Effects of temperature and polarization current on a laser signal quality in fiber optics communication systems

Bendehiba. Dahmane (1), Brahim.Lejdel (2)

(1) Electrical Engineering Department,Technology Faculty, University of El-Oued, El-Oued, Algeria.

(2) IT Department, Technology Faculty, University of El-Oued, El-Oued, Algeria.

E-mail: (1)bdahmane@cds.asal.dz , (2) brahim-lejdel@univ-eloued.dz

***Abstract*— this paper concerns the analysis and evaluation of the effects of polarization current and temperature of an optical fiber laser based on audio communication systems. For that purpose, we will study the effects of polarization current and temperature on the two main parameters of the communication chain; the transmitter (vertical cavity surface emitting laser) and the receiver (at the end of optical communication chain). The frequencies range considered are between 20Hz and 20 kHz, which correspond to the audible field. The quality of the restored signal depends on the different harmonics that it contains. We need to perform spectrum measurement quality by monitoring and measuring two factors TDH and SNR for the different experiments. The experimental results show that a high-quality audio laser signal can be obtained in fiber optics communication systems employing a vertical cavity surface emitting laser at a temperature of 10 °C and a current of 5 mA without the need for optimized optics.**

Keywords: total harmonic distortion, signal-to-Noise-Ratio, vertical cavity surface emitting laser (VCSEL), fiber optic, photodiode (PID), audio Engineering Society (AES-EBU), coded pulse modulation (PCM).

Abbreviations and Acronyms

THD	Total harmonic distortion	(%)
SNR	Signal-to-Noise-Ratio	(dB)
Dnoise	Noise power spectral density	(dBm/Hz)
Buseful	Useful transmission band	(Hz)
A0	Signal amplitude	(mV)

I. INTRODUCTION

In the last forty years, the optics field has experienced a major change, in particular, since the discovery of lasers. This growth has been accompanied using optical frequencies in communications. Since that moment, progresses in lasers, detectors, sensors, optics, and electronics are the end results of many successful proofs in optical systems [1, 2]. The National Aeronautics and Space Administration (NASA) Deep Space Optical Communications Project “is to develop key technologies for the implementation of a deep space optical transceiver and ground receiver that will enable greater than 10X the data rate of a state-of-the-art deep space RF system (Ka-band) for similar spacecraft mass and power In the light of this, the optical society of America has sponsored the first conference on integrated optics successfully [3]. In February 1972 [4], it was speaking about both optical fibers and on optical integrated circuits have been realized. In February 1974, two articles were presented on optical fibers [6, 7] during the second conference in this series [5]. On the other hand, there are two main parameters that have contributed in enlarging the subscriber loop in many systems by the integration of optical fibers into telecommunications and data-transmission networks. In other words, this produces a huge bandwidth for voice, video, and data signals transmission [8].

According to the request of bandwidth and higher throughput, particularly in buildings and campus backbones, LEDs could not maintain the same rate of progress. In other words, the developed industry has provided a new high-speed laser light source called Vertical Cavity Surface Emitting Laser (VCSEL). These VCSELs are low-cost and appropriate to the multimode transmission systems 850 nm, allowing data rates of 1 Gb/s and 10 Gb/s. With the development of these VCSELs, multimode optical fiber is useful for operation with lasers [9].

On the other hand, the increasing demand of larger bandwidths as the only way to cover the needs of both cloud computing and web services, allowed the increase of data communication rates from 1 and 10Gb/s to 40Gb/s and 100 Gb/s. It appears that many system designers may think that single-mode optical fiber is the best choice. Despite many advantages such as higher speed and range, multimode optical fiber is easily appropriate for most distant enterprises and data center networks, at a lower price than single-mode fiber [10].

Today, the digital audio format based on the AES-EBU interface is widely used in most multimedia devices because of some advantages [11], such as the use of a single signal to transmit Clock data and information and no continuous component as part of the signal power spectral density. In addition, the use of the 24-bit word length makes it suitable for business applications [11, 12]. A serial digital transmission of multi-channel audio signals has been reported in [13], where an analog multichannel audio signal has been converted to a digital audio signal using a 44.1 kHz PCM technique.

Recently, some experimental results on audio signal transmission system based on optical fiber links have been reported in the literature [14, 15, 16]. An eight-channel audio data in real time has been experimentally demonstrated on the basis of an optical code division multiple access (OCDMA) system using the optical communication [16].

