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Research paper

Study on soliton pulse and its characteristics for fiber optic communication

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Abstract

From time immemorial communication is an essential need for human beings. Communication happens through the channel. Among many channels for communication, Fiber is a vital wired channel that has infinite bandwidth and high noise immunity against electromagnetic interference. The phenomenon of dispersion is the major problem for high bit rate and long-haul optical communication systems. An easy solution to this problem is optical Solitons - Pulses that preserve their shape over long distances. Soliton based optical communication systems establish over distances of several thousands of kilometers with considerable information carrying capacity by using optical amplifiers.

Keywords:*Bandwidth; Dispersion; Fiber; Soliton.*

1. Introduction

A soliton is a self-reinforcing pulse which maintains its shape when it travels with uniform velocity. Cancellation of nonlinear and dispersive effects in the medium produces solitons. A wave gets dispersed as it propagates over a longer distance. , and the waves can propagate over a more substantial distance without affecting the original waveforms. Waves in shallow water and plasma waves are the examples of solitons. Ordinary nonlinear wave equations derived by Kortweg and de Vries can be used to describe both of these waves.

This equation is also known as KdeV equation. A soliton propagates faster when its amplitude increases. The collision occurs when two solitons of same amplitude appear. This collision does not destroy waveforms of both the waves. At the time of the collision, the magnitude of the wave becomes smaller than the sum of the two waves. The superposition principle fails in nonlinear behavior. Similar kind of nonlinear wave propagation takes place in light waves guided along an optical fiber.

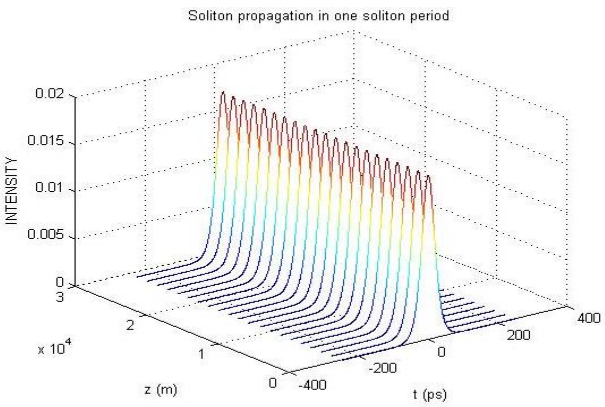

Fig. 1: Soliton Pulse.

What are Solitons?

1.1. Description

Soliton pulses technically play a crucial role for long-haul optical fiber communications and in mode-locked lasers. In the case of the mode-locked laser, soliton-like pulses can be formed when the dispersion of pulses and nonlinearity in the laser cavity are not much pronounced. Solitons also find application in various techniques for pulse compression involving optical fiber; Few examples being adiabatic soliton compression involving no exchange of heat(Q=0) and higher-order soliton compression.

1.2. How to generate spatial solitons

Ashkin and Bjorkholm[1] in the year 1974 reported the first experiment on the generation of spatial optical solitons using a cell filled with sodium vapor. Generation of liquid solitons in carbon disulphide was reported after a period of more than ten years by Barthelemy et al.[2].Spatial solitonswere demonstrated in glass, semiconductors, and polymers[3].Several experiments have been reported on solitons in nematic liquid crystals which are also referred as "Nematicons"[4].

1.3. Characteristics of solitons

The characteristics of the soliton are that their wave packets do not spread. This nature of soliton provides a kind of limitation on its wave motion. Wave packets have a natural proclivity to broaden when it travels through a linear medium. This characteristic is observed in other systems like density waves in fluid, charge waves in condensed matter, and EM waves in media with a little absorption. In optics, a localized pulse in space or in time can either broaden in its temporal shape, its spatial extent, or both. The chromatic dispersion is the cause for widening in temporal pulses as the various frequency components that form the temporal pulse consists of different velocities. The narrowest pulse forms when the relative phase among all elements is zero. However, when the pulse starts to propagate, the frequency components propagate at different phase velocities. Hence their relative phase does not become zero and the pulse broadening results. Diffraction causes the broadening of pulses in space which is called `beam' [19].
The nonlinear properties of the medium in which the pulse propagates along with the dispersion characteristics of the pulse determine the spectral and phase characteristics of the optical pulse.Therefore, the nonlinear effects of the medium and dispersion are of great importance. Hence, the non-homogenous waveguide structure takes its significance.

