PicoWay Mechanism of Action

The PicoWay from Syneron-Candela is a picosecond pulse solid-state laser system intended to treat skin conditions with high pulse energy and extremely short duration in the range of 300-500 picoseconds (ps)[1]. The device is capable of operation at 1064 nm and 532 nm wavelengths.

Effect of pulse duration on treatment efficacy
Until now, the most commonly used lasers for tattoo removal employ 5-50 nanosecond (ns)[2] pulse durations which are adequate to target micrometer-sized pigment granules because of the comparable thermal relaxation time of the larger particles. These pulse durations are readily generated by Q-switched lasers.

Tattoo pigment particle fragmentation occurs from a buildup of pressure, also known as stress, caused by rapid heating of the particle by short laser pulses. For rapid heating of tattoo particles, there are three major sources of photomechanical stress: thermal stress, acoustic stress, and explosive vaporization.

Photothermal stress occurs when the expansion of the tattoo particle from rapid heating is restricted by the medium it resides in. As the particle expands during rapid heating, there is pushback from the water and tissues in the skin causing a rise in pressure known as thermal stress, which can be significant and large enough to cause fracture of the particle.

Photoacoustic stress occurs when the laser pulse width is so short that the particle cannot expand fast enough, leading to a buildup of pressure which leads to particle fracture.

Explosive vaporization occurs when short, thermally confined laser pulses are used which cause the temperature of the tattoo granules to reach upwards of 1000°C. As heat diffuses into the tissue, the water in the tissue rapidly heats beyond its boiling point and becomes superheated. Once nucleated, the superheated water boils with explosive forces. Resident cells such as macrophages and fibroblasts (for tattoo granules) and melanocytes and keratinocytes (for melanosomes) are ruptured as a result of these forces and release the pigments into the cytoplasm[3] where the body is better equipped to clear the pigments via lymphatic drainage and other mechanisms.

Similar to selective photothermolysis, thermal stress is optimum when the laser pulse is short compared to both the thermal diffusion time and the acoustic diffusion time and is related to the particle size.

Common Q-switched lasers available today have pulse widths of 5ns or more and are clearly not optimum for tattoo clearance procedures. They lack acoustic stress confinement and are just barely thermally confined even at the larger particle sizes.

At picosecond laser pulse widths, acoustic stress can be orders of magnitude larger than thermal stress leading to more efficient fracturing for similar pulse energies, particularly for smaller pigmented particles. In addition, with picosecond lasers, less pulse energy is required to achieve similar acoustic fracture pressures, resulting in a reduced risk of scarring.

Picoway's picosecond pulses more effectively confine the energy to the pigment particle, resulting in increased photoacoustic breakup of the target. This allows for effective treatment with lower fluences, thereby decreasing the thermal energy transfer to surrounding tissues and minimizing the risk of scarring. Picoway has pulse durations shorter by an order of magnitude than those of Q-switched lasers allowing the laser energy to reach the pigment more effectively, and with less interaction with surrounding tissues. (Figure 1)

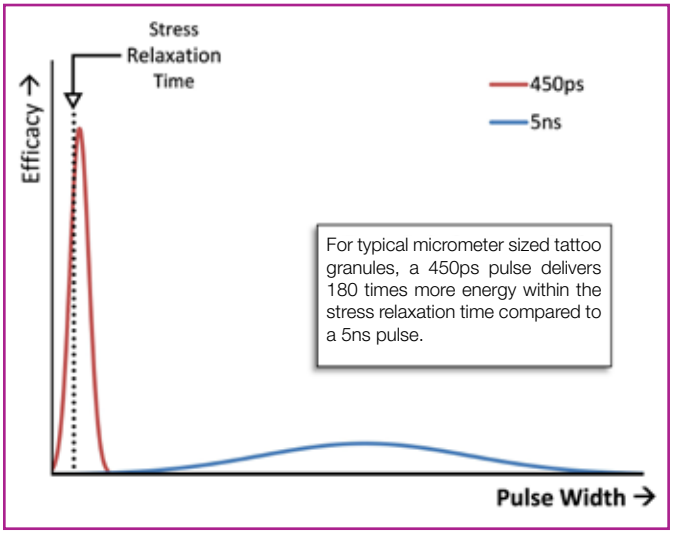


Figure 1: Comparison of the efficacy of PicoWay's picoseond laser pulse with Q-Switch laser pulse.

[1] Picosecond - (ps) a unit of time equal to 10^{-12} of a second
[2] Nanosecond - (ns) a unit of time equal to 10^{-9} of a second
[3] Cytoplasm - the gel-like substance enclosed within the cell membrane containing all the of the contents of the cells
[4] Basement membrane - a thin sheet of fibrous tissue underlying the epidermis and separating the upper epidermis layer of skin including melanosomes from the lower dermal layers.