In this paper, we present the effects of both temperature and the polarization current on the transmitter (vertical cavity surface emitting laser (VCSEL)) and the receiver of an optical fiber laser based audio communication system. We monitor and measure two factors TDH and SNR for the different experiments on temperature and polarization current. On the other hand, we restore the values of temperature and bias when high-quality audio signal transmissions (based on optical fiber laser) are achieved.
The remainder of the paper is organized as follows. Section 1 shows the audio communication in fiber optics link parameters used in this work. Sections 2 discuss the results and analysis. Finally, the conclusion is presented in Section 3

II. EXPERIMENTAL SET-UP

This experiment was concentrated on an audio communication system in fiber optic. Generally, the communication chain will need an optical transmitter (VCSEL), an optical transceiver (PIN) and the fiber optic (Fig.1). The experimental characterization and analysis are presented in table 1.

Table 1 shows the items or materials that are used in the long term experiment. These are laser diode (VCSEL), optical fiber, and photodiode (PID).

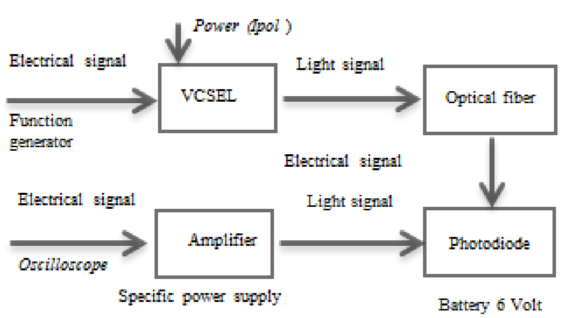

Fig. 1: Audio communication using fiber optic

III. RESULTS AND DISCUSSION

In order to improve the effect temperature and polarization current on audio signal quality in fiber optic, we present the analysis effect on:

- The transmitter of Laser diode VCSEL
- The Reception of optical audio communication Chain

Table 1: Summary of system parameters

Item	Specification	Function	Nbere of items
VCSEL	high-performance 850 nm	vertical cavity surface emitting laser	1
DET210	spectral response: 200-1100 nm peak response : 0.29 A/W	high-speed photo detector	1
fiber	multimode fiber : 1,5 nm	higher bandwidth and can	1
amplifier	amplification factor : 15	amplifies an optical signal directly	1

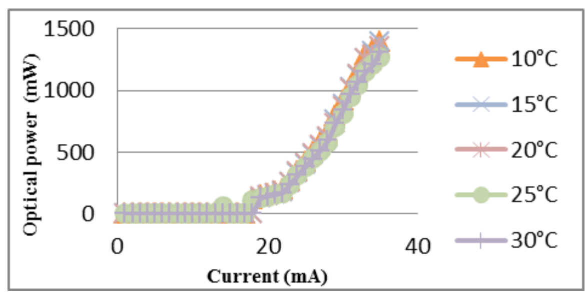

Fig. 2 Optical power versus current

A. *Laser diode Transmitter (VCSEL)*

The transmission of audio signals using the laser diode VCSEL as a transmitter was demonstrated experimentally.

First, we test the effect of polarization current by measuring the output power versus polarization intensity for different Temperatures values.
Figure 2 shows the polarization current effect on the optical power delivered by the laser. The current should not exceed 10 mA, in order to don't damage the VCSEL. With this From the characteristic, we know the threshold current and therefore the intensity interval we set for the diode.
After the first test, we test the temperature effect on the transmitter. Figure 3 shows that the laser diode is also sensitive to temperature variations. We identify two parameters that characterize our laser that are the threshold current and the slope of the linear part, or the performance of the VCSEL.

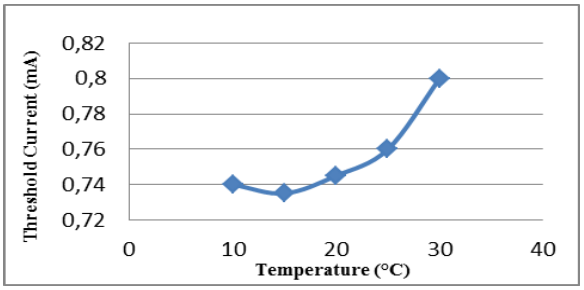

Fig. 3 Threshold current versus temperature

It is clear that from Figure 4, the increase in temperature causes a slight decrease in power in the linear part. The VCSEL is therefore more efficient for low temperatures.

