Time-varying orbital angular momentum generated by a metasurface

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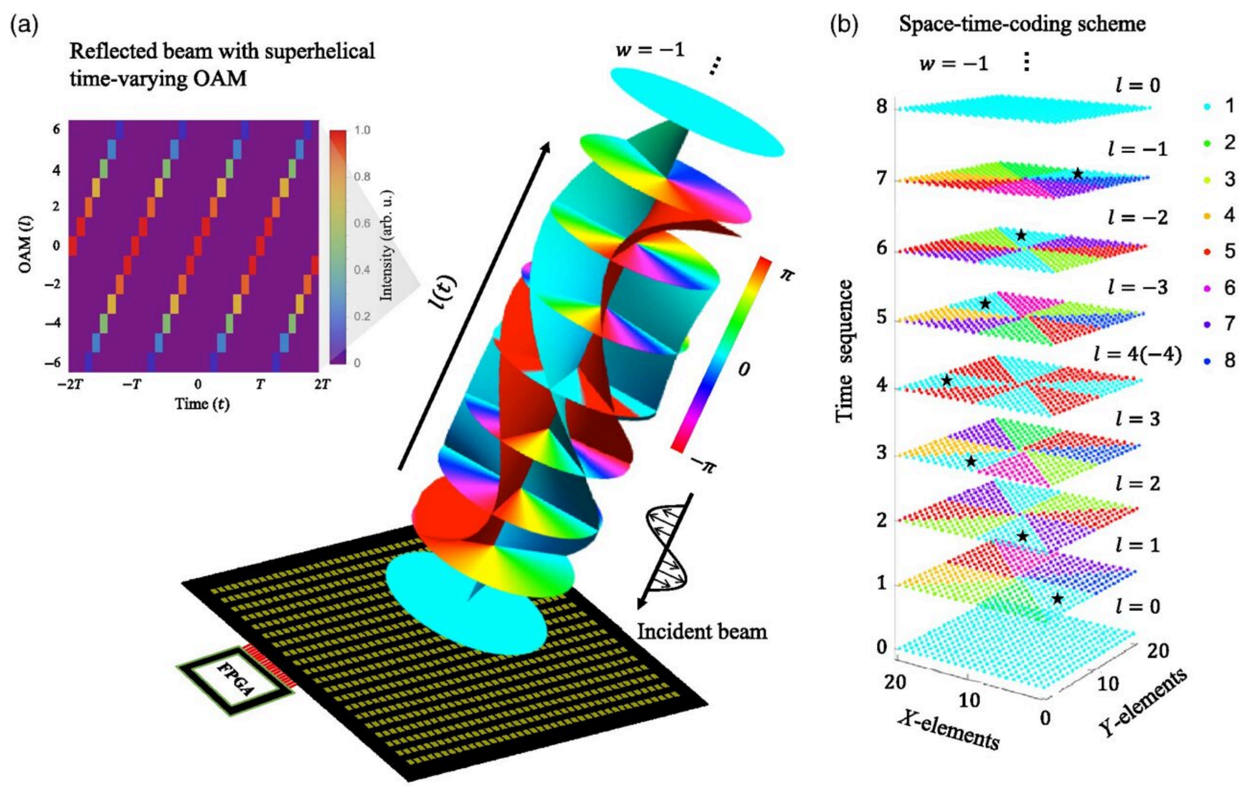

Time-varying OAM beam generation. (a) Time-varying OAM beam with topological charge l(t) varying from 0, 1, 2, 3, 4(−4), −3, −2, and −1 periodically in time, with envelope phase profile [omitting exp(jωt) for brevity] shown at different layers in time. The cyan and red curved surfaces geometrically join up the 0 and π phase on different layers, showing a twist completing one cycle in the clockwise direction defined with winding number w=−1. The beam is generated by a space-time-coding digital metasurface controlled with FPGA. (b) Digital coding scheme of the metasurface with 3-bit coding digits “1” to “8” representing the 0 deg to 315 deg in every 45 deg for the reflection phase profile (in addition to reflection from a perfect metal) at each time instance. The black stars mark the twisted trajectory of zero phase position with coding digit "1.". Credit: *Advanced Photonics* (2023). DOI: 10.1117/1.AP.5.3.036001

The orbital angular momentum (OAM) of electromagnetic waves—a kind of "structured light"—is associated with a helical or twisted wavefront.

The helical modes are characterized by a topological charge. OAM beams with distinct topological charges are mutually orthogonal, which allows them to carry information and to be multiplexed. OAM multiplexing affords increased channel capacity and spectral efficiency—highly useful in fiber-based and free-space communications. OAM beams also have qualities that are useful for optical trapping, lattices, and more.

Unlocking the potential of OAM has advanced thanks to persistent research efforts globally. As reported in *Advanced Photonics*, researchers from The Hong Kong University of Science and Technology (HKUST) and City University of Hong Kong (CityU) recently developed time-varying OAM beams using a space-time encoded digital metasurface. They used a field-programmable gate array (FPGA) to control the reflection phase of the atoms at the metasurface in the microwave regime.

By exploiting the flexible programmability of the metasurface, they construct different modes of the time-varying OAM beams having a time-dependent phase profile in each time layer. This allows not only a time-varying topological charge but also a higher-order twist in the envelope wavefront structure of the OAM beam in terms of a nonlinear time-dependence in phase, which functions as an additional degree of freedom to allow greater capacities for application.

For their experimental demonstration, the team developed a two-probe mapping method to dynamically map the time-varying OAM field including amplitude and phase patterns at various instants of time. In addition, they performed spectrum analysis targeting OAM mode decomposition on measured field patterns, which demonstrated the high mode purity of the generated time-varying OAM and the designed higher-order twist in the envelope wavefront structure.

Their innovative approach, combining the metasurface's space-time digital encoding and the two-probe field mapping technique, results in a versatile platform for generating and observing time-varying OAM—as well as other spatiotemporal excitations.

The proposed time-varying OAM beams have application potential for dynamic particle trapping, time-division multiplexing, information encryption, and beyond.

More information: Jingxin Zhang et al, Generation of time-varying orbital angular momentum beams with space-time-coding digital metasurface, *Advanced Photonics* (2023). DOI: 10.1117/1.AP.5.3.036001

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