

Digital Aspects of Pulse Broadening and Self-focusing Properties of Fiber Optics

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Abstract

Optical fibers are fundamental to modern communication and photonic technologies because they enable the transmission of information over long distances with high bandwidth and low signal loss. However, nonlinear and dispersive effects can influence the propagation of optical pulses, particularly in high-speed and high-power fiber-optic systems. This study examines the digital aspects of pulse broadening and self-focusing properties in optical fibers, focusing on how computational and digital techniques can improve the analysis and control of these phenomena. Pulse broadening mainly occurs due to chromatic dispersion and modal dispersion, causing an optical pulse to spread as it travels through a fiber and potentially resulting in inter-symbol interference. Self-focusing is a nonlinear optical effect associated with the intensity-dependent refractive index, in which a high-intensity optical beam can undergo spatial confinement during propagation. Digital modeling and numerical simulation methods provide effective approaches for studying the combined influence of dispersion and nonlinear effects. Computational techniques such as the split-step Fourier method can be used to solve the nonlinear Schrödinger equation and simulate pulse propagation under different fiber parameters and operating conditions. Digital signal processing can further assist in compensating for dispersion, reducing transmission impairments, and improving signal quality. The integration of simulation, data analysis, and intelligent optimization can support the design of efficient fiber-optic communication systems and nonlinear photonic devices. This study highlights the importance of digital approaches for understanding pulse dynamics and self-focusing behaviour and for developing reliable, high-capacity optical communication technologies.

Keywords: Optical Fiber, Pulse Broadening, Self-Focusing, Digital Signal Processing, Fiber Optics, Chromatic Dispersion, Nonlinear Optics, Numerical Simulation, Split-Step Fourier Method, Optical Communication.

