40Gb/s optical 3R-regeneration Based on XPM in PCF

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Abstract—We demonstrate 3R-regeneration method based on XPM in PCF. The most important part of this system is a MZI Optical Switch which have one high-Nonlinear PCF arm. By adjusting the length of the PCF, we can make the centre of the optical pulse obtain a phase shift about π, this optical pulse transmitted through the PCF interfere with the optical pulse transmitted through the other arm, the degraded data signal get regeneration. The experiment is simulated with Optisystem.

Keywords—3R-regeneration, PCF, XPM

I. INTRODUCTION

In light communications network in the, fibre and various light devices of loss will caused signal of attenuation; dispersion (Group speed dispersion and polarization die dispersion), will led light signal of broadening and malformation, occurs code between interference, makes system of BER increased, limit has network node level joint of ability, serious effect communications quality, eventually limit has system and network of transmission rate and distance [1]. So full off 3R regeneration repeatedly to Re-amplifying, Re-timing, Re-shaping become essential [2,3].

Re-shaping is an important part in all-optical 3R regeneration, it determines the final output of signal regeneration performance. Re-shaping optical signal using optical switch to judgement and core technology is shaping the design of the optical switch. Currently implemented in all-optical 3R-optical method of the judgement are: based on semiconductor saturable absorption effect of electro-optical modulator (EAM), based on Nonlinear Optical loop mirror (NOLM), Mach based on XPM effects of SOA have de Interferometer (SOA-MZI) or Michelson Interferometer (SOA-MI). Which based on EAM of light switch system using EAM of nonlinear cross saturated absorption effect, performance stability, but EAM work Shi need DC partial reset voltage, so is does not Shang full significance Shang of full light judgment; based on Nonlinear optical ring mirror (NOLM) of light open work rate high, but exists size large, and difficult integrated; based on SOA of Mach a has de interference instrument (SOA-MZI) light switch system because semiconductor carrier slow recovery time characteristics limit has switch work speed, effect its level joint ability.

This article by using Photonic Crystal fiber nonlinear effects [4], constructed based on Photonic Crystal fiber XPM effects of all-optical switch, realizing all-optical 3R regeneration, simple structure, low cost, stable performance.

II. THEORETICAL ANALYSIS

When there is a strong power in optical fiber magnetic field, the electrodes caused by external electric field strength and applied electric field strength e p's of nonlinear relations can be expressed as

\[ P = \varepsilon_0 (x E^{(1)} + x E^{(2)} + x E^{(3)} E E + \ldots) \]

(1)

In the formula: \( \varepsilon_0 \) is the permittivity of vacuum, \( \chi^{(j)} \) is j-order susceptibility tensor. In the quartz glass, because the media is inversion symmetry, \( \chi^{(2)} \) disappeared, \( \chi^{(3)} \) has become the most important non-linear components. In monochrome approximate cases, to separate fast changing parts of the electric field, write the following form:

\[ E (r, t) = \frac{1}{2} \sum \varepsilon (E_1 e^{-i\omega_1 t} + E_2 e^{-i\omega_2 t}) + c \cdot c \]

(2)

Crystals of nonlinear polarization can be expressed as:

\[ P_{NL}(r, t) = \varepsilon_0 \epsilon \chi^{(3)} (E (r, t) E (r, t) E (r, t)) \]

(3)

(2), substitute (3):

\[ P_{NL}(r, t) = \frac{1}{2} \sum \varepsilon_0 \epsilon \chi^{(3)} \left( E_{11} E_{22} E_{33} + E_{12} E_{21} E_{33} + E_{13} E_{31} E_{22} + E_{23} E_{32} E_{11} \right) + c \cdot c \]

(4)

\[ P_{NL}(\omega_1) = \chi_{eff} |E_1|^2 + 2 |E_1|^2 E_1 ; \]

\[ P_{NL}(\omega_2) = \chi_{eff} |E_2|^2 + 2 |E_2|^2 E_2 \]

\[ P_{NL}(2 \omega_1 - \omega_2) = \chi_{eff} (E_1^* E_1^* E_1^* E_1^* + \ldots) \]

\[ \chi_{eff} = \frac{3 \varepsilon_0 \epsilon}{4} \chi^{(3)}_{xxxx} \]

Used as an effective nonlinear parameters.

