ISSN 2047-3338

Sensitivities Dependence on Laser Pulses Soliton Propagation under Pure and Sea Waters

Mohamed M. E. El-Halawany
Electronics and Electrical Communication Engineering Department
Faculty of Electronic Engineering, Menouf 32951, Menoufia University, Egypt

***Abstract*— In this paper, the steady state of improvement performance of the thermal and chirping sensitivities of the soliton propagations of nonlinear optical pulses in an static pure water and sea water is deeply and parametrically studied. The interaction of such powerful laser beam and the pure, sea waters has been investigated over wide ranges of the affecting parameters through model taking into account the coupling of the pure , sea waters. The stabilities of the processed major effects (the product of power and square of the pulse width, pulse width, and bit-rate) are analyzed on the basis of the thermal sensitivity (where the cause is temperature variations) and the chirping sensitivity (where the cause is the spectral variations). The physical parameters of the waters are considered both temperature-dependent and spectral-dependent parameters as well as salinity-dependent. The obtained types of solutions are valuable in obtaining a physical feel for the problem and obtaining an order-of-magnitude estimate of the severity of the effects of the controlling parameters.**

***Index Terms*— Soliton Propagation, Pure Water, Sea Water, Laser Pulses and Thermal Sensitivities**

I. INTRODUCTION

THE problem of high energy laser interactions with water [1] or with water droplets is an extremely difficult one, because a number of different nonlinear phenomena [2, 3] such as shock waves deformation of the liquid, heating and evaporation etc. occurs on different time scales. The reflection of infrared waves from water surface is about zero and it is less than 2% for visible radiations Phase-shift and heterodyne technique was used for the measurement, and the laser beam was modulated by a sine wave having a fixed frequency. The optimum design and low-noise elements made it possible to detect a light power about 20 nW at operating frequenc[4, 5]. Using time-resolved imaging and scattering techniques, the directly and indirectly monitor the breakdown dynamics induced in water by femtosecond laser pulses over eight orders of magnitude in time. For resolve, for the first time, the picosecond plasma dynamics and observe a 20 ps delay before the laser-produced plasma expands. The attribute this delay to the electron-ion energy transfer time[5,6]. With the availability of powerful laser beam during the last two decades, a large number of interesting nonlinear phenomena such as parameteric instabilities, breakdown, and thermal blooming has bean deeply studied [7-12]. The soliton propagation of nonlinear optical pulses in an inhomogeneous static pure water and clearest sea water is studied.

The physical parameters of the medium are considered both temperature-dependent and frequency-dependent parameters as well as salt-dependent [13-16]. In this paper, is to study the soliton propagation of nonlinear optical train of laser pulses in either pure water or seawater under different thermal and spectral conditions. The following topics that relevant to the investigated problem are deeply analyzed:

The product of the power of the beam and the square of its time-width, the thermal sensitivity of the above product which acts as a criterion for the thermal stability, and the chirping sensitivity of the above product which acts as a criterion for the chirping stability.

II. MODEL ANALYSIS

Optical properties of pure waters in the 200-800 nm spectral regions are measured [17-19]. By means of simple approximations derived from irradiative transfer theory, the measured data are then compared with values of the diffusion attenuation coefficient determined for clearest natural waters. The comparative analysis and new data allow a consistent and accurate set of optical properties for clearest natural waters and for pure fresh water and sea water to be estimated from 300 to 800 nm. Finally, the recorded data clarifies a window around the 450 nm. By its nature, especially at powerful irradiance, fluids (glasses as air, plasmas, and water pure or salt) are nonlinear dielectric media. The emphasis, in investigations concerned with nonlinear phenomena in fluids, has been paid to the derivations of the field-dependent dielectric constant. Thus, the knowledge of optical constants of the fluid under consideration in the range of classical optics is of special importance to investigate the interaction process [12, 20, 21].

The refractive index n (λ, T, S) can be computed via:

$$n(\lambda,T,S)=\left(n_{oo}+n_{o1}T+n_{o2}T^2\right).$$
$$=Exp\left(n_{10}+n_{11}T+n_{12}T^2\right)\lambda^2 \qquad (1)$$

Where λ is the optical wavelength, μm, and $n_{i,s}$ are function of temperature, S is the salinity (0.0% or 35% only). The numerical values of $n_{i,s}$ are as shown in Table 1 below.

Table 1

	Pure water	Sea water
n_{oo}	1.01409	1.27265
n_{1o}	$-2.56662x10^{-2}$	$-1.75003x10^{-2}$
n_{o1}	$2.38468x10^{-3}$	$6.53698x10^{-4}$
n_{11}	$-2.404x10^{-5}$	$-7.72701x10^{-5}$
n_{o2}	$-4.26387x10^{-6}$	$-1.28984x10^{-6}$
n_{12}	$5.771x10^{-8}$	$1.34502x10^{-7}$

The nonlinear refractive index n_2 is given as:

$$n_2 = 0.25\varepsilon_o n\left(n^2 - 1\right)V / \hbar\omega \qquad (2)$$

Both V and $\hbar\omega$ are salt-dependent physical parameters and are cast as:

$$V = [2.3356856 + 0.0110696S]x10^{-29} \qquad (3)$$

$$\hbar\omega = [7.554 + 6.936S]x10^{-18} \text{ Joule} \qquad (4)$$

Where V is the average atomic volume of sea water and $\hbar\omega$ is the energy of first excited state of sea water, S is the ratio of the salt.