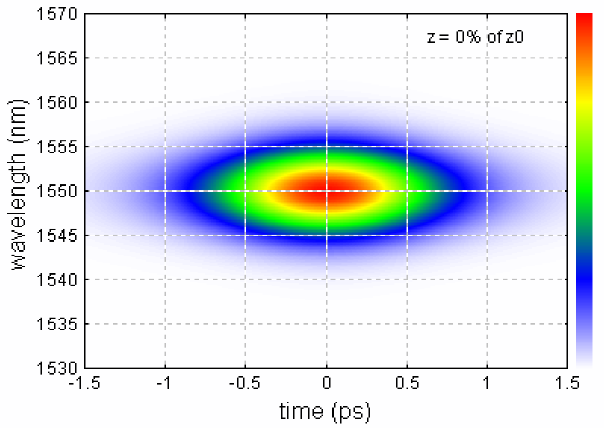

Fig. 2: Soliton Spectrum.

If the fiber is axially in homogenous, it was proved that the width of the soliton pulse of the first order (n=1) propagating in the fiber with considerable losses remains unchanged. Specifically, a fiber with conic core was preferred for the use. In case of the conic core, the group velocity (as a function of distance) would decrease in proportion to the exponential decay of solitons and is inversely proportional to the square of core radius. [5].The dynamics of inter soliton interaction in a homogenous structure acquires a specific significance. Fundamental solitons in the GHz range that travel in fiber with little dispersion can generate new spectral components which are proved from the experiment of Mamyshev Et al. A stable sequence of soliton arises due to the self-control of phases and amplitudes of the generated elements. [6]. A lot of theoretical approaches have been developed to investigate the dynamics of solitons in waveguides that are periodically perturbed. [7 - 9]. The demonstration by Sipe and Winful using Bloch-Floquet theory shows the possibility of the propagation of the Schrodinger solitons in a nonlinear medium with exclusive distribution of the refractive index which varies with the wavelength. Hasegawa and Kodama have applied lie transformation subsequent averaging to the NSE with a periodic perturbation. The dynamics of the soliton, in this case, is similar to the evolution of the guiding center of the Larmor motion of a charged particle in a slowly varying magnetic field. In fact, the period of perturbation falls in resonance with the specific period of the soliton, then the dispersion waves are produced, and its guiding center can be split into two or more solitons. Authors also showed the plot of propagation regions of two coupled solitons for a given period with the amplitude of the perturbation [8]. This plot shows resonant curves of multiple resonances. The resonant effects observed in the plot shows within the region where the curves of numerous resonances are parallel to the demarcation line which separates the amplitude space into the regions corresponding to the stable and unstable regions of propagation of coupled solitons.

2. Applications

In recent years, the focus on the area of optical solitons has grown steadily. This field of study has outstanding potential for technological applications. Many exciting research problems both from a fundamental and an applied point of view are present in this area. Many new optical devices are in different stages of development. [10]. Soliton research has been conducted in many diverse fields such as particle physics, molecular biology, quantum mechanics, geology, meteorology, oceanography, astrophysics, and cosmology. The technologically most significant area of soliton research is the study of solitons in optical fibers wherein the primary objective is to use soliton pulse as the information carrying "bits" in optical fibers. Many research reviews and monographs are available on the history of soliton communication systems [11 - 15]. Another most critical developments for soliton transmission systems is the introduction of dispersion management. Alternating fibers with opposite sign of chromatic dispersion along the transmission line is being used for this purpose. [16]. Over the last decade, the rate of transmission of data has increased four times in its magnitude. Many techniques have been developed over the previous few years to study the systems with strong dispersion management. Very recently, the development of optical fiber fabrication techniques that suppress the water absorption peak in the 1400nm wavelength region improves the possibility of massive wavelength-division multiplexing across the whole wavelength range to from 1200 to 1600nm. [17]. Increasing the number of channels and increasing the single channel bit rate are the two complementary methods to have a tremendous increase in the capacity. In both the cases, the designer of communication systems faces primarily the same difficulty that arises from the interplay of the four significant impairments:

1) Chromatic dispersion
2) Nonlinearity
3) Amplifier noise
4) Birefringence which is also called Polarization mode dispersion.

Hence the use of soliton would help to reduce these impairments and therefore would give an uplift in the field of fiber optics.

3. Conclusion

Because of their very high carrying capacity and repeater less transmission, soliton based optical fiber communication systems, using EDFA's are more suitable for long-haul communication. For field applications, further improvement and modification of these systems are required. In future, when transmission demand will increase and device technology will improve. They will be indeed employed in the field. Also, for optical computation multi Gigabits per second data rate can be achieved by using soliton based optical switches.

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