▼ Journal of Research (Science), Bahauddin Zakariya University, Multan, Pakistan.
Vol.17, No.1, January 2006, pp. 01-07 ISSN 1021-1012

ALL OPTICAL TWO CHANNEL PSK COMMUNICATION

S. J. Iqbal, M. Yousuf Hussain, A. M. S. Ramzia and H. B. Ahmad
Department of Electrical and Electronics Engineering, Faculty of Engineering, University Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia.
email: syedjav@yahoo.com

Abstract: Two-channel phase shift keying (PSK) optical communication using a single laser light source has been investigated with the help of Michelson Interferometer for encoding signals and homodyne technique was used for decoding signals. Light from the laser source was divided into three parts out of which two parts were used to carry two signals independently and the third part was used as a reference signal for decoding both signals. All of the three parts of light waves were originated from the same laser source but transmitted with different planes of polarization. In this system, on the receiving end, these three light-waves were recombined in sets of two signals with the reference signal that decodes the two light-wave signals independently.

Keywords: Coherent length, free space communication, optical communication, polarization maintaining fiber, PSK communication.

INTRODUCTION

There are two ways of increasing the rate of data transfer, one is by increasing the number of bits per channel and the second is by increasing the number of channels. Usually in both the cases signal is detected with the help of beat signal by using heterodyne technique [Mikaelian *et al*. 2002]. In this paper we described how the number of channels can be doubled by using different plane polarized light. New homodyne technique is used for decoding signals. Homodyne decoding is more efficient than heterodyne technique. In heterodyne technique about 30% power goes to the first order sideband that carries information and rest of the signal's power is wasted [Mikaelian *et al*. 2002]. In heterodyne technique, frequencies of two different channels can not be placed too close to each other because there is a possibility of interference between the two channels. The homodyne technique not only improves signal to noise ratio (SNR) but also makes signal about two times more efficient than heterodyne technique.

All the experiments conducted so far reported that at 40Gb s^{-1} with 0.8bs^{-1} Hz^{-1} spectral efficiency, adjacent channels are orthogonally polarized to minimize the linear cross talk using differential phase shift keying (DPSK) [Gnauck *et al*. 2003]. In this technique the varying phase shift is used for decoding signals. But this DPSK also added into the complexity in communication [Gilbreath *et al*. 2001]. In our experiment, orthogonally plain polarized light was used which not only reduced the cross-talk but also made it possible to add another channel. For PSK communication, phase should not change randomly, which mean medium should not add noise to the phase. It could be free space which maintains phase [Mikaelian *et al*. 2002]. If phase is not maintained, PSK communication is still possible but detection must be differential phase shift keying provided other non-linear effects are suppressed [Haiqing Wei and David Plant 2004]. If polarization is maintained then very high capacity transmission is possible [Spirou *et el*. 2001]. In our experiment we have combined both properties, polarization and phase shift, for high-speed-communication.

EXPERIMENTAL

The experimental setup of one way two-channel phase shift communication system designed by using Michelson interferometer is shown in Fig. 1. Light from the laser diode (LD) at first passed through the polarizer (Pol), then variable aperture (Vap) then through the half wave plate and lastly through the non-polarized beam splitter (NPBS1).

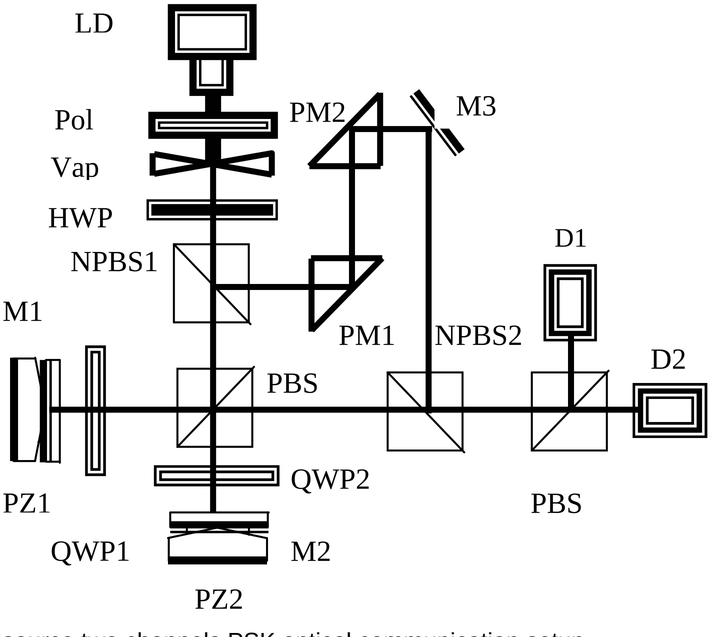

Fig. 1: Single source two channels PSK optical communication setup.

