亮点报道：超表面集成量子模拟运算：开启相位重构的新思路

DOI: 10.12086/oee.2025.251011.h02

相位重构作为光学领域的一项关键技术，其核心目标在于从光波的强度信息中还原出相位信息。但它面临着一系列技术难题，特别是在复杂光场环境下，相位重构的精度和稳定性可能因噪声干扰和算法收敛性问题而受到影响。

湖南大学罗海陆教授团队提出了一种全新的量子模拟运算系统。此系统巧妙地将多通道超表面与量子纠缠源相结合，具备在低信号光子水平下达成高信噪比的定量相位重构的能力。传统的相位重构往往伴随着复杂的操作步骤，而这一技术有效地简化了传统相位重构的复杂程度。它在多个重要领域展现出应用潜力，例如在光学芯片领域，有助于提升模拟运算芯片的性能与功能；在波函数重建方面，能够提供更精准有效的方法；在无标记生物成像领域，能够在低光子水平对透明细胞实现无标记、高信噪比和高对比成像。

在此实验过程中，研究人员通过精确控制触发端的偏振态，实现了对超表面上光学模拟运算的非局域操控，进而成功获得了相位重构所需的四种微分运算。在此基础上，利用积分运算将光场的相位梯度信息准确转换为相位分布信息，顺利实现了定量相位重建。

Opto-Electronic Advances, 2025, **8**(4): 240239.
https://www.oejournal.org/article/doi/10.29026/oea.2025.240239

Highlights: Integrated metasurface for quantum analog computation: a new scheme to phase reconstruction

DOI: 10.12086/oee.2025.251011.h02

Phase reconstruction, as a key technology in the field of optics, aims to recover phase information from the intensity information of light waves. However, since most detectors can only capture light intensity data, directly measuring the phase of light waves has always been technically challenging and remains unachievable.

Prof. Hailu Luo's research group from the School of Physics and Electronics at Hunan University have proposed an metasurface-integrated quantum analog computing system. This system ingeniously combines multi-channel metasurfaces with quantum entanglement sources, enabling quantitative phase reconstruction with high signal-to-noise ratio at low signal photon levels. Traditional phase reconstruction often involves complex operation steps, while this technology effectively simplifies the complexity of traditional phase reconstruction.

The experimental results show that during this experiment, the researchers achieved non-local manipulation of optical analog computation on the metasurface by precisely controlling the polarization state of the trigger. Consequently, they successfully obtained the four differential operations required for phase reconstruction. On this basis, the researchers accurately converted the phase gradient information of the optical field into phase distribution information by using the integral operation, thus realizing quantitative phase reconstruction.

Opto-Electronic Advances, 2025, **8**(4): 240239.
https://www.oejournal.org/article/doi/10.29026/oea.2025.240239