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Research Paper

Generation of Short Time Width Optical Soliton Pulse Inside an Optical Fiber

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KEYWORDS : Electro-optic modulator, non-linear optical fiber, optical soliton

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ABSTRACT

Short time width pulse is very much essential in optical communication system. The acceptance of the all optical soliton (AOS) pulse in communication field will be automatically enhanced if the time widths of the pulses are shorten. Here I propose a new idea to generate a short time width soliton pulse inside the optical fiber media. For this purpose the electro-optic behavior and the non-linear character of the fiber media are exploited actively. Here, I use L-type biasing of the electro-optic modulator (EOM) in amplitude modulation scheme. The optical Gaussian pulse (OGP) is first modulated by the modulator and then fed into the non-linear optical fiber (NLOF).

Introduction:

In order to respond a huge demand of information processing, the old analog metal cable based communication are lagging behind as they can not be useful for very high speed (above GHz) communication with high signal / noise ratio. On the other hand the use of optical fiber system can handle these issues very successfully. Here laser pulses are used as the carrier bits of information, where the information is encoded by the laser pulses. By making the optical pulse (OP) as short as possible, one may tremendously increase the amount of information sent in a second. Still there is a problem on the limit of the width of the laser pulse. Again if one injects too many short pulses into a fiber, they may overlap with each other after propagating over a certain distance due to dispersion effect., In this situation to avoid this superimposition with the immediate proceeding pulses, optical soliton pulse (OSP) has proved its potentiality for the use in optical fiber communication. OSP is such type of OP which can propagate over a long distance without any distortion, attenuation and chirping. When a particular intense OP travel through the NLOF such that the chirping effect due to self phase modulation and non-linearity balance each other inside the fiber media, then OSP generate. Now if the time width of the OSP is shortens then the information carrying capacity will be increase tremendously.[1,2]

A new approach is reported Here to generate a short time width OSP inside the NLOF media by using longitudinally biased (L type biased) EOM. The OGP is first send through the EOM, set in amplitude modulation mode. The amplitude modulated OGP is then fed into the NLOF, where it first interacts with the nonlinear character of the media. By controlling the biasing signal very accurately we can transfer the OP to OSP and at the same time the time width is decrease to almost half of its previous value.

L-type EOM in amplitude modulation scheme (AMS)

Figure (1) shows an EOM in AMS in LMO where an unpolarised OGP of time width τ and circular frequency ω is passed through a polarizer (P) oriented with its pass axis along the Y-direction and the output beam is passed through an analyzer with its pass axis along the X-direction.

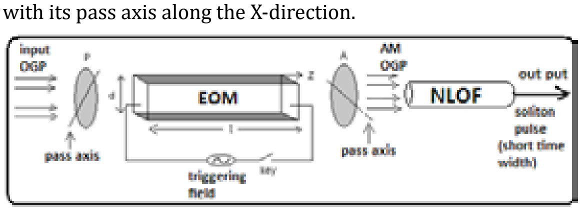

Fig.1: Schematic diagram of proposed technique. Here, P is polarizer, A is analyzer.

Now, if an unpolarised pulse is made incident along Y axis, then two components of linearly polarized pulses polarized along X' and Y' directions will be obtained. Where X' and Y' directions are 45^0 angle to the X and Y axis respectively. These two components which were in same phase at the input end (Z=0) of the EOM are no longer in phase at the outlet of the EOM (i.e. at Z=l). The phase difference between these two components at the output end there by depends on the triggering field.

When such two retarded linearly polarized OGPs are superposed, then an elliptically polarized wave is formed in general. If this elliptically polarized wave passes through an analyzer, oriented perpendicular to the input polarization state then an amplitude modulated pulse (AMOGP) will be obtained at the outer face of the analyzer.

If the biasing field is sinusoidal in nature having angular frequency ω_m and peak voltage V_0, then the emerging AMOGP will be as[3,4,5]

$$E_{AM} = A\exp\left(-\frac{t^2}{\tau^2}\right)\left[\exp i\left(\theta+\frac{\phi}{2}\right)-\exp i\left(\theta-\frac{\phi}{2}\right)\right] \qquad \text{----- (1)}$$

Such an AMOGP as shown in eqn. (1) is then passed through the optical fiber where it interacts with the nonlinearity of the media.

