CHAPTER 1

INTRODUCTION TO LASER PHYSICS AND LIGHT-BASED