Vortex light, a novel tool to discriminate helicity from chirality in chiral media

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A complete characterization of quantum systems implies the detection of both amplitude and phase. This directly leads to the use of interferometric techniques. On the other side, there exist a large number of quantum phases in solids that involve nonlocal invariants, phases, and chiral degrees of freedom. So the question arises, whether methods that are supplemented by phase factors could be further developed [1, 2]. We have recently started to extend our repertoire of experimental techniques using the transfer of quantized angular momenta with structured light in inelastic light scattering experiments. Such photon states carry orbital angular momentum (OAM) in addition to spin angular momentum (SAM, chirality, circular polarization). Presently, applications of OAM exist in super resolution microscopy, the manipulation of trapped ions and BECs, quantum information transfer, and the search for dark matter [3].

Vortex light with a helical phase, described by Laguerre-Gaussian functions, is prepared from circularly polarized light (SAM) using spiral plates that introduce a topological charge into the wave front. The coupling of optical OAM to matter is far from trivial. In lowest order (dipole approximation) there exist no coupling [4]. More recently, it has been shown that strong focusing (optical spin-orbit entanglement), higher order couplings, optical cavities, and electronic resonances amplify light matter coupling up to single molecule level [5]. This enhancement is comparable to the effect of electronic resonances on Raman optical activity or surface enhanced Raman scattering.

We have performed systematic studies of several chiral / topological model systems to search for OAM features different from SAM. The corresponding data shows low energy, diffusive fluctuations within chiral phases that are probed by OAM transfer. As a prerequisite resonant scattering is required. In this sense there is a similarity to the Hanle effect in resonant X-ray scattering of atoms showing polarization anomalies.

In the case of chiral liquid crystals we use structured photon fields with different OAM and SAM to probe chiral fluctuations [6]. In the regime of iridescence with a well-defined pitch length of chirality, we find low energy Raman scattering that can be decomposed into helical and chiral components depending on the scattering vector and the topological charge of the incident photon field. Based on the observation of an anomalous dispersion we attribute quasi-elastic scattering to a transfer of angular momenta to roton-like quasiparticles. The latter are due to a competition of short-range repulsive and long-range dipolar interactions [6]. Our experiments may lead to an avenue of novel interference phenomena in inelastic light scattering.

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