1. INTRODUCTION

Optical access networks have been considered as very attractive infrastructures to satisfy the increasing traffic demands. Up to now, a various types of structures and techniques have been proposed based on time-division-multiple access (TDMA) or wavelength-division-multiple access (WDMA). However, due to inherent structures their own, the cost per an user is quite so high that alternative approaches for high-speed access network with low cost need to be investigated as the optical code-division-multiple access (OCDMA) systems which the individual codes are assigned to each user at the transmitter and matched codes are also assigned at the receiver[1]. OCDMA systems enable to access multi-users simultaneously and asynchronously using the single wavelength which promise occupying the lower bandwidth than that of WDMA.

In this paper, we evaluated and analyzed the fiber dispersion penalty of 2.5 Gb/s OCDMA signals changing chirping parameters of ring laser which must give the useful criteria for the proper chip length, data rate, transmission distance, and chirping parameter in designing the optical access network using OCDMA techniques.

2. TRANSMISSION SYSTEM MODEL

We considered a system model as shown in Fig. 1. The optical source was assumed short pulse, generated from ring laser or MLLD with short pulse width and modeled with Gaussian function. The signal bandwidth of OCDMA signals are so broad that the fiber dispersion penalties can be determined by the base band signal. The short pulse with 2.5 Gb/s repetition rate are encoded in the time domain and modulated with 2.5 Gb/s pseudo random bit sequence (PRBS) $2^7 -1$ which is represented by

$$X_{\text{cbo}}(t) = \sum_{k} a_k C(t)$$

where $a_k = 0, 1 \text{ and } C(t)$ is a Gaussian input pulse for 2.5 Gb/s signal. Encoder results in time spreading the signal $X_{\text{cbo}}(t)$. This algebraic construction on the prime sequence code begins with the Galois Field $GF(p) = \{0,1,\ldots, p-1\}$ of prime number $p$. A prime sequence $S_i = (s_{i,0}, s_{i,1}, \ldots, s_{i,p})$ is constructed by $s_{i,j} = i \cdot j \pmod{p}$, where $i,j \in GF(p)$ the Galois field of $p$. Each prime sequence $S_i$ is mapped into a binary sequence $C_i = (c_{i,0}, c_{i,1}, \ldots, c_{i,p})$ and this is given by below equation [2].
\[ C_{\lambda} = \begin{cases} 1, & \text{for } i = s_i + jp \quad (j = 0,1,2, \ldots, p-1) \\ 0, & \text{otherwise} \end{cases} \]  \hfill (2)

Each bit period generated by a PPG (Pulse Pattern Generator), is subdivided into small units, chips $N = p^2$. In the paper written by Wing C. Kwong, the peak of the cross-correlation function is therefore at most two and the number of marks per code sequence and the auto-correlation peak both equal $p$ in GF(p) [2].

Before transmitting encoded signal into SMF, the optical signal is amplified by erbium-doped fiber amplifier (EDFA), and SMF is modeled as a low pass filter with flat amplitude response and linear group delay within the data bandwidth. So, the transfer function of SMF transmission is denoted by

\[ H(f) = e^{-j\alpha D(\lambda)^2 f^2} = e^{-j\beta f} \]  \hfill (3)

where

\[ \alpha = \frac{nD(\lambda)^2}{c} - L \]  \hfill (4)

\[ f = v - v_c \]  \hfill (5)

parameter $\nu$ is the optical frequency, $v_c$ is the optical carrier frequency, $L$ is the fiber length, $\lambda$ is the operating wavelength, and $c$ is the speed of light. In this case, dispersion parameter, $D$ is 15 ps/nm-km and $\beta$ is negligible. The peak power of time-spread signal is quite low so that fiber nonlinearities are neglected [3]. We consider the chirped CDMA signal broadening over SMF. Full width at half maximum (FWHM) of the pulse related to the parameter $T_{0}$ is given by

\[ T_{FWHM} = 2(\ln 2)^{1/3} T_0 \approx 1.665 T_0 = \frac{1}{B \cdot N} \]  \hfill (6)

In this work, $T_0$ represents the chip width $T_0 = 15$ ps. In this paper, RL or MLLD as an optical source and SMF as transmission line are assumed. Thereby, chirp is mark or space and typical

\[ \beta_c = -20 \text{ps}^2/\text{km} \] is used.

Optical dispersion penalty is estimated by calculating the amount of eye degradation at the output of the electrical filter. The electrical dispersion penalty $P_0$ is defined by the following:

\[ P_0 = 10 \log \left( \frac{a}{b} \right) \]  \hfill (9)

where $a$ is the eye opening of the back-to-back signal without any distortion while $b$ is the eye opening of the transmitted signal over an optical fiber of 40 km in Fig.2 a) Back to Back, \(\overline{a}\) b). Both signals are through filter with 1.7GHz bandwidth. The optical dispersion penalty is equal to the electrical dispersion penalty for all coherent system [3]. The OCDMA signal after SMF is launched into the pre-amplified optical receiver which consists of optical pre-amplifier and conventional optical receiver. The optical bandwidth is selected to be broader than and equal to the electrical bandwidth corresponding to 0.707 times of bit rate and all filters are fourth-order Bessel type.

Fig. 3 Waveforms after optical CDMA decoder

(a) back to back

(b) after 60 km SMF
The data bit stream out of output node still remains the original information previous SMF after decoding in Fig. 3-(b). After that, receiving this bit stream pass through low pass Bessel filter with 1.7GHz 3-dB bandwidth.

3. CONCLUSIONS

Most of this paper has deal with prime sequence codes for optical CDMA system considered chromatic dispersion using computer simulation.

In our study, we focus on ring laser source which has both of negative and positive chirp with SMF considered negative group velocity parameter (GVD). The results show the dispersion penalty with propagated distance for each chirp value, in Fig. 4. In about chirp = -2, dispersion penalty is about 1.5-dB at SMF 40 km. While in chirp free, 1-dB penalty appears at 100 km in codeword $C_2 = (1 0 0 0 0 0 1 0 1 0 0 0 0 0 1 0)$ of GF(4). While in case of negative chirp, pulse compression give rise to negative dispersion penalty (less than $\Delta 0.01$dB) at a few km. And in case of other three codewords except $C_2$ of GF(4) the chromatic dispersion penalty is similar to that of $C_2$. The error range among different codewords in GF(4) is smaller than 0.5-dB and that in GF(p) is also the same case.

In Fig. 5, the results show the variance of dispersion penalty at a few tens distance (km) as $p$ of GF(p) increases for access network. If $p$ of Galois field increases, the chip rate should be high and give some interference easily due to chromatic dispersion. So, according to circumstances (distance and dispersion penalty), we can design GF(p) in adapting to CDMA system. From the results, as the distance of optical transmission increase, so dispersion penalty in considered OCDMA system increase gradually. The absolute value of negative chirp need more power dispersion penalty. Moreover, at the same time, as chirp value goes low, dispersion penalty is also increased and performance degrades.

In conclusion, the number($p$) of prime code at the same 2.5 Gb/s data rate determines optical dispersion penalty and our works show what is feasible number of pseudo-orthogonal codes at each a few distances for optical CDMA according to design performance limited.

REFERENCES


