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Physics and Application of Photonic Plasma

JASON FLEISCHER, Princeton University

In nonlinear optics, different modes of light can interact with each other; if there is a statistical ensemble of modes, it can be treated a photonic plasma. This mapping can be formalized mathematically, using radiation transport theory, and observed experimentally, using pulses or beams in nonlinear media. Here, we use optical beams in a photorefractive crystal to demonstrate fundamental properties of photonic plasma, including Debye screening, Landau damping, shock waves, instabilities, and turbulence. We then image phase-space dynamics that are difficult – if not impossible – to observe in material plasma, e.g. internal momentum exchange in turbulence and the formation of BGK modes. We also discuss how far the analogy can be pushed, including ion behavior, magnetic fields, and dynamics in toroidal (cavity) geometry.

In the second part of the talk, we discuss the back-reaction of plasma on optics. In particular, we examine the signal-carrying power of light and treat the nonlinear coupling of signal and noise as a photonic beam-plasma instability. The interaction is a dynamical stochastic resonance, allowing signal to grow at the expense of noise, with plasma theory matching the experimentally measured resonances in coupling strength, noise statistics and signal mode content. The results highlight the value of plasma physics in imaging and, more generally, suggest a new branch of "applied plasma" in statistical optics.