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Enhancing precision in refractive surgery: a study of low-energy femtosecond lasers

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This work aims to enhance the precision and safety of refractive surgery by developing a compact, cost-effective femtosecond laser system with a high repetition rate. The motivation behind this research stems from the need to improve surgical accuracy, which is hypothesized to be achievable through higher laser repetition rates (1), a feature characteristic of compact resonators. In line with this, a low-energy Kerr-lens mode-locked Ti:Sapphire laser oscillator was developed, operating at a 1 GHz repetition rate. This laser, utilizing a bow-tie cavity with dispersion-compensating mirrors and a Peltier temperature regulation system (2), achieved an average output power of 0.94 W at 7.4 W of pump power, with a broadband emission centered at 756 nm. Despite generating low-energy pulses of 1 nJ with a temporal width of 61 fs and a peak power of 15 kW, the energy output was insufficient for direct application in refractive surgery. To overcome this limitation, an in-depth analysis of laser-PMMA interactions was conducted using Polymethyl methacrylate (PMMA) as a corneal surrogate. This analysis aimed to elucidate the laser-induced ablation parameters essential for surgical applications. The study involved micromachining techniques characterized by surface and volume analysis, conducted with two different femtosecond lasers, examining varying combinations of pulse overlap and energy levels to determine the threshold pulse energy required for damage. (3) The results revealed that higher repetition rates with low-energy pulses produced more precise damage compared to high-energy, low repetition rate pulses. These findings indicate that compact, high repetition rate femtosecond lasers with low-energy pulses offer substantial potential for improving the precision of refractive surgeries, while also facilitating equipment miniaturization and cost reduction.

Palavras-chave: Femtosecond laser; Laser-matter interaction; Laser surgery.

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