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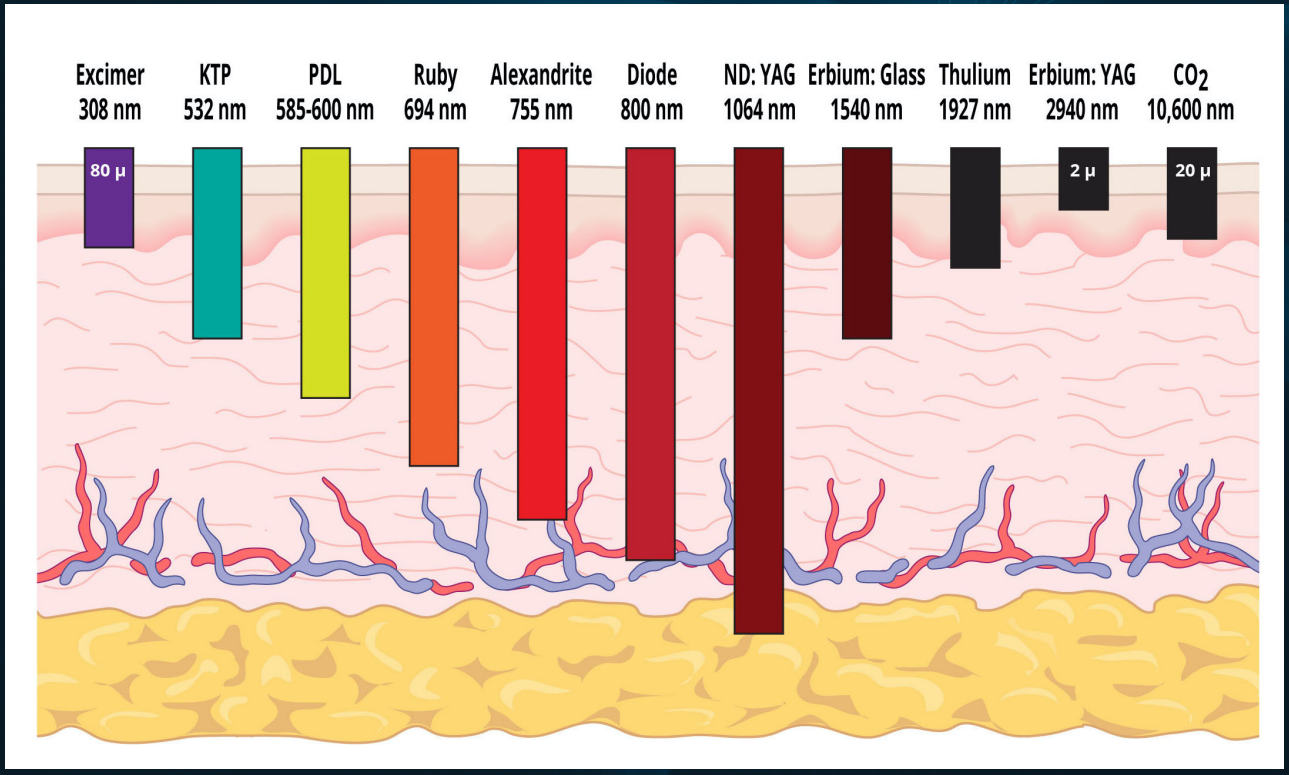
LASER PRIMER

LASERS AND OTHER ENERGY-BASED TECHNOLOGIES IN DERMATOLOGY



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INTRODUCTION

Lasers and other energy-based devices can be efficacious therapeutic tools in one's armamentarium for treatment of dermatologic conditions and lesions. However, laser medicine and surgery is not always a focus of dermatology curriculum or day-to-day practice. Our hope is for this primer to be an easy-to-use resource for early laser learners. Our primer begins with Section One, a brief overview of laser theory basics including key terms and a chart summarization of the most common dermatologic lasers. Section Two provides a broad overview of common lasers and energy-based devices as well as their respective dermatological indications, both FDA-approved and otherwise. Section Three is organized by common dermatological conditions with the most appropriate laser treatment options and helpful tips listed for each. Finally, our primer concludes with Section Four on general laser safety recommendations. Throughout this book we have also included space for you to jot down notes of your own tips, tricks, or settings. We hope this primer proves to be a useful resource to you as an introduction to laser medicine and surgery.

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LASER FUNDAMENTALS

LASER THEORY BASICS

Intoduction

LASER is an acronym for “Light Amplification by the Stimulated Emission of Radiation”. “Stimulated emission” is the idea that one photon can stimulate the creation of another photon by interacting with an excited atom.

Lasers work by pumping many atoms with the help of mirrors into an excited state from which a very large amount of stimulated emission can occur.

Laser light is distinct from regular light in that is:

- Monochromatic (it produces a uniform single wavelength)
- Coherent (all waves are in phase spatially and temporally)
- Collimated (or non-divergent).

