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RESEARCH ARTICLE

THEORETICAL STUDY ND-YAG LASER BEAM INTERACTION WITH SEVERAL SOLID MATERIALS BY THREE DIMENSION MODEL

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ABSTRACT

Study of the interaction of laser radiations (Nd-YAG) laser at (1.0 6μm) wave length with pulse duration (100 μsec) on some solid material (Ag,Au,Sn,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.

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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). Theabltion of nickel using mode –loked 25 ps (FWHM) Nd-YAG laser, had been studied by Willis *et al*. in 2002 (David *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*. in 2002. In laser drilling of metals Increasing the pulse intensity increases the ejection velocity and decreases the average particle size, were drawn by Voisy in 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*. in 2005. The models of interactions of laser beams with materials, had been studied Sreckovic in 2007.

Theoretical part

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

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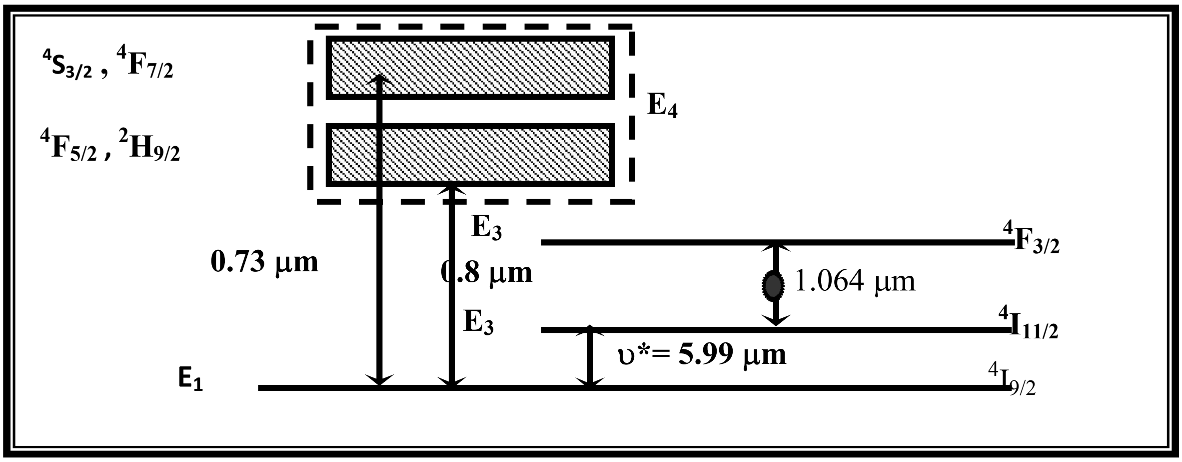

Figure 1. Nd-YAG laser sketch illustration

Laser 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 (Karr, 1971) 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 *et al*., 2001; Ziyad Tariq Ahmed Mohammed Al- Kathali, 2005). Energy absorbed is transformed into heat within the material of introduction can be cut or puncture, or weld material

And the equation of heat transfer to the material in one dimension are (Aaron Peled *et al*., 2008)**:**

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

Where T temperature, k thermal conductivity, density of the material, and c specific heat, Q 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

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

Divideequation (2)onkwe get

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

Where K represents the thermal diffusivity

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

Q represents the amount of heat transmitted to article

----------- (5)

$$Q = I_0 \mu \exp(-\mu z)$$

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

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

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

$$\frac{\partial^2 T}{\partial z^2} + \frac{\mu I_0}{k}\exp(-\mu z) = \frac{1}{K}\frac{\partial T}{\partial t} \quad \text{-------------(9)}$$

The application of boundary conditions

$$\left.\frac{\partial T}{\partial t}\right|_z = 0 \quad \text{......................(10)}$$

