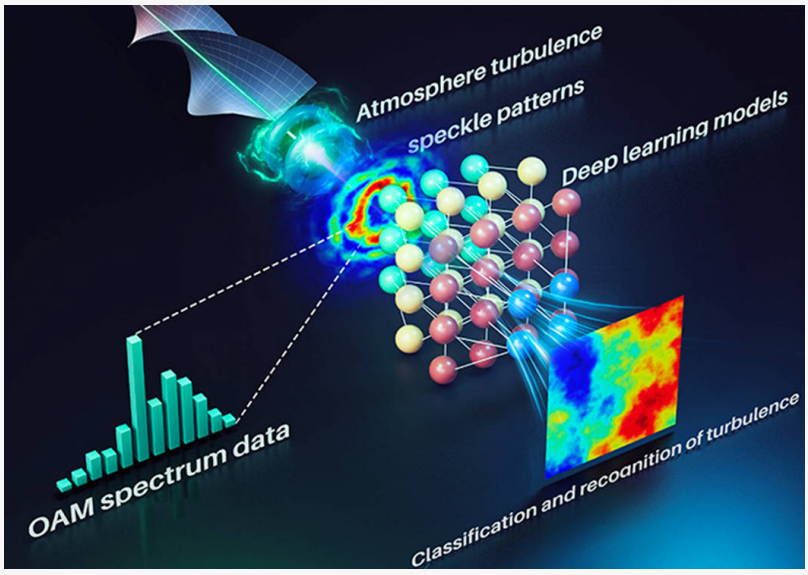
Optical metrology review explores new possibilities with twisted light

GA, UNITED STATES, January 8, 2025 /EINPresswire.com/ -- Twisted light, which carries orbital angular momentum, is driving modern metrology by altering paradigms on what is measurable, and allowing probing and sensing with ultra-high precision and accuracy. Researchers from China and South Africa share their expert insights on the future trajectory of this dynamic field.



Conceptual notion of twisted light probing a complex medium.

Metrology serves as the cornerstone of modern industry, providing the key standards by which we measure the world. Optical metrology, in particular, has historically leveraged on the notion of interference, essentially unchanged since the days of Thomas Young more than 200 years ago. However, can one glean more information by extrapolating the concept of fringes to other degrees of freedom?

In a recent paper (DOI: 10.1038/s41377-024-01665-1) published in Light Science & Applications, a team of scientists led by Prof. Lixin Guo from Xidian University have shared their perspectives on the past, and future of optical metrology involving orbital angular momentum (OAM). The paper explores fundamental principles, applications, and seminal advancements in the field. The researchers demonstrate how twisted light carrying OAM can be used for new paradigms in measurement, for instance, 3D particle position tracking, utilizing a modern interpretation of the Doppler effect by observing frequency shifts that depend on both OAM and polarization.

“The original Doppler effect could only track movement toward or away from the observer, but the incorporation of orbital angular momentum in both scalar and vector light allows motion tracking in all directions, including rotational movement,” says Prof. Andrew Forbes, a corresponding author from South Africa. “This advancement has revolutionized the metrology of dynamic systems.”

It is not only the shift in paradigm for existing tools but also the invention of completely new instruments that is propelling the field forward. One such example is the concept of an OAM spectrum serving as the 'signature' of a system: when OAM light passes through a complex medium, its OAM is altered, resulting in changes to the shape of the OAM spectrum (see Figure 1).

"This OAM fingerprint of the medium contains a wealth of information that can be harnessed," says Dr. Mingjian Cheng, the lead author. As the review highlights, if the OAM spectrum is interpreted by machine learning and AI, it opens the door to real-time analysis and recognition of complex media, with OAM light serving as a probe, a topic that is gaining traction very fast.

The review not only covers metrology with classical light but also utilizing OAM in quantum entangled superpositions and single-photon states. Transitioning into the quantum domain holds the potential to reduce noise and enhance accuracy and precision with fewer measurements. However, this aspect of the field remains in its early stages of development.

"Quantum metrology using OAM is still an emerging field with numerous untapped opportunities," says Prof. Andrew Forbes.

The comprehensive review spans a wide range of applications, from nano-sensing at the microscopic scale to measuring black holes at the cosmic scale. It provides an authoritative overview that will prove invaluable to both entry level and experienced researchers alike.

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