SOLITONS STEMS FROM THE DELICATE BALANCE OF "NONLINEARITY" AND "DISPERSION" IN THE MODEL EQUATIONS

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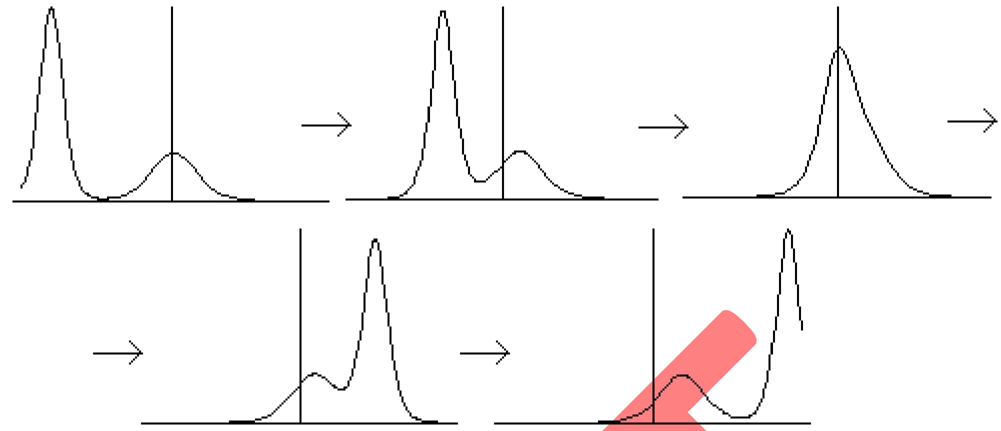
ABSTRACT

A topological soliton, or topological defect, is any solution of a set of partial differential equations that is stable against decay to the "trivial solution." Soliton stability is due to topological constraints, rather than inerrability of the field equations. The constraints arise almost always because the differential equations must obey a set of boundary conditions, and the boundary has a non-trivial homotopy group, preserved by the differential equations. Thus, the differential equation solutions can be classified into homotopy classes. There is no continuous transformation that will map a solution in one homotopy class to another. The solutions are truly distinct, and maintain their integrity, even in the face of extremely powerful forces.

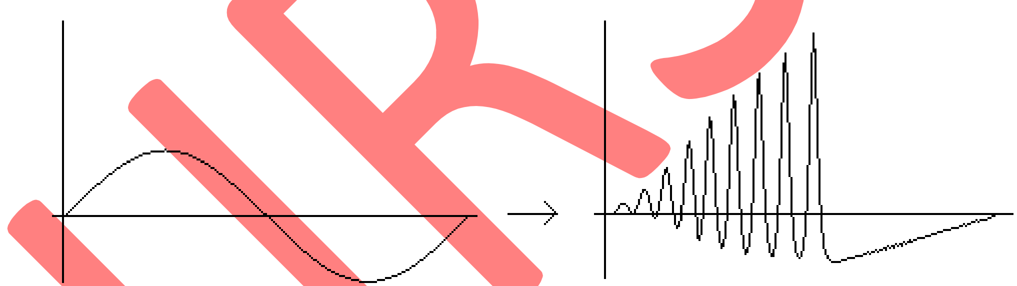
INTRODUCTION

The term "soliton" was introduced in the 1960's, but the scientific research of solitons had started in the 19th century when John Scott-Russell observed a large solitary wave in a canal near Edinburgh. In the days of Scott Russell, there was much debate concerning the very existence of this kind of solitary waves. Nowadays, many model equations of nonlinear phenomena are known to possess soliton solutions.

Solitons are very stable solitary waves in a solution of those equations. As the term "soliton" suggests, these solitary waves behave like "particles". When they are located mutually far apart, each of them is approximately a traveling wave with constant shape and velocity. As two such solitary waves get closer, they gradually deform and finally merge into a single wave packet; this wave packet, however, soon splits into two solitary waves with the same shape and velocity before "collision".



The stability of solitons stems from the delicate balance of "nonlinearity" and "dispersion" in the model equations. Nonlinearity drives a solitary wave to concentrate further; dispersion is the effect to spread such a localized wave. If one of these two competing effects is lost, solitons become unstable and, eventually, cease to exist. In this respect, solitons are completely different from "linear waves" like sinusoidal waves. In fact, sinusoidal waves are rather unstable in some model equations of soliton phenomena. Computer simulations show that they soon break into a train of solitons.



Definition:

A single, consensus definition of a soliton is difficult to find. Drazin and Johnson (1989) ascribe 3 properties to solitons:

1. They are of permanent form;
2. They are localized within a region;
3. They can interact with other solitons, and emerge from the collision unchanged, except for a phase shift.

More formal definitions exist, but they require substantial mathematics. Moreover, some scientists use the term *soliton* for phenomena that do not quite have these three properties (for

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instance, the 'light bullets' of nonlinear optics are often called solitons despite losing energy during interaction).