Kerr-type nonlinear refractive index is employed to obtain the soliton pulse transmission. This nonlinearity can be expressed either as [12, 21-25].

$$n^2 = n_o^2 + 2n_o N_2 P_o^2 / A_o \qquad (5)$$

Where n_o is the linear part of the refractive index, P_o is the launched peak power of the laser leam, A_o is the effective cross sectional of the beam area and N_2 is another representation of the nonlinear coefficient where

$$N_2 = 2z_o n_2 / n_o, \quad \text{m}^2/Watt \qquad (6)$$

Where z_o =120π.Ω. The nonlinear coefficient n_2 (m^2/v^2) is estimated on the same bases of Reference [4, 25] as a simple quantum mechanical formula as in Eqn. (2). The form of light soliton [26, 27] of the electric field is given by:

$$< A(\eta) > = \phi_o \sec h(\eta) \qquad (7)$$

with
$$\phi_o^2 = \frac{-\left(1 - \frac{1}{f_o^2 R^2}\right)\left(f_o f_o^{\backslash\backslash}\right) + \left(\frac{1}{f_o^2 R^2}\right) f_o^{\backslash 2}}{\left(n_2 / n_o\right) f_o^2 \tau^2} \qquad (8)$$

Thus ϕ_o is the peak electric field, where all the appeared parameters take their usual previous definitions.
The different derivatives are computed as follows:

$$f_o = \frac{\omega_o}{cn_o} = \frac{2\pi}{\lambda n_o} \qquad (9)$$

$$f_o^{\backslash} = \frac{n}{c}\left(1 - \frac{\lambda}{n}\frac{\partial n}{\partial \lambda}\right) \qquad (10)$$

$$f_o^{\backslash\backslash} = \frac{\lambda}{2\pi c^2}\left(\lambda^2 \frac{\partial^2 n}{\partial \lambda^2}\right), \qquad (11)$$

$$\frac{\partial n}{\partial \lambda} = 2\lambda n_1 n, \text{ and} \qquad (12)$$

$$\frac{\partial^2 n}{\partial \lambda^2} = 2n_1\left(n + \lambda \frac{\partial n}{\partial \lambda}\right) \qquad (13)$$

The refractive index and the normalized radial temperature are radially averaged and employed through the computations as follows:

$$< n >= \frac{1}{R}\int_o^R ndr \qquad (14)$$

$$< T_n(r) >= \frac{1}{R}\int_o^R T_n(r)dr \qquad (15)$$

Where R is the laser beam radius, m. The peak power content across the laser beam is given by:

$$P_o = \int I_o e^{-0.5r^2/R^2} 2\pi r dr \quad = 2\pi R^2 I_o\left[1 - e^{-0.5}\right]$$
$$= \frac{1}{2}\upsilon_g \varepsilon_o n^2 A_o\left(\phi_o^2\right) \qquad (16)$$

Where υ_g is the group velocity, $\upsilon_g = \frac{c}{n}$, and the dielectric constant of the medium $\varepsilon = \varepsilon_o n^2$ where ε_o=8.854x10^{-12} F/m. The power beamwidth-square product is given by:

$$P_o \tau^2 = \frac{1}{2}\upsilon_g \varepsilon_o n^2 A_o\left(\phi_o^2 \tau^2\right) \qquad (17)$$

Considering the pulse bit rate B_r is given by:

$$B_r = \frac{1}{2\tau} \qquad (18)$$

We find that:

$$P_o / B_r^2 = 2\upsilon_g \varepsilon_o n^2 A_o\left(\phi_o^2 \tau^2\right) \qquad (19)$$

Where τ is identified as the "width" of the pulse. The heat transfer coefficient of clear water as well as sea water, H, is considered as [27, 28]:

$$H = 1/60 \quad \text{watt/m}^2\ {}^oK \qquad (20)$$

Based on [23, 26, 29] for sea water, and for pure water, the thermal conductivity (K) is reported:

$$K = a_o + a_1 T + a_2 T^2 + a_3 P \text{ Watt/m.K} \qquad (21)$$

Where P is the pressure in bars, and a_o, a_1, a_2 and a_3 are functions of the salinity, are given in Table 2.

Table 2

	Pure water	**Sea water**
a_o	0.54887	0.55296
a_1	2.67 x10^{-5}	1.8364 x10^{-5}
a_2	-1.4182x10^{-7}	-3.3058x10^{-7}
a_3	3.4025 x10^{-5}	3.4025 x10^{-5}

The net reduction in the beam intensity resulting from both absorption and scattering is refered as attenuation. The attenuation coefficient σ_t is given as [28, 30, 31]:

$$\sigma_t = \sigma_a + \sigma_s \quad ,\text{m}^{-1} \qquad (22)$$

Where: σ_a is the absorption coefficient, m^{-1}, σ_a is the scattering coefficient, m^{-1}. The fractional loss in power due to absorption by the water is: $I_a(z,\lambda) = I_o e^{-\sigma_a(\lambda)z}$ (23)

Where I_o is the beam intensity at the entrance $I_a(z,\lambda)$ the beam intensity along the propagation path, and z is the propagation distance. The loss of power due to redirection of photons out of the beam path by the scattering process and is given by: $I_s(r,z) = I_o e^{-\sigma_s(\lambda)z}$ (24)

The absorption coefficient σ_a of either pure water or sea water is correlated and the optical wavelength (0.4 ≤ λ, μm ≤ 0.5) under the form:

$$\sigma_a(\lambda) = \sum_{i=0}^{6} \sigma_{ia}\lambda^i = 1.2542 + 0.1409\lambda - 4.4786\lambda^2$$

$$-141.85\lambda^3 + 420.098\lambda^4 + 119.55\lambda^5 - 849.637^6,$$

mean square error is $0.4\mathrm{x}10^{-6}$ (25)

Where $\sigma_a(\lambda)$ and K(T) are expressed by Eqns.(25) and (21), respectively. In the present study the following equations are assumed (using Eqn. (7):

$$I(r,z) = \frac{1}{2} I_o e^{-\sigma_t(\lambda)z} \cdot e^{-0.5r^2/R^2} \quad (26)$$

The factor 0.5 is the duty ratio (τ/2τ) of the optical pulse. Using separation of variables, T(r,z)[26,29,32,33] can be written as:

$$T(r,z) = T(r)T(z) = \frac{1}{2} T(r)\left[1 + e^{-\sigma_t(\lambda)z}\right] \quad (27)$$

Where $\sigma_t(\lambda)$ is given by Eqn. (22), $T_n(r) = T(r)/T_o$ (28-a)

$\rho_o = r/R$, and (28-b)

$k_n = k/k_o$ (28-c)

Where T_n is the normalized radial temperature, ρ_o is the normalized radial position, and k_n is the normalized thermal conductivity. For mathematical treatment we get:

$$K\nabla^2 T + \left[\left(\frac{\partial T}{\partial r}\right)^2 + \left(\frac{\partial T}{\partial z}\right)^2\right]\frac{\partial K}{\partial T} = -\sigma_a(\lambda) I(r,z) \quad (29)$$

The use of Eqns.(26-28) into Eqn.(29) yields

$$\beta_1 k_n \nabla^2 T_n + \frac{\partial k_n}{\partial T_n}\left[\left(\frac{\partial T_n}{\partial \rho}\right)^2 \beta_1^2\right] +$$

$$\frac{\partial k_n}{\partial T_n}\left[+\sigma_t^2 R^2 T_n^2 \beta_2^2\right] = -I_n e^{-0.5\rho^2} \cdot e^{-\sigma_t z} \quad (30)$$

With $\beta_1 = 0.5\left(1 + e^{-\sigma_t z}\right)$, (31-a)

$\beta_2 = 0.5 e^{-\sigma_t z}$, (31-b)

$k_n = 1 + \beta_1 C_1 T_n + \beta_1^2 C_2 T_n^2$, and (32-a)

$I_n = \sigma_a I_o R^2 / 2k_o T_o$. (32-b)

The above quantities are dimenionless and C_1 and C_2 are given in Table 3.

