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Generation of suitable spectrum pulse for linear optical sampling by using highly nonlinear fiber

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1 Introduction

To meet the increasing demand of new applications in modern telecommunications, the optical fiber communication technology has been notably developed. Now in optical system, the signal can span several hundred GHz bandwidth with advanced modulation formats and this large bandwidth provide data rates over several Tb/s per fiber. For characterizing such large capacity optical signals with high time resolution and monitoring the optical performance, an optical sampling technique is needed [1-3]. The linear optical sampling is promising to observe and monitor such broadband signals.

2 Purpose of Research

The linear optical sampling technique (LOS) which realizes the time resolved measurements of optical data signals at high bit rates and wide bandwidth. So wideband local sampling pulse is needed for LOS whose spectrum encompasses entire C-band (1530 to 1565 nm). Commercial pulse laser sources hardly provide such wide spectra. So, method for obtaining wide spectra is desired.

2.1 Method

Normally commercial Passive Mode Locked Laser (PML) emits 1ps width pulse whose spectrum is several hundred GHz that is not sufficient for LOS. The C band (1530 to 1565 nm) is most widely used for long distance optical fiber communication system. So to encompass this entire C band the (4 – 5) THz width spectrum pulse is needed for LOS.

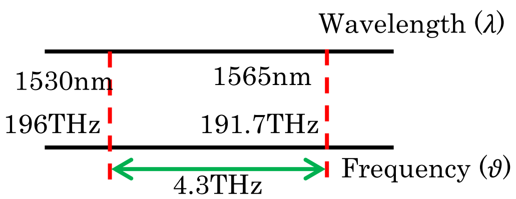

Fig 1: Spectral width for C band

To create optical sampling pulse over several THz bandwidths, we have used nonlinear effect in highly nonlinear fiber. Here we have investigated by using the computer simulation based on FFT Beam Propagation Method (FFT-BPM), and analyze the Nonlinear Schrodinger Equation (NSE). We searched the conditions for obtaining wideband pulse, whose spectral width is larger than 4.3 THz and good spectral flatness also needed. That is used to examine spectral response of optical devices.

2.2 Formula

Any pulse, while propagating in an optical fiber, suffers the effect of signal loss for attenuation and dispersion which causes of pulse broadening. Also suffer from non-linear effect that's leads to increase the dispersion (broaden the spectrum of optical pulse). This phenomenon can be simulated by using the nonlinear Schrodinger equation. The nonlinear Schrodinger equation generally cannot be solved analytically, so numerical approach is needed. The FFT beam Propagation method (FFT-BPM) is an effective tool for analyzing the Nonlinear Schrodinger Equation (NSE).

The Nonlinear Schrodinger Equation is given by

$$i\frac{\delta A}{\delta z} = -j\frac{\alpha}{2}A - \frac{1}{2}\beta_2\frac{\delta^2 A}{\delta \tau^2} + \gamma|A^2|A$$

Here,

$\alpha/2$ = Fiber loss

β_2 =Chromatic dispersion

γ = Non liner effect

$$\text{Non liner coefficient, } \gamma = \frac{n_2\omega}{cA_{eff}}$$

For optical pulse propagation in highly nonlinear optical fiber, the change in pulse waveform which occurs due to wavelength dispersion and nonlinear affects that described by this Nonlinear Schrodinger Equation (NSE).

3 Result and Discussion

By using computer simulation based on nonlinear Schrodinger equation, I have investigated and searched the parameters, which realize appropriate pulse spectra for LOS. For the input pulse 1ps within the investigation parameter (Fiber length L= 20-200 m, peak power P_0 = 40-80w, Dispersion D= +17 to -17 ps/nm/km, A_{eff}=12mm^2, D_{slp} = 0.019;ps/nm^2/km, nonlinear refractive index n_2=3.2x10^{-20}, Fiber attenuation coefficient a = 0.23 * 2x10^{-4}) I have obtained several spectral pulse with different width.

Table 1 Output spectral width for various dispersion of highly nonlinear fiber of 20 m length.