LEGENDS

LD	Laser Diode
Pol	Polarizer
Vap	Variable Aperture
PM1, 2	Prism Mirrors
D1, 2	Detectors
HWP	Half Wave Plate
M1, 2, 3	Plane Mirror
PBS	Polarized Beam Splitter
PZ1, 2	Piezoelectric Device
NPBS1, 2	Non-Polarized Beam Splitter

Polarizer (Pol) was used to control the plane of polarization of the light beam. The variable aperture (Vap) and half-wave plate (HWP) are used to control the intensity and for setting the angle of plane of polarization. The non-polarized beam splitter (NPBS1) splits the light into two equal parts. The wave which straight passes through will be a signal carrying light wave other one which is perpendicular become reference light. Reference wave is reflected by two right angled prism mirrors (PM1, PM2) then it is reflected by the plane mirror (M3) and after reflection from M3 it reaches at non-polarized beam splitter (NPBS2). Two prisms and one mirror (M3) is used to match path length of reference light with other two signal carrying light waves. Other part of the beam which straight passes through the NPBS1 again splits into two by polarized beam splitter (PBS1). Plane of polarization of light beam incident on PBS1, is adjusted to 45^o to the polarization axis of the PBS1. PBS1 splits light into two orthogonal light beam with two different plane of polarization. Both of these light waves travel as two independent orthogonal waves with different planes of polarization. One light wave travels towards piezoelectric (PZ1) and the other towards another piezoelectric (PZ2). Two plane mirrors M1 and M2 are mounted on the piezoelectric PZ1 and PZ2, respectively.

Light wave which is reflected from mirror M1 passes twice from quarter-wave-plate (QWP1) before returning to polarized beam splitter PBS. During this process quarter wave plate rotates the plane of polarization by 90^0. Now this encoded light wave straight passes through PBS. Similarly second orthogonal light wave is reflected back from M2. It also twice passes through quarter wave plate (QWP2) whose plane of polarization is also rotated by 90°. Now this light wave is reflected by PBS. Piezoelectric devices PZ1 and PZ2 are used for the encoding of the signals by vibrating along the beam axis. Now these two light waves carrying signals are combined with the reference light-wave by non-polarized beam splitter NPBS2 as shown in Fig. 1.

These three light-waves traveled through free space or through polarization maintaining optical fiber. At the receiving end the reference light wave splits into two perpendicular plane polarized waves by PBS2. The two signal carrying plane polarized-light-waves are separated by polarized beam splitter (PBS2). Each signal light-wave interacts with the component of the reference light-wave which has the same coherent length and same plane of polarization. The detector D1 decodes the signal coming from PZ1 and the detector D2 decodes the signal coming from PZ2.

Using channel-1, the graphs for the input and output signals are shown in Fig. 4. Similarly piezoelectric PZ2 is used as input for channel-2. Its corresponding output is obtained at the detector D2. Using channel-2, the plots for input and output signals are shown in Fig. 5.

RESULTS

To test the optical communication system two different types of signals were generated using 555-timer and simple TTL devices. First 555 timer was connected with proper resistance and capacitor to produce 50% duty cycle square wave. This signal was connected with 74LS193 BCD counter which is further connected with NOT and NOR gates. This circuit generates two types of signals with constant phase difference as shown in Fig. 2. These signals were directly connected to oscilloscope and output is shown in Fig. 3.

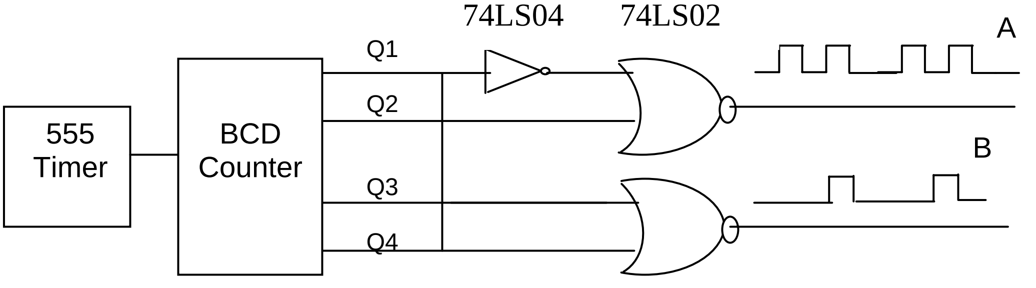

Fig. 2: TTL logic to generate two different signals with fixed phase difference.

