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Soliton and its Underlying Principle of Information Carrying Bits

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ABSTRACT

Soliton are narrow and high intensity pulses which can retain their shape by compensating the effects of SPM(Self phase modulation) and GVD (Group velocity dispersion) Mechanisms. In soliton kerr effect cancel the dispersion effect and thus pulse shape is maintained. Optical solitons play a major role in optical communication in which the solitons are treated as information carrying bits. The two exactly opposing mechanisms GVD in anomalous dispersion regime and SPM make optical soliton wave propagation through optical fibre.

KEYWORDS Soliton, SPM(Self phase modulation), GVD (Group velocity dispersion), Pulses

1.1.1 INTRODUCTION

Properties associated with soliton:

In general a wave cannot travel very long distances and gets affected after collision with another wave with regard to its amplitude, velocity, etc.

But a new kind of waves called as soliton waves could travel rapidly and unattenuated over very long distance even thousands of kilometer [1] and also a soliton of large height and greater velocity when merge with soliton with slower waves of less height, the large height soliton emerges out undistorted with their shape and identity uncharged but there would be change in phase only.

Following are the properties associated with solitons [4-6]

- They interact with other soliton as normal waves.
- After interaction emerge out by retaining their shape and amplitude but there is phase change
- They can travel long distances.
- They are permanent and localized waves.
- In soliton kerr effect cancel the dispersion effect and thus pulse shape is maintained.

Few more important properties of solitons are:

- Speed of wave is directly proportional to the size of the wave and width depends on the depth of water in water channel or water tank.
- Normal wave merge or combine but in case of soliton waves of two different size, small wave is overtaken by large wave and soon splits in to two separate wave again of small and big size waves.
- These waves can travel large distances and are stable retaining their shape and size.
- They do not steepen out or flatten out by decreasing their amplitude and maintain their shape of well defined water heap.
- If the water tank depth is (h) and η is the amplitude of the wav the expression for the velocity of soliton wave is given by $v = \sqrt{g}\,(h + \varsigma)$.
- Small size wave travels with less velocity.

1.1.2: Optical fibres

Optical fibres are cylindrical dielectric waveguides consisting of a central core of one index of refraction (n_1) surrounded by a concentric cladding with a slightly different index of refraction (n_2) in order to guide light through the length of the fibre by the process of total internal reflection[2]. The optical fibres guide electro-magnetic waves in the region of visible spectrum which has frequency over 100THz. This frequency is almost hundred thousand times greater than microwaves and hence much more information can be carried by an electro-magnetic wave through fibres. In general waveguides introduce certain boundary conditions on the electromagnetic fields that must be met at the interfaces between the wave guide regions [4]. As a result, only certain combination of waves will meet these boundary conditions and be allowed to propagate. Such combination of waves is known as modes. In fact the modes of an optical fibre are those transverse field distributions of electric and magnetic fields that propagate through the optical fibre with definite phase and group velocities and without any change in their polarization state or in their transverse field distributions. Depending on the number of modes propagating through the fibre one can classify fibres as single mode or multimode fibres.

1.2.1: Results and Discussion:

As the intensity of the incident pulse is high (that is Pico-second/nano-second pulses), the response of the fibre be-comes nonlinear and one has to take the nonlinear effects also to study pulse propagation.

Group velocity dispersion:

In single mode fibres also pulse dispersion takes place. Here different frequency components present in the in-put pulse travel at different velocities leading to the temporal broadening [8] of the pulse. This spreading of group velocity is known as chromatic dispersion or group velocity dispersion (GVD). Two mechanisms responsible for GVD are

a) Material dispersion:

This arises due to the dependence of refractive index of the fibre material on frequency. The dopants like (GeO_2, P_2O_2) in the core are responsible for this dispersion.

b) Waveguide dispersion:

This is due to the explicit dependence of propagation constant on wave-length. This depends on the fibre design parameters such as the core radius and the core-cladding index difference.

Kerr effect and self phase modulation:

In an optical fibre the lowest nonlinearity is the $\chi^{(3)}$ non-linearity. The role of the real part of $\chi^{(3)}$ is to change the refractive index proportional to the intensity $|E|^2$. This phenomenon of intensity dependence of refractive index is known as Kerr effect. Now, in the presence of Kerr effect a self induced phase shift is experienced by the optical field during its propagation through optical fibre, this phenomenon is known as self phase modulation (SPM).

Due to the SPM the leading edge of the pulse is down-shifted in frequency and the trailing edge is up shifted in frequency leaving the central frequency of the pulse unchanged. Thus the chirp that arises here is in an opposite sense to the chirp which occurs due to anomalous dispersion.

Results and Discussion:
The two exactly opposing mechanisms, GVD in anomalous dispersion regime and SPM discussed above leads to predict optical soliton wave propagation through single mode optical fibre[5].

Soliton propagation through optical fibre suffers a major impediment due to fibre loss, an inevitable loss arising due to fibre property, and hence requires expensive repeaters to be installed periodically in order to regenerate them.

The first long distance all optical soliton transmission, showing soliton propagation for over more than 4000kms, uses a recirculating loop. In the mean time, fibre amplifiers have been also developed to over-come the difficulties arising in Raman fibre amplifiers. To be specific, the invention of erbium doped fibre amplifiers enhanced the study on the optical soliton regeneration. In 1989 Nakazawa, Kimura and Suzuki [7] demonstrated experimentally the reshaping of optical solitons. Following this an immense amount of research work is being carried out at present in this direction. It has also been observed that light ampli-fication in erbium doped glass fibres allows intercontinental communication at 10 billion bits per second and opens new avenues of data transmission via optical solitons [3].

CONCLUSIONS:
If a wave is in motion, the compression of pulses occurs by SPM (Self phase modulation) and broadening of pulse occurs by GVD (Group velocity dispersion).

If these two mechanisms compensate each other the pulse do not change shape (called fundamental solitons).

If Pulses undergo periodic change in shape then they are called higher order soliton.

If these two mechanisms compensate each other the pulse do not change shape (called fundamental solitons) and thus solitons are used as information carrying bits.

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