Analysis of the Implementation for Laser Techniques in Eye Surgery

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Abstract. As a matter of fact, the laser techniques have been rapidly development thanks to the improvements of material science offering high quality gaining material. With the advent of the chipper pulse amplification, Q-switch as well as mode lock techniques, high power femtosecond laser is available easily in recent years. Contemporarily, the femtosecond laser has become widely adopted in various fields, especially ophthalmic surgery. With this in mind, this study will provide an overview of femtosecond laser in usage for eye surgeon. To be specific, it will include principle, features, applications as well as other requirements for utilizing the facilities. Moreover, the state-of-art facilities will also be demonstrated at the same time. According to the analysis, the limitations will be demonstrated simultaneously. In addition, the improvements requirements as well as the possible routines will also be discussed. Overall, these results shed light on guiding further exploration of laser techniques in medical usage.

Keywords: Femtosecond laser system, eye surgery, laser ablation.

1. Introduction

In 1916, Albert Einstein defined the stimulated emission of identical photons from excited atoms. Due to the increased number of scientists, ideas generated during the war, and increased investment from the government and business, this theoretical framework had quickly grown following the end of World War II. Since Theodore Maiman's invention of the first laser, which produced a bright red light, more than 50 years have passed in which laser technology has advanced [1-3]. These days, lasers can fulfil the needs of a wide range of applications, including those in science, consumer goods, telecommunications, engineering, medical, dealing with materials, and a lot of other fields.

The FS laser is a solid-state infrared laser with a wavelength of 1053nm and a pulse duration of 100 femtoseconds (10^{-15}s), which causes stromal tissue disintegration by photon ionisation, resulting in the production of a rapidly growing cloud of free electrons and ionised molecules. Femtosecond laser has experienced three development stages in history, from the original dye laser to sapphire laser, and then to the latest photonic crystal fiber laser, a total of 40 years of development. With the development of technology, the pulse width of femtosecond laser is shorter and shorter, and the peak power of the pulse is larger and larger, and it has gradually moved from the laboratory to the industrial application [4-6]. It has follwing features:

- A very short pulse width. Pulse width refers to the duration when the laser power is maintained at a certain value. The duration of femtosecond laser are only a few femtoseconds, is currently the laboratory conditions to obtain the shortest pulse technology, Billy electronically method to obtain the shortest shorter pulses thousands of times.
- High pulse peak power. The peak power of a femtosecond laser is the instantaneous power it has during the pulse duration. Because of its extremely short duration, even in the case of small energy, its instantaneous power can reach 100 trillion watts, which is 100 times more than the current total power generation in the world, and it is one of the future energy choices.
- Covering a wide spectrum. A pulse width can contain up to millions of dozens of femtosecond pulse frequency spectrum composition, the equivalent of millions of keeping equal frequency with different center wavelength interval of continuous wave (the CW laser), the specificity of femtosecond laser in measuring standard and precise measurement of the major applications.

The following information will focus mostly on the use of femtosecond lasers in eye surgery. The first FS laser-assisted corneal surgery prototype was presented in the US in the early 1990s, and in 2001, it received FDA approval for the formation of corneal lamellae during LASIK. Improvements have occurred during the last two decades. The likelihood of negative effects and recovery time have been decreased with lower laser pulse intensity and higher frequency. The principal applications of the FS laser include producing LASIK flaps, reshaping the corneal bed, performing penetrating keratoplasty, and making corneal incisions. Furthermore, the FS laser may remove corneal lenticules to treat numerous kinds of ametropia [8].

The project intends to compile and synthesise information on the use of lasers in medicine, particularly femtosecond laser eye surgery. The purpose of the article is to analyse the treatment's guiding principles and to exhibit performances, facilities, and applications.

2. Basic Decscriptions and Principle

Femtosecond laser myopia surgery is a new generation of laser myopia surgery in the world. The surgical incision is small, and the whole process uses femtosecond laser to make microlenticular corneal slices, so as to change the corneal refractive power and achieve the purpose of correcting myopia. It in the femtosecond laser lens sheet, instead of excimer laser cutting; A new era of refractive surgery has been opened by replacing traditional corneal flap fabrication with a tiny incision. Because the surgical incision is in the twelve o 'clock direction of the cornea. The same cherry bite that smiles at the surgeon is also known as "SMILE smile surgery". All surgical correction for femtosecond laser myopia is wider: by comprehensive degrees 1000 degrees in the past, to expand to myopia. Within 1000 degrees, 500 degrees astigmatism. Its biomechanical stability: maintain the integrity of the corneal surface, the biomechanical stability of the whole cornea, long-term postoperative trauma, safety and worry free. Less chance of postoperative dry eye: Less damage from corneal surgery, less chance of dry eye [8].

A high-intensity laser beam that is concentrated at a point inside the eye and is less than a micron in width. The resulting electrons absorb photon energy and travel more quickly because multi-photon absorption causes some tissue molecules to ionise. As the process is repeated, electrons are able to reach a high enough kinetic energy and may be given enough energy to ionise molecules, continually producing electrons [9, 10].

