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The singularities of light: intensity, phase, polarization

Geometry dominates modern optics, in which we understand light through its singularities. These are different at different levels of description.At the coarsest level, where light is described in terms of the rays of geometrical optics, the singularities are caustics: focal lines and surfaces – the envelopes of ray families. These singularities of bright light are classified by the mathematics of catastrophe theory. Wave optics smooths these singularities and decorates them with rich interference patterns, widely applicable, for example to rainbows, ship wakes and quantum scattering.Wave optics introduces a new quantity, namely phase, which has its own singularities. These are optical vortices, a.k.a nodes or wavefront dislocations. Geometrically these singularities of dark light are lines in space, or points in the plane. They occur in all types of quantum or classical waves. Currently, optical phase singularities are being used to rotate small particles (optical spanners) and as a possible way to detect extra-solar planets.On a finer scale, where the vector nature of light cannot be ignored, the new phenomenon is polarization. This possesses its own singularities, also geometrical, describing lines where the polarization is purely circular.As well as representing interesting physics at each level, these optical and wave geometries illustrate the idea of asymptotically emergent phenomena.