Solid Several with Interaction Nd-YAG Laser Beam Study Theoretical Model Dimension Three by Materials

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Abstract

study of the interaction of laser radiations (Nd-YAG)laser at (1.06µm)wave length with pulse duration (100 µsec) on some solid material(Ag,Au,Sn and CO)by using three dimension function solutions that is laser beam transition function and through this we can study thermal distribution on surface and into materials and thermal dropping into material when the laser beam intensity is steady and variable with time. From research results seem that the thermal distribution into material and on surface is decrease when the laser beam intensity is variable with time . We conclude that the absorption coefficient of material is grater when the interaction process is better. In research we are using matlab 7 program for applications.

Kay word: lasar ND-YAG, interaction , theoretical ,model.

الخلاصة

درس تفاعل اشعة ليزر (Nd-AYG) ذو طول موجي 1.06 µm وزمن النبضة 100 µsec مع بعض المواد الصلبة (Co,Sn,Au and Ag) باستخدام حلول المعادلة التفاضلية ثلاثية الابعاد وهي معادلة انتقال اشعة الليزر الى المادة ومن خلالها قمنا بدراسة توزيع درجة الحرارة على سطوح المواد وداخلها وانحدارها داخل المادة عندما تكون شدة شعاع الليزر ثابتة ومتغيرة مع الزمن. ومن نتائج البحث ظهر ان توزيع درجة الحرارة داخل المادة وعلى السطح ينخفض عندما تتغير شدة شعاع الليزر مع الزمن. ولقد امكن الاستنتاج انه كلما كان معامل امتصاص المادة للشعاع اكبر كلما كان عملية التفاعل افضل. وتم استعمال برنامج الماتلاب (Matlab 7) لتنفيذ كافة البرامج المتعلقة بهذا البحث.

الكلمات المفتاحية : ليزر ندينيوم – ياك ، تفاعل ، موديل ، نظري

1-Introduction

The lasers capability to metal and vaporize of metals made due its ability for welding, cutting and drilling applicable(Khaleeq-ur-Rahman, et al.,2004). The abltion of nickel using mode–loked 25 ps (FWHM) Nd-YAG laser , had been studied by (Willis et al.,2002) .[The interaction of any energetic beam with a solid leads to a change in the solids surface and the interior of the crystal، had been studied by (Gakovic et al.,2002).In laser drilling of metals increasing the pulse intensity increases the ejection velocity and decreases the average particle size ،were drawn by (Voisy ,2002). The interaction laser beam with the target(steel)is influenced by parameters such as the wavelength,pulse length and transport medium characteristics ،had been studied by(Yang *et al.*,2005).The models of interactions of laser beams with materials ،had been studied(Sreckovic,2007).

2-Theoretical part

2-1 - Nd-YAG laser

The neodymium laser - Yak solid-state lasers commonly used in scientific research and experiments (Bunkin,et al.,1985; Langley,et al.,1999) as well as in the field of education and to access it in a number of laboratory tests for young learners in the field of solid-state laser (Diodati,*et al*.,2002).

Effective medium composed of Aatriom crystal alloy Karnit ($Y_3Al_5O_{12}$) grafted neodymium ions. . Longer (Nd: YAG) important material in the solid-state lasers (Karr,1971) Article host (YAG) be transparent to the wavelength of between (0.35-7) µm which are located including selected wavelength (1.064µm) laser emission

2-2laser beam interaction with materials

Laser is a beam of electromagnetic advantage of properties not available in any other source is high intensity ،coherence ،wavelength chromaticity and less divergence ،and these properties help to the possibility to focus the laser beam on an area of narrow, very close to the wavelength of radiation [9] When the fall of the laser beam on the surface Article, a part of the light beam is absorbed and the other part carried out and the rest is reflected and thus the total energy be equal to the sum of the three departments (Zhou,2001;Ziyad,*et al*.,2005) .Energy absorbed is transformed into heat within the material of introduction can be cut or puncture, or weld material. The equation of heat transfer to the material in one dimension are(Aaron, *et al*.,2008)**.**

$$\nabla \bullet (k\Delta T) + Q = \rho \bullet c\left(\frac{\partial T}{\partial t}\right) \quad \text{--------------(1)}$$

Where T is the temperature, k is the thermal conductivity, ρ is the density of the material, c is the specific heat and Q is the energy absorbed per unit volume. Of metals and the particular application, when the temperature Debye, can assume that k (T), c (T) is variable with temperature. So , we assume that the specific heat and thermal conductivity for a fixed period of time

$$k\,\frac{\partial^2 T_{(z,t)}}{\partial z^2} - \rho \bullet c\left(\frac{\partial T}{\partial t}\right) = -Q \quad \text{-----------(2)}$$

Divide equation (2) on k we get

$$\frac{\partial^2 T}{\partial z^2} - \frac{1}{K}\left(\frac{\partial T}{\partial t}\right) = -\frac{Q}{k} \quad \text{----------- (3)}$$

