Study of acoustic wave generated by Q-switched laser on derma

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To study characteristics of acoustic wave generated by Q-switched laser on dermal pigmented lesions, Pieces of derma peeled from a cavy's body are plucked their hair. The pieces of derma are radiated by Q-switched laser with different energy intensities. Momentary signals of acoustic wave generated by the Q-switched pulsed laser on dermal pieces are detected isochronously with sensors connected to a multi-channel digital oscilloscope. The signal data are analyzed with a personal computor. Clear signal curves of acoustic waves are obtained in the experiment. The amplitudes of the signals present the positive correlation with the energy intensity of the single pulse laser. The acoustic wave signals have practical meanings of reference to the real-time control of laser energy intensity in the course of the therapy of Q-switched laser on dermal pigmented lesions.

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Short pulse laser can excite broad band acoustic pulse in materials. This fact can be utilized to research properties of materials in a way of non-contact[1,2]. This way of means is called the method of laser acoustic spectrum which has been paid much attention. By the method of laser acoustic spectrum, various types of wave can be excited simultaneously, such as transverse wave, longitudinal wave, and surface waves etc., and various samples with different shapes and sizes of can be tested and studied. The method has played an important role in the research of properties of mathematics, thermology, optics, and microstructure of films and sill-like materials.

However, acoustic wave excited by Q-switched laser on derma has not been researched yet. Q-switched laser can generate micro explosion on derma. The acoustic wave comes from the micro explosion has the information of properties of the micro explosion. Study of the acoustic wave excited by Q-switched laser on derma has not only the guidance meaning to the existing laser therapy, but also the important theoretical and practical meanings to widen up the applications of laser in medicine.

In recent years, Q-switched laser technics has been utilized to treat dermal pigmented lesions according to the elements of selective thermolysis of laser[3,4]. The curative effect of this therapy is very good. But the mechanisms of the material on which dermal pigmented lesions are removed effectively by Q-switched laser have not been understood clearly. There are a lot of questions about the therapy waiting for explanation. Fundamental research is up to date restricted to the levels of morphological observation mainly[5,6]. But, the beginning split second process within which laser pulse interacts with dermal tissues and the mechanisms of the interaction has not been investigated in detail.

General theory believes that the pigmented granules in dermal tissue would expand rapidly because of heating and be disintegrated into tiny chippings under laser pulse[3,4]. Next, a chronic inflammatory reaction process would occur in the dermal tissue. The tiny chippings of pigmented granules would be engulfed gradually by immune cells and be removed from the human body. Observational results have shown that the cavities would be brought about to dermal cellular tissues, with the pigmented chippings distributing around the age of the cavities after pulse laser action, and the granules diminish evidently. In the next several weeks, there is a process of chronic inflammation reaction and restoration. During the process, inflammatory cells including neutrophilic granulocyte, lymphocyte etc. infiltrate around blood vessels. The pigmented chippings are phagocytized in macrophages and fibroblasts. Later the cavities would disappear gradually, and the pigmented granules become illegible till rehabilitation in the main. Lastly a new derma without pigment would be reconstructed.

However, the split second physical process during which the cavities mentioned above generate, develop and change, and the relationships between the evolutional characteristics of the cavities and the inflammatory reactions and the restoration process have not been researched in depth. Apparently, the split second physical process is the prerequisite of the following processes of the inflammatory reactions and the restoration. It holds the balance to the whole curative effect. So it is significant to investigate the process and its characteristics happened in the initial instant, approximately the intervals of the order of magnitude of microseconds, during which the pulse laser interacts with the dermal tissues.

In this research, acoustic waves excited by Q-switched laser on derma are tested. Clear acoustic wave signals are obtained. The experimented result suggests that detection and analysis of acoustic wave signals excited by Q-switched laser on derma can provide useful supplemental specification for the controlling and adjusting of laser parameters in the process of laser therapy.

The Q-switched Nd:YAG laser is 1064 nm in wavelength, 10 ns in pulse duration, and 500 mJ in maximal energy output. Digital storage oscilloscope (Tektronix TDS340), electret acoustic sensor, photodiode, energy meter (molectron EPM1000). Guinea pig is black and white in hair color.

Put the guinea pig to death, shave its black hair and take the hairless derma, cut the derma into circle pieces of 2 cm in diameter. Fix the dermal piece at a five-dimensional console. Pulse laser is focused on the dermal piece through a beam splitter, a damping plate, and a convex lens. The light spot size of pulse laser can be

