Research on Thermal Damage Effect of a New Laser Weapon on Human Skin

FANXIAO ZHANG, ZHEXIN HAN, WANG HAO and JIAYU XIA

ABSTRACT

The laser cascade ionization weapon, a new non-lethal weapon with high shooting precision, has a broad application prospect. However, it is still lack of theoretical and experimental research on which type of laser to cause damage to the human skin. This paper use ANSYS software to establish the model of the thermal damage effect of laser to human skin, followed by the simulation of laser irradiation of human skin, thermal injury effect through the simulation of different laser caused by different initial intensity on the human skin, it is found that the most suitable laser wavelengths in the manufacture of laser cascade ionization weapons.

KEYWORDS

International Conference, International Conference, International Conference.

INTRODUCTION

As an important force to safeguard the security and stability of country, the armed force must constantly enrich the means of accomplishing the task so as to ensure the completion of various missions. At present, the armed police are still lack of an effective non-lethal weapon, it is necessary to consider whether the laser will cause serious damage to the human bodies that it may causes temperature raises. Therefore, this paper will analyze the thermal properties of human skin and establish the model of human skin so as to analyze the effect of thermal damage under different conditions. Furthermore, the laser band is used to screen the laser weapon.

ESTABLISHMENT OF SKIN STRUCTURE

When the laser is transmitted in the tissue, the intensity decreases with increasing distance and has the following characteristics [1]:

\[ \frac{dl}{dx} = I \mu_a \]  \hspace{1cm} (1)

\( I \) Represents laser intensity, \( \mu_a \) is absorption coefficient of medium, \( dx \) is dielectric thickness.
When the laser enters the skin, it is absorbed by different substances causing the change of temperature. The absorption coefficient of different wavelength laser is different. The absorption of the main components of infrared laser is water, and the absorption of the main components of ultraviolet and visible light is protein and melanin [2]. The content of water in human skin accounts for 70%, the protein and melanin is much less. Therefore, the absorption coefficient of water is used to approximate the absorption coefficient of skin tissue in the modeling of human skin tissue.

The temperature change of skin caused by laser can be divided into three stages [3]: produce, absorption and thermal transmission. Therefore, the variation equation of laser intensity in skin tissue is obtained taking into account the combined effects of various factors.

\[
I = (1 - R)I_0 \exp\left[-(\mu_a + \mu_s)z\right] \exp\left\{-4\ln 2\left[\frac{(t - \tau_p)^2}{\tau_p^2}\right]\right\}
\]  

(2)

In order to establish a skin model that conforms to the actual situation, the thermal properties of the skin tissue should be taken into account, including specific heat, thermal conductivity and density.

There are three forms of heat transfer in the skin tissue [4]:

First, heat conduction, it can be calculated in the following ways [5]:

\[
Q = -kA(T_2 - T_1) \Delta t / \Delta L
\]

(3)

\(Q\) represents the heat transferred between substances; \(k\) is thermal conductivity.

Second, convection [6], it can be described by the Newton heat transfer equation:

\[
f = h(T_2 - T_1)
\]

(4)

\(f\) Represents the amount of heat passed; \(h\) is heat transfer coefficient.

Thirdly, metabolism. Due to the time between the laser and the skin is short, the influence of the metabolism on the temperature is not considered in the calculation.

In summary, lasers used as ionization weapons should keep the temperature rise below 100 degrees and cannot be irradiated for a long time.

**THERMAL DAMAGE ANALYSIS OF HUMAN SKIN BY LASER AT DIFFERENT WAVELENGTHS**

**Thermal damage analysis of human skin by 1064nm laser**

Figure 1 and Fig. 2 are the three-dimensional temperature profiles of the skin tissue caused by the laser and the central temperature change curve at the initial intensity \(I_0 = 1 \times 10^{10}\) W/cm².
It is found by simulation that the maximum temperature caused by 1064nm laser is increased to 2100K, and the minimum temperature is also 500K even if the laser intensity is decreased which greatly exceeds the safe temperature and does not meet the requirements of laser cascade ionization weapons.

**Thermal damage analysis of human skin by 532nm laser**

Figure 3 and Fig. 4 are the three-dimensional temperature profiles of the skin tissue caused by the laser and the central temperature change curve at the initial intensity $I_0=1\times10^{10}$W/cm$^2$. 
Simulation results show that the temperature rise is much smaller than that of 1064nm laser. Its range of temperature is 325-425K, and its minimum value has met the requirements of laser cascade ionization weapons, however, its highest value is 425K, and still may cause harm to humans, so the overall is still not satisfied with the requirement.

**Thermal damage analysis of human skin by 248nm laser**

Figure 5 and Fig. 6 are the three-dimensional temperature profiles of the skin tissue caused by the laser and the central temperature change curve at the initial intensity $I_0=1\times10^{10}$W/cm$^2$. 

Experiments show that the range of change is 317-362K, and the irradiation time is very short, so it will not cause serious harm to human body, and meet the requirements of laser cascade ionization weapons.

CONCLUSION

At present, laser cascade ionization weapons are still in conceptual research stage in our country which need lots of theoretical and experimental work before final forming. With the continuous development of laser technology, the advent of short wavelength, high-power and compact lasers will make laser cascade ionization weapons become reality from concept stage.

REFERENCES