Where K represents the thermal diffusivity

$$K = \frac{k}{\rho \bullet c} \quad \text{------------(4)}$$

Q represents the amount of heat transmitted to article

$$Q = I_0 \mu \exp(-\mu z) \quad \text{------------(5)}$$

$$I(z) = I_0 \exp(-\mu z) \quad \text{------------(6)}$$

$$\frac{\partial^2 T}{\partial z^2} - \frac{1}{K}\frac{\partial T}{\partial z} = -\frac{\mu I_0}{k}\exp(-\mu z) \quad \text{----------(7)}$$

Where I (z) the intensity of the beam when the incident cut a distance of z, I_0 is the intensity of the beam incident when z = 0, the equation can be written

$$\frac{\partial^2 T}{\partial z^2}+\frac{\mu I_0}{k}\exp(-\mu z)=\frac{1}{K}\frac{\partial T}{\partial t} \quad \text{------------- (8)}$$

The application of boundary conditions

$$\left.\frac{\partial T}{\partial t}\right|_z = 0 \quad \text{-----------(9)}$$

$$T(\infty,t)=0$$

The solution equation (8) is expressed as follows(Jean, et al.,2009):

$$T_{(z,t)}=\frac{2I_0}{k}\sqrt{K\cdot t}\,ierfc(\frac{z}{2\sqrt{K\cdot t}})-\frac{I_0}{k\mu}\exp(-\mu z)+\frac{I_0}{2k\mu}\exp[\mu^2K\cdot t-\mu z]erfc(\mu\sqrt{K\cdot t}-\frac{z}{2\sqrt{K\cdot t}})$$

$$+\frac{I_0}{2k\mu^2}\exp[\mu^2K.t+\mu z].erfc(\mu\sqrt{K.t}+\frac{z}{2\sqrt{K.t}})-------(10)$$

$$\frac{dT(z,t)}{dt}=\exp(-\mu.z)-\frac{I}{k}erfc(\frac{z}{2\sqrt{K.t}})+\frac{2I}{k}\exp(K.\mu^2.t-\mu.z).erfc(\mu\sqrt{K.t}-\frac{z}{2\sqrt{K.t}})$$

$$+\frac{I}{2k}\exp(K.\mu^2,t+\mu.z).erfc(\mu\sqrt{K.t}+\frac{z}{2\sqrt{K.t}})-------(11)$$

Note that

$$erf(z)=\frac{2}{\sqrt{\pi}}\int_0^z\exp(-t^2)dt \quad \text{-------------- (12)}$$

$$erfc(z)=1-erf(z)=\frac{2}{\sqrt{\pi}}\int_z^{\infty}\exp(-t^2)dt \quad \text{-----------(13)}$$

$$ierfc(z)=\int_0^z erfc(z)dz=zerfc(z)+\frac{1}{\sqrt{\pi}}(1-e^{-z^2}) \quad \text{---------(14)}$$

$$T_S(0,t)=k.\mu\left[2\frac{\sqrt{K.\mu^2.t}}{\Pi}+\exp(K.\mu^2.t).erf(\mu\sqrt{K.t})-1\right] \quad \text{-------------(15)}$$

Where T_S is the surface temperature .(Yufeng et al.,2004)

$I(z)=(s.p.E_{normal})/(A.t)$ --------------(16)

Where p real number that implies (p=6.8241) and s =3.95 put to balance the magnitude of two sides of equation (16)

3-Results and Discussion

Equation (16) has been applicated of in the MATLAB7 program ,to draw a relationship between the intensity of laser beam Nd-YAG as a function of time pulse is also shown in Figure (1) to extract polynomial of intensity of laser beams.

