

## Depth of Penetration

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### **Depth of penetration of an 850nm wavelength low level laser in human skin.**

[Esnouf A](#), [Wright PA](#), [Moore JC](#), [Ahmed S](#).

School of Health Sciences and Social Care, Brunel University, Uxbridge Campus, UB8 3PH, UK. alan.esnouf@brunel.ac.uk

Low Level Laser Therapy is used for a wide variety of conditions including superficial skin sores, musculoskeletal and joint problems, and dentistry. Knowledge of the penetration depth of laser radiation in human skin is an essential prerequisite to identifying its method of action. Mathematical simulations and estimates from the literature suggest that the depth of penetration of laser radiation using wavelengths from 630nm up to 1100nm may be up to 50mm. The aim of this study is to directly measure the penetration depth of a Low Level Laser in human tissue. Human abdominal skin samples up to 0.784mm thickness were harvested by dermatome following abdominoplasty procedures. These samples were irradiated by a Gallium Aluminium Arsenide Laser (Wavelength 850nm near infra-red invisible light, 100mW, 24kHz, 0.28mm diameter probe) and the transmitted radiation measured with an Ophir Optronics 'Nova' external energy meter. The intensity of laser radiation reduced by 66% after being transmitted through a 0.784mm sample of human abdominal tissue. In this study most laser radiation was absorbed within the first 1mm of skin.

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### **NIR Light Penetration Depth in the Rat Peripheral Nerve and Brain Cortex.**

[Abdo A](#), [Sahin M](#).

Department of Biomedical Engineering, New Jersey Institute of Technology, NJ, USA.

Near infrared (NIR) light energy has been used in medical applications both for diagnostic and treatment purposes. A priori knowledge of optical tissue properties is necessary in these applications; not only of human but also in animals for testing of devices. However, published data on the optical properties of neural tissue in rodents are

rare. The aim of this study was to measure the penetration depth of light into the rat peripheral nerve and brain cortex at NIR wavelengths. Penetration depth was calculated from measurements of transmitted light for various thicknesses of the neural tissue. We found the penetration depth in the rat sciatic nerve to be  $0.35 \pm 0.023$  mm and in the white matter  $0.35 \pm 0.026$  mm. The penetration depth of the gray matter was  $0.41 \pm 0.029$  mm. Compared to the data reported in literature for the human brain, the rat peripheral and the brain cortex attenuate the NIR light much more strongly.

[Phys Med Biol.](#) 2004 Nov 7;49(21):4861-77.

## **Comparison of human skin opto-thermal response to near-infrared and visible laser irradiations: a theoretical investigation.**

[Dai T](#), [Pikkula BM](#), [Wang LV](#), [Anvari B](#).

Department of Bioengineering, Rice University, Houston, TX 77251, USA.

Near-infrared wavelengths are absorbed less by epidermal melanin, and penetrate deeper into human skin dermis and blood than visible wavelengths. Therefore, laser irradiation using near-infrared wavelengths may improve the therapeutic outcome of cutaneous hyper-vascular malformations in moderately to heavily pigmented skin patients and those with large-sized blood vessels or blood vessels extending deeply into the skin. A mathematical model composed of a Monte Carlo algorithm to estimate the distribution of absorbed light, numerical solution of a bio-heat diffusion equation to calculate the transient temperature distribution, and a damage integral based on an empirical Arrhenius relationship to quantify the tissue damage was utilized to investigate the optothermal response of human skin to near-infrared and visible laser irradiations in conjunction with cryogen spray cooling. In addition, the thermal effects of a single continuous laser pulse and micropulse-composed laser pulse profiles were compared. Simulation results indicated that a 940 nm wavelength induces improved therapeutic outcome compared with a 585 and 595 nm wavelengths for the treatment of patients with large-sized blood vessels and moderately to heavily pigmented skin. On the other hand, a 585 nm wavelength shows the best efficacy in treating small-sized blood vessels, as characterized by the largest laser-induced blood vessel damage depth compared with 595 and 940 nm wavelengths. Dermal blood content has a considerable effect on the threshold incident dosage for epidermal damage, while the effect of blood vessel size is minimal. For the same macropulse duration and incident dosage, a micropulse-composed pulse profile results in higher peak temperature at the basal layer of skin epidermis than an ideal single continuous pulse profile.

