残差编码器-解码器神经网络助力从场分布到超表面整体设计

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相比于单一的相位或者幅值调控，复振幅调制超表面可以获得更高的图像重建质量。然而，目前流行的全息超表面设计方法是基于惠更斯-菲涅耳理论设计、超表面单元优化、数值仿真和实验验证这几个步骤，其中单元的优化与仿真的过程中将消耗大量的计算资源。

为了优化超表面的设计过程，提高超表面的设计效率，空军工程大学人工结构功能材料研究团队应用残差编码器-解码器卷积神经网络架构直接映射电场分布和输入图像，并用于超表面一体化设计。残差编码器-解码器卷积神经网络能够较好地将电场分布进行压缩与特征提取，并解压还原出输入图像的像素。首先利用衍射理论计算电场分布并对预训练网络进行训练，然后将其作为迁移学习框架进行迁移，将数值仿真的电场分布与输入图像进行映射，从而实现通过电场分布直接得到超表面结构的设计。网络训练结果表明，数据集的归一化平均像素误差约为 3%。作为验证，对超表面样件进行了制备、仿真和测试。重构后的超表面电场与目标电场具有较高的相似性，这证明了设计的有效性。这项工作为超表面设计提供了一种整体的场-图设计方法。

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Direct field-to-pattern monolithic design of holographic metasurface via residual encoder-decoder convolutional neural network

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Complex-amplitude holographic metasurfaces (CAHMs) with the flexibility in modulating phase and amplitude profiles have been used to manipulate the propagation of wavefront with an unprecedented level, leading to higher image-reconstruction quality compared with their natural counterparts. However, prevailing design methods of CAHMs is based on Huygens-Fresnel theory, meta-atom optimization, numerical simulation, and experimental verification, which results in a consumption of computing resources.

The researchers Prof. Jiafu Wang and Prof. Shaobo Qu from Air Force Engineering University applied residual encoder-decoder convolutional neural network to directly map the electric field distributions and input images for monolithic metasurface design. A pretrained network is firstly trained by the electric field distributions calculated by diffraction theory, which is subsequently migrated as transfer learning framework to map the simulated electric field distributions and input images. The training results show that the normalized mean pixel error is about 3% on dataset. As verification, the metasurface prototypes are fabricated, simulated, and measured. The reconstructed electric field of reverse-engineered metasurface exhibits high similarity to the target electric field, which demonstrates the effectiveness of our design. Encouragingly, this work provides a monolithic field-to-pattern design method for CAHMs, which paves a new route for the direct reconstruction of metasurfaces.

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