Selective Photothermolysis

The first lasers developed affected targets in the skin non-selectively and non-preferentially.

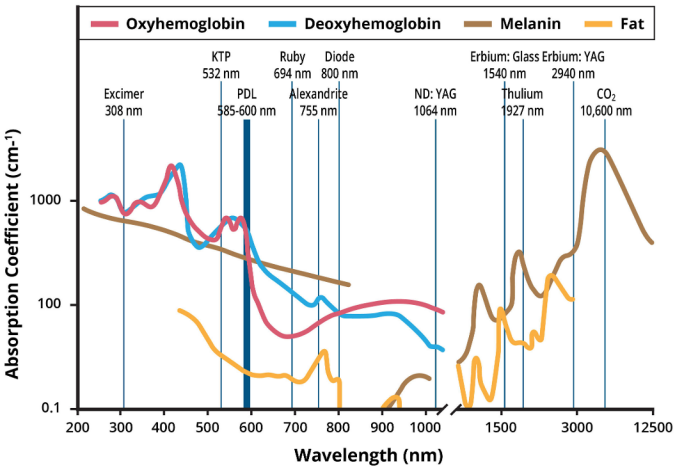
By adding gain mediums between the two reflectors, lasers are able to target select chromophores.

Examples of gain mediums include dyes (rhodamine dye), crystals (alexandrite), gas (carbon dixoide), and semiconductors (diode).

In 1983, Dr. Parrish and Dr. Anderson used these properties to their advantage and formulated the theory of selective photothermolysis.

This theory allows us to use lasers to selectively target chromophores in the skin to treat specific molecules such as hemoglobin, melanin, water.

Figure 1 demonstrates the absorption spectra of these various chromophores as well as the specific lasers which target them.



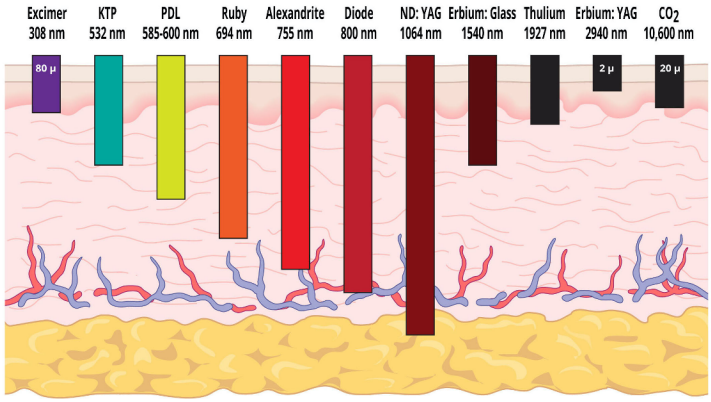
Laser Depth of Penetration

In general, laser penetration depth in the skin is proportional to wavelength. Thus, as the wavelength increases, the depth to which the laser travels in the skin also increases.

For example, even though the pulsed dye laser is a “go to” for vascular structures, if treating deeper structures (such as blue reticular veins), a 1064 nm laser can be used. With a longer wavelength, a 1064 nm laser will penetrate deeper, nearly reaching the subcutaneous fat, and therefore better reaching the desired target.

Depth of penetration increases proportionally with wavelength until about 1400 nm at which point it becomes inversely proportional. This is because at this wavelength the main chromophore target is water, which limits penetration of the laser mainly to the epidermis and superficial dermis where there is a high concentration of water.

Figure 2 demonstrates the approximate depth of penetration of each laser into the skin.



These figures are presented at the beginning of each laser section to highlight each laser's specific absorption and depth of skin penetration.

KEY TERMS AND ABBREVIATIONS

Ablative fractional laser (AFL): carbon dioxide or Er:YAG laser that causes fractionated microthermal treatment zones (MTZs; see below) with tissue injury and a coagulation zone via direct tissue vaporization leading to collagen remodeling

Chromophore: compound that absorbs light at a particular wavelength (i.e. hemoglobin, melanin, water)

Collimated: light waves that are parallel or non-divergent

Coherence: when light waves travel in phase and the crests and troughs are synchronous

Energy-based device (EBD): a device that is not a "laser" but generates energy or heat by a different means (such as radiofrequency, ultrasound, microwaves)

Fluence: energy per unit area measured in joules per centimeter squared

Fractional photothermolysis: production of microscopic treatment zones (MTZs) via nonablative and ablative laser devices without injuring surrounding tissue

Frequency: the number of waves or cycles that pass in a given unit of time (cycles per second or hertz)

LASER: acronym for "light amplification by stimulated emission of radiation"; a device that produces light that is monochromatic, collimated, and coherent

Light: the visual perception of electromagnetic radiation

Long-pulsed (LP)*: a device that does not contain a quality switch (usually millisecond pulse duration)