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

The solution equation (9) is expressed as follows (Jean Francois Coutuly *et al*., 2009):

$$T_{(z,t)} = \frac{2I_0}{k}\sqrt{K\cdot t}\,ierfc\left(\frac{z}{2\sqrt{K\cdot t}}\right) - \frac{I_0}{k\mu}\exp(-\mu z) + \frac{I_0}{2k\mu}\exp[\mu^2 K\cdot t - \mu z]\,erfc\left(\mu\sqrt{K\cdot t} - \frac{z}{2\sqrt{K\cdot t}}\right)$$
$$+ \frac{I_0}{2k\mu^2}\exp[\mu^2 K.t + \mu z].erfc\left(\mu\sqrt{K.t} + \frac{z}{2\sqrt{K.t}}\right) - - - - - - - (11)$$

Note that

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

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

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

$$Ts(0,t) = \frac{I}{k.\mu}\left(2\frac{\sqrt{K.\mu^2.t}}{\pi} + \exp(K.\mu^2.t) * erfc(\mu\sqrt{K.t}) - 1\right. \quad ------(15)$$

Where T_S is the surface temperature

$$\frac{dT(z,t)}{dt} = \exp(-\mu.z) - \frac{I}{k}erfc\left(\frac{z}{2\sqrt{K.t}}\right) + \frac{2I}{k}\exp(K.\mu^2.t - \mu.z).erfc\left(\mu\sqrt{K.t} - \frac{z}{2\sqrt{K.t}}\right) + \frac{I}{2k}\exp(K.\mu^2.t + \mu.z).erfc\left(\mu\sqrt{K.t} + \frac{z}{2\sqrt{K.t}}\right) \text{---------------(16)}$$

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	$22.4*10^7$
Ag	4.28	10.49	0.234	$26.82*10^7$
Sn	6.37	7.3	0.23	$10.06*10^7$
CO	0.7	8.85	0.41	$13.8*10^7$

RESULTS AND DISCUSSION

Equation (17) has beenapplicated of in the MATLAB7program ,to draw a relationship between the intensity of laser beam Nd-YAG as a function of time pulse is also shown in Figure (2) to extract polynomial of intensity of laser beams (Yufeng Peng *et al.,* 2004).

$$\boldsymbol{I(t)} = \frac{\mathbf{s.p.E_{normal}}}{\mathbf{A.t}} \quad \text{------------------------(17)}$$

Where p real number that implies (p=6.8241).

Where s =3.95 put to balance the magnitude of two sides of equation (17)

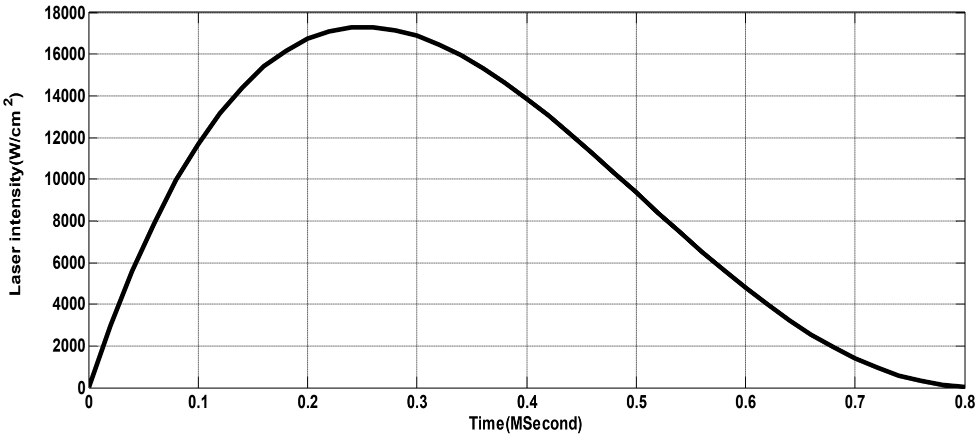

Figure (3) the energy density of the laser pulse as a function of time...