Explanation:

Dispersion and non-linearity can interact to produce permanent and localized wave forms. Consider a pulse of light traveling in glass. This pulse can be thought of as consisting of light of several different frequencies. Since glass shows dispersion, these different frequencies will travel at different speeds and the shape of the pulse will therefore change over time. However, there is also the non-linear Kerr effect: the refractive index of a material at a given frequency depends on the light's amplitude or strength. If the pulse has just the right shape, the Kerr effect will exactly cancel the dispersion effect, and the pulse's shape won't change over time: a soliton.

Many exactly solvable models have soliton solutions, including the Korteweg deVries equation, the nonlinear Schrödinger equation, the coupled nonlinear Schrödinger equation, and the sine-Gordon equation. The soliton solutions are typically obtained by means of the inverse scattering transform and owe their stability to the inerrability of the field equations. The mathematical theory of these equations is a broad and very active field of mathematical research.

EXPERIMENTAL RESULTS & DISCUSSION

Experimental Setup

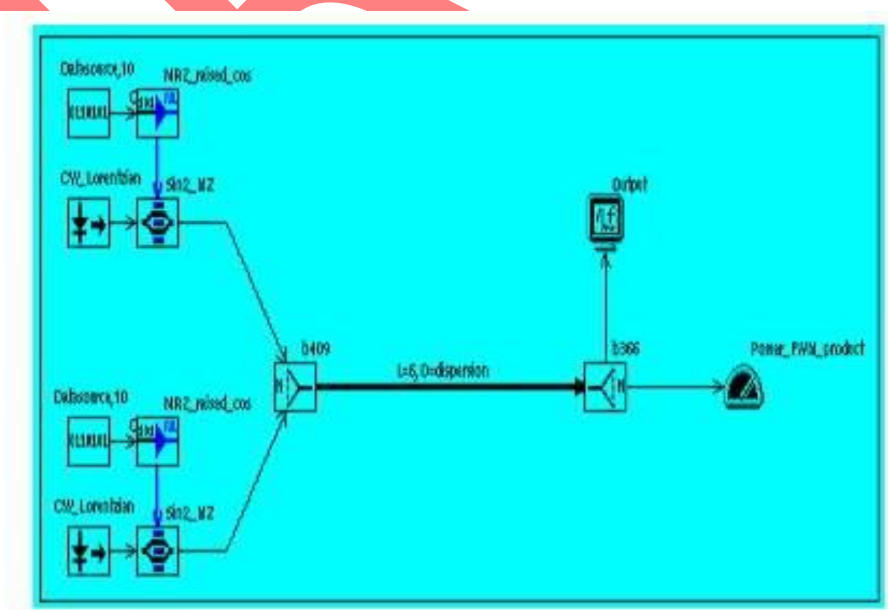

Fig. 2.12: Experimental Setup

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The experimental setup in Fig. 2.12 contains data source, Continuous wave laser source, Mach Zender modulator, driver, splitter, combiner, spectrum analyzer, and a power meter. The data source produces data at a rate of 10 GB/s or higher in the form of ones and zeroes. This data is then transferred to the driver which is a device that is used to convert the binary zeroes and ones into electrical format i.e. NRZ or RZ format. The signal is then passed on to Mach Zender modulator. A modulator is a device that modulates carrier signal according to the modulating signal. Here the modulating signal is the one passed on from the driver and the carrier signal wavelength is provided by the continuous wave laser.

It must be noted that the optical signal is transmitted at a particular wavelength generated by the continuous wave laser and at a particular power level. The two optical signals of particular wavelength and power are multiplexed through combiner and are transmitted through the optical fiber cable. The optical signal at the receiving end is passed on to splitter through which multiple analyzing components can be attached to make analysis of the received signal.

RESULT AND DISCUSSION

In this experimental setup the two lasers are operating at center frequencies of 193.025 THz and 193.075. Fig. 2.13 shows the input wavelengths to the optical combiner, Fig. 2.14 shows the FWM cross products and Fig. 2.15 shows plot of power vs. dispersion.

