Nonlinear Optics of Sochastic Field Waveforms

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Methods of statistical analysis offer new insights into a nonlinear dynamics of stochastic optical field waveforms, providing a framework that helps understand supercontinuum generation driven by stochastic laser pulses, as well as dynamic instabilities and filamentation of stochastic laser beams. Unlike deterministic self-focusing, whose criterion is expressed in terms of a well-defined self-focusing threshold, its stochastic counterpart is a probabilistic process whose combined probability for a sample of N laser pulses builds up as a function of N. We show that the ratio P/P_{cr} of the laser peak power P to the critical power of self-focusing P_{cr}, which plays a central role in deterministic self-focusing, keeps its status as a key governing parameter in stochastic self-focusing. However, in contrast to its deterministic counterpart, the P/P_{cr} ratio of a stochastic laser beam is no longer an indicator of whether self-focusing will occur, but is, rather, a predictor of when the self-focusing is expected, in the sense of the first passage time, given the statistics of the laser field. We will also examine supercontinuum generation driven by stochastic laser pulses. The statistics of extreme bandwidths emerging from such a process is shown to converge, in the large-sample-size limit, to a generalized Poisson distribution whose mean is given by the exponent of the respective extreme-event statistics.