When the electron density reaches $10^{20}/cm^{3f}$, a plasma constructed by plenty of free moving ions and electrons is generated, which is extremely absorbing for photons of all wavelengths. The remainder of the laser pulse is primarily absorbed by the plasma during the ablation process, leading to higher temperature and energy density.

The plasma with high thermal energy quickly converts to gases, resulting in the confinement of thermoelastic strains. Because of momentum conservation, stress waves with both tensile and compressive components emit. Once pulse energy density is delivered to an extent of suffice, the tensile stress wave becomes powerful enough to induce tissue fracture, resulting in the production of a cavitation bubble.

Furthermore, high temperature of the plasma, which creates water vapour and gases such as hydrogen, oxygen, methane, and ethane, might cause fast evaporation of tissue inside the focus volume. The growing pressure pulls the surrounding tissue further out, and the internal pressure eventually falls, even below the value in standard condition, due to the inertia of the ‘escaping’ material, resulting in the bubble dynamically bursting. Another shock wave might result from the bubble's demise. An overall sketch is given in Fig. 1.

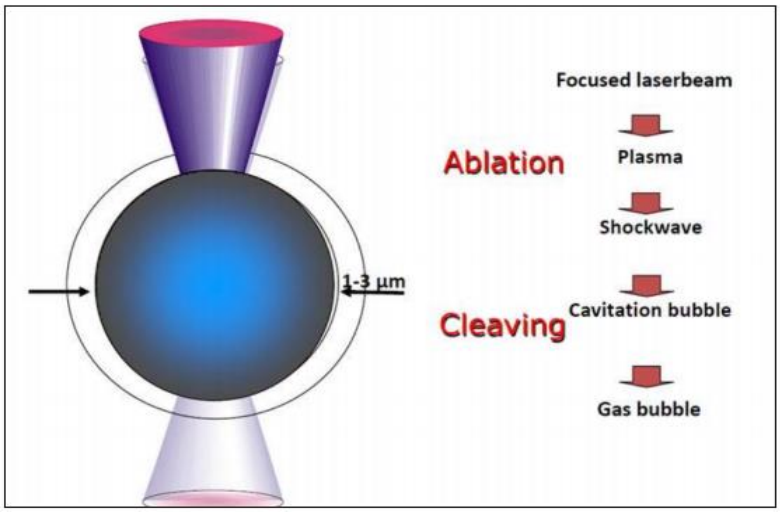

Figure 1. A skech of the FS laser surgery.

3. The State-of-art Facilities

The femtosecond laser refractive surgery system "VisuMax, it is the role of the femtosecond laser and excimer laser, completely avoid part of excimer laser corneal tissue ablation, but this part with femtosecond laser corneal tissue is made, the form complete, largely reduces the damage to the corneal physiological structure. A typical sketch of the facility VisuMax is shown in Fig. 2. The all-femtosecond laser refractive surgery system "VisuMax" leads the corneal refractive surgery into the all-femtosecond laser era. At present, the role of most brands of femtosecond laser systems in corneal refractive surgery is only to replace the corneal knife to make corneal flap. After the corneal flap is made, excimer laser is also used to ablate part of the corneal stromal layer thickness and reduce the corneal curvature (radian), so as to achieve the purpose of correcting myopia. And Carl. The Zeiss "VisuMax" system uses femtosecond laser to make the flap and reduce the corneal curvature, making the corneal refractive laser surgery goodbye to excimer laser for the first time. The VisuMax platform is to perform refractive correction by cutting tissue in the cornea, that is, to combine the action of femtosecond laser and excimer laser into one [10].

Figure 2. A skech of the FS laser surgery facility VisuMax.

4. Performances

Full femtosecond laser myopia surgery VS ordinary laser myopia surgery lamellar knife + excimer laser: the surgeon uses the corneal lamellar knife to manually make the open corneal flap, and then uses the excimer laser therapeutic instrument to perform corneal ablation. Postoperative visual acuity is fast, but the disadvantage is that the mechanical disc knife system has certain risk, may occur in corneal flap complications, postoperative corneal flap folds in under the action of external force and

displacement of the risk. Femtosecond laser + excimer laser: Compared with LASIK, it is safer and more accurate to use femtosecond laser instead of mechanical knife to make corneal flap, and then use excimer laser for corneal cutting. However, the above two ways, there will be about 20mm incision, and because of the use of excimer laser, the surgical laser process will smell burnt. Remind everyone: to understand all aspects and their own situation, in the professional doctor's advice to make a choice. If there is anything unclear, you can trust me. The range of myopia corrected by half-femtosecond and excimer laser surgery is within 1000 degrees. Full femtosecond laser surgery: full femtosecond primer surgery is more advanced, don't have to make open type flap, but with the cutting on the femtosecond laser therapeutic apparatus in the cornea, and then through a small incision around 2 mm. Because like a SMILE curved small incision, and the abbreviation of "whole femtosecond laser surgery" is a SMILE, so operation is also known as a SMILE. The full femtosecond laser surgery corrected myopia within 1000 degrees and astigmatism within 500 degrees. During laser scanning, lower negative eyeball pressure is attracted. Only about 2 mm incision without flap, so full of femtosecond laser is more suitable for love sports myopic patients. As a matter of fact, the laser surgery the main problem is the dry eye, glare. After surgery, according to the doctor's advice, develop good eye habits, but also healthy life. Don't do intense exercise, the vast majority of people will disappear in three months to half a year, because the full femtosecond incision is very small, so these symptoms will be reduced a lot. A typical processes is given in Fig. 3.