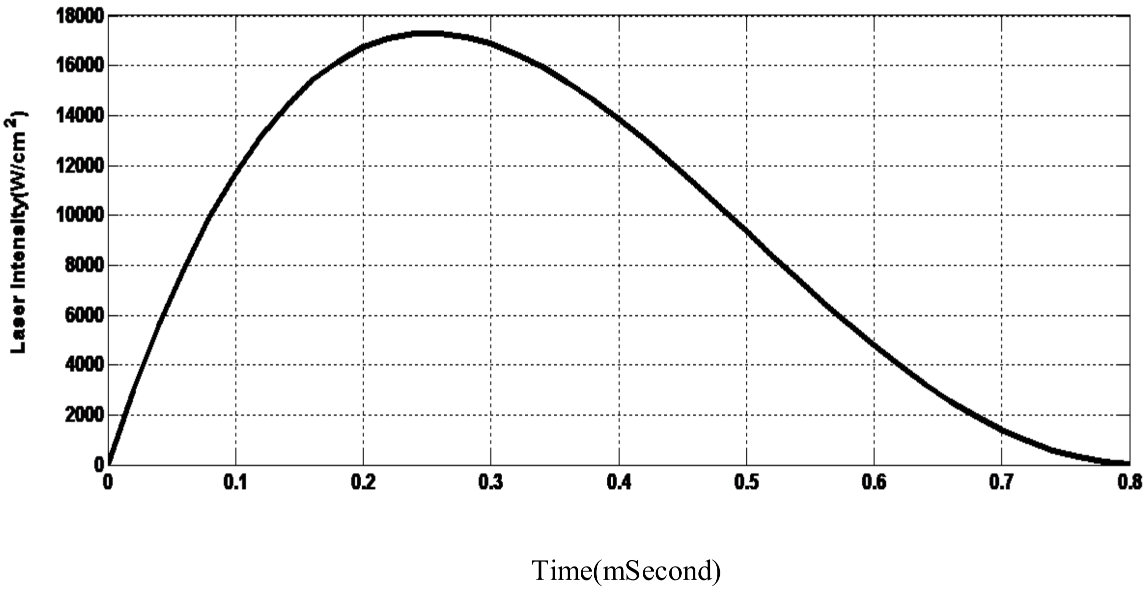
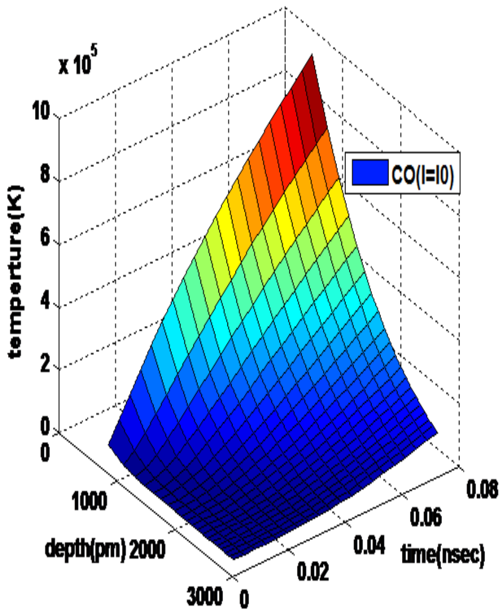
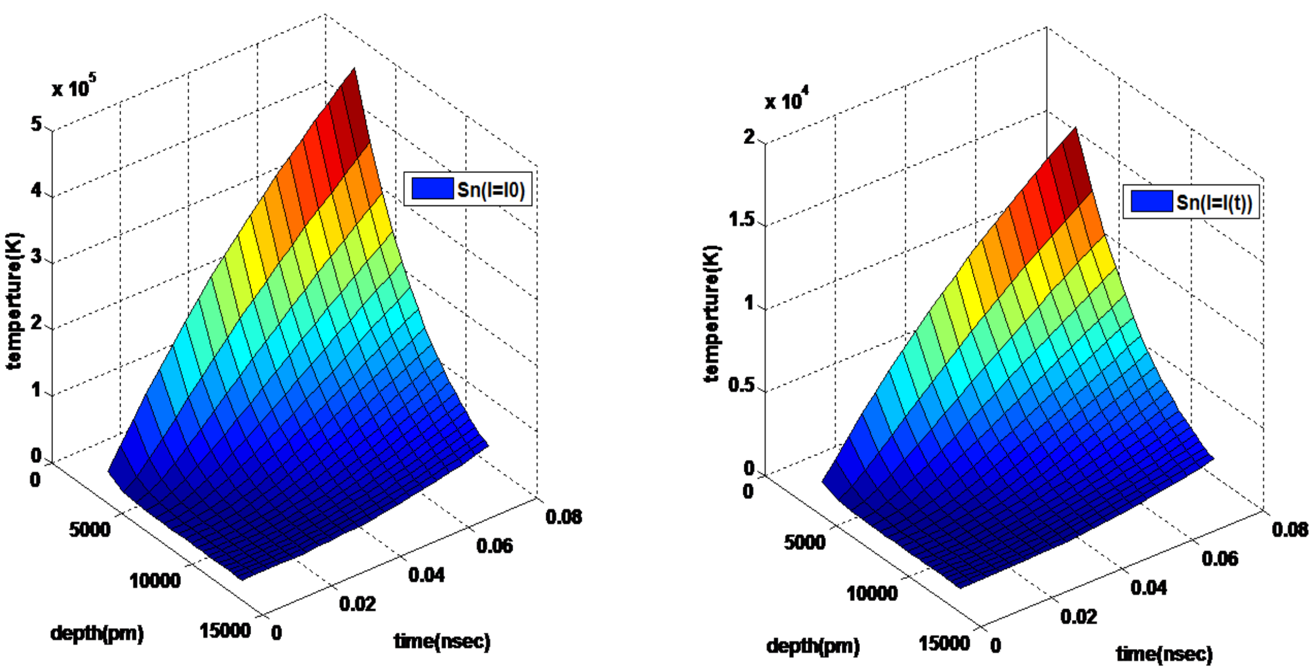


Figure (1) the energy density of the laser pulse as a function of time...