Generation of short OSP inside optical fiber media:

When the AMOGP interact with the nonlinear property of the fiber media then the electric polarization inside the OF media will be as

$$P_{AM} = \varepsilon_0\chi^{(1)}[E_{AM}] + \varepsilon_0\chi^{(3)}[E_{AM}]^3 \qquad \text{------- (2)}$$

Here we can neglect the higher order non-linear terms due to their very low values.

After expanding the 1st term of equ. (2) by using Fourier identities and Bessel functions we may interprit that this term does not exist due to phase mismatch with the frequency of the input pulse.

Similarly as earlier if we simplify the 2nd term of equ. (2), then the real part of this term will be as

$$\varepsilon_0\chi^{(3)}[E_{AM}]^3 = \varepsilon_0\chi^{(3)}A^3\exp\left(-\frac{3t^2}{\tau^2}\right) \times \left[\begin{array}{l} \text{[illegible]} \\ +2\sum \text{[illegible]} \\ +4\sum \text{[illegible]} \end{array}\right] \qquad \text{--- (3)}$$

Where, ζ, ζ_2, θ and ϕ depends on the characteristics and dimension of the EOM in this mode and the characteristics of the external biasing field.

Among these five phase terms, only 2nd & 5th terms may exist for some fixed values of S, the other terms does not exist due to phase mismatch with ω.

The whole matter is now discussed by two cases.

Case 1: When the modulated frequency ω_m is equal to the 1/(2S - 1) fraction of 2 ω then the corresponding electric polarization inside the OF media becomes as,

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$$(P_{\Delta\omega})_1 = \varepsilon_0\chi^{(3)}A^3\exp\left(-\frac{3t^2}{\tau^2}\right)\times\left[2J_{(s+1)}(S_1)\cos\left(\omega t-\frac{3\omega n_0 l}{C}\right)\right] \quad \text{------ (4)}$$

Case 2: When the modulated frequency ω_m is equal to 1/s fraction of ω then the electric polarization will be as,

$$(P_{\Delta\omega})_2 = \varepsilon_0\chi^{(3)}A^3\exp\left(-\frac{3t^2}{\tau^2}\right)\times\left[6J_{1s}(S_1)\cos\left(\omega t-\frac{3\omega n_0 l}{C}\right)\right] \quad \text{------- (5)}$$

Thus, equations (4) and (5) represent the electric polarization inside the non-linear OF media according to two different cases respectively. In both cases the time width of electric polarization is smaller than that of the input OGP. The amplitude of the electric polarization are different in different cases but the phase difference wrt the input pulse is equal in both situation which depends on the dimension of the modulator used here.

Conclusion:

Form the above discussion, it is clear that the amplitude of the out put pulse depends on the value of peak voltage (V_0) of the triggered signal and the value of S which also depends on ω_m. Therefore, the amplitude and also the power of the pulse inside the OF media may be controlled very accurately by controlling the triggering field. Thus it is not at all difficult to obtain a particular intensity pattern inside the fiber media to form an OSP inside the OF by simply controlling the modulator externally. Therefore, for a particular power profile, the OGP transfer to the soliton pulse inside the fiber.

Again from eqn. (4) & (5), it is clear that the time width of pulse inside the fiber media is $\frac{\tau}{\sqrt{3}}$ which is smaller than that of the input i.e. nearly equal to 58% that of the input optical pulse. So, this simple technique may by used to shorten the time width of the optical pulse. At the same time by controlling the modulator externally one can transfer the optical signal to solitonic one.

Almost the same idea may be adopt to achieve the OSP inside the fiber media by exploiting the L-type modulator in phase modulation mode, where the pulse intensity inside the fiber can be controlled by triggering the modulator with a proper sinusoidal field. In that scheme a comparatively very high operating voltage is required to generate the proper pulse of such power so that an OSP is formed inside the fiber media. Where as in the present scheme, we apply a comparatively low valued sinusoidal field. Therefore, the proposed technique is far better than the previous one from the power point view.

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