Quantum-Like Entanglement in Classical Optics

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In the past two decades, quantum optics has had a huge impact on the field of information technology. Quantum information and quantum computing have started to become part of our everyday life. For example, in this new communications era, we can envision transmitting sensitive information channels that are nearly 100 percent secure using quantum cryptography. Also, earlier this year, the first functional quantum computer was reported.[1]

Most of the concepts in quantum optics are rather abstract and difficult to visualize for the layman. However, we are accustomed to one of them from science fiction literature and movies: teleportation. Today, teleportation is transforming from fiction into reality.

In its current form, quantum teleportation is not quite like that seen in *Star Trek*; only bits of information have been teleported. The main ingredient for quantum teleportation and quantum computers is a feature called entanglement that is related to the communication that may exist between two quantum particles that are far apart from one another. Researchers around the world are developing and pursuing new experiments on quantum-entangled particles.

It's been a long time since the quantum Schrödinger equation was recognized to be mathematically equivalent to the classical optics paraxial wave equation, and, similarly, the time-independent Schrödinger equation was found to be isomorphic to the Helmholtz equation. There might be some quantum systems that can be described using classical physics and vice versa.

An example of this can be seen by noticing that coherent states of the quantum harmonic oscillator have the same high-order Cartesian Hermite-Gaussian modes as their paraxial classical optics counterpart. Using this fact, we reported the use of tailor-made quantum operators to solve a problem of beam propagation in inhomogeneous media. The inhomogeneity is elliptical and tilted with respect to the Cartesian reference frame where the beam is defined (see figure). Also, we proposed how to "prepare" the classical system to investigate its behavior like a quantum system.[2]

To create such inhomogeneity, we proposed the use of a Kerr nonlinear medium whose refractive index is known to depend on the light-beam intensity with which it is illuminated. Making the impinging beam elliptical and large enough, the central region of the induced refractive index can be approximated by a quadratic function. We showed how, by launching a Hermite-Gaussian beam through the prepared gradient index medium, at the output of the sample there will be a beam described by a quantum-like entangled function.

The purpose of the work was twofold: to show how to use quantum optics methods to solve classical optics propagation problems and create a classical system to emulate a quantum one showing the potential for studying quantum optics with classical systems.[3]

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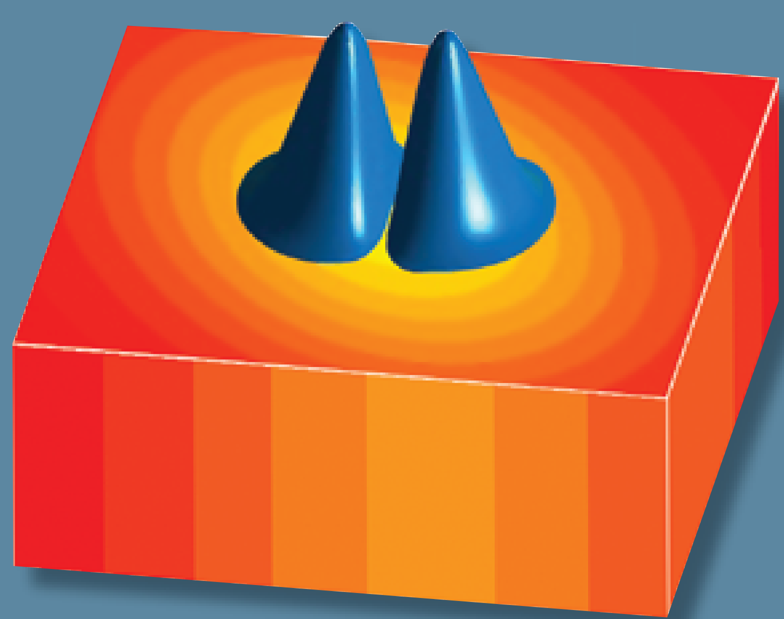

A Hermite-Gaussian beam propagating in an elliptical gradient index medium can create a beam described by a quantum-like entangled function.