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Technology Snapshot

Los Alamos NATIONAL LABORATORY

Nanoscale Tunable-Index OAM Beam Generation Using van der Waals Materials

A compact, integrable platform for nanoscale control of structured light, enabling advanced optical and quantum technologies.

Applications

Sectors: photonics, quantum information science, optoelectronics

Areas: structured light generation, nonlinear optics, wavefront shaping

Industries: high-speed data communications, quantum communications, optical sensing

Markets: nanoscale optical interconnects, quantum light sources, metasurface-enabled photonics, structured light nanophotonic systems

Partnership Opportunities

LANL is seeking partners with expertise in metasurfaces, vertical-cavity surface emitting lasers, and/or two-dimensional system integration to commercialize this platform. Ideal collaborators include developers of integrated photonics, structured light emitters, and nanophotonic components.

Technology Readiness Level 3

Core nonlinear processes have been demonstrated in van der Waals materials at lab scale. Integration with metasurface architectures and nanoscale optical systems is the next development milestone.

IP Information

This technology is patent pending.

Contact Information

For inquiries, contact FCI at licensing@lanl.gov.

Overview

Structured light beams with tunable wavelength and orbital angular momentum (OAM) are enabling new frontiers in optical communication and quantum information science. However, conventional methods for generating such beams rely on spatial light modulators or bulk nonlinear optical crystals, which limit scalability and integration.

This new platform leverages van der Waals materials to tune both the wavelength, OAM, and radial structure of vortex beams, using nonlinear optical processes such as sum frequency generation, difference frequency generation, four-wave mixing, and higher-order harmonic generation, all over exceptionally broad spectral ranges due to the elimination of phase matching constraints.

The result is an ultracompact material platform that supports robust structured-light manipulation, readily integrable with vertically-integrated free-space nanophotonic vortex light sources to enable applications in optical and quantum communication and optical sensing.

Advantages

- Allows for the free tuning of wavelength, orbital angular momentum, and radial index across a broad spectral range.
- Integrates into compact, planar, nanophotonic platforms.
- Supports seamless compatibility with metasurfaces and similar nanophotonic devices.
- Delivers high nonlinear conversion efficiency in a minimal volume.
- Eliminates the need for bulky optical components such as spatial light modulators (SLMs) and bulk nonlinear crystals.
- Enables both quantum and classical applications in integrated optics.

Technology Description

The technology leverages the unique nonlinear optical properties of atomically thin van der Waals materials to manipulate all the elementary properties of structured light-fields carrying orbital angular momentum.

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Technology Description, **Continued**

These materials enable broadband nonlinear conversion (due to the absence of phase matching constraints) with improved efficiency and compactness compared to traditional bulk nonlinear optical crystals at comparable length-scales.

Unlike existing solutions, this platform would eliminate the need for external spatial light modulators and bulk nonlinear optical crystals. It is fully compatible with metasurfaces and can be integrated into nanophotonic and optoelectronic devices for wavelength-tunable structured light generation.

Market Application

This technology is well suited for integrated photonics platforms in both classical and quantum domains.

Potential uses include:

- enabling high-density data transmission through OAM-multiplexed optical interconnects;
- producing compact, tunable structured-light sources for quantum communication; and
- enhancing optical sensing and detection using structured-light techniques.

The ability to robustly generate and manipulate OAM beams at the nanoscale would open new possibilities for data transmission, quantum communications, and light-matter interaction control in next-generation optical devices.

Next Steps

LANL is seeking partners to advance this platform through:

- integration into metasurface and vertically-integrated photonic architectures;
- demonstration of high-efficiency, broadly-tunable, free space OAM beam generation on-chip; and
- application development in quantum light generation and optical/quantum communication systems.

Collaborators will support device fabrication, application testing, and commercial pathway development for nanoscale structured light emitters.

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