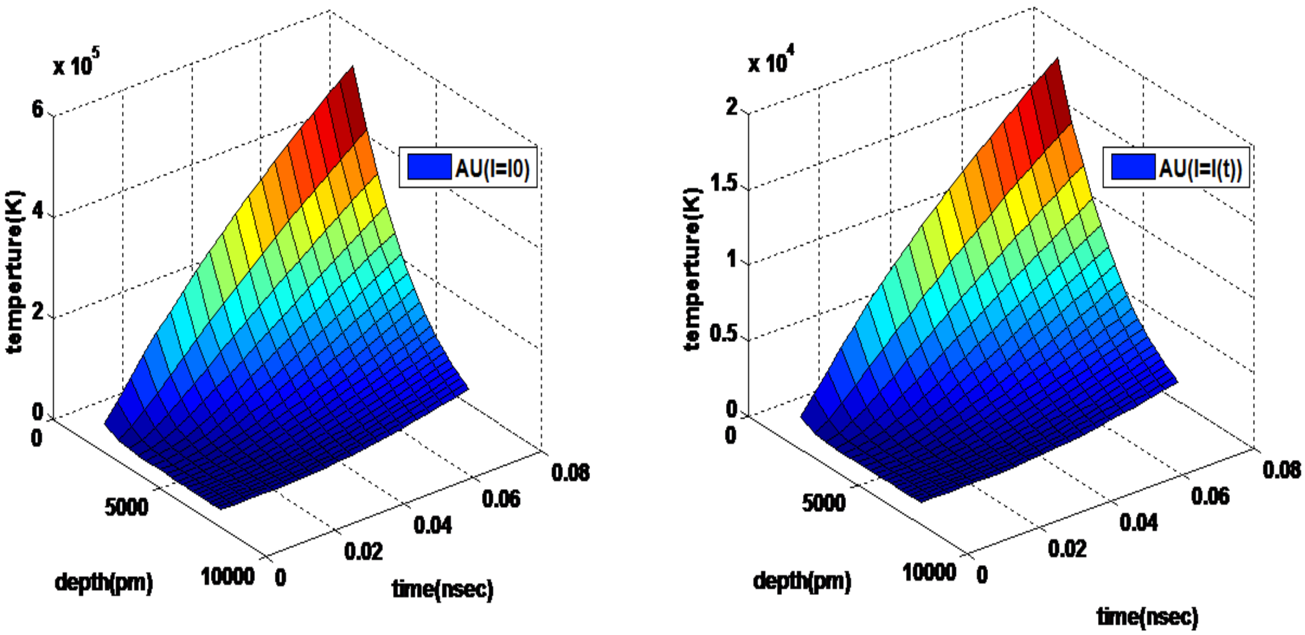
I(t)=26.694+1.5525*(10^5)* dt -4.1419 *(10^5)*(dt^2)+2.6432*(10^5) *(dt^3) +71510*(dt^4)-72426*(dt^5) and the applied equations (10) and (11) and (15) in the MATLAB program to calculate the temperature distribution within the material and on the surface and the decline of the temperature inside the material when the intensity of the laser beam fixed and variable with time. Note through shapes (2) and (3) and (4) and (5) the temperature distribution within the material when the intensity of the laser beam fixed and variable with time, where it is clear that the temperature rises the more time and less the more depth proliferation warming in all materials and also note that the temperature distribution at least when it changes the intensity of the laser beam with time and when comparing these forms note that the metal cobalt be ratings Ahararth interior bigger than the rest of the material due to differences in thermal properties of materials as shown in the table (1)



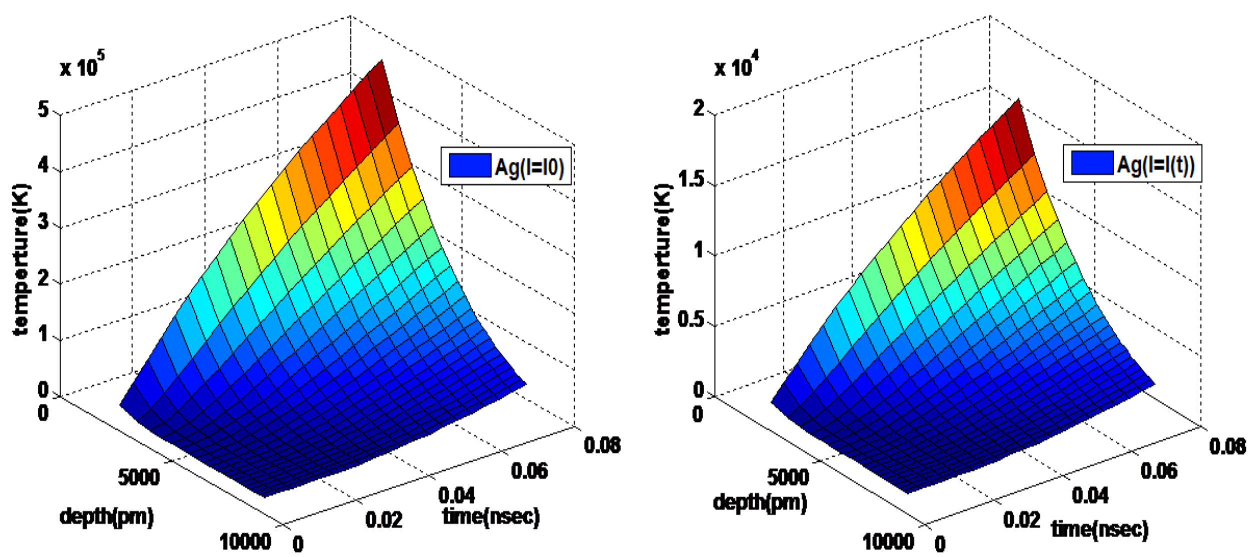
Figure(2) temperature distribution inside metal cobalt