P_0 (W)	D-8(ps/nm/km)	D-11(ps/nm/km)	D-14(ps/nm/km)	D-17(ps/nm/km)
	-8	-11	-14	-17
80	6.5THz	5.6THz	5.1THz	4.6THz
70	6THz	5.3THz	4.6THz	4.5THz
60	5.6THz	4.9THz	**4.4**THz	4.2THz
50	5.2THz	4.5THz	4.2THz	3.9THz
40	4.7THz	4.2THz	3.8THz	3.5THz

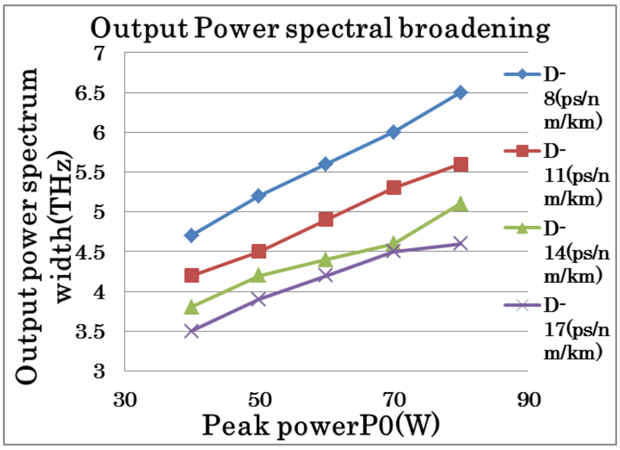

Fig: 2 Spectral broadening of output pulses.

In this graph, the horizontal axes indicate input peak power and vertical axes indicate width of output spectra for different dispersion in 20 m long optical fiber.

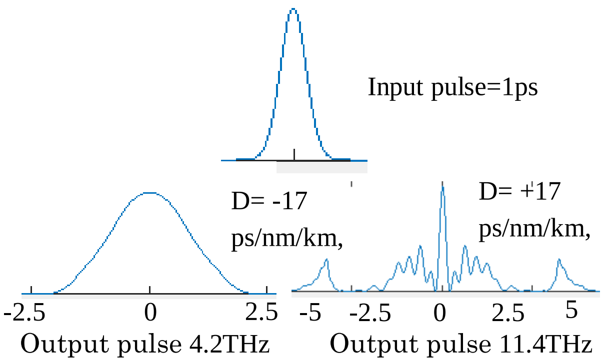

Fig 3: Spectral pulse difference based on dispersion

For the different dispersion based on input peak power (40-80) w the spectral broadening observation in 20m single mode fiber is shown in figure 2 and 3.

In table 2, dispersion keeps constant at -14ps/nm/km the fiber length has been changed within the input peak power 40-80w. Here, the output spectral width is almost same for specific input power at constant dispersion. Output spectral width is almost same but spectral flatness become anomalous with the increase of fiber length. Effect of Dispersion becomes larger with the increase of fiber length. That's why output spectrum becomes larger and anomalous. As a result output signals overlap each other and data become rough-and-tumble.

Table 2 Spectral width for different fiber length

Length (m)	P0=80 w	P0=70 w	P0=60 w	P0=50 w
20	5.1THz	4.8THz	4.4THz	4.2THz
50	5.1THz	4.8THz	4.5THz	4.2THz
100	5THz	4.8THz	4.5THz	4.2THz
150	5.1THz	4.8THz	4.4THz	4.1THz
200	5THz	4.7THz	4.5THz	4.2THz

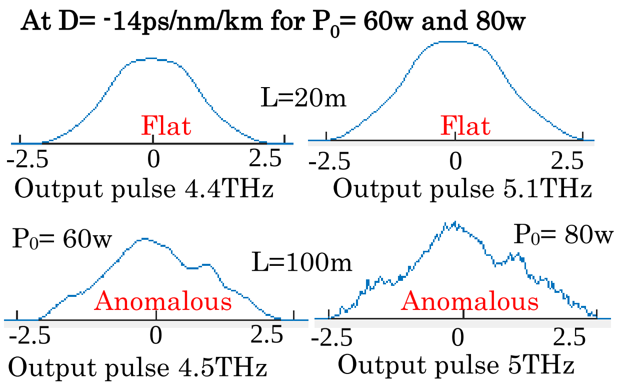

Fig 4: Spectral flatness based on fiber length increment

4 Summary

With the increase of input peak power the output Power spectrum pulse width is increases. And, for constant input peak power and dispersion, output spectrum pulses width is almost same in different length of optical fiber. Flatness of spectral pulse becomes anomalous with the increase of fiber length. So, combination between input peak power and dispersion is very important to get best output spectrum pulse for LOS. For negative dispersion, we get approximately perfect pulse for C band. Here got the best spectral pulse, which's width is 4.4 THz and flatness also good, regarding the input parameter (Po=60w, D=-14 ps/nm/km, L=20 m). which is very close to desired Pulse (width 4.3THz). We can use this 4.4 THz pulse for Liner optical sampling as it is greater than 4.3THz and good flatness

References

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