Pigmented Lesions

Dyschromia is caused by an imbalance in the amount of melanosomes in skin, either too little (hypopigmentation) or too much (hyperpigmentation) relative to adjacent skin. Melanosomes are normally located in the epidermis but occasionally can break through the basement membrane[4] and reside in the upper dermis as in melasma.

Similar to tattoo granules, melanosomes are more effectively treated with picosecond pulses compared to nanosecond lasers. Most melanosomes fall into one of two classes, the brown to black eumelanosomes or yellow-reddish pheomelanosomes. Each melanosome is quite large and holds many (1000+) melanin particles, each particle being 10 to 15nm in diameter. Therefore the mechanism of action is predominantly fragmentation of melanosomes and scattering of the melanin particles.

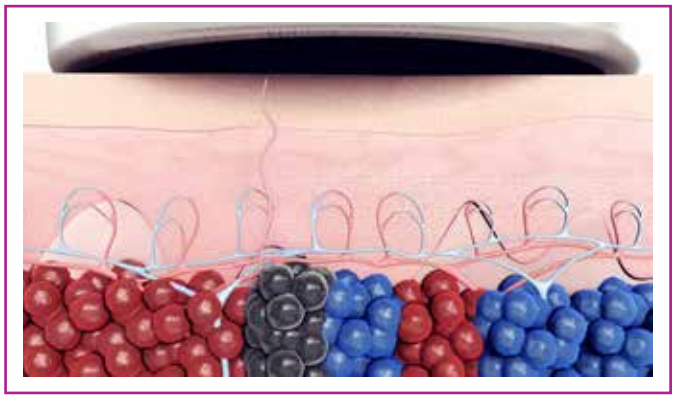
PicoWay's 532nm wavelength delivers more effective treatments for pigmented epidermal lesions due to the 8-fold higher absorption of melanin at 532nm compared to 1064nm. The 1064nm wavelength can be effective if less aggressive treatment is desired or deeper dermal treatments are preferred such as for melasma.

Pigmented epidermal lesions include solar lentigines, ephelides, café au lait macules and seborrheic keratosis, while pigmented dermal lesions include melanocytic nevi, blue nevi, nevus of Ota, and nevus of Ito. Mixed epidermal and dermal pigmented lesions include melasma, Becker's nevus, nevus spilus, and postinflammatory hyperpigmentation.

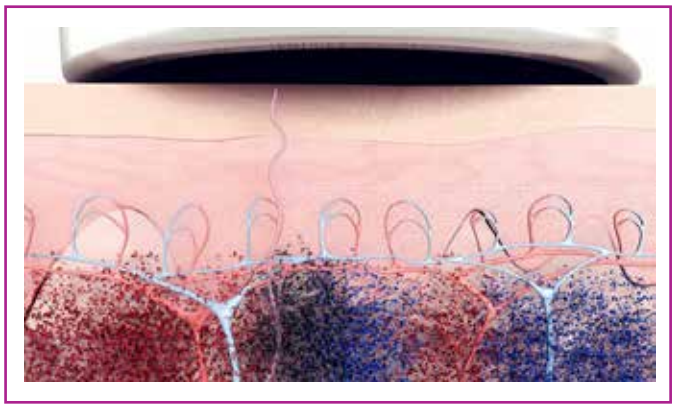
Tattoo Removal

Tattoos consist of thousands of particles of tattoo pigment suspended in the skin. While normal human growth and healing processes will remove small foreign particles from the skin, tattoo pigment particles are permanent because they aggregate into resident cells and become too large to be removed. To selectively target tattoo ink, the best wavelength is chosen to achieve selective absorption for each ink color, while minimizing the nonspecific thermal effects from the primary endogenous chromophores, hemoglobin and melanin. (Figure 2)

Figure 2:



a. Tattoo ink before PicoWay treatment



b. PicoWay technology shatters the pigment into miniscule particles that can easily be removed by the body.

The mechanism for laser removal of tattoos is widely believed to be a two-step process. In the first step, the short laser pulse causes instantaneous fragmentation of ink aggregates into smaller pieces. In the second step, the smaller pieces are then phagocytized[5] by macrophages over a period of weeks. These two mechanisms correspond with clinical observations of an immediate reduction in visible pigment in the first week after treatment, followed by gradual fading over the next several weeks. Multiple treatments with increasing laser fluence are necessary as the average aggregate size gets smaller after each treatment.

[5] Phagocytosis - a process by which certain living cells called phagocytes ingest or engulf other cells or particles.