Figure(3) temperature distribution inside metal silver

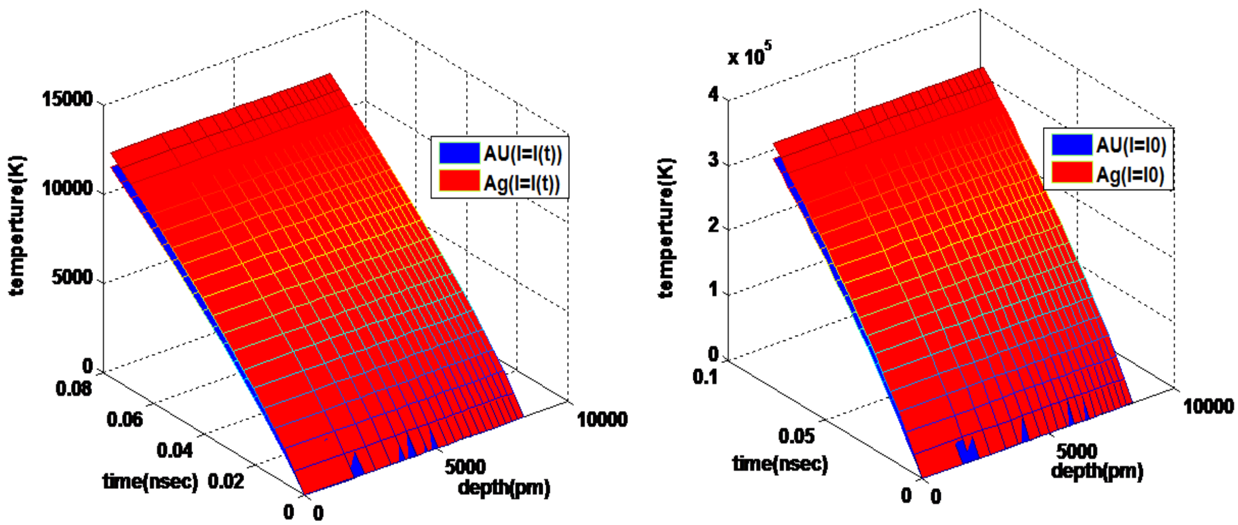


Figure(4)temperature distribution inside metal Tin

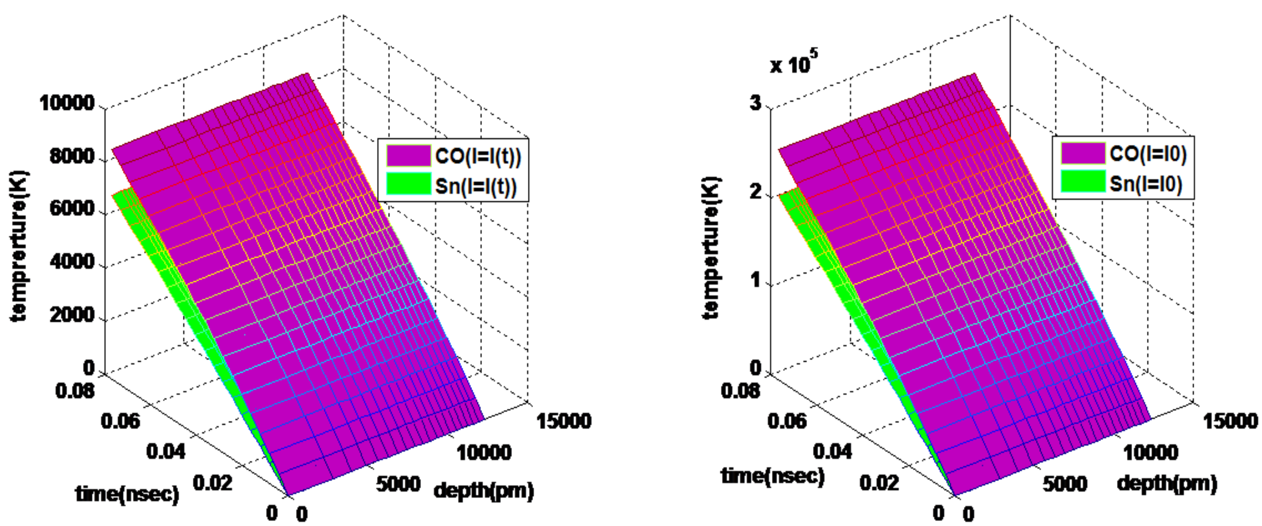


Figure(5) temperature distribution inside metal gold

While Figures (6) and (7) illustrate the comparison between the high surface temperature of the metal gold and silver and metallic cobalt, tin when the intensity of the laser beam fixed and variable with time as it is clear that the temperature distribution on the surface of metals less when changing intensity with time and also note that the high surface temperature in the metal silver is greater than gold, as well as the high surface temperature of cobalt metal largest of tin in both cases is due to the absorption coefficient of silver greater than the absorption coefficient of gold as well as the absorption coefficient cobalt largest tin absorption coefficient as shown in the table (1).