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 (11) and (15) and (16) 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 (3) and (4) and (5) and (6) 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)

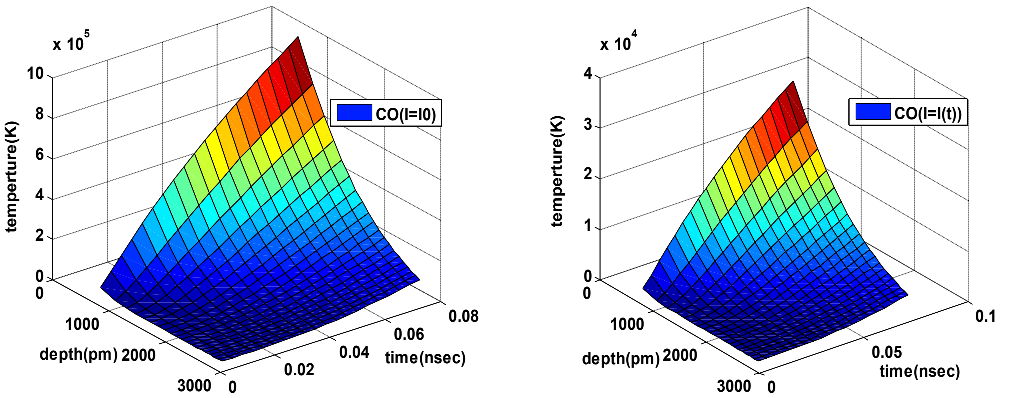

Figure 3. Temperature distribution inside metal cobalt

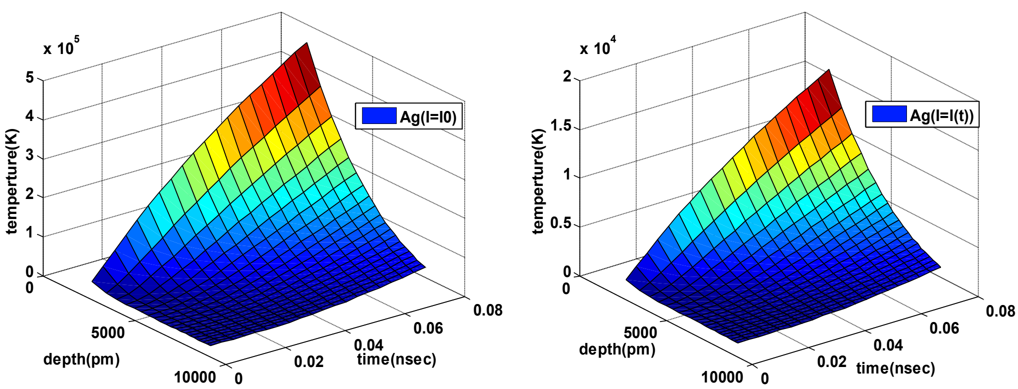

Figure 4. Temperature distribution inside metal silver

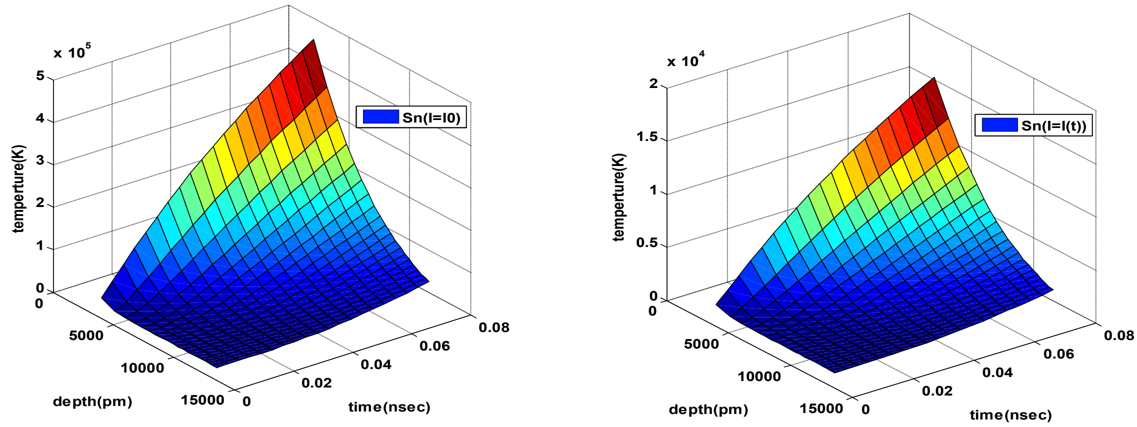

Figure 5. Temperature distribution inside metal Tin

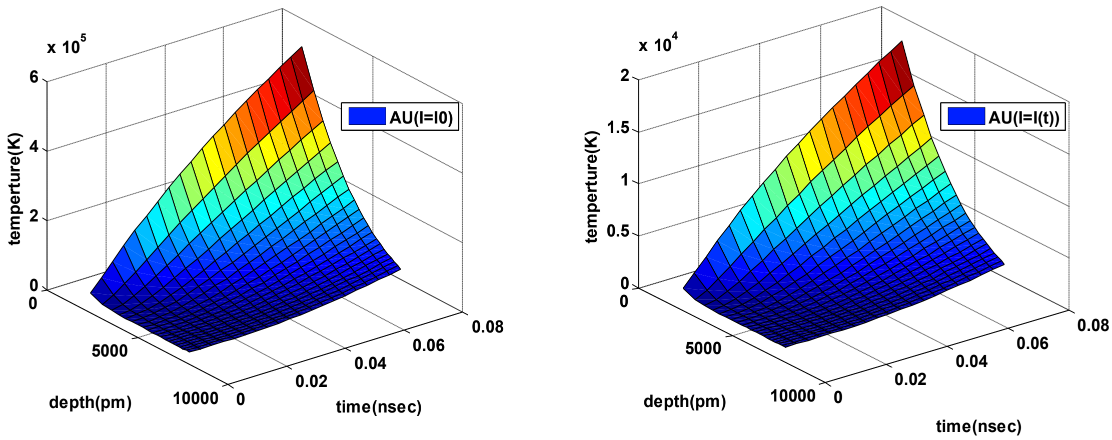