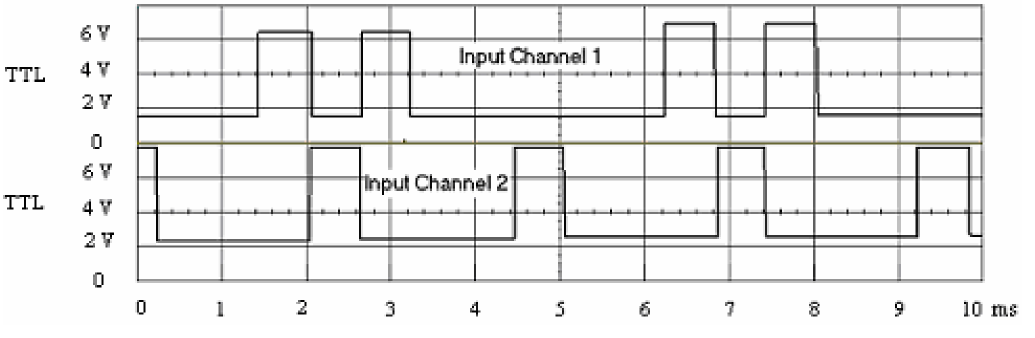

Fig. 3: Two input signals generated by TTL circuit with constant phase difference.

When same signals were connected to piezoelectric drivers the shape of optical signal output was not the same as input signals as obvious from Fig. 4. This is due to the high capacitance of piezoelectric drivers and due to fringes effect. These optical outputs were obtained by the interference of reference wave coming from M3 mirror and optical signals coming from PZ1 and PZ2 referring to Fig. 1. The generated signal pulses were used as input signals for different channels, i.e. signal-A.

These two signals were generated in such a way that they had different duty cycles and different pulse shapes but their phase difference with respect to each other was kept constant.

After connecting the channel-1 and channel-2 with piezoelectric devices, the output signal was transmitted and detected at the receiver side. First beam was expanded by convex lens which produces fringes. Due to

varying signal these fringes change their position depending on signal. A photo-detector was placed to detect the varying intensity of the fringes. Signal coming from photo-detector was amplified and connected directly to oscilloscope, which displays input and output signals simultaneously.
To test whether two channels are independent, firstly channel-1 was used while channel-2 was kept off. Optical output of channel-1 was detected. TTL input and optical output of channel-1 were recorded and plotted as shown in Fig. 4.

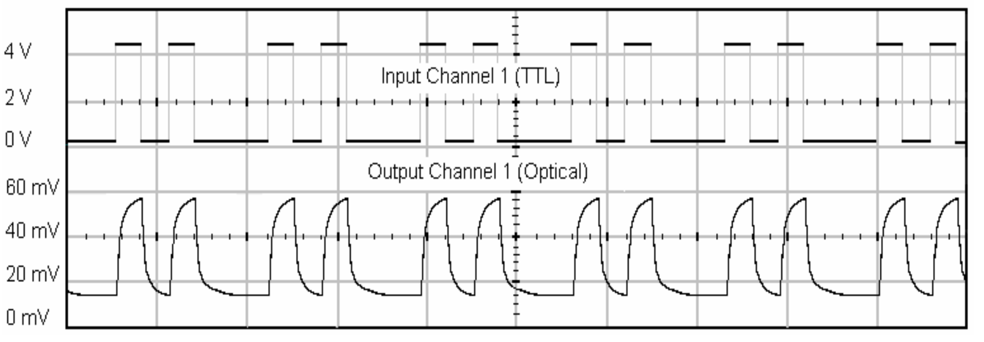

Fig. 4: Input Channel-1 at TTL and corresponding optical output detected by Detector-1.

Secondly, TTL signal was applied to channel-2 while channel-1 was kept off. TTL input and optical output from channel-2 were recorded and plotted as shown in Fig. 5. Lastly, both the inputs were activated and their inputs and outputs were recorded and plotted simultaneously as shown in Fig. 6.

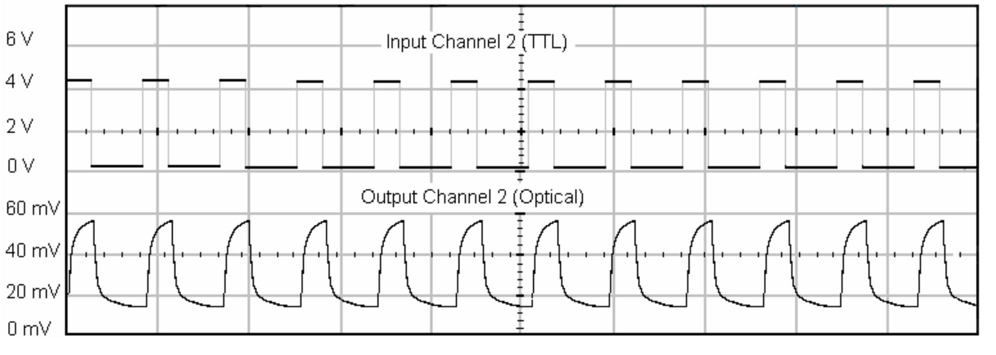

Fig. 5: Input channel-2 at TTL output and corresponding optical output at Detector-2.