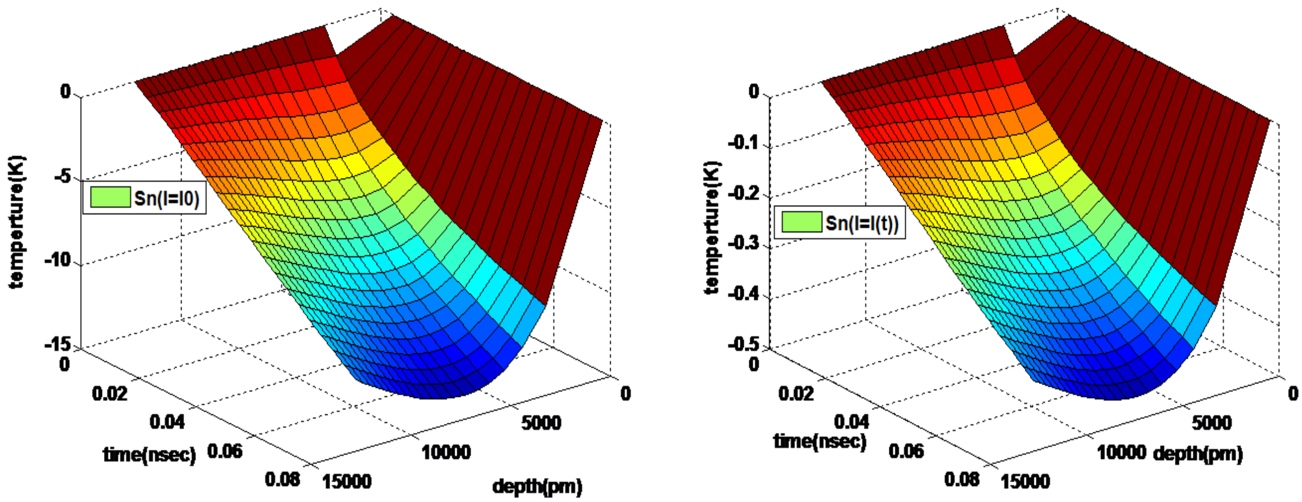


Figure(6) temperature distribution on the surface of metal gold and silver

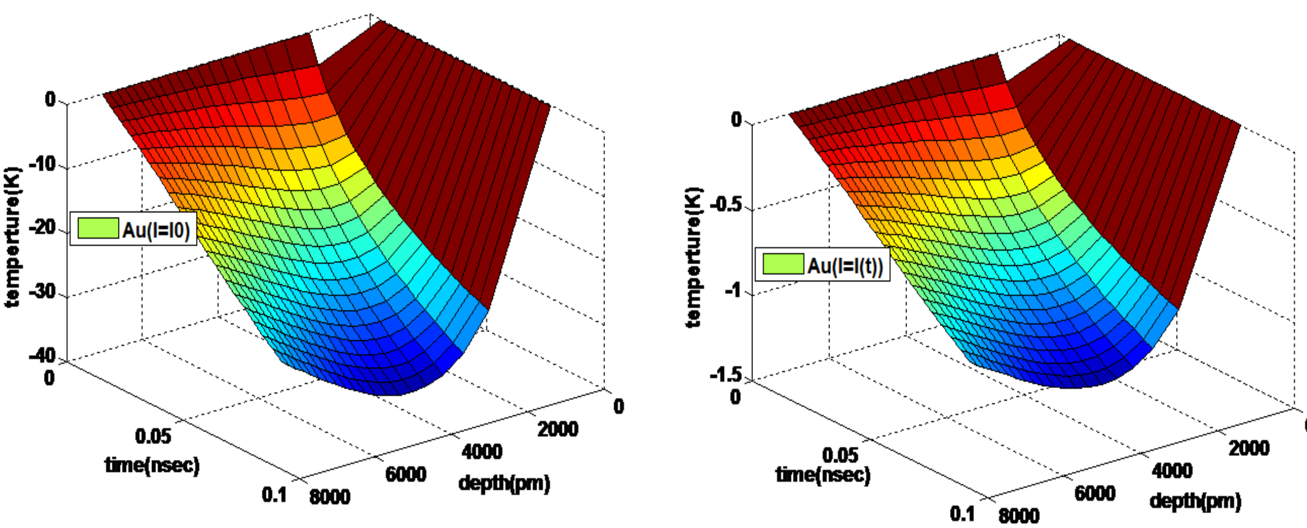


Figure(7) temperature distribution on the surface of metal cobalt and tin

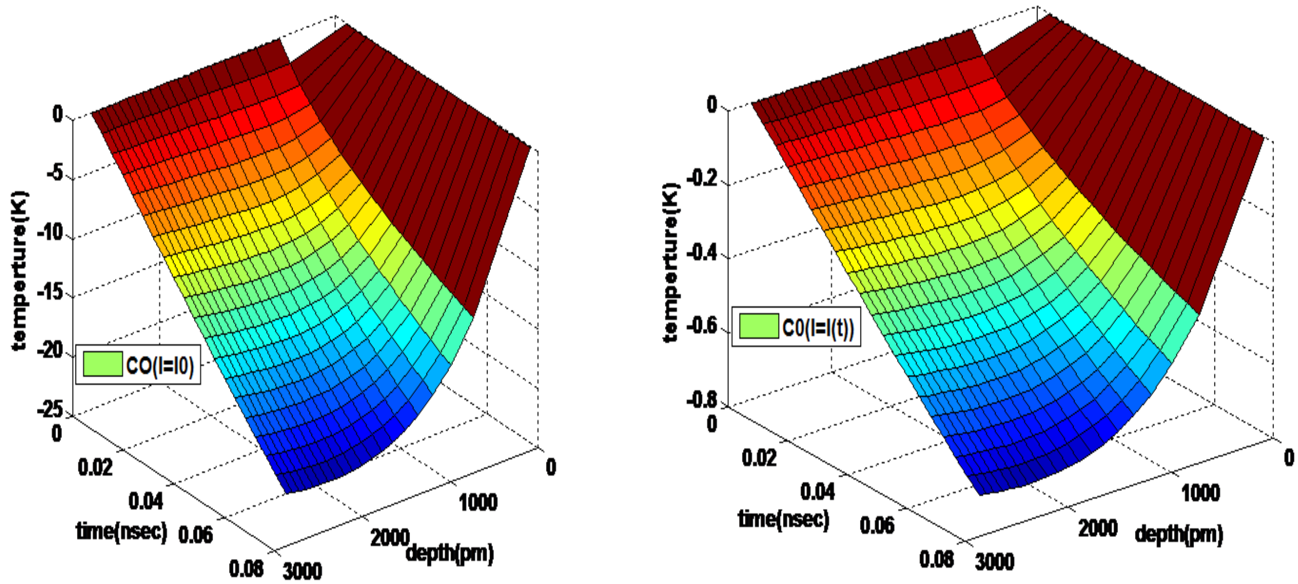
The forms (8) and (9) and (10) and (11) describes the substantial decrease in the temperature inside the