[Lasers Med Sci.](#) 2002;17(2):70-8.

## **Correlations between light penetration into skin and the therapeutic outcome following laser therapy of port-wine stains.**

[Ackermann G](#), [Hartmann M](#), [Scherer K](#), [Lang EW](#), [Hohenleutner U](#), [Landthaler M](#), [Bäumler W](#).

Department of Dermatology, University of Regensburg, Germany.

For several years the flashlamp-pumped pulsed dye laser (FPDL) has been the favoured method for the treatment of port-wine stains (PWS). The therapeutic outcome of FPDL laser therapy depends on the anatomical location of the PWS and is mainly attributed to morphological parameters such as size and depth of the PWS blood vessels. The aim of this study was to show a correlation between the therapeutic outcome following FPDL therapy and the optical properties of the skin overlying the PWS vessels. For this purpose the therapeutic outcome following FPDL treatment (585 nm; 0.45 ms) of 884 PWS situated on different body sites was evaluated by judging the grade of fading of PWS colour. On the other hand the light penetration into 123 skin samples (thickness 0.10-1.35 mm) was determined between 450 nm and 1030 nm and compared with the PWS laser therapy outcome for equal locations by statistical analysis. PWS on the neck, trunk, arms or legs yielded a higher mean grade of fading as compared to PWS on the head. Within the face, a wide range of fading was evident. The light penetration into skin increased linearly with increasing wavelength and location-dependent differences were found. The attenuation coefficient was  $22.8 \pm 5.3 \text{ mm}^{-1}$  at 585 nm. No significant or strong correlation was observed between the therapeutic outcome of PWS laser therapy and the light penetration into skin. However, a correlation was obvious by plotting the respective profile plots. Therefore, among other effects, in particular morphological parameters of PWS vessels, the optical properties of the skin contribute to a small extent to the clinical outcome of PWS laser therapy.

[Lasers Med Sci](#). 2001;16(3):224-9.

## **Does low penetration of human skin by the normal mode ruby laser account for poor permanent depilatory success rates?**

[Topping A](#), [Gault D](#), [Grobbelaar A](#), [Sanders R](#), [Green C](#), [Linge C](#).

RAFT Institute of Plastic Surgery, Mount Vernon Hospital, Northwood, Middlesex, UK.

Studies reported to date have shown a good depilatory response from patients treated with the normal mode ruby laser (NMRL) over 12 weeks, but a low response over a time period greater than this. Previous publications have suggested that this could be

accounted for by the apparently poor skin penetration of laser light and so this study attempted to assess whether this was indeed the case. Skin samples of varying thicknesses were taken from six Caucasian patients and their depths measured. Each was laid individually on an energy meter before having pulses from an NMRL compatible with clinical doses (4.75 J/cm<sup>2</sup>, 9.24 J/cm<sup>2</sup> and 13.41 J/cm<sup>2</sup>) fired on the epidermis. Several samples had the laser fired repetitively on the surface to assess whether this caused any change in laser/skin fluence depth profiles. Repetitive firing of the NMRL on the epidermis of skin samples did not alter the energy recorded by the meter beneath. The fluence/depth profiles were constructed showing the majority of energy was lost within the first 1 mm of the skin surface (50%) which then further reduced over distance but at a much slower rate. The maximum depth of penetration was 14.8 mm (SD +/- 0.478) which appeared to be a function of wavelength and not fluence. The results suggest that laser penetration of skin should be adequate for generating enough heat at the hair bulge and bulb, potentially causing permanent damage. The implications of this study are that it is probably the presence of the correct chromophore in large enough amounts which is required for successful permanent depilation to occur.

[BJU Int.](#) 2000 Oct;86(6):638-43.

## **Light penetration in bladder tissue: implications for the intravesical photodynamic therapy of bladder tumours.**

[Shackley DC](#), [Whitehurst C](#), [Moore JV](#), [George NJ](#), [Betts CD](#), [Clarke NW](#).

Paterson Institute for Cancer Research, Christie Hospital, Departments of Urology, Hope Hospital, Salford Royal Hospitals Trust, Salford, South Manchester University Hospital, and Christie Hospital, Manchester, UK.