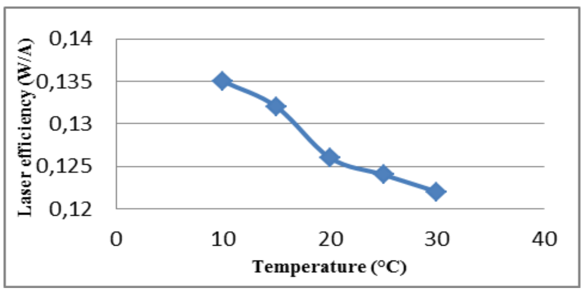

Fig. 4 Laser efficiency versus temperature

B. Optical audio communication Chain

An audio signal has many harmonics believed to degrade its quality. In order to assess the transmission quality of the audio signal, we used two test signals of the two factors TDH and the SNR and using the two equations below (1 and 2). There are 2 parameters that may affect these two factors, the temperature and the polarization current.

$$THD = \frac{\sum_{n=1}^{\infty} A_n^{\ 2}}{A_0^{\ 2}} \quad where\ A_n \succ 0 \qquad (1)$$

$$SNR = \frac{A_0^{\ 2}}{D_{noice} * B_{usefal}} \qquad (2)$$

1) *Effect of polarization current*

Figure 5 represents the SNR at different values of polarization current. It is clearly shown that, the RSB increases linearly with the input polarization current until the maximum value. Moreover, as the power of the signal increases linearly with polarization current, the signal to noise ratio increases also. On the other hand, when the polarization current is 5mA, the SNR is maximal.

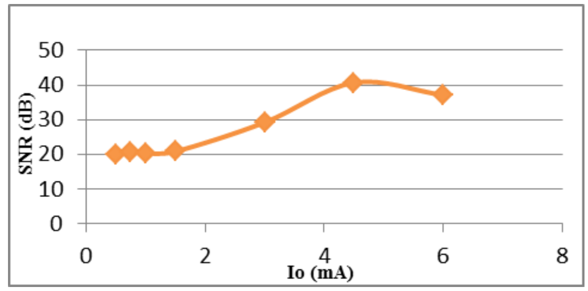

Fig. 5 SNR versus polarization current

Figure 6 shows the THD versus polarization current. We find a high value of TDH for a low intensity. This could be due to the excessive proximity of the zone where the power emitted by the VCSEL is practically nil. Then a better consideration can be made if the polarization current is around 5mA, the THD is minimal.

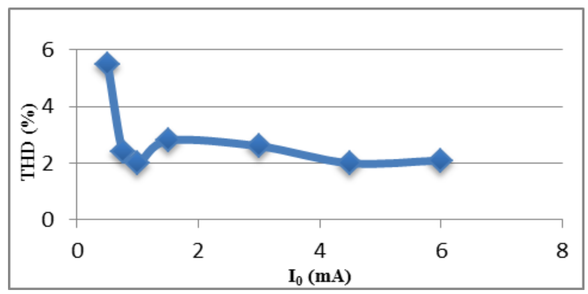

Fig. 6 THD versus polarization current

2) *Effect of temperature*

Figure 7 shows the signal to noise ratio (SNR) versus temperature. There is just a small decline of SNR when the temperature increases. This is probably due to a general excitement which leads to an increase in the noise.

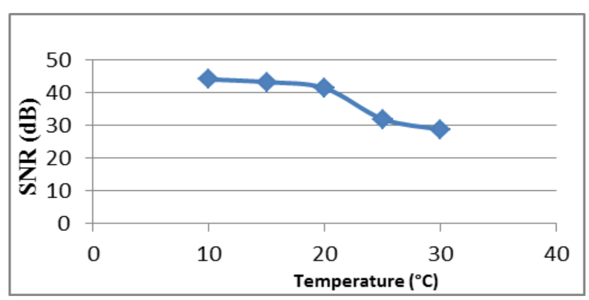

Fig. 7 SNR versus temperature

Figure 8, below, shows the plot of the THD versus temperature. The quality of the transmitted signal decreases (THD increases) as the temperature increases. This is probably due to a general excitation (heat) which increases the noise.

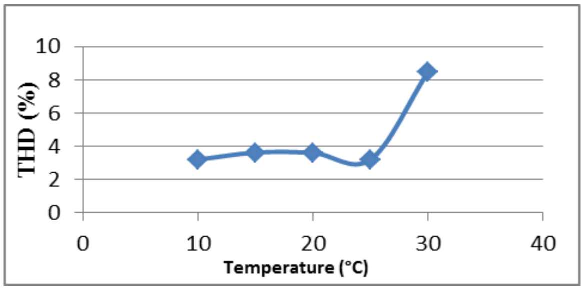

Fig. 8 THD versus temperature

IV. Conclusion

During these experiments, we have been able to highlight certain evolutions of the THD and the SNR according to the main parameters of our experiment.
The effects of temperature and polarization current on an optical fiber transmission system for audio signal employing VCSEL diode laser was constructed.
In our results, we show that the temperature and polarization current values for high-quality audio communication system employing VCSEL has to be 10°C and 5 mA, respectively. On the other hand, it must be taken to secure that all connection should be perfect. Here we achieved the aim of our paper.

