Development of Picosecond 755-nm Alexandrite Laser for Treatment of Skin Aging

Seokwon Oh, MS
Hanyoung Ryu, PhD
Youngseok Seo, PhD

R&D Center, Wontech Co., Ltd., Daejeon, Korea

We have developed a picosecond 755 nm alexandrite laser system. To generate picosecond laser pulses, we used self-injection techniques including Q-switch and cavity dump without mode-locking method. We have achieved through a comprehensive combination of complex optical technique, thermodynamic design, high power design, high-speed driver, and precise control technique. The uniform energy of the beam profile allows a safe and effective treatment outcome to be predicted.

Key words

Picosecond laser, Alexandrite laser, Picowon, Removing tattoos, Pigmented lesions

Supplementary video file: This article contains supplementary material (It is available at <https://youtu.be/71mHV0nxHwM>).

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Correspondence

Youngseok Seo
R&D Center, Wontech Co., Ltd., Daejeon
34028, Korea
E-mail: Physys@wtlaser.com
<https://orcid.org/0000-0001-7939-5428>

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INTRODUCTION

In the past decades, lasers with shorter pulses have been developed in a variety of industries including medical, defense, semiconductor, and manufacturing. Since the report of selective photothermolysis, various medical laser devices have been developed to more precisely achieve the challenge of treating pigmented lesion [1]. In dermatology, picosecond lasers treat lesions with 1/3 to 1/2 of the energy used in nanosecond lasers. Picosecond lasers have more photoacoustic effects and less photothermal effects, compared to nanosecond lasers [2,3]. Therefore, the risk of collateral damages to surrounding tissue is less. As more people want to obtain younger and healthier appearing face themselves, picosecond laser treatment is a quickly growing field in cosmetic dermatology.

A 755 nm alexandrite picosecond laser device, Cynosure's Picosure™, was first approved by U.S. food and drug administration (FDA) in December 2012 [4]. Alexandrite picosecond laser is used for skin rejuvenation, removing tattoos, treating a scar, and pigmented lesions [5,6]. The laser gain medium of alexandrite ($\text{Cr}^{3+}:\text{BeAl}_2\text{O}_4$) lasers is an alexandrite crystal doped with chromium ions (Cr^{3+}). One has to consider that in contrast to Nd:YAG lasers, alexan-

drite lasers are not four-level lasers but are operated in a quasi-four-level regime, as shown in Fig. 1 [7]. Alexandrite laser can be operated at wavelengths in the range from 700 to 800 nm, in many cases around 755 nm, where the maximum laser gain can be achieved. Alexandrite also has a large gain variation depending on temperature, and polarization-dependent absorption [8,9].

To generate a picosecond laser pulse, we used the self-injection technique, including Q-switch and cavity dump, without mode-locking method [10]. A high voltage and ultra-fast driver are required for cavity dumping. Laser head was composed of alexandrite crystal rod, Pockels cell, polarizer, high reflective coating mirror, and an output coupler (partially-reflective mirror), as shown in Fig. 2. Dual Xenon flash lamps were used as a light pumping source. To maintain the uniform temperature of alexandrite crystal and flash lamp, the water-cooling system and heater were designed and applied.

RESULTS AND CONCLUSION

We have been developed a picosecond 755 nm Alexandrite laser system, and named the system "PICOWON". The laser output pulse width can be adjusted by varying amplitude (voltage) and width (picosecond) in the pulse generator. The developed laser typically can be operated at pulse width in the range from 600 to 800 ps. Fig. 3 shows the laser output pulse width measured using a digital oscilloscope (DPO 4104B/1GHz 5GS/s, Tektronix) and silicon pho-

Fig. 1. Energy levels and laser transition of the quasi-four-level alexandrite laser [7].

Fig. 2. Schematic diagram of the laser cavity.

Fig. 3. Measured laser output pulse width.

Fig. 4. Measured laser output beam profile.

Table 1. Developed laser system specifications

Specifications	Value
Wavelength	755 nm
Laser type	Picosecond Alexandrite Laser
Pulse energy	230 mJ
Pulse width	600-800 ps
Peak power	0.33G W (700 ps)
Pulse rate	1-10 Hz
Spot size	2, 3, 3.5, 4, 5, 5.5, 6, 8 mm
Start up time	< 15 minutes
Dimensions	500(W) * 960(D) * 900(H)
Weight	100 Kg

photodetector (ET-2030, EOT). The maximum average output energy of 230 mJ was achieved in the picosecond regime. To increase the repetition rate, the thermal lens effect must be compensated. Therefore, we performed a task to stabilize the temperature of the laser head and increased the repetition rate to 10 Hz. Fig. 4 shows the beam profile measured using laser cam-HR (1098577, Coherent). It shows a top hat-shaped beam pattern and means a uniform spatial distribution.

Table 1 shows features of developed 755 nm picosecond laser specifications. We developed two types of handpieces, which are zoom and MLA (Micro Lens Array) handpiece with spot size in the range from 2 to 8 mm.

DISCUSSION

Wontech developed the first commercially available alexandrite picosecond laser in Korea, as shown in Fig. 5. To make a high-efficiency alexandrite picosecond laser, it can be achieved through a comprehensive combination of com-

Fig. 5. Developed picosecond laser (PICOWON).

plex optical technique, thermodynamic design, high power design, high-speed driver, and precise control technique. High peak power in shorter pulse duration provides better efficacy in treatments of pigments, tattoo removal. Uniform energy of the beam profile allows safe and effective treatment results to be predicted.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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