PhD Thesis Defense CARMELO ROSALES GUZMAN 'Photonic Applications Based on the Use of Orbital Angular Momentum of Light'

CARMELO ROSALES GUZMAN

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CARMELO ROSALES GUZMAN

Quantum Engineering of Light

ICFO-The Institute of Photonic Sciences

Structured light beams, that is, beams whose phase changes from point to point in the transverse plane, provide an alternative tool to search for new applications, or simply to expand the capabilities of current applications where commonly used light beams have encountered physical limitations. Applications can be found not only in the field of optics but also in areas as diverse as astrophysics, telecommunications and quantum computing, to name a few. In this thesis we put forward three new applications in which the use of structured light beams plays a crucial role. In the field of optical remote sensing, the Doppler Effect is widely used to measure the component of the velocity along the line of sight, i.e., the longitudinal component. The Doppler Effect alone does not allow the measurement of the transverse component. In this context, structured light beams provide a tool that makes this possible: its structured phase. The main idea resides in the fact that this beams, reflected from transversally moving targets, are frequency shifted proportional to the velocity of the target. The information of the velocity can be extracted using interferometric methods, in a similar way to the longitudinal Doppler shift. In a first experiment we validated this theoretical concept for two particular cases: rotation and longitudinal motions along the transverse plane of illumination. Some current existing techniques to measure small layer thicknesses are based on the use of common-pant interferometers. In particular the self-referencing type, in which both the reference and the signal beams are generated locally. A reflective surface is engineered in the form of a ridge or cliff, in such a way that when illuminated with a Gaussian beam, half of it is reflected from the top and the other half from the base. These two "new "beams" acquire a phase difference that depends on the height of the ridge and the wavelength of the illuminating source. The phase variations are detected on-axis in the far field as intensity changes. Hence, if we place a thick layer on top of the ridge, the change in intensity will immediately yield the height of the layer. This scheme becomes highly sensitive to small phase variations when the height of the ridge is 1/8 of the wavelength, known as the quadrature condition. This restriction might unfortunately limit the use of this technique to specific cases, since it highly depends on the construction of the ridge. To overcome this drawback we proposed and demonstrated experimentally a technique in which the quadrature condition is not needed a priori. Our approach is based on the use of spatial mode projection. For its implementation, we project the light reflected from the sample onto appropriately tailored spatial modes. Finally, we investigated theoretically the role that light endowed with Orbital Angular Momentum (OAM) might play for the discrimination of chiral molecules. Traditionally, this discrimination has been always related to Circularly Polarized Light (CPL), this is, to the Spin angular momentum of light. In this approach, the chiral response of molecules only depends on the properties of the same, and in many cases is very small. An approach to enhance this response was proposed very recently, in which the electromagnetic field that illuminates the molecule is properly tailored, in such a way the chiral response depends on both the molecular properties and the electromagnetic field. These types of electromagnetic fields have been termed ''chiral fields'' and are characterised through a quantity known as optical chirality (denoted as C). This quantity measures the contortion of the field at each point in space, the higher the value of C, the higher the chiral response. In our approach, we started from exact solutions to the Helmholtz equation. We found that a proper superposition of the two beams produces an on-axis, enhanced chiral response that can be several times larger.

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Thesis Advisor: Prof. Juan P. Torres