Figure 6. Temperature distribution inside metal gold

While Figures (7) and (8) 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).

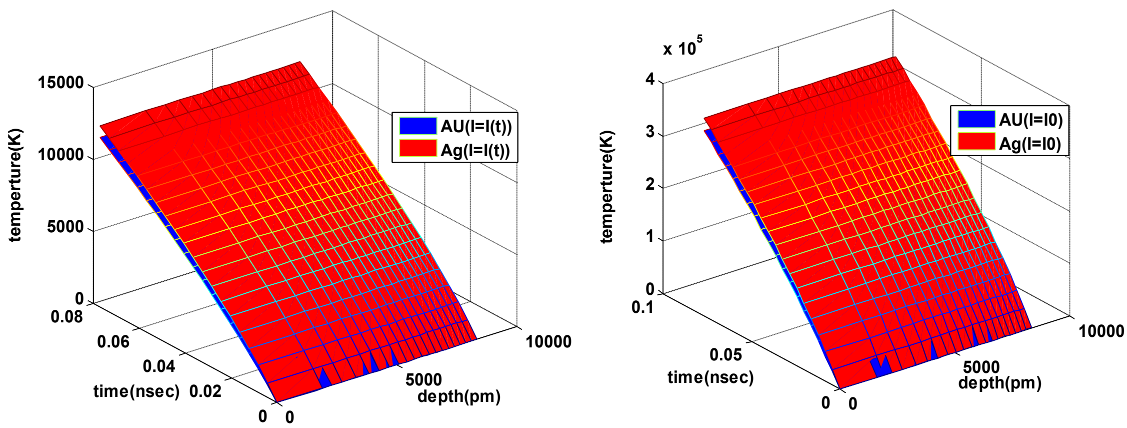

Figure 7. Temperature distribution on the surface of metal gold and silver

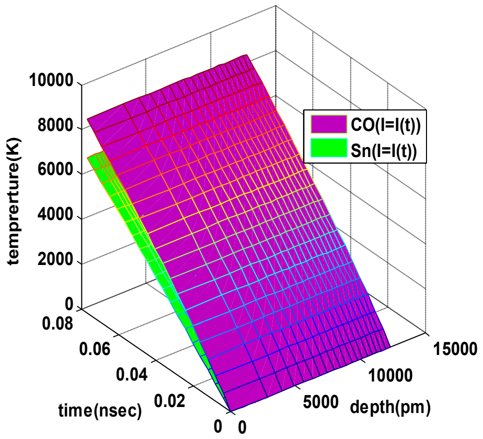

Figure 8. Temperature distribution on the surface of metal cobalt and tin

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 specificin silver metal and because of the variety thermal properties him and the biggest absorption coefficient