material greater depth proliferation warming, especially in the case of changing the intensity of the laser beam with time and specific in silver metal and because of the variety thermal properties him and the biggest absorption coefficient



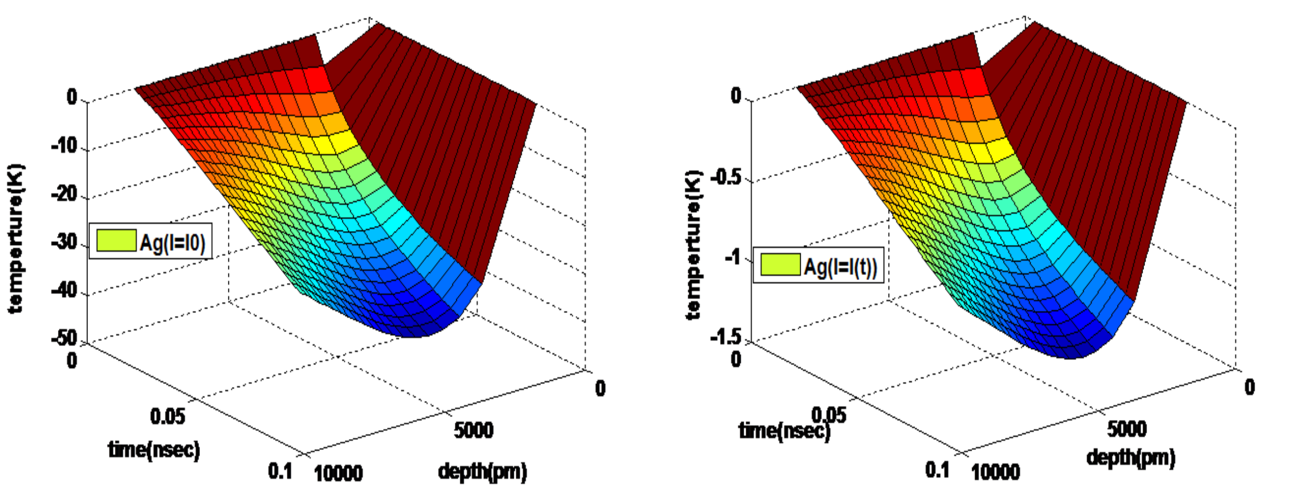
Figure(8) temperature gradient inside the Tin metal at constant laser intensity and variable with time



