Physicists map spiraling light to harness untapped data capacity

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Physicists with the Institute of Ultrafast Spectroscopy and Lasers (IUSL) at The City College of New York have presented a new way to map spiraling light that could help harness untapped data channels in optical fibers. Increased bandwidth would ease the burden on fiber-optic telecommunications networks taxed by an ever-growing demand for audio, video and digital media. The new model, developed by graduate student Giovanni Milione, Professor Robert Alfano and colleagues, could even spur enhancements in quantum computing and other applications.

"People now can detect (light in) the ground channel, but this gives us a way to detect and measure a higher number of channels," says Mr. Milione. With such heavy traffic funneled through a single channel, there is great interest in exploiting others that can be occupied by complex forms of light, he explains.

The team published their work in the July 25 issue of Physical Review Letters. Mr. Milione will present it at the Optical Society of America's "Frontiers in Optics 2011" conference, October 16 - 20 in San Jose, Calif.

He was selected as a finalist in The Emil Wolf Outstanding Student Paper Competition, which highlights excellence and presentation skills of students at the conference. He and other finalists will be recognized at the OSA Foundation Chairman's Breakfast Wednesday, October 19.

Polarization is everything to a physicist tracking light in an optical fiber or laser. More than a way to cut glare with sunglasses, polarization refers to a specific direction and orientation of the light's movement and electric field — when it isn't going every which way as it does when emanating from a light bulb, for example.

"Being able to follow polarization and other changes as light travels gives you insight into the material it travels through, " explains Milione. This helps control the light and can essentially give a fingerprint of the material being analyzed.

Detecting the polarization also lets users finely tune a laser. Such control can allow a laser to burn away one layer of material while leaving the other layers it passes through intact.

Until now, only the simplest form of light, the ground state, could be mapped and controlled. Multiple higher channels in an optical fiber, which could be occupied by more complex light, were left sitting idle.

A globe-shaped model, called the Poincaré Sphere, has long been used to map such simple light. This light has peaks and troughs, like waves on the ocean, and moves or vibrates in "plane waves." One maps how light intersects the sphere in the same way one pinpoints a location on Earth using longitude and latitude.

But complex light moves with both spin and orbital angular momentum, more or less like the movement of our moon as it spins on its axis and orbits the Earth.

Such light twists like a tornado as it travels through space and takes the form of what are called vector beams and vortices. To map these vortices the researchers expanded the existing sphere to develop their Higher Order Poincaré Sphere (HOPS).

The team studies even more complex patterns of light, such as star-shaped forms. Their model uses the HOPS to reduce what could be pages of mathematics to single equations. These are the mathematical tools that will harness the complex light for use in technology.

"The sphere facilitates understanding, showing phase vortices are on poles and vector beams are on the equator," explains Milione. "It organizes the relationship between these vortices of light."

"This kind of organization on the higher level Poincaré Sphere could clear the path to a number of novel physics and engineering efforts such as quantum computing and optical transitions; could greatly expand the sensitivity of spectroscopy and the complexity of computer cryptography; and might further push the boundaries what can be 'seen'," said Dr. Alfano.

More information: G. Milione, H.I. Sztul, D.A. Nolan, and R.R. Alfano. Higher-Order Poincaré Sphere, Stokes Parameters, and the Angular Momentum of Light, *Phys. Rev. Lett.* 107, 053601 (2011) link.aps.org/doi/10.1103/PhysRevLett.107.053601

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