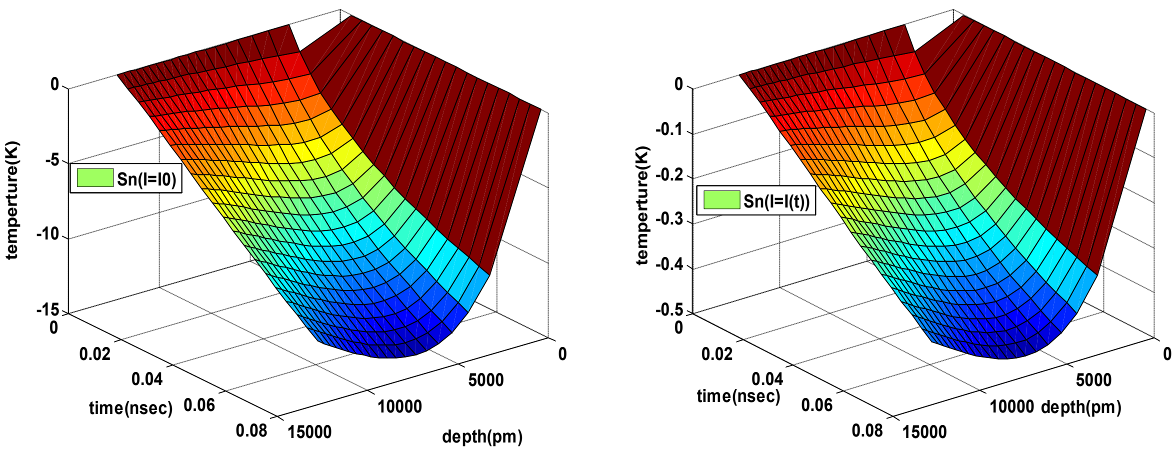

Figure 8. Temperature gradient inside the Tin metal at constant laser intensity and variable with time

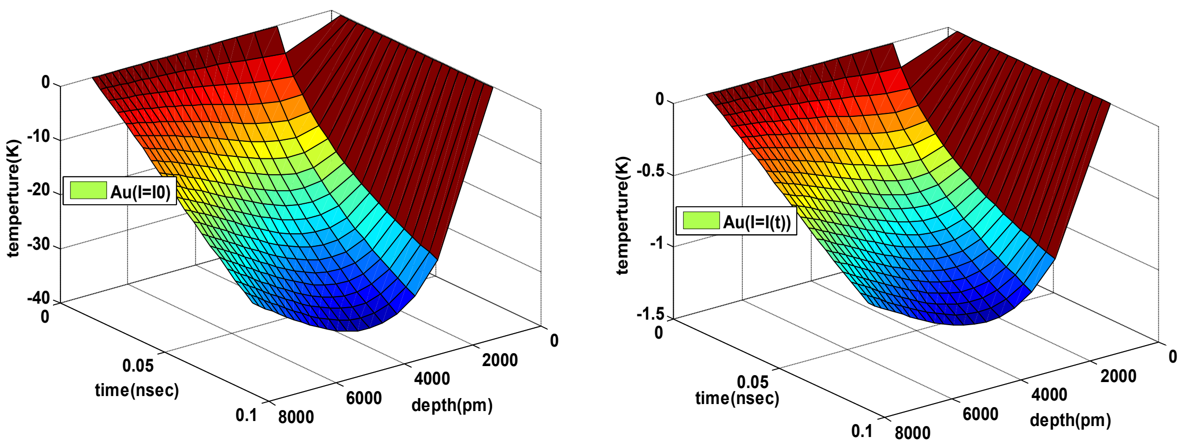

Figure 9. Temperature gradient inside the gold metal at constant laser intensity and variable with time