Microthermal treatment zone (MTZ): columns of injury made to the skin by AFL via direct tissue vaporization or nonablative fractional lasers (NAFL; see below) via thermal energy to stimulate collagen remodeling

Monochromatic: when light produces a single uniform wavelength

Nonablative fractional laser (NAFL): non-CO_2 or Er:YAG laser that causes fractionated MTZ without tissue injury via thermal energy leading to collagen remodeling

Picosecond device (PS)*: a device containing a pulse duration of picoseconds

Power: the rate of delivery of energy; measured in watts or joules per second

Pulse duration: the duration of exposure of the laser pulse (i.e. milliseconds, nanoseconds, or picoseconds)

Q-switch (QS)*: a device that contains a quality switch, which promotes production of a very short single pulse (usually nanosecond pulse duration)

Selective photothermolysis: selective thermal damage to a particular chromophore within tissue

Spot size: the spot diameter that encompasses 86% of the power output

Thermal relaxation time (TRT): the amount of time it takes the temperature of a target to return to ambient temperature following heating. The size of a given target influences TRT. In general, if an object is heated for a period equal to or shorter than its TRT, the accumulated heat is confined to the target object alone.

Wavelength: the distance between two corresponding crests or troughs

*****Q-switched (QS) lasers and long-pulsed (LP) lasers are distinct and have different treatment indications. Typically, many lasers at a given wavelength have both a long-pulsed and Q-switched counterpart (now many lasers also have a picosecond counterpart). These lasers are used for different indications and cannot be used interchangeably. Throughout this primer the authors differentiate from QS/LP/PS laser options to avoid confusion.*

COMMON LASERS IN DERMATOLOGY

Laser	Wavelength (nm)	Chromophore	Pulse Duration	Typical Applications	Clinical Endpoint*
Excimer	308	Proteins, DNA	Nanoseconds	Psoriasis, vitiligo, atopic dermatitis	Erythema, mild edema
Potassium Titanyl Phosphate (KTP)	532	LP: hemoglobin	LP: milliseconds	LP: PWB, telangiectasias, scars	Purpura, vessel darkening, vessel disappearance
		QS/PS: melanin, red tattoo ink	QS/PS: nanoseconds/picoseconds	QS/PS: epidermal pigmented lesions, tattoos	Immediate whitening
Pulsed-dye (PDL)	585-600	Hemoglobin, (weak) melanin	Milliseconds	PWB, scars, telangiectasias	Purpura, vessel darkening, vessel disappearance
Ruby	694	LP: melanin	LP: milliseconds	LP: epidermal pigmented lesions, hair removal	Perifollicular erythema, edema
		QS: melanin, tattoo ink	QS: nanoseconds	QS: epidermal/dermal pigment, tattoos (black, blue, green)	Immediate whitening
Alexandrite (Alex)	755	LP: melanin, (weak) hemoglobin	LP: milliseconds	LP: epidermal pigmented lesions, vascular lesions, hair removal	Perifollicular erythema, edema
		QS/PS: melanin, tattoo ink	QS/PS: nanoseconds/picoseconds	QS/PS: epidermal pigmented lesions, tattoos (black, blue, green)	Immediate whitening
Diode	~800	Melanin, hemoglobin	Milliseconds	Hair removal, vascular lesions	Perifollicular erythema, edema
	1450	Water	Milliseconds	NAFL, texture, photoaging	Erythema, edema, pinpoint bleeding
Neodynium-doped yttrium aluminum garnet (Nd:YAG)	1064 532 (frequency-doubled)	LP: melanin, (weak) hemoglobin	LP: milliseconds	LP: hair removal, venous lake, hypertrophic PWB	Perifollicular erythema, edema
		QS/PS: melanin, tattoo ink	QS/PS: nanoseconds/picoseconds	QS/PS: epidermal pigmented lesions, black tattoo (1064), red tattoo (532), melasma	Immediate whitening, edema
Erbium (Er):Glass	1540	Water	Milliseconds	NAFL, texture, photoaging	Erythema, edema, pinpoint bleeding
Er:Fiber	1550	Water	Milliseconds	NAFL, texture, photoaging	Erythema, edema, pinpoint bleeding
Erbium/Thulium	1550/1927	Water	Milliseconds	NAFL, texture, photoaging	Erythema, edema, pinpoint bleeding
Thulium	1927	Water	Milliseconds	NAFL, texture, photoaging	Erythema, edema, pinpoint bleeding
Hybrid Fractional Laser	1470/2940	Water	Milliseconds	NAFL/AFL texture, photoaging	Erythema, edema, pinpoint bleeding
Er:YAG	2940	Water	Milliseconds	AFL, texture, photoaging	Erythema, edema, pinpoint bleeding
Carbon Dioxide (CO_2)	10,600	Water	Milliseconds	AFL, texture, photoaging	Erythema, edema, pinpoint bleeding

*****Undesirable endpoints include skin graying, necrosis, and Nikolsky sign.*