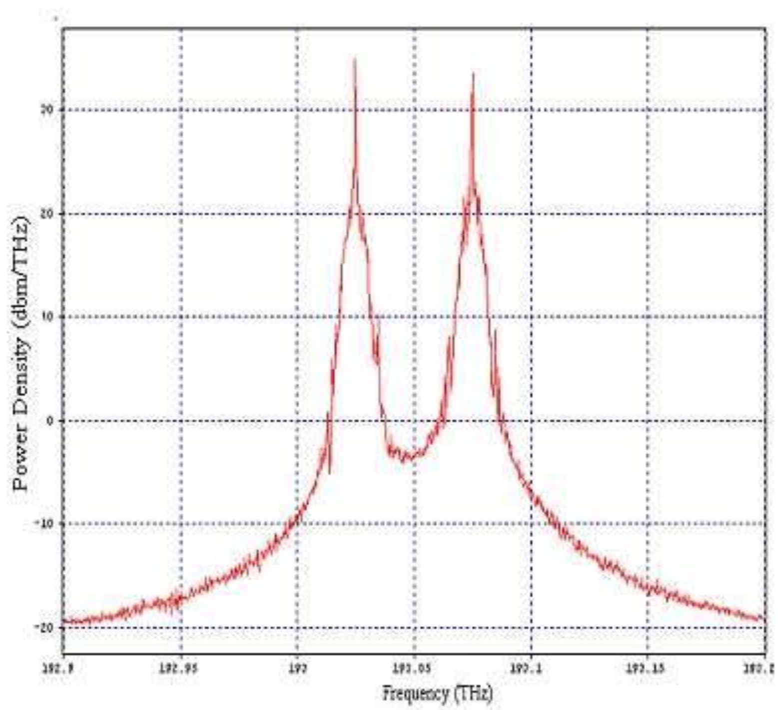

Fig. 2.13: Input Wavelengths (Power density vs. Frequency)

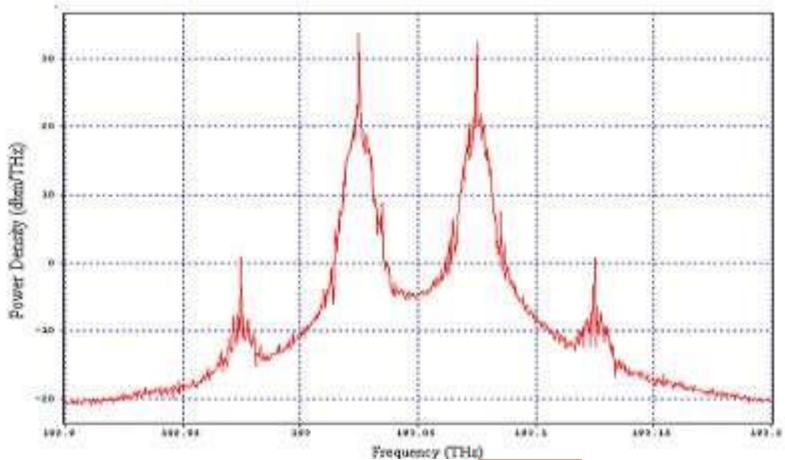

Fig. 2.14: Output Wavelengths (Power density vs. Frequency)

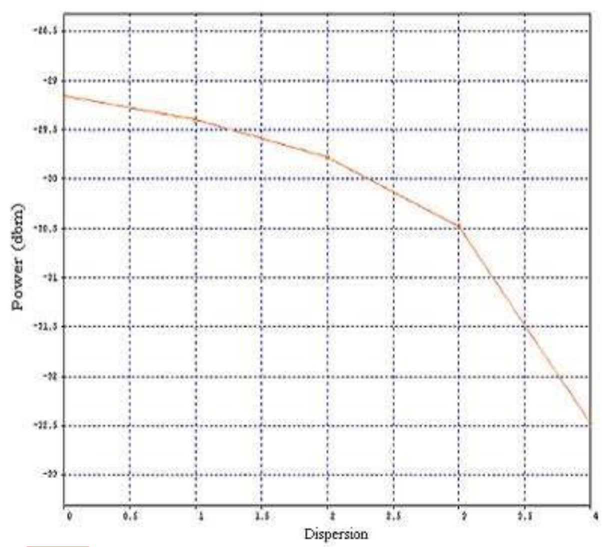

Fig. 2.15: Power vs. Dispersion plot

Optical fibers exhibit a variety of nonlinear effects. Nonlinear effects are feared by telecom system designers because they can affect system performance adversely. Presence of these non linear effects in the optical fiber communication systems like WDM systems can adversely affect the communication between two receiving ends. That is it can lead to transference of wrong or incorrect data to the receiving end due to interchannel mixing if the sideband wavelengths generated due to FWM coincide with the original wavelengths carrying data.

These nonlinear effects can be managed through proper system design. There are many ways by which these nonlinear effects can be reduced. However, nonlinear effects are also useful for many device and system applications: optical switching, soliton formation, wavelength conversion, broadband amplification, demultiplexing, etc. New kinds of fibers have been developed for enhancing nonlinear effects.

CONCLUSION

In this work, we have proposed a new type of the multidimensional model in nonlinear optics. It combines self-defocusing nonlinearity and normal group-velocity dispersion with periodic modulation of the local refractive index in the one or two transverse directions (in the 2D and 3D models, respectively). Strictly speaking, multidimensional (spatiotemporal) solitons cannot exist in media of this type, as the system's spectrum contains no true bandgap. Nevertheless, solitons which seem as completely localized ones are predicted by the variational approximation, and found in direct simulations.

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