Table 3

	Pure Water	Sea water
C_1	$0.14594\mathrm{x}10^{-1}$	$0.996311\mathrm{x}10^{-2}$
C_2	$-0.775156\mathrm{x}10^{-4}$	$-0.179351\mathrm{x}10^{-3}$

A. The Sensitivity Analysis

The sensitivity analysis of the major three quantities $P_o\tau^2$, τ, and B_r is processed based on the following definations:

B. The thermal sensitivities

$S_T^{P_o\tau^2}$ ≡ thermal sensitivity of the product $P_o\tau^2$

$$= \frac{\Delta\left(P_o\tau^2\right)/P_o\tau^2}{\Delta T/T} = \frac{T}{P_o\tau^2} \cdot \frac{\partial P_o\tau^2}{\partial T} \quad (33)$$

S_T^{τ} ≡ thermal sensitivity of the pulse width

$$= \frac{\Delta\tau/\tau}{\Delta T/T} = \frac{T}{\tau} \cdot \frac{\partial\tau}{\partial T} \quad (34)$$

$S_T^{B_r}$ ≡ thermal sensitivity of the bit-rate

$$= \frac{\Delta B_r/B_r}{\Delta T/T} = \frac{T}{B_r} \cdot \frac{\partial B_r}{\partial T} \quad (35)$$

C. The chirping sensitivities

$S_\lambda^{P_o\tau^2}$ ≡ chirping sensitivity of the product $P_o\tau^2$

$$= \frac{\Delta\left(P_o\tau^2\right)/P_o\tau^2}{\Delta\lambda/\lambda} = \frac{\lambda}{P_o\tau^2} \cdot \frac{\partial P_o\tau^2}{\partial\lambda} \quad (36)$$

S_λ^{τ} ≡ chirping sensitivity of the pulse width

$$= \frac{\Delta\tau/\tau}{\Delta\lambda/\lambda} = \frac{\lambda}{\tau} \cdot \frac{\partial\tau}{\partial\lambda} \quad (37)$$

$S_\lambda^{B_r}$ ≡ chirping sensitivity of the bit-rate

$$= \frac{\Delta B_r/B_r}{\Delta\lambda/\lambda} = \frac{\lambda}{B_r} \cdot \frac{\partial B_r}{\partial\lambda} \quad (38)$$

III. SIMULATION RESULTS AND DISCUSSIONS

In the present paper, we will parametrically investigate the effects of the following set of controlling parameters at Z=0.0:

a- The variations of the beam radius, R.,
b- The variations of the optical wavelength, λ,
c- The variations of the medium temperature, T, and

The following set of variables is under investigation

a- The product, $P_o\tau^2$, The pulse width, τ, he bit rate, B_r, the thermal sensitivities, and the chirping sensitivities. The ranges of the controlling parameters are as follows: $0.01 \leq R$, m ≤ 0.1, $0.4 \leq \lambda$, μm ≤ 0.5, $290 \leq T$, °K ≤ 310, $I_o = 60$ kWatt/m^2, and $Z = 0.0$ m

A. The effects of the Variations of Radius, R

The variations of the set of variables $\{P_o\tau^2, \tau, B_r\}$ against the variations of R at asumed set different values are displayed in Figs.1-3 where the following correlations are depicted:

a- Whatever the set of controlling parameters, both $P_o\tau^2$ and R posses positive correlation.,
b- Whatever the set of controlling parameters τ and R posses a positive correlation and consequently B_r and R possess negative correlations, and
c- Whatever the set of controlling parameters, both sea water possesses higher values of $P_o\tau^2$, higher values of τ and less values of B_r than the corresponding values of pure water.

