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·专题综述·

Developments and Medical Applications for Compact Excimer Lasers

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Abstract: Improvements in materials and gas discharge technologies have enabled excimer lasers to be a primary tool for industry, medicine and research, especially for medical applications in the ultraviolet (UV) spectral range. In this paper, we talk about some medical applications of a kind of novel compact excimer lasers. In addition, current and future technological developments, such as solid-state switch, corona preionization and metal/ceramic cavity technologies, are discussed, which will strengthen the position of the compact excimer lasers in medical areas.

Key words: compact excimer laser; gas discharge; ultraviolet spectral range

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紧凑型准分子激光器的发展及其在医学中的应用

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摘　要: 由于在绝缘材料和气体放电技术方面的进展,处于紫外波段的准分子激光器已经在工业、科学研究,特别是医学等领域成为主要应用工具。在本文中,我们将介绍新颖紧凑型准分子激光器在医学中的应用。此外,在文章中对紧凑型准分子激光器所采用的关键技术,诸如固态开关、电晕预电离和金属/陶瓷腔等技术进行了详细的讨论。

关键词: 紧凑型准分子激光器;气体放电;紫外波段

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1 Introduction

Since their invention in 1972, excimer lasers have evolved from laboratory curiosities to the Primary tools of industry, medicine and R&D. Today, there are certainly not many types of lasers which have found such wide markets as excimer lasers (see Fig.1)[1]. Over the last years the main growth results from increasing industrial use followed by medical applications while new sales into R&D applications stay nearly constant. As the trend for "smaller size, better quality and higher speed" is evident in integrated microchips for information industry, medical and biotechnological applications. Nowadays, the compact excimer laser is the promising part due to its unique features: high repetition rates, long lifetime, ease to use and ease to system integrate.

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In the present paper we talk about the medical applications and developments of the compact excimer lasers respectively.

2 Medical applications

Up until a few years ago, laser surgery was performed almost exclusively with "hot-cut" lasers (usually Nd:YAG and Co_2 lasers). However, some ophthalmic and dermatologic surgery was not available with infrared lasers because of their intrinsic tissue heating and evaporating fluids. As far as the excimer laser is concerned, the ultraviolet laser beam and biological tissue interaction is described as photoablation (see fig. 2), so called "cold-cut".

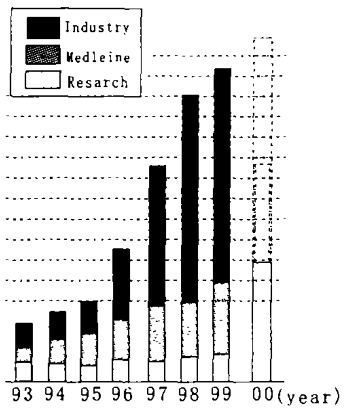

Fig.1 The development of total worldwide marlet of excimer lasers beween 1993 and 2000

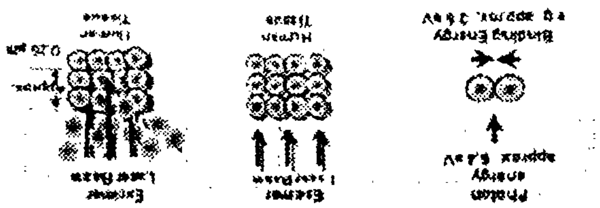

Fig.2 Principle of photoablation with excimer laser beam

The high photon energy of the excimer laser interacts directly with the molecule bondings of the exposed tissue. Therefore, the ultraviolet beam removes human tissue directly without side effects. The largest application of excimer lasers for medical use is refractive laser surgery. Excimer laser radiation at the wavelength of 193nm is extremely suitable for processing corneal biological tissue. Refractive laser surgery, in terms of reshaping the surface of the human cornea with a UV-excimer laser was proposed in 1983 by Steve Trockel and R. Srinivason[2]. In the early nineties first clinically controlled studies were performed and today it is almost a routine surgical procedure, which divided into the three different methods PRK, PTK and LASIK. With the development of compact excimer laser and surgery technology, we only talk about the advanced "customized ablation" LASIK surgery.

With the first generation of ArF excimer laser systems, excimer lasers with high output energies and low repetition rates are used. Because of the characteristics of the kind of excimer laser, large area "mask-projection" ablation mode was used to shape the corneal surface. In this mode, only spherical or regular astigmatic corrections on the eye could be performed. Besides, the so called central island phenomenon was a typical problem. With increasing reliability and accuracy of video keratographic systems, which generates a map of the radius of curvature of the patient's eye, the demand for a more flexible laser system for the corneal shaping laser systems arises. As a consequence, "flying spot" scanning compact excimer laser system were introduced for clinical applications. Here a smaller beam and homogenizer diameter of less than 2mm is scanned across the corneal surface. Due to the smaller beam diameter and the gained flexibility caused by the scanning procedure, a variety of irregularities on the corneal surface can be corrected[3,4]. The customized ablation is based on measurements of the corneal topography or the wavefront deviations[5] when the light passes the cornea and lens by means of an aberrometer. Wavefront optical aberrations usually are induced by the cornea and the lens at the periphery, where their natural shape deviates from the ideal shape.