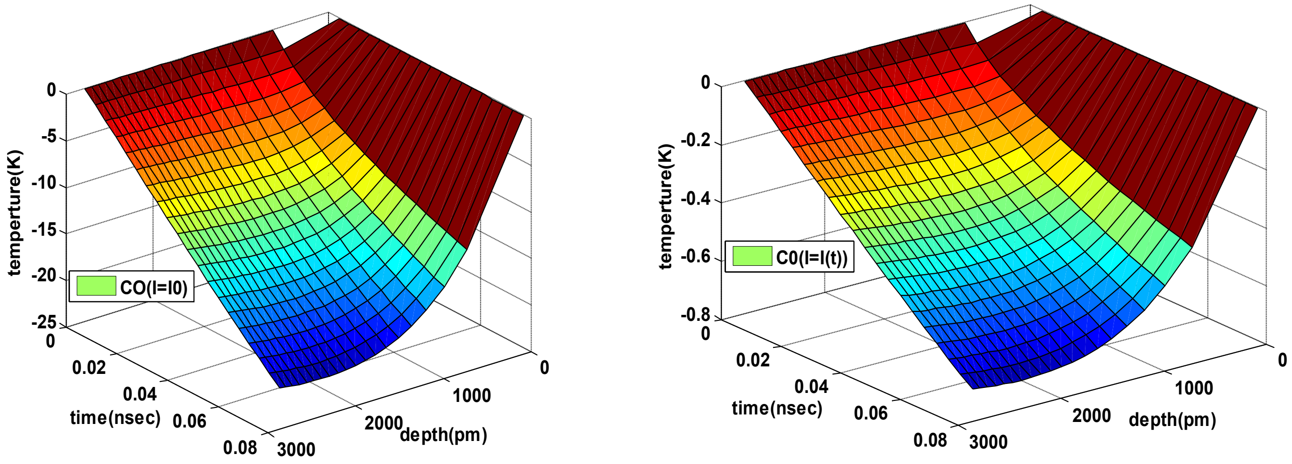

Figure 10. Temperature gradient inside the cobalt metal at constant laser intensity and variable with time

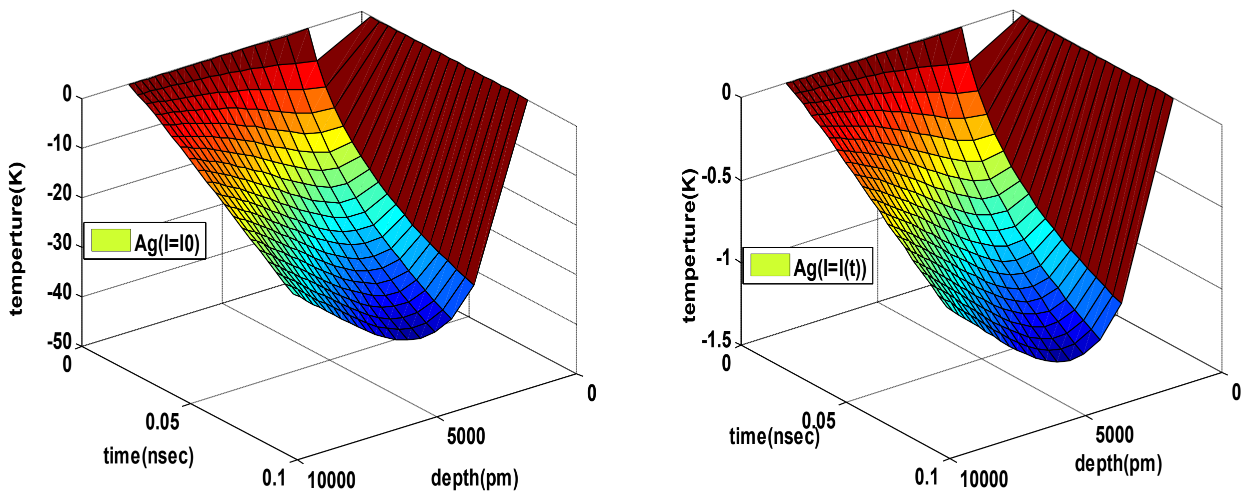

Figure 11. Temperature gradient inside the silver metal at constant laser intensity and variable with time

Conclusion

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).

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