Adaptive Pumping for Control of Multimode Fiber Amplifiers and Lasers

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Abstract

We present a theoretical and experimental study of two systems based on an amplifying multimode fiber, where the modal composition of the core-guided pump beam is tailored by means of wavefront shaping techniques. Provided that the lightwave used for pumping is coherent, its shaping prior to injection will affect the complex, speckle-like spatial patterns of excitation within the amplifier volume, which in turn act upon the signal as heterogeneous gain; As a consequence, we are offered the intriguing prospect of affecting not only the propagation of a lightwave through a given disorder, but to some extent also the disorder itself. In the first system, the fiber serves as an amplifier for an injected multimodal signal, and we explore the degree to which the pump shaping may control the transmission function for said signal. We show that dependence upon the pump configuration surprisingly survives several interesting physical mechanisms which, at first sight, would appear to severely limit it. This insight is then carried on to the second system, where a cavity configuration allows the fiber medium to freely lase. The system behavior features striking parallels to that of random lasers, despite the absence of 'classical' scattering mechanisms in the gain medium; more importantly the pump shaping shows a surprisingly strong ability to control the complex emission, in particular the selection of individual spectral lines and the stabilization of single-mode operation. The results expose an intriguing interplay between the spectral and the spatial domains of the system lasing dynamics and the modal competition, and offer a new framework for the control of similar laser systems.