Quantum Condensed Matter Research Group found several extraordinary features in electromagnetism, optics, and classical interpretations of quantum phenomena.

Purpose and achievement: In standard electromagnetism (EM), the field Lagrangian is not dual symmetric. This leads to problematic dual-asymmetric forms of the energy–momentum, spin and orbital angular-momentum tensors. To resolve this discrepancy between the symmetries of the Lagrangian and Maxwell equations, we put forward a dual symmetric Lagrangian formulation of EM. This dual EM preserves the form of Maxwell equations, yields meaningful energy–momentum and angular-momentum tensors, and ensures a self-consistent separation of the spin and orbital degrees of freedom. This provides a rigorous derivation of several results.

Reference: K.Y. Bliokh, A.Y. Bekshaev, F. Nori, *"Dual electromagnetism: helicity, spin, momentum, and angular momentum",* New J. Phys. (March 2013) [highly cited paper for 2013].

Purpose and achievement: Recent experiments (*Science* 2001) reported the observation of 'average trajectories of single photons' in a two-slit interference experiment. This was possible by using the quantum weak-measurement method, which implies averaging over many events, i.e. in fact, a multi-photon limit of classical linear optics. We give a classical-optics interpretation of this experiment and other related problems.

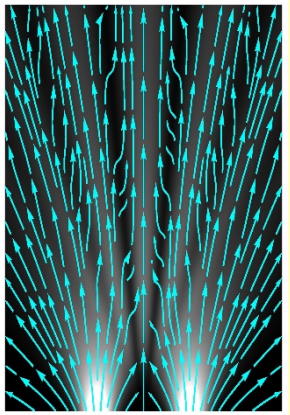

Fig. 2. **Photon trajectories in complex wave interference** →

Outlook: Plan to continue linking quantum weak measurements with classical measurements.

References: K.Y. Bliokh, A.Y. Bekshaev, A.G. Kofman, F. Nori, *"Photon trajectories, anomalous velocities, and weak measurements: a classical interpretation",* New J. Phys. (July 2013). J. Dressel, K. Y. Bliokh, F. Nori, *Classical Field Approach to Quantum Weak Measurements,* Phys. Rev. Lett. (March 2014).

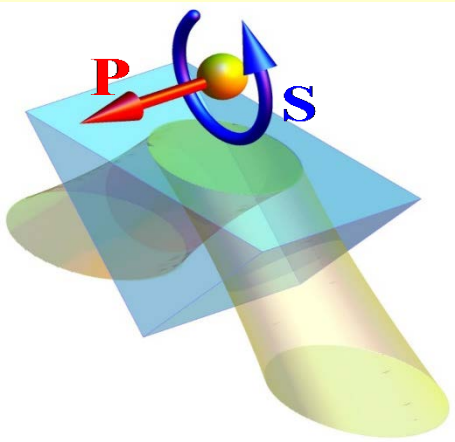

Fig. 3. Extraordinary momentum and spin in *evanescent* waves. In sharp contrast to the usual electromagnetic waves (photons), such evanescent waves possess **transverse helicity-dependent momentum P** and **transverse helicity-independent spin S**.

Purpose and achievement: propagating optical waves (photons) carry momentum and longitudinal spin determined by the wave vector and circular polarization, respectively. We have shown that exactly the opposite can be the case for evanescent optical waves.

Outlook: experiments on this just started. These would allow the observation of novel properties of light.

Reference: K.Y. Bliokh, A.Y. Bekshaev, F. Nori, *"Extraordinary momentum and spin in evanescent waves",* Nature Communications (March 2014). ISI highly cited paper.