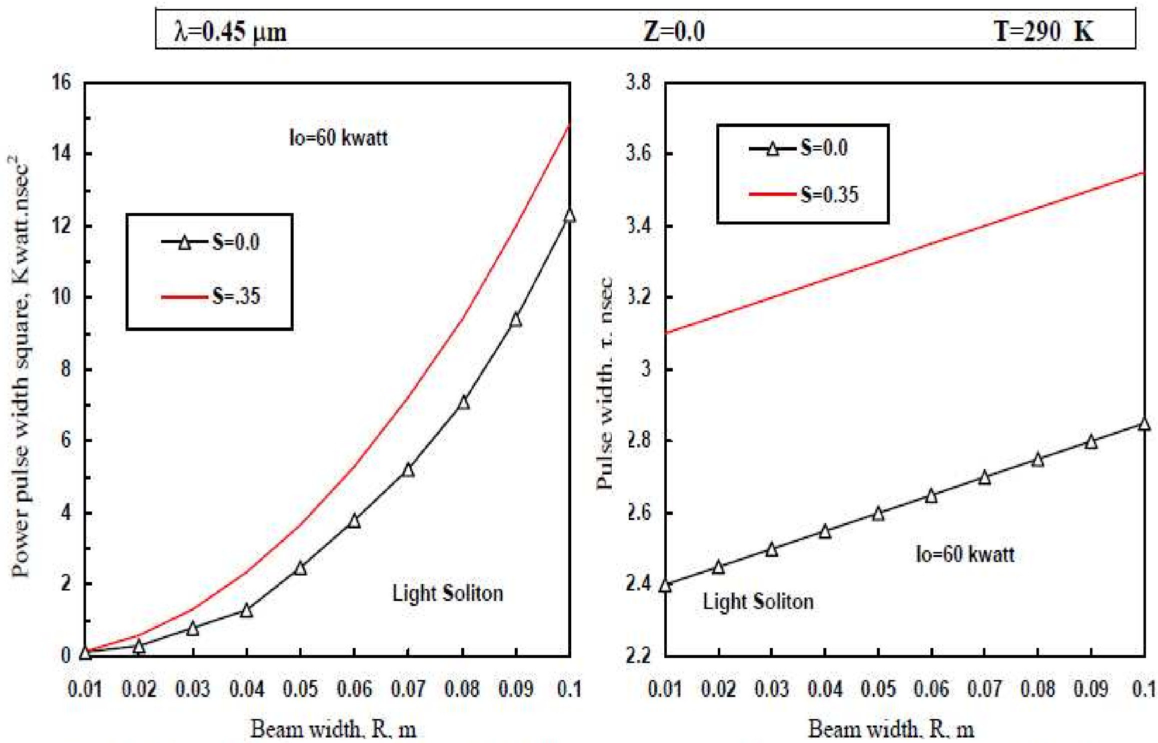

Fig.1. Variations of $P_0\tau^2$ against variations of R at the assumed set of parameters.

Fig. 2. Variations of τ against variations of R at the assumed set of parameters.

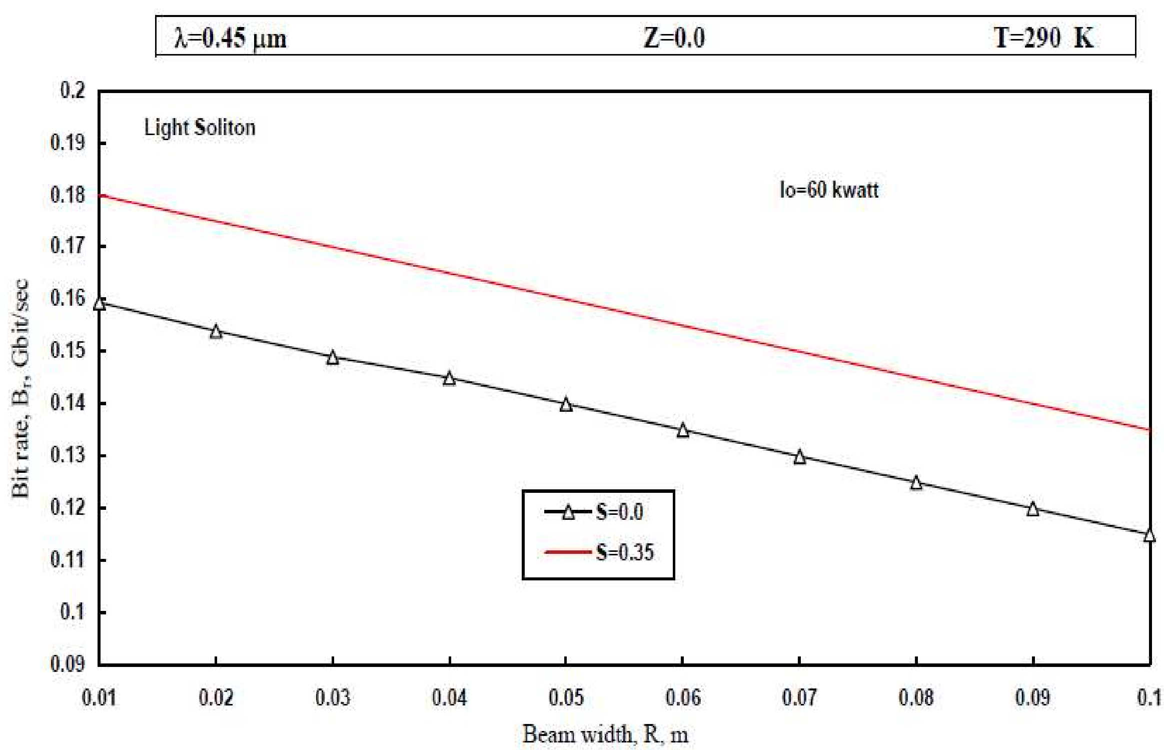

Fig. 3. Variations of B_r against variations of R at the assumed set of parameters.

λ=0.45μm I_o=60 KWatt/m^2 Z=0.0 R=0.05 m

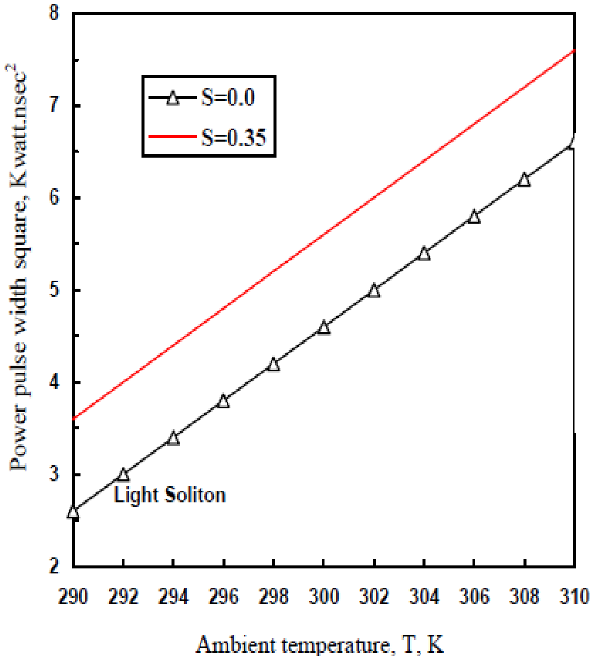

Fig. 4. Variations of $P_o\tau^2$ against variations of T at the assumed set of parameters.

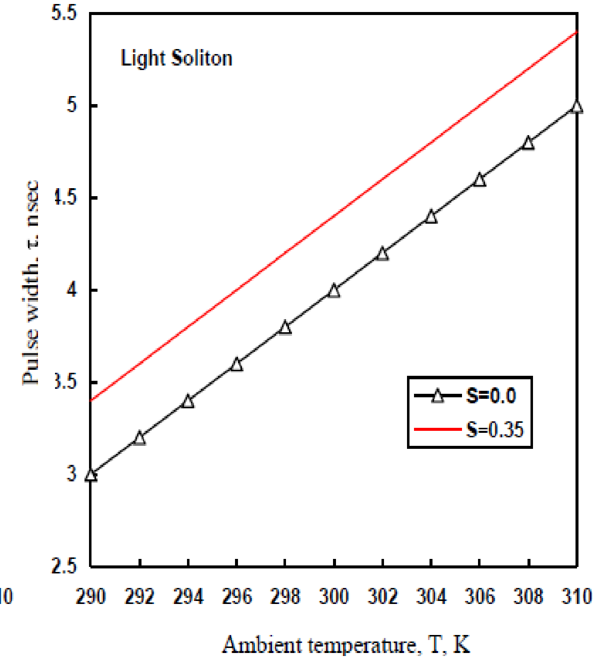

Fig. 5. Variations of τ against variations of T at the assumed set of parameters.

