Energy deposition depth of a Nd:YAP laser in human skin

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SUMMARY

Nd:YAP laser emitting at 1342 nm appears promising for nonablative skin rejuvenation, due to lower absorption in epidermal melanin and higher absorption in water as compared to the 1064 nm light from Nd:YAG lasers. The aim of our study was to verify these relations in vivo and quantify the energy deposition depth of a Nd:YAP laser in intact human skin. A comparison with the results obtained with more common Nd:YAG laser should enable design of a safe and effective treatment protocol for future human studies.

Measurements were performed on the forearm of a healthy volunteer with Fitzpatrick skin type II. The test site was tape-stripped to remove the superficial layer of stratum corneum and irradiated with a prototype Nd:YAP laser (Fotona d.d., Ljubljana) with a 5 ms pulse duration and radiant exposure of 2.8 J/cm^2. For comparison, the same test site was irradiated also with a commercial Nd:YAG laser (Dualis VP; Fotona) at 1064 nm, 5 ms pulse duration and radiant exposure of 1.5 J/cm^2.

Energy deposition of both lasers was characterized using pulsed photothermal radiometry (PPTR). This technique is based on measurement of transient change in mid-infrared (IR) emission following pulsed laser exposure. It allows reconstruction of laser-induced temperature depth profiles in optically scattering biological tissues in a non-invasive and non-contact manner.[1, 2]

The mid-IR radiation emitted in the spectral range of 3–5 μm was collected using a fast IR camera (SC 7500, by FLIR). Calibrated radiometric signal transients were obtained from a 1.5 × 1.5 mm^2 area in the center of the irradiated test site. Laser-induced temperature profiles were then reconstructed from such PPTR signals using a custom iterative minimization algorithm, developed and implemented recently in our group [1].

Fig. 1 presents the resulting depth profiles of temperature rise, induced in the test site using the Nd:YAP or Nd:YAG laser. Both temperature profiles feature a pronounced subsurface peak at approximately 30 μm, corresponding to epidermal melanin absorption, and a monotonic (nearly linear) decrease starting from a secondary subsurface peek, deeper in the dermis. A quantitative analysis reveals that, on average, 90% of the absorbed laser energy was deposited within the top 0.9 mm of skin when using the Nd:YAP laser. With the Nd:YAG laser, in contrast, 90% of the absorbed energy was deposited at the depth up to 1.2 mm.

For presentation in Fig. 1, both profiles were scaled up to reach the same maximal temperature rise of 40 °C, which roughly corresponds to the thermal damage threshold for the epidermis. (The corresponding radiant exposures are given in the legend). The results indicate that at such conditions, temperature rise in the upper dermis achievable with the Nd:YAP laser is nearly twice as large as with the Nd:YAG laser. At the same time, the former laser induces a lower temperature rise than the latter at dermal depths beyond approximately 0.8 mm.

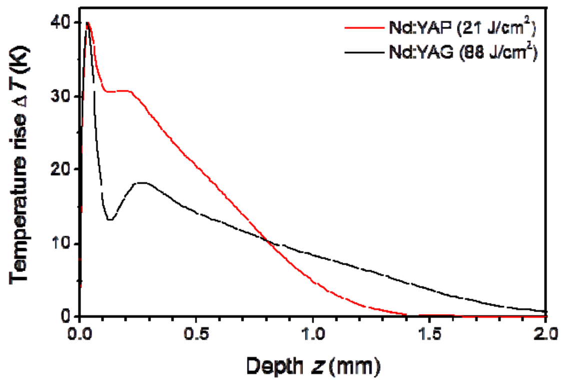

Fig. 1: Temperature rise induced in intact human skin by irradiation with Nd:YAP (*red line*) and Nd:YAG lasers (*black line*). Both temperature profiles are normalized to the maximal temperature rise of 40 °C, reached in the epidermis (note the corresponding radiant exposures given in the legend).

Sinvce non-ablative rejuvenation targets primarily dermal components in the papillary and reticulary dermis, up to 0.5 mm below the skin surface [3], we can conclude that the Nd:YAP laser is more suitable for nonablative photorejuvenation of skin than Nd:YAG.

In conclusion, our measurements suggests that the Nd:YAP laser should allow a controlled heating of the upper dermis at a lower risk for thermal damage to the epidermis and subcutis when compared with the customary Nd:YAG laser.

Acknowledgment

The authors thank Fotona d.d. for the loan of laser equipment.

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