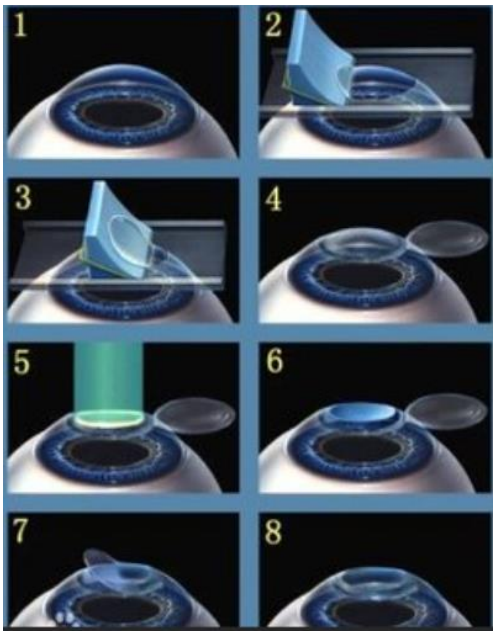

Figure 3. A skech of the FS laser surgery for eyes.

5. Applications

Due to the characteristics of very short pulse width, high peak power and wide spectrum coverage, femtosecond laser has many excellent characteristics in fine machining that traditional processes do not have. Very short pulse width, can generate extremely high power in an instant, so there is no excess heat, thus avoiding the material cracking, damage, melting and other phenomena in the processing process, and then get very high quality processing effect, which is particularly important for the fine machining of brittle materials such as glass and sapphire. It is precisely because of the excellent characteristics of femtosecond laser that it is increasingly used in the field of industrial production. Specifically, there are the following:

Special-shaped screen cut. Traditional mobile phone screen mostly USES the right Angle, this kind of screen making relatively simple, the technical level is relatively low. As people to full screen mobile phone is becoming more and more popular, however, if still use right Angle, easy to cause the screen is fragile, so it is necessary to screen for cutting. The phone's screen still is given priority to

with the LCD screen, the screen with glass as substrate, not only high hardness, and fragile, not appropriate with traditional cutting methods for fine processing. With the emergence of femtosecond laser direct cutting technology, because of its use of high power beam cutting, with high precision, good cutting effect, no damage to the material and many other advantages, so as to solve the shortcomings of the traditional process.

Factors to the three major characteristics of femtosecond laser can be widely used in processing all kinds of vulnerability and high-performance materials, such as glass, sapphire, ceramics, etc. Because the femtosecond laser focuses the beam into the ultra-fine space, the cracks in the material can be avoided during the processing, and the processed aperture has a smooth inner wall, which minimizes the generation of surface debris. Femtosecond laser can also be used for a variety of materials within the micro processing, etching, do the hyperfine processing.

In the medical field, due to the very short pulse width and high power of femtosecond laser, no excess heat is generated during the action, which greatly reduces the pain and additional injury of the patient. At present, the most mature femtosecond laser technology in the medical field is the treatment of myopia. The accuracy of the corneal flap made by femtosecond laser is controlled within 10 micmeters, which is much higher than the accuracy of the traditional plate knife layer, and effectively avoids the surgical complications that are easy to cause by using metal knife to make the corneal flap, and improves the safety of surgery.

With the continuous development of semiconductor materials, integrated circuits are becoming more and more miniaturized and complicated, which requires continuous refinement of processing technology, and the limitations of traditional manufacturing technology have become increasingly prominent. Semiconductor wafers, for example, are becoming thinner and smaller, making them more difficult to process. Femtosecond laser technology is a highly focused beam with extremely short laser pulses and extremely high peak power, so it is possible to remove an extremely thin layer of material without affecting the underlying material, so as to achieve material processing quality and accuracy.

6. Conclusion

To sum up, the FS laser assists several types of eye surgeons with sophisticated therapy. In terms of the good influence it has on surgical operations and the safety standards it meets, the FS laser is a well-developed technology. Nevertheless, there are some defects and drawbacks. The precise method via which bubbles are created during laser-induced optical breakdown has not been observed. Adhesion can be produced and exacerbated if bubbles flow randomly across the targeted flap region. This issue may result in flap rips, often known as a "opaque bubble layer." Furthermore, the probability of rainbow glare occurring during LASIK flap production is not negligible. Because the grating pattern on the rear side of the flap, which may have been made accidently by the surgeons, diffracts light and causes confusion. Although the limitations are significant, the significance of the FS laser in corneal surgery is well recognized. In the future, the uses and benefits of FS laser in the medical industry may grow and increase. Overall, these results offer a guideline for FS laser improvements in medical applications

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