Figure(9) temperature gradient inside the gold metal at constant laser intensity and variable with time



Figure(10) temperature gradient inside the cobalt metal at constant laser intensity and variable with time



Figure(11) temperature gradient inside the silver metal at constant laser intensity and variable with time

Conclusions

It can be concluded that the temperature distribution inside the material and on the surface at least, the more depth of thermal spread and increases the more time. When you change the intensity of the laser beam with time, the temperature distribution within the material and on the surface and decline within the material will fall. The main conclusion is that the absorption coefficient material plays an important role in the distribution of temperature inside the material and on the surface in addition to the thermal properties of the material (thermal conductivity and heat capacity and density).

Table (1) Thermal properties and absorption coefficients for (Au,Ag,Sn,Co)metals

Metals	Thermal conductivity	density	specific heat	absorption coefficient
Au	3.15	19.3	0.131	10^7*22.4
Ag	4.28	10.49	0.234	10^7*26.82
Sn	6.37	7.3	0.23	10^7*10.06
CO	0.7	8.85	0.41	10^7*13.8

Reference

Khaleeq-ur-Rahman, M. M.S.Rafique,Khurram Siraj , Shazia Shahid 2004"‘Theoretical and Experimental Comparison of Splashing in Different Materials “, 3Ist EPS Conference on Plasma Phys. Lond0n , 28 June -2 July ECA Vol .28G,P-2.049

David A. Willis, Xianfan Xu,’ 2002 Heat transfer and phase change during picoseconds laser ablation of nickel’, International Journal of Heat and Mass Transfer 45 3911–3918.

B ilijana Gakovic ,Milan Trtica ,Zlatko Rakocevic , 2002. ‘ Photon-Beam Sputtering and Surface Morphology of TLTANIUN-CERAMIC’

Voisey K.T..,S.S.Kudesia , W.S.O.Rodden , 2002.’Melt Ejection During Laser Drilling of Metals ‘, Submitted to Mat .Sct and Eng .Oct.

Ynay Sook Koh , 2005’Laser cleaning as conservation technique for corroded metal Artifacts ‘,Lulea university of technology department of Applied physics and Mechanical

Sreckovid M.,J.Ilic , A.Kovacevic, S.Pantelic, 2007.”Models of Interaction of Laser Beams with Material of Interest for Optical Components and Provoked Damages “, Proceedings of International School and Conference on Optics and Optical Material , ISCOMO7,Belgrade,September3-7,

Bunkin, F.V. B.S. Luk’yanchuk, G.A. Shafeev, E.K. Kozlova, A.I. Portniagin, A.A. Yeryomen, P.Mogyorosi, and J.G. Kiss, 1985. “Si Etching Affected by IR Laser Irradiation”, Applied Physics A, Vol.37, pp(117-119),

Langley, A.J. E.J. Divall, N. Girard, C.J. Hooker, M. Hutchinson, A. Lecot, D. Marshall, D. Neely, and P.F. Today, 1999. “Development of a multi-Tera watt, Fem to Second Laser Facility-Astra”, CLF Annual Report,

Karr, M.A. “Nd:YA1G-$Ba_2NaN_{b5}O_{15}$ 0.66- Harmonic Source”, 1971. Journal of applied physics”, Vol.42, No.11, pp(4517-4519), published by the American institute of physics,

Diodati, F.P. A.A. Hnilo, M. Mario, C. Marconi, O. Martinez, and A. Too, 2002, “Teaching the Physics of a Diode – Pumed Laser”, http://www.Laser ptics.com.ar/EDUCATION.

Zhou X., K. Imasaki , H. Furukawa , H. Umino , K. Sakagishi and S.Nakai , 2001. "Astudy of the Surface Produce on Zinc- Coated Steel During Laser Ablation Cleaning" , Surface and Coatings Technology

Ziyad Tariq Ahmed Mohammed Al- Kathali,'' ,2005. The Optimum Operating Cases of CW-CO_2 Laser''

Aaron Peled,Mihai Oane,Florea Scarlat,Ion Mihailescu,Geo Georgescu, 2008"The Study of Classical High Power Lasers Calorimetry With Applications On Thin Films", Romanian Reports in Physics ,V60,N4, P.1077-1086,

Jean Francois Coutuly, Pascal Deprez , Florin Breaban ,Jean Paul Longuemard , 2009. " Optimisation of Apaint Coating Ablation Process by TEA- CO2 Laser : Thermal Field Modeling and Real –Time Monitoring of The Process" , Jourunal of materials processing Technology,

Yufeng Peng ,Yaoli Wei and Zhenlong, 2004. "Femtosecond Laser- Induced Damage in Dielectrics" , Optical Applicata, ,N 3,