λ=0.45μm I_o=60 KWatt/m^2 Z=0.0 R=0.05 m

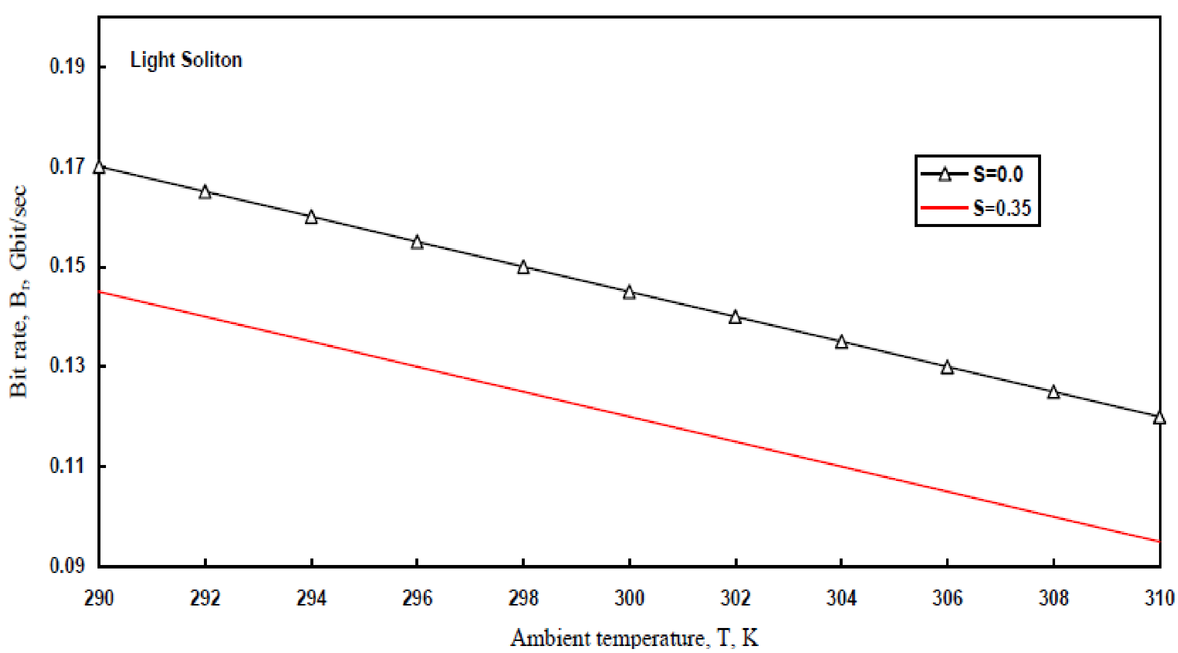

Fig. 6. Variations of B_r against variations of T and the assumed set of parameters.

λ=0.45µm	I_O =60 KWatt/m^2	Z=0.0

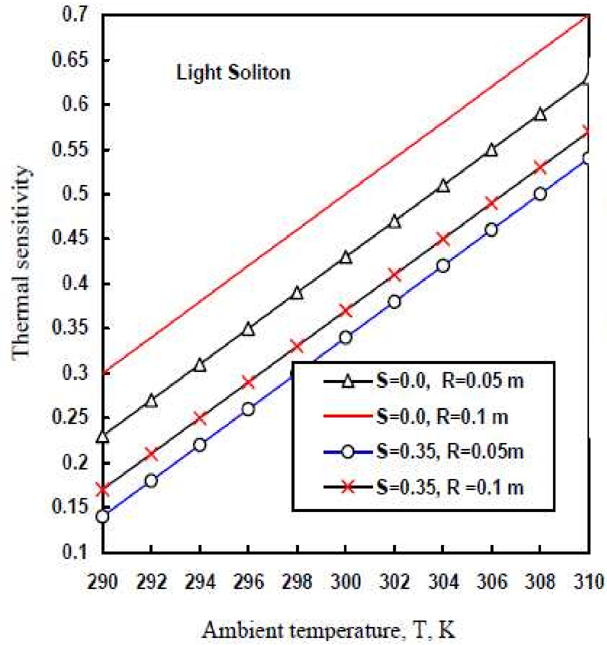

Fig. 7. Variations of $S_T^{P_0 r^2}$ against variations of T at the assumed set of parameters.

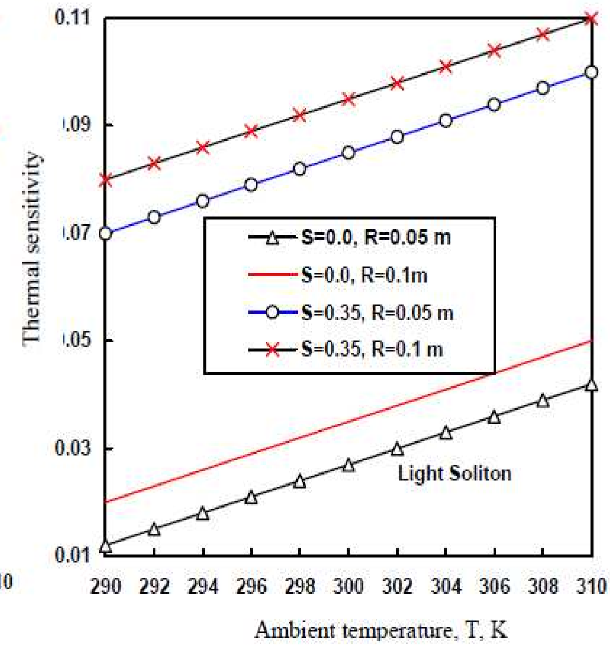

Fig. 8. Variations of S_T^{r} against variations of T at the assumed set of parameters.

