Application of a quantum action principle to a simple beam splitter experiment

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We have proposed [1] that a time-symmetric, realistic quantum theory can be based on an extension of the principle of stationary action. The action is ordinarily defined as the spacetime integral of the Lagrangian density, involving integration over one spacetime coordinate (four dimensions) for a single particle, or N spacetime coordinates for N particles. Based on the observation that the square of the action is stationary wherever the action is, we required stationarity of the superaction, defined as an integral over 2N spacetime coordinates that resembled the squared action except that the integrand included a factor coupling one set of N coordinates with the other set. The inclusion of the coupling factor made the theory explicitly nonlocal in space and time; it also made the wave equation nonlinear, in general an integrodifferential equation (IDE). We proposed that the IDE should be solved over a region of spacetime subject to boundary conditions imposed over its entire boundary; heuristically, those conditions are initial conditions, boundary conditions in 3-space, and final conditions. The theory is retrocausal because the solution in the interior of the region depends in part on conditions later in time. In an idealized measurement, the initial conditions come from the experimental preparation, and the reading of the outcome provides a "natural boundary condition" as a final condition. We argued that a theory of this type can explain wavefunction collapse under measurement in a natural way while still agreeing with conventional theory for cases corresponding to "no measurement". Such a theory has other advantages, such as explaining EPR correlations and delayed-choice experiments, but parts of the formalism are incomplete.

In order to understand and develop this theory further, we here apply it to a simple beam splitter experiment involving a single photon. Although the theory seems to require the inclusion of the photon source and both detectors in the description, it may be possible to capture the essential features in just two particles–the photon, and an electron in the half-silvered mirror that either oscillates and produces a reflecting surface current, or remains stationary and allows the photon to be transmitted.

[1] A. K. Harrison, Found. Phys. 52 (2022) 22.