Besides, 248nm radiation of KrF excimer laser show better transmission but this wavelength is not permitted for medical applications due to its high mutagenic risk. At 308nm XeCl laser the mutagenic risk is neglectable and fiber transmission is satisfactory. Though the absorbance has decreased to more than one order of magnitude at 308nm, surgical interventions which allow a thermal damage of some 10μm and possible applications. The main clinical application for 308nm radiation is laser angioplasty where occluded vessels are opened by means of photoablation via an optical fiber. The future promising attempts of 308nm XeCl photoablation are dermatology to reduce psoriasis plaque and another ophthalmological application to reduce the introcular pressure on glaucoma surgery through optical fiber delivery system.

3 Compact excimer laser developments

the excimer laser has found its place in industry and medicine in large part because of the metal/ceramic cavity as halogen and UV-resistant insulators. In combination with the solid state switch and corona preionization, the compact lasers can now be operated in 2kHz and more than 1 billion pulse lifetimes[6].

The heart technology of any excimer laser is its electrical discharge circuit including high voltage switch, capacitors for energy storage and transfer, preionization arrangement and electrodes design. The first excimer lasers did use thyratrons as fast high voltage switches in rather conventional electrical circuits. The pulsed power circuit must switch tens of kilovolts on a few nanosecond time scales. Later commercially and mutually excimer lasers are normally pumped by high voltage pulse power circuit in combination with the magnetic switch control (MSC). However, the development of very high repetition rates compact excimer laser in the mid and late 90's met the limit of the MSC technology. At 2KHz repetition rates, for example a thyratron would survive only 23 days or less. The key to solve the lifetime issue was solved by completely eliminating the thyratron and replace it by semiconductor. The developments of the pulsed power circuit with low voltage semiconductor switch combined with magnetic isolator and pulse transformer to achieve the required discharge voltage could be introduced into the compact excimer laser.

A decisive breakthrough towards a longer service lifetime and more homogenous discharge in compact excimer laser was achieved with the optimization of corona preionization (Fig.3). To ignite a homogenous high pressure glow discharge, the gas must be ionized about 100ns before the main discharge. For this purpose, the beam was traditionally produced by spark preionization method, while corona primer is the advanced method compared with the conventional method. The result is a more homogenous ignition effect and leading to an impressive pulse to pulse stability, less electrode erosion.

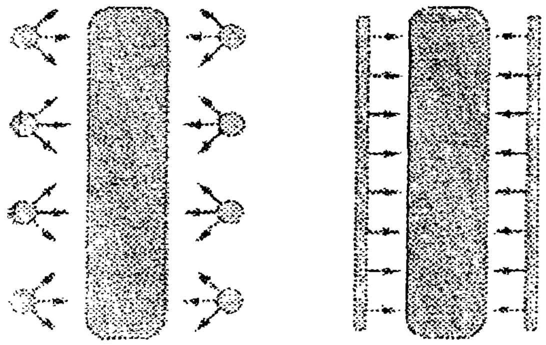

Fig.3 Spark preionization (left), proceeds from discrete spark gaps while corona preionization (right) is homogenously radiated over the electrode length.

Internal corrosion has long been one of the most serious problems limiting excimer laser performance and reliability. Over time, the corrosive gases used in excimer laser chemically react with the laser tube and its components. These resulting contaminants quench laser action, thereby reducing laser operation efficiency which can significantly limit the lifetime of a gas fill. Another milestone in the compact excimer laser technology is achieved by the development of the metal/ceramic laser cavity construction that significantly reduces corrosion. Specifically all insulators and high voltage feedthrough in the laser cavity are made from corrosion resistant high density ceramics. The metal parts of the laser tube are of special carbon- and silicon-free alloys to avoid the generation of contaminants such as SiF4 and CF4, which have a detrimental effect onto laser operation even at low concentration at the ppm level[7].

4 Conclusions

In the more than 25 years after their discovery excimer laser have been used increasingly in a variety of R&D, medical and industrial applications. The key of the success of the excimer laser is its unbeatable UV performance with power levels and photo energy not available from any other laser source. Compact in design can be integrated into virtually and medical system. Revolutionary and evolutionary technological achievements have translated into significant improvements of the parameters, the performance, and the ease of handling and reliability of compact excimer laser. In the long run, the compact excimer laser will experience healthy competition in medical field.

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Biography

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