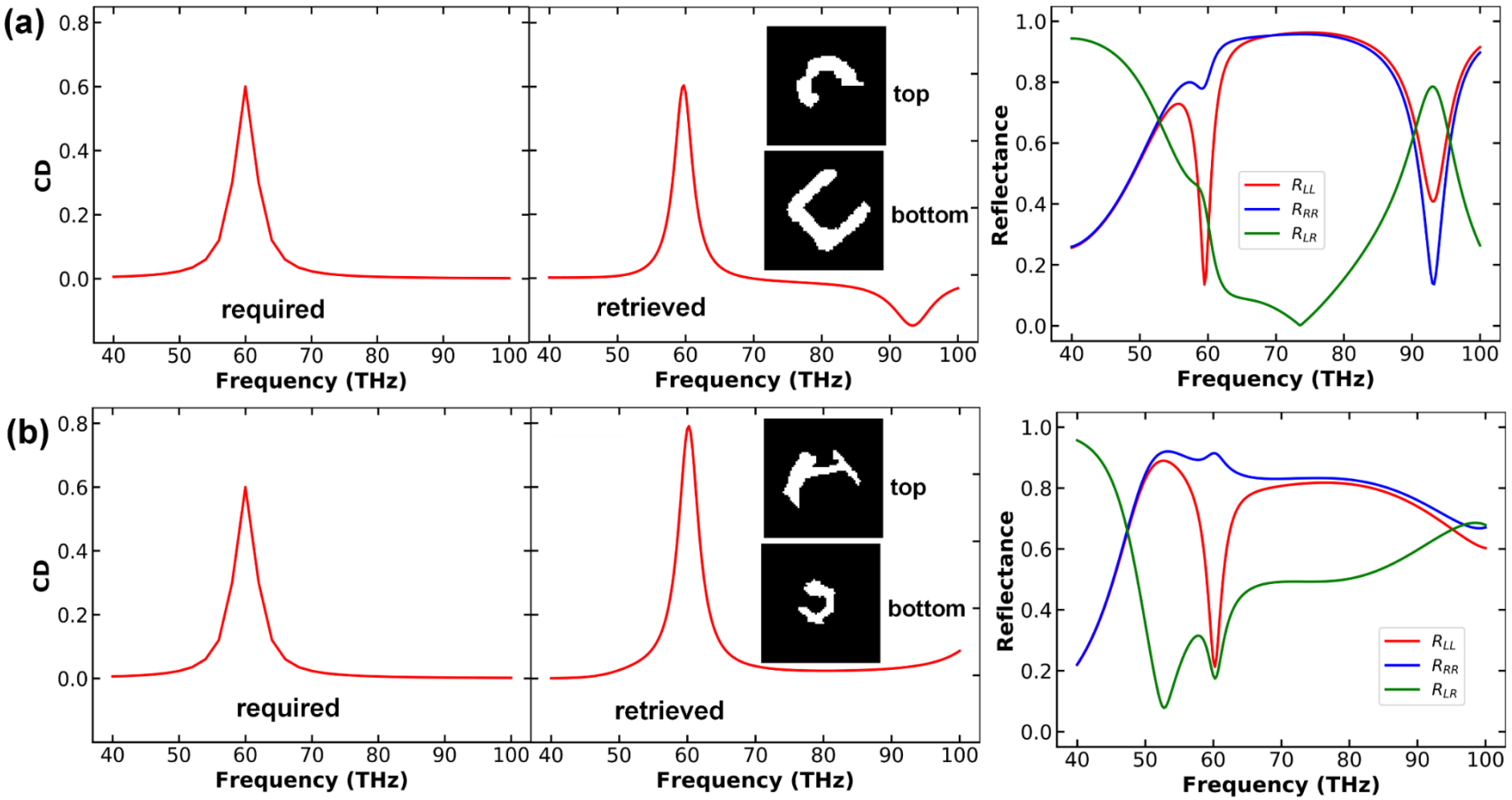


On-Demand Design of Single-Layer Anisotropic Metamaterials



W. Ma et al., Adv. Mater. 31, 1901111 (2019)

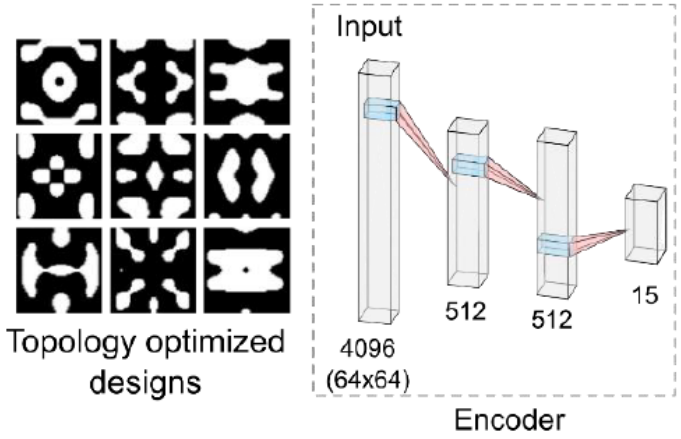
On-Demand Design of Bi-Layer Chiral Metamaterials



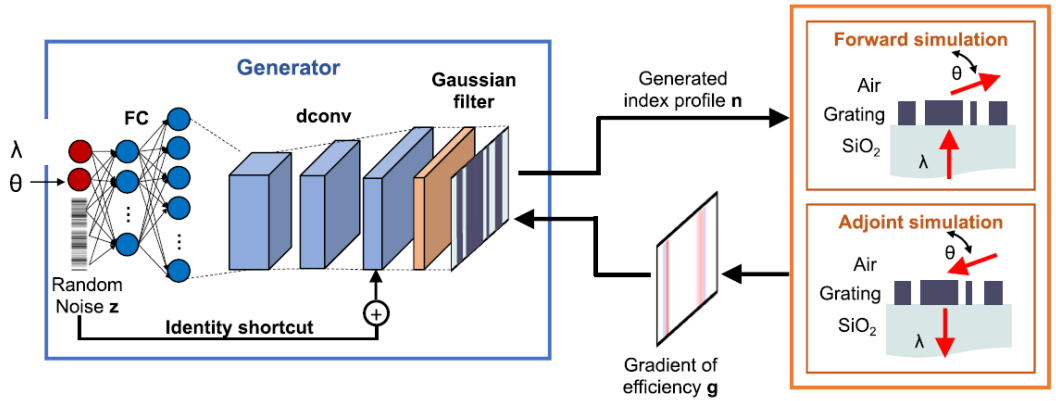
W. Ma et al., Adv. Mater. 31, 1901111 (2019)

Merging Deep Learning with Topology Optimization

- Apply topology optimization to generate high-quality training data for neural networks.
- Use topology optimization to further refine the structures inversely designed by the deep learning models.
- Construct hybrid models that integrate deep learning and topology optimization techniques for global optimization.



Z. A. Kudyshev et al., Applied Physics Reviews 7, 021407 (2020)



J. Jiang and J. Fan, Nano Letters 19, 5366 (2019)

Acknowledgement

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Prof. Wei Ma and Prof. Zuojia Wang (Zhejiang Univ.)
Prof. Lin Li (East China Normal Univ.)

Collaborators

Prof. Wenshan Cai (Georgia Tech.)

Prof. Hongsheng Chen (Zhejiang Univ.)

Profs. Ruwen Peng, Mu Wang, Peng Zhan and Zhenlin Wang (Nanjing Univ.)

Prof. Junsuk Rho (POSTECH)

Prof. Liang Pan (Purdue)

Profs. Nian Sun and Paul Champion (NU)

Financial Support