Spatiotemporal pulse shaping with multimode nonlinear guided waves

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***Abstract*—We experimentally and theoretically investigate complex temporal pulse reshaping that accompanies Kerr beam self-cleaning in multimode optical fibers. We also study the output beam shape dependence on initial conditions.**

Keywords—Pulse propagation and optical solitons; transverse effects; nonlinear fiber optics; fiber lasers.

Nonlinear multimode optical fibers (MMFs) have recently emerged as easily accessible platform to control complex spatiotemporal beam reshaping phenomena [1]. Light intensity oscillations associated to the self-imaging effect in graded-index (GRIN) MMFs lead, via the Kerr effect, to a dynamic long-period index grating which may phase-match the generation of ultra-broadband sideband series [2-4]. For relatively short, virtually lossless GRIN fibers, beam self-cleaning activated by the Kerr effect is observed, at lower power thresholds than the Raman beam cleanup [5,6]. The output highly multimode speckled beam evolves, at high powers, into a high brightness bell-shaped beam sitting on a low-power background of high-order modes. This Kerr beam self-cleaning is shown to be even reinforced in the presence of strong loss or gain, e.g., in a passive or active ytterbium doped MMF [7], which leads to its possible exploitation in high power multimode fiber laser sources [8].

We shall overview recent experiments, which demonstrate the spatiotemporal pulse break-up and significant temporal compression that accompany the self-cleaning process [9]. At the same time, we shall describe experiments revealing the dependence of the output beam shape and the efficiency of the self-cleaning process on the input beam conditions, such as transverse dimension and incidence angle [10].

Although numerical simulations based on the full 3D nonlinear Schroedinger equation with a parablic potential reproduce well the beam cleaning effects in GRIN fibers [5], to gain a physical understanding of its underlying modal redistribution it is necessary to resort to (approximate) modal developments of the propagation equation. We shall present the results of such studies, suggesting that the origin of the observed nonlinear modal reshaping is a new form of parametric instability.

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