References

[1] K. E. Wilson and J. R. Lesh, ‘‘BOverview of the ground-to-orbit lasercom demonstration’’,*Proc.SPIEVFree-Space Laser Commun.*Technol. IX, vol. 2990, pp. 1–9, Jan. 1997

[2] B. Smutny et al, ‘‘BIn-orbit verification of optical inter-satellite communication links based on homodyne BPSK’’,*Proc.SPIEVFree-Space Laser Commun*. Technol. XX, vol. 6877, pp. 687702-1–687702-6, 2008.

[3] NASA,Deep Space Optical communications (DSOC), 2016,[online]:Available: ‘‘https://gameon.nasa.gov/projects/deep-space-optical communications-dsoc ’’.

[4] S.J. YOO, J.W. LIM, Y. SUNG, Y.H. JUNG, H.G. CHOI., ‘‘Fast switchable electrochromic properties of tungsten oxide nanowire bundles’’, *Appl. Phys*. Lett. 90, 173126 (2007)

[5] P. M. Petroff, A. Lorke, A. Imamoglu., ‘‘Epitaxially self-assembled quantum dots’’, *Phys. Today 54*, 94 (2001).

[6] Y. Arai, T. Yano, S. Shibata., ‘‘High refractive-index microspheres as optical cavity structure’’, *J.Sol-Gel Sci*. Technol. 32, 189 (2004).

[7] **S**.F. Tang, C.D. Chiang, P.K. Weng, Y.T. Gau, J.J. Luo, S.T. Yang, C.C. Shih, S.Y. Lin, S.C.Lee, ‘‘High-temperature operation normal incident 256×256 InAsGaAs quantum-dot infraredphotodetector focal plane array’’, *IEEE Photonics Technol*. Lett 18, 988 (2006).

[8] D.M. Pustai., ‘‘Realizing functional two-dimensional Photonic crystal devices, Ph. D. Dissertation (University of Delaware’’, Newark, DE 2004).

[9] Julien PERCHOUX., ‘‘caractérisation et modélisation du bruit d'intensité de vcsels (algaas) et de son influence sur le bruit de phase des liaisons opto- hyperfréquences’’, Ecole nationale supérieure de l'aéronautique et de l'espace, 2005. French.

[10] Tony Irujo., ‘‘Multimode or Single-Mode Optical Fiber, *A Furukawa Company*’’, Jan 2017. USA.

[11] Angelici M, Bianchessi M, Feste SD, Serina N‘‘ New architecture for an AES-EBU digital audio receiver’’. IEEE T. Consum. Electr. 1997, 43(3):694-698. 10.1109/30.628696View ArticleGoogle Scholar

[12] Rumsey F, Watkinson J‘‘ Digital Interface Handbook. 3rd edition. Focal Press, Burlington’’; 2003.Google Scholar

[13] Song M, Kwon O, Chung Y: A serial connection technique of speakers for multi-channel audio systems’’. IEEE T. Consum. Electr. 2005, 51(2):611-616.

[14] Delgado F, Quintana I, Rufo J, Rabadan JA, Quintana C, Perez-Jimenez R, ‘‘ Design and implementation of an Ethernet-VLC interface for broadcast transmissions’’. IEEE Commun. Lett. 2010, 14(12):1089-1091.View ArticleGoogle Scholar

[15] Guerra-Medina MF, Gonzalez O, Rojas-Guillama B, Martin-Gonzalez JA, Delgado F, Rabadan J, ‘‘Ethernet-OCDMA system for multi-user visible light communications’’. Electron Lett. 2012, 48: 227-228. 10.1049/el.2011.4035View ArticleGoogle Scholar

[16] O'Brien D, Turnbull R, Minh HL, Faulkner G, Bouchet O, Porcon P, Tabach ME, Gueutier E, Wolf M, Grobe L, Li J, ‘‘ High-speed optical wireless demonstrators: conclusions and future directions’’. J. Lightwave Technol. 2012, 30: 2181-2187.View Article