DISCUSSION

Results show that output signal is similar to input signal. We also observed that both channels are independent of each other. If we observe closely then we can see that both the two signals are distorted. First distortion is in the shape of the wave, as the input signal is square wave and the output signal looks like a sine wave. It is due to the capacitance of piezoelectric. Because of large area of crystal each piezoelectric has large capacitance. Input signals are recorded before the piezoelectric devices where it is square wave. Second there is some time delay between input and output signal. This time delay is less than 10^{-3} second. This time delay is due to inertia of the mirror attached with piezo-electric. All these results confirm that one-way two-channel phase shift communication is possible.

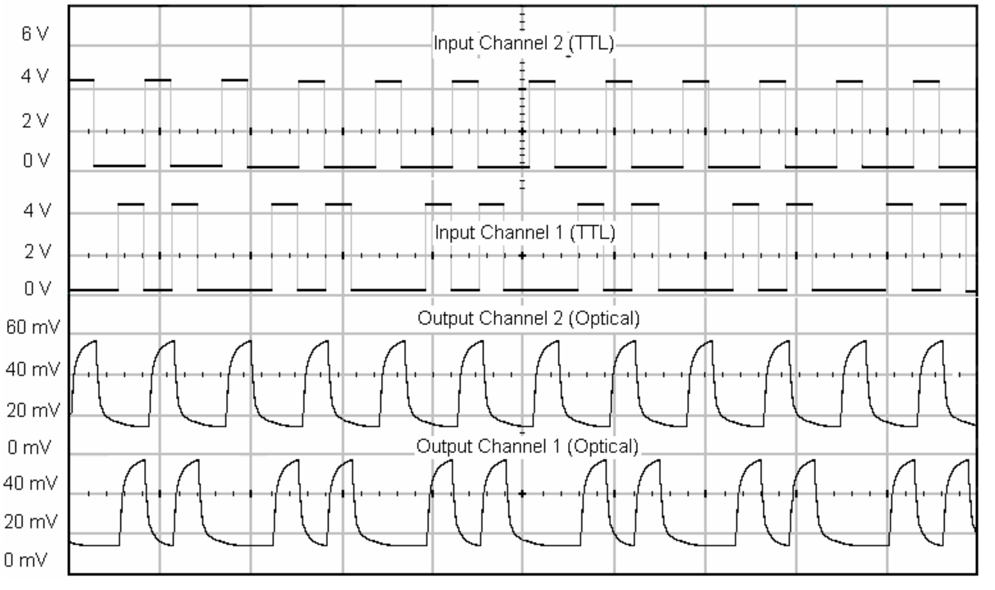

Fig. 6: Two input signals from TTL and two output optical signals.

Acknowledgements

We acknowledge the contribution of H.B. Ahmad, who was my (S.J. Iqbal) supervisor for the whole project, and Mr. Praba who helped us in understanding many difficult processes that we did not know before, and the Department of Physics where this project was completed. We are also thankful to University of Malaya for granting an opportunity to use their experimental facilities.

References

Gilbreath, G.C., Rabinovich, W.S., Meehan, T.J., Vilchek, M.J. (**2001**) “Lagre-aperture multiple quantum well modulating retro-reflector for free space optical data transfer on unmanned aerial vehicles”, *Opt. Eng*., 40, 1348-1356.

Gnauck, A.H., Raybon, G., Chandresekhar, S., Leuthold, J., Doerr, C., Stultz, L. and Burrows, E. (**2003**) ”25 x 40-Gb s^{-1} Copolarized DPSK transmission over 12 x 100 km NZDF with 50-GHz channel spacing”, *IEEE Photonics Technology Letters*, 15(3), 467-469.

Haiqing Wei and David V. Plant (**2004**) “Simultaneous nonlinearity suppression and wide-band dispersion compensation using optical phase conjugation”, *International Journal of Optics* (OSA), 12(9), 1938-1958.

Mikaelian, T., Weel, M., Kumarakrishnan, A. Battle, P.B., Swanson, R.C. (**2002**) “A high-speed reflector for free-space communication based on electro-optic phase modulation”, *Aerospace Conference Proceedings*, 9-16 March, IEEE, 3, 1487-1492.

Spirou, G., Mikaelian, T., Weel, M., Vorozcovs, A., Andreyuk, A., Kumarakrishnan, A., Battle, P.B. and Swanson, R.C. (**2001**) “A high speed modulation retro-reflector for Lasers,” *Bull, Amer. Physics Soc.*, 46, 108.