(4) produced a new frequency\( 2 \omega_1 - \omega_2 \); \( 2 \omega_1 - \omega_1 \); areas belonging to the four-wave mixing discussions, certain conditions must be met in order to produce, and the actual process in General does not meet, so ignore the two. The remaining two have a nonlinear effect on refractive index. You can see:

\[ P_{NL}(\omega_j) = \varepsilon_0 \epsilon^{N_L} E_j \quad (j = 1, 2) \]

(6)

Associate it with a linear part together:

\[ P(\omega_j) = \varepsilon_0 \epsilon_j E_j \]

(7)
Where:
\[ \varepsilon_j = \varepsilon_j^{nl} + \varepsilon_j^l = (n_j^l + \Delta n_j)^2 \]

\( n_j^l \) is the linear part of the refractive index, \( \Delta n_j \) is caused between three nonlinear effect of refractive index change. Use \( \Delta n_j \approx n_j^l (j = 1, 2) \) the nonlinear part is
\[ \Delta n_j = \varepsilon_j^{nl} / 2n_j = n_j (|E_j|^2 + 2 |E_{j-1}|^2) \]

By (9), optical refractive index and its strength not only relevant, but also with other waves related to the strength of common transport. When you are in optical fiber transmission, will get a strength-related nonlinear phase:
\[ \phi_j(z) = \frac{\alpha_j z n_j}{c} \Delta n_j = \frac{\alpha_j z n_j}{c} \left(|E_j|^2 + 2 |E_{j-1}|^2\right) \]

Type on, corresponding to the first House is divided against itself to modulation of SPM, corresponding to the second is the cross-phase modulation XPM.

Then \( E_{3-j} \), is divided against itself to modulation can be ignored, (2-10) can be simplified to:
\[ \phi_{NL} = 2\gamma P_p L \]

Where \( \gamma = \frac{c}{c} \) is the nonlinear coefficient of the medium, and \( P_p = |E_{1-j}|^2 \), \( L = Z \) for the interaction length.

III. PROGRAMME DESIGN

Using cross-phase modulation to make this programme a three port optical switch, optical signal with the light switch and then Re-shaping. (1) is a three-port based on the Mach-Zehnder Interferometer optical switching, is also a central part of the programme. Pump light (clock pulse) as a switching signal, after amplification and signal photo merging into the PCF nonlinear effects all the way. As the signal power is far less than the pump power, so self phase modulation effects can be ignored. By (2-11) volume of cross-phase modulation signal light phase-shifting \( \Phi_{NL} = 2\gamma P_p L \) that occurs. Adjust the values of \( L \) has both beam linear phase difference is an \( \pi \) odd number of times; at the same time through the nonlinear phase shift of the XPM effect in Photonic crystal fibers in clock pulse peak power for \( \pi \); two-channel optical signal after interference. As figure (2) by as shown in because in clock pulse peak Department, upper and lower signal light code Yuan Center has \( 2\pi \) integer times of phase difference, therefore occurs phase long interference and improve, and corresponds clock pulse power for 0 part because upper and lower two road signal light of phase difference for \( \pi \) odd number times, produced phase Xiao interference and reduce, suppression has noise; to implementation signal Re-shaping and purification of purpose. Reason for using Photonic Crystal fiber in the experiment are: General silica fiber \( \gamma \) value is small (2.7W-1Km-1), and now know of ultra

IV. SIMULATION RESULTS

Figure (4) and (5) the contrast can be seen in transit due to the loss of optical fiber and optical device can cause signal attenuation; dispersion will lead to broadening and deformity and mixed with the noise of the light signal. (6) degraded signal serious damage, eye stitch blur, noise margins is extremely low.
regeneration method. Method is simple, reliable performance, make the regeneration of signal quality improved significantly. [7] the use of four-wave mixing in methods are as follows:

Comparison with this system: two eye-diagram of the system regenerates the signal noise margins the same (all 7.5E-314); however this system more simple and compact design, two roots are used in Photonic Crystal fiber and wavelength conversion using. This system only is a signal using a Photonic Crystal fiber and Re-shaping, reduce the complexity of the design and manufacturing, production cost savings, and reduced the volume increased system integration.

REFERENCES

Figure 1. The 3ports optical switch for reshaping.

Figure 3. Schematic diagram of our proposed all-optical 3R regeneration.

Figure 8. Schematic diagram of Reference.