**OBJECTIVES:** To assess (i) the optical properties and depth of penetration of varying wavelengths of light in ex-vivo human bladder tissue, using specimens of normal bladder wall, transitional cell carcinoma (TCC) and bladder tissue after exposure to ionizing radiation; and (ii) to estimate the depth of bladder wall containing cancer that could potentially be treated with intravesical photodynamic therapy (PDT), assuming satisfactory tissue levels of photosensitizer. **Materials and methods** The study included 11 cystectomy specimens containing invasive TCC (five from patients who had previously received external-beam bladder radiotherapy, but with recurrent TCC) and three 'normal' bladders removed from patients treated by exenteration surgery for extravesical pelvic cancer. Full-thickness bladder wall and tumour samples were taken from these specimens and using an 'intravesical' and a previously validated interstitial model, the optical penetration depths (i.e. the tissue depth at which the light fluence is 37% of incident) were calculated at wavelengths of 633, 673 and 693 nm. **RESULTS:** There were no significant differences in light penetration between normal and tumour-affected bladder tissue at each wavelength. There were significant differences in light penetration among wavelengths; light at 693 nm penetrated approximately 40% further than light at 633 nm ( $P < 0.002$ ). The light currently used in bladder PDT (633 nm) has a mean (SEM) optical

penetration depth of 4.0 (0.1) mm within TCC. In addition, at this wavelength, there was 29% greater light penetration in previously irradiated than in unirradiated bladder wall ( $P = 0.001$ ). This did not occur in the tumour-affected bladder. **CONCLUSIONS:** Bladder tissue is relatively more translucent than other human tissues and there is therefore great potential for PDT in the treatment of bladder cancer. As there is no difference in light penetration between TCC and normal bladder tissue, a tumour-specific response with diffuse illumination of the bladder will depend on drug localization within the tumour. The currently used wavelength of 633 nm can be expected to exert a PDT effect within bladder tumour up to a depth of 20 mm. Increasing the wavelength will allow deeper pathology to be treated.

[Phys Rev E Stat Phys Plasmas Fluids Relat Interdiscip Topics](#). 2000 Feb;61(2):1899-903.

## **Measurement of the energy penetration depth into solid targets irradiated by ultrashort laser pulses**

[Fraenkel M](#), [Zigler A](#), [Henis Z](#), [Eliezer S](#), [Andreev NE](#).

Racah Institute of Physics, Hebrew University, Jerusalem, Israel.

The energy penetration depth of a short (100 fs) Ti-sapphire laser pulse (0.8  $\mu\text{m}$ ) of intensity  $3 \times 10^{16}$  W/cm<sup>2</sup>, in solid density materials has been measured. High-Z (BaF<sub>2</sub>) and low-Z (MgF<sub>2</sub>) solid layers targets were used. The penetration depth was determined from the measurement of the x-ray emission spectra, as a function of the target thickness. The investigation of these spectra showed that in the low-Z case, solid density material to a depth of 50 nm was heated to a peak electron temperature of approximately 150 eV. For the high-Z material, the penetration depth corresponding to this temperature exceeded 100 nm. This is evidence of a larger heat penetration depth in a high-Z material in comparison to a low-Z material. A model based on electron heat conduction is used to estimate the energy penetration depth. It is suggested that the larger heat penetration in high-Z material is due to heating of the material, caused by the radiation flux, generated by the electron heat conduction.

[Acupunct Electrother Res](#). 1993 Jan-Mar;18(1):17-21.

## **Poor penetration of infra-red and helium neon low power laser light into the dermal tissue.**

[Kolari PJ](#), [Airaksinen O](#).

Department of Physical Medicine and Rehabilitation, Kuopio University Hospital, Finland.

The skin transmittance for low power laser light was studied in vitro. The penetration of both He-Ne and infra-red lasers was observed for only a few millimeters. The most important absorption was observed at the depth level of 0.4 and 0.5 mm. These results suggested that the dermal vascular plexus barrier seemed to decrease the penetration at that level. This finding should mean that the laser therapy did not have really direct effects on the deep tissues. However, the effects can be mediated by many different pathways.