Effective q-plate gadgets with tunable retardance and achromaticity

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Abstract: Pancharatnam derived the conditions under which a composite gadget made of multiple waveplates could function as an achromatic waveplates. In a similar spirit, we derive the conditions under which a composite gadget made of q-plates functions as an effective q-plate, with tunable retardance and we examine the constraints under which achromaticity can be acheived. We illustrate the construction of an achromatic half and quarter-wave q-plate using three standard q-plates. s

Liquid crystal based waveplates called q-plates are used for generating orbital angular momentum (OAM) states of light and for the efficient conversion of spin angular momentum (SAM) to OAM[1]. In a classic work, Pancharatnam showed how an achromatic waveplate can be realized using three standard waveplates[2]. We extend this idea to q-plates, which has azimuthally varying optical axes. Here, we address the following question: when can a sequence of q-plates acts like a single effective q-plate? By an effective q-plate, we mean: (i) Its effective optical axes direction at all azimuthal angles φ is confined to the equatorial plane of the Poincare sphere and (ii) Its effective retardance Γ is independent of the azimuthal angle φ. We consider three q-plates arranged in sequence such that, retardance $\Gamma_1 = \Gamma_3$, topological charges $q_1 = q_3$ and $\alpha_{01} = \alpha_{03}$. This arrangement satisfies condition (i) given above. The effective retardance Γ, in this case is given by: $\cos\Gamma = \cos\frac{\Gamma_2}{2}\cos\Gamma_1 - \sin\frac{\Gamma_2}{2}\sin\Gamma_1\cos 2(\Delta q\varphi + \Delta\alpha 0)$, where $\Delta q = q_1 - q_2$ and $\Delta\alpha_0 = \alpha_{01} - \alpha_{02}$. The requirement that effective retardance be independent of φ imposes constraints on the Γ_1, Γ_2 and $q_{1,}\ q_2$. After discussing these conditions, we demonstrate how a q-plate with tunable retardance may be achieved. Further, we illustrate how achromats can be constructed using three q-plates of identical topological charge subject to condition given in figure below. The range of retardance values (Γ_1, Γ_2) for which an effective retardance $\Gamma = \pi/2$ and π, are realizable is shown in Fig. 1. Using the wavelength dependence of retardance for a commercial q-plate studied in reference 3, the possible effective retardances achievable as a function of the wavelength using our approach is shown in the bottom panel of the figure.

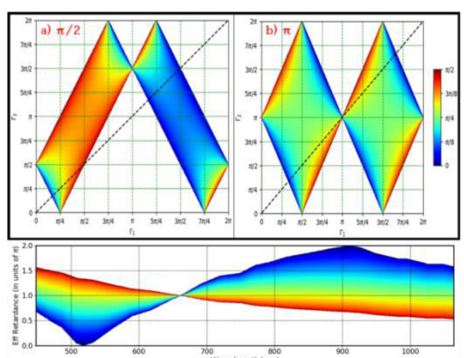

Fig. 1: (Top) Possibility of realizing q-plate with an effective retardance of (a) $\Gamma = \frac{\pi}{2}$ and (b) $\Gamma = \pi$ using three q-plates of identical topological charges q≠1, with outer plates having retardance Γ_1 and the central plate having retardance Γ_2 is shown. (Bottom) The possibility of realizing various retardances as a function of wavelength using three standard commercial q-plates of Thorlabs make, studied in the reference[3]. The color coding is for the relative orientation of the central waveplate with respect to the outer plate.

References

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