λ=0.45µm	I_O =60 KWatt/m^2	Z=0.0

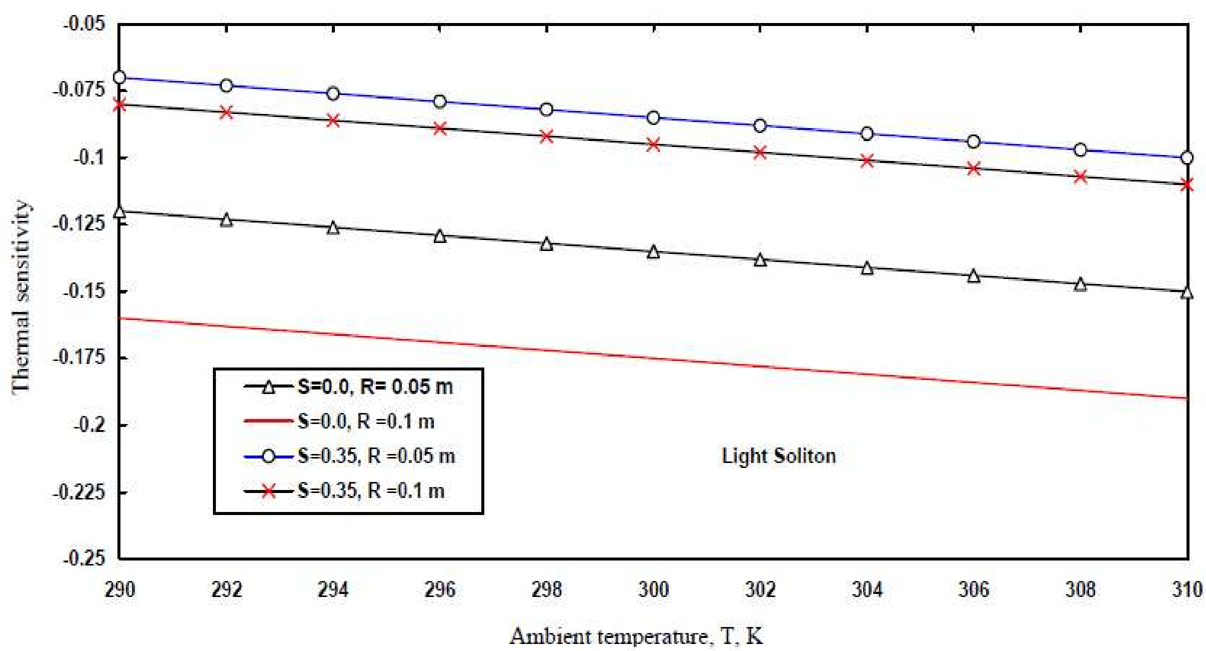

Fig. 9. Variations of $S_T^{B_r}$ against variations of T and the assumed set of parameters.

T=290 K I_o **=60 KWatt/** m^2 **Z=0.0**

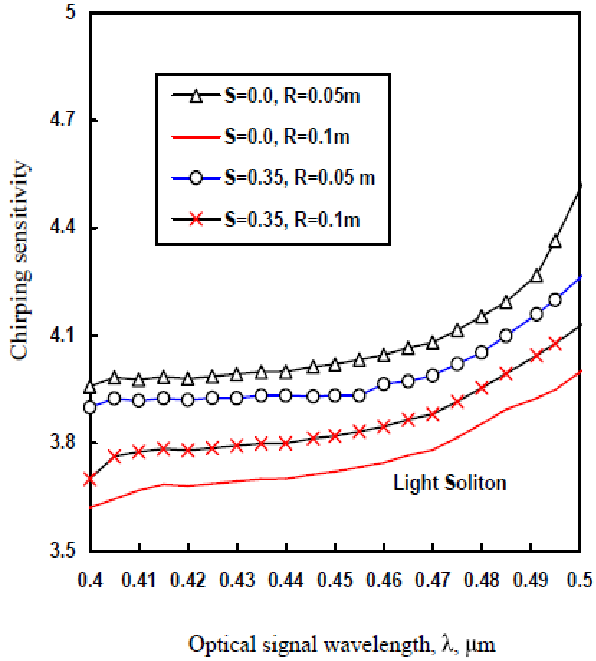

Fig. 10. Variations of $S_{\lambda}^{P_o \tau^2}$ against variations of λ at the assumed set of parameters.

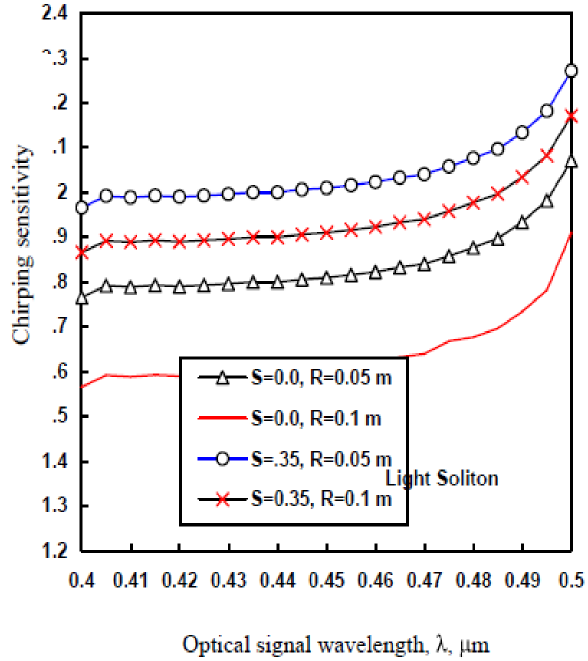

Fig. 11. Variations of S_{λ}^{τ} against variations of λ at the assumed set of parameters.

