Spatially Structured Optical Beams via Geometrical Phase

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Birefringent crystal devices are instrumental in shaping optical beams within both classical and quantum domains. Such devices encompass wave plates, spatial light modulators, and space-varying structured birefringent materials. The latter has garnered significant attention as they enable the coupling two independent photonic degrees of freedom: polarisation and phase front. The scientific principles underpinning these devices, known as the geometrical phase or the Pancharatnam-Berry phase in the optical (and quantum) domain, classify them as Pancharatnam-Berry Optical Elements (PBOE) [1]. The most recognised and extensively utilised PBOE is the q-plate, a device characterised by an optic axis that varies linearly with the azimuthal angle [2]. Q-plates have been deployed across a multitude of sectors, including quantum information and simulation, microscopy, and surface structuring [3]. Recently, q-plates and other PBOEs based on subwavelength structures have been fabricated, including but not limited to nanostructured glasses, plasmonic metasurfaces [4], and semiconductor microcavities. Interestingly, PBOEs can also naturally occur. Polymer spherulites serve as an apt example. These semicrystalline structures showcase spherical symmetry and typically develop when a molten polymer is cooled slowly, thereby enabling polymer chains to establish ordered configurations. Crystallisation commences around point defects, creating lamellae structures that expand radially from the defect centre in the absence of temperature gradients. The resulting radially oriented fibrillar structure, visible at low magnification, consists of one or more crystals extended in the radial direction. This radial formation of the fibrillar structure carries a topological structure of +1, allowing for spin-to-orbital angular momentum coupling on an incident beam [5].

These patterned birefringent devices, or slabs, can be utilised to create optical beams with precisely engineered intensity, phase, and polarisation states, spanning from near-infrared to visible to the XUV domain [6-7]. They can further be employed in the fabrication of flat optical devices, such as magic plates [8]. In my forthcoming presentation, I will discuss spin-orbit coupling for birefringent materials and their applications in shaping optical beams at varying wavelengths. I will also explore their use in addressing fundamental questions and in quantum information processing.

References (if needed)

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