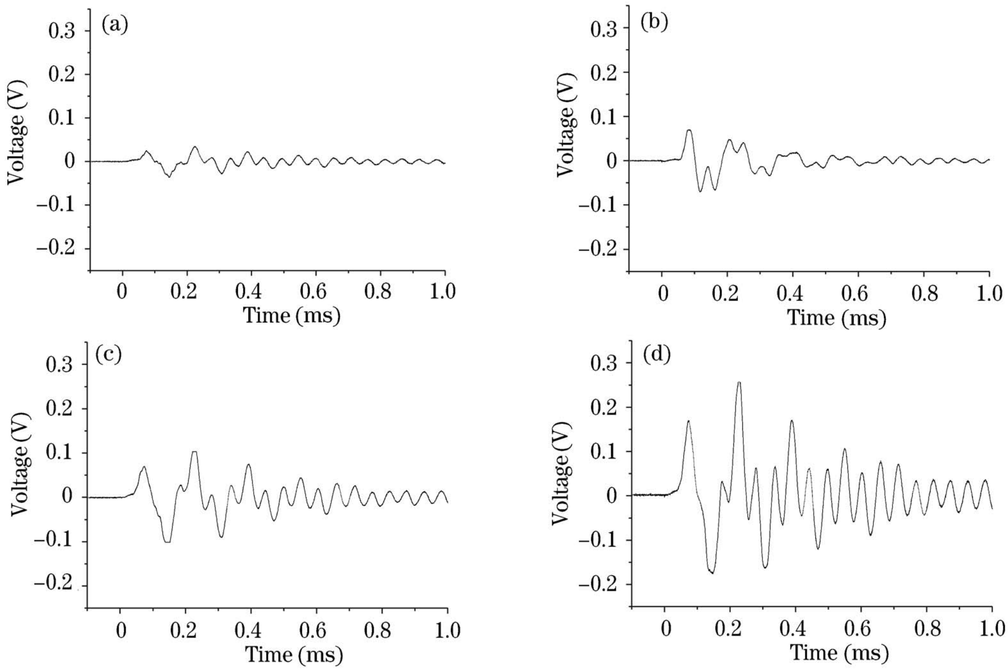

Fig. 1. acoustic wave signals excited by pulse laser.

adjusted by changing the distance between the convex lens and the dermal piece. The energy density of pulse laser hitting on the dermal piece can be controlled by the adjustment of distance. The activating signal of experiment is supplied by a photodiode capturing the reflected light of laser. The electret acoustic sensor is placed closing to the derma of guinea pig. Get the probe of the sensor near to the spot of laser on derma. The signals of acoustic wave are received by the sensor, turned into electrical signals recorded by the digital storage oscilloscope, and transmitted lastly to a microcomputer to be analyzed further.

The photodiode picks up the reflected laser from the beam splitter offering a time zero point for the digital storage oscilloscope to record waveforms. The actual measured splitting ratio of reflection and transmission of energy of the beam splitter is 1:19. The energy meter is used for testing real time energy of a single pulse of laser.

The signals of acoustic wave detected by the electret acoustic sensor in the split second of laser action on derma are shown in Fig. 1. Figures 1 (a), (b), (c), and (d) correspond respectively to the laser energy intensities of 1.0, 2.0, 3.0, and 4.0 J $/\mathrm{cm}^2$. The first peak value of the acoustic wave signal on the curve starts at 0.06 ms. The duration of the signal is about 2 ms (the signal of the acoustic wave in Fig. 1 is shown only 1 ms in duration). Spectral analysis shows that two frequency components are included in the acoustic wave signals in Fig. 1. The fundamental frequency is 6000 Hz, and the high order frequency is 18000 Hz.

In addition, Fig. 1 shows that the amplitude of the acoustic wave signal increases with the increase of laser energy intensity. The curves are different obviously to each other in the amplitude, and easy to be differentiated.

When a high-power pulse laser is focused on a soild target, a small portion of the material at the focal spot first vaporizs and ionizs via an inverse *bremsstrahlung* process followed by the formation of high-temperature and high-pressure plasma at the target surface with explosive removal of materials[3,4]. Once generated, the blow-off plasma will induce a mechanical impulse to the target. If in the water region, the expansion of generated plasma is confined so that the plasma-induced recoiling pressure against the solid is increased. These studies were stimulated by the need to enhance the generated pressure initially for metallurgical studies, and more recently medical applications also use this concept.

Furthermore, there is cavitational bubble phenomenon in the water region when pulse laser operates. It is a special phenomenon of laser-matter interaction occurs in liquids. It plays an important role in the domain of hydromechanics and laser medicine. When the bubble collapses in the vicinity of solid boundary, a high-speed jet directed towards the wall is produced. When there is no water layer between bubble and solid boundary, the jet will cause a higher impulse against the wall. This impact force usually achieves a comparable value up to the yield strength of materials, which generally causes a tear to the target.

In this project, the materials of targets are pigmented granules in the dermal tissue. In the extremely shot time, the pigmented granules would experience a series terrible processes of high temperature, high pressure, and high intensity of impact force. The characteristics of acoustic wave generated by Q-switched laser on dermal pigmented lesions is studied. Clear signal curves of acoustic waves are obtained in the experiment. The experimental result shows that the amplitudes of the signals present a positive correlation relation with the energy intensity of the single pulse laser. This suggests that the acoustic wave signals have practical meanings of reference to the real-time control of laser energy intensity in the course of laser radiation of the therapy Q-switched laser on dermal pigmented lesions.

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