T=290 K I_o **=60 KWatt/** m^2 **Z=0.0**

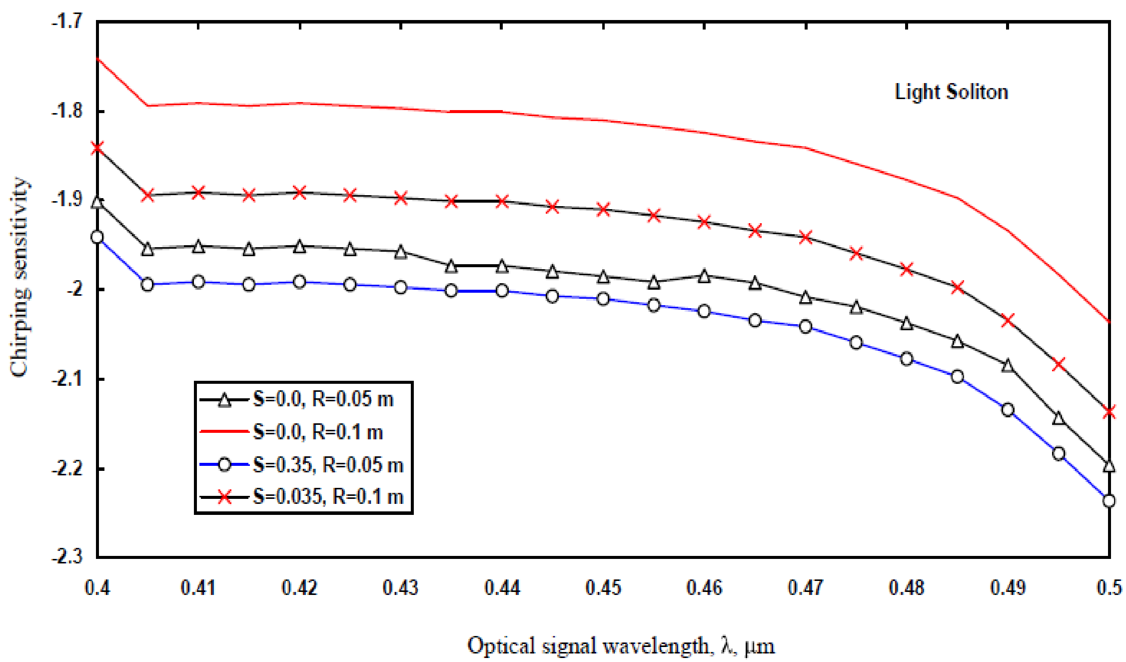

Fig.12. Variations of $S_{\lambda}^{B_r}$ against variations of λ and the assumed set of parameters.

B. The Effects of the Variations of Ambient Temperature, T

The variations of the set of variables $\{P_o\tau^2, \tau, B_r\}$ against the variation of T at asumed set different values are displayed in Figs. 4-6, where the following correlations are found:

a. $P_o\tau^2$ and T are in a posses positive correlation,

b. τ and T are in a posses positive correlation and consequently B_r and T are in posses negative correlations, and

c. Sea water possesses higher values of $P_o\tau^2$, higher values of τ and less values of B_r than the corresponding values of pure water.

C. The Thermal Sensitivities of $\{P_o\tau^2,\ \tau,\ B_r\}$

Based on these displays (Figs-7-9) , the following features are found:

a. Whatever the set of controlling variables both $S_T^{P_o\tau^2}$ and S_T^{τ} increases positively as T increases while $S_T^{B_r}$ increases negatively,

b. As the level of power increases $\{R\}$ the same sort of variations is obtained but the magnitudes of the different sensitivities increase, and

c. As the salinity (S) increases, the same sort of variations are found but the magnitudes of the different sensitivities decrease.

D. The Chirping Sensitivities of $\{P_o\tau^2,\ \tau,\ B_r\}$

Based on Eqns. (36-38) the chirping sensitivities of $P_o\tau^2$, τ and B_r are computed via special software which numerically processed the differentiations. At level of powers where I_o are kept constant and T is employed as a parameter, the different chirping sensitivities are displayed in Figs.10-12. Based on the displayed in Figs. 10-12) shows the following features are found:

a. Whatever the set of controlling parameters both $S_\lambda^{P_o\tau^2}$ and S_λ^{τ} increases positively as λ increases while $S_\lambda^{B_r}$ decreases.

b. As the level of power increases $\{R\}$, the same sort of variations are depicted ,but the magnitudes of the different sensitivities decrease, and

c. As the salinity {S} increases, the same sort of variations is depicted, but the magnitudes of the different sensitivities increase.

IV. CONCLUSIONS

Based on the basic made and the results of the laaser soliton beam under (pure and sea waters), the wide ranges of variations of the set of controlling parameters, for pure water (S=0.0%9) and sea water (S=0.35%), from this work we get the following conclusion items:

a) For increase the salinty, S , and the beam width radius, R then increase the $P_o\tau^2$, τ, while decrease the B_r

b) The variations of $P_o\tau^2$, τ, and B_r with T are the soitr of variation in item a

c) The thermal sensitivities $S_T^{P_o\tau^2}$, S_T^{τ} are increased for increase T, while $S_T^{B_r}$ slowly negative increase

d) The thermal sensitivities $S_T^{P_o\tau^2}$, S_T^{τ} are increased for increase R, while $S_T^{B_r}$ decreases

e) The chirpping sensitivities $S_\lambda^{P_o\tau^2}$, S_λ^{τ} are increased for increase λ (stable operation), good chirpping sensitivity at λ = 0.45 µm, while $S_\lambda^{B_r}$ is slowly negativeely increase(stable operation), good chirpping sensitivity at λ = 0.45 µm

f) The chirpping sensitivities $S_\lambda^{P_o\tau^2}$, S_λ^{τ} are decreased for increase λ (stable operation), good chirpping sensitivity at λ = 0.45 µm, while $S_\lambda^{B_r}$ is slowly negativeely increase(stable operation), good chirpping sensitivity at λ = 0.45 µm

REFERENCES

[1] C. Joshi, "Interactions of Ultra-Intense Laser Light with Matter", Physics Today, pp.36-43, January 1996.

[2] Mohamed M. E. El-Halawany, Abd El_Naser A. Mohamed, Said M. El-Halafawy, and Gamal A. Soliman," Soliton Propagation of Laser Pulses Undrr Waters", Electronic Engineering Bulletin, No.14, pp. 1-19, July 1997.

[3] S.A. Vitsinskii, V. D. Diuin and A. V. Keller, " Laser Radiation for Probing a Water Medium," J. Opt. Technol., Optical Society of America, Vol.65, No.6, pp. 505-507, June 1998.

[4] A. Yariv, Quantum Electronics, 2nd Ed., John Wiley & Sons, Inc. , U. S. A, 1985.

[5] Chris B. Schaffer, et. al., "Dynamics of femtosecond Laser Induced Breadown in Water from Femtoseconds to Microsecoinds", Optics Express, © Optical Society of America (OSA), Vol.10, No.3, pp. 196-203, 11 February 2002

[6] T. I. Lakoba and G.P. Agrawal, "Optimization of the Average Dispersion Range for Long-Haul Dispersion Managed Soliton Systems", J. Lightwave Technol., Vol. 18, No.11, pp. 1504-1512, Nov. 2000.

[7] R. H. Stavn and A. D. Weidenann, "Optical Modelling of Clear Ocean Light Field: Raman Scattering Effect", Applied Optics,Vol.27, No.19,pp.4002-4011, October 1988.

[8] N. M. Wassef, Laser Propagation in Sea water, M. Sc. Thesis, Fac. Eng., Alex. Univ., 1993.

[10] Abdel-Naser A. Mohammed, "High Speed Submarine Optical Fiber Communication System: Pressure and Temperature Effects", IIUM Engineering Journal, Vol. 1, No.1, pp. 42-55, MALAYSIA, January 2000.

[9] J. A. Knauss, Introduction to Physical Oceanography, 2nd Ed, Prentice Hall, Inc., USA, 1997

[11] S. Kang, "Propagation of Gaussian Beams in Dielectric Waveguides", J. Lightwave Technol. Vol.10, N0.9, pp.1185-1187, September 1992.

[12] F. Z. El-Halafawy, A. A. Aboul-Enein, E. A. El-Badawy, and N. M. Wassef, "Thermal Blooming of Powerful Lasers in Pure Waterand Clearest Saltwater", Alex. Eng. Jour (AEJ), Vol.32, No.1, pp.B13-B20, January 1993.

[13] M. Nakazawa, Optical Soliton Transmission, in Optical Amplifiers and their Applications, edited by S. Shimada and H. Ishio, John Wilely & Sons, U. K., 1994.

[14] M. Serckovice, el.al., " Models of Interactions of Laser Beams with Materials of Interest," Procc. Of the International School and Conference Optics and Optical Materials ISCOMO7, Belgrad, Serbia, Vol.112, pp.935-940, Sep.3-7, 2007.

[15] J. R. Apel, Principles of Ocean Physics, Ed. By W. I. Donn, AP, U. S. A., 1987.

[16] Abd El-Naser A. Mohammed, Abd El-Fattah A. Saad, and Ahmed Nabih Zaki Rashed, "Spectral Sensitivity Coefficients (SSCs) of the Based Materials for Photonic Devices Under Optical Wavelength and Temperature Sensing Variations in Modern Optical Access Networks," International Journal of Library and Information Science, Vol. 1, No. 4, pp. 43-54, September 2009.

[17] K. A. El-Nahla, and A. A. Mohammed, "A useful Curve Fitting Algorithm Using the Approach of Functional Expansions", Elect. Eng. Bulletin, Fac. Elect. Eng., Menouf, No. 9, pp. 78-91, January, 1995.

[18] John R. Vacca, Optical Networking Best Practices HandBook, Ajohn Wiley & Sons, Inc., Publication, 2007

[19] Philipp Rohwetter, et.al, Laser Induced Water Condensation in Air" Nature Photonics, Advance ONlLINE Publication: 2 may, 2010, WWW.nature.com?naturephotonics, 2010.

[20] Josep Prat, Next-Generation FTTH Passive Optical Networks, Print Springer, ISBN 978-1-4020-8469-0, 2008

[21] G. Chosh et al., "Pressure–Dependent Sellmeier Coefficients and Material Dispersions for Silica Fiber Glass", J. of Lightwave Techonl., Vol. 16, No. 11, pp. 2002 – 2005, Nov. 1998.

[22] S. M. El-Halawany, A. A. Mohammed, A. A. Abou-Koura, and F. Z. El-Halafawy "Propagation of Powerful Electromagnetic Waves in Waters: On Thermal Blooming", Elect. Eng. Bulletin, of Fac. Elect. Eng. , Menouf, No.9, pp.92-113, January 1995.

[23] A. Yariv, Quantum Electronics, 2nd. Ed., John Wiley & Sons, Inc. , U. S. A, 1985.

[24] A. Sahara, T. Inui, T. Komukai, H. Kubota, and M. Nakazaw," 40 Gb/s RZ Transmission over a Transoceanic Distance in a Dispersion Managed Standard Fiber Using a Modified Intine Synchronous Modulation Method". J. Lightwave Technol., Vol.18, No.10, pp. 1364-1373,Oct.2000.

[25] Abd El-Naser A. Mohammed, and Ahmed Nabih Zaki Rashed, "Comparison Performance Evolution of Different Transmission Techniques with Bi-Directional Distributed Raman Gain Amplification Technique in High Capacity Optical Networks," International Journal of Advanced Engineering & Applications, Vol. 1, No. 1, pp. 1-9, January 2010.

[26] A. Hasegawa, and Y. Kodama, "Signal Transmission by Optical Solitons in Monomode fiber", Proc. IEEE, Vol. 69, No. 9, pp.1145-1150, September 1981..

[27] C. Joshi, "Interactions of Ultra-Intense Laser Light with Matter", Physics Today, pp.36-43, January 1996.

[28] M. Mikheyev, Fundamentals of Heat Transfer, Pease Publisher, Moscow, USSR, 1976.

[29] J. P. Riely and G. Skirrol, Chemicaw Oceanography, Vol.2, 2nd Ed., AP, N. Y, 1975

[30] G. Charlet, M. Salsi, P. Tran, M. Bertolini, H. Mardoyan, J. Renaudier, O. Bertran-Pardo, and S. Bigo, "72x100Gb/s transmission over transocenic distance, using large effective area fiber, hybrid raman-erbium amplification and coherent detection," in Proc of OFC, San Diego, USA, 2009.

[31] Pilipetskii, A.N.; "High-capacity undersea long-haul systems," J. Selected Topics in Quantum Electronics, Vol.12, Issue 4, pp. 484 - 496, Aug. 2006.

[32] Sh. Mohammed Nejad and M.H. Haji Miesaeidi, "Altitude Measurement Using Laser Beam Reflected from Water Surface", Iranian Jornal of Electrical & Electronic Engineering, Vol.1, pp.36-40, January 2005

[33] Charlet, G.; Bigo, S.; "Upgrading WDM submarine systems to 40-gbit/s channel bitrate," Proceedings of the IEEE, Vol.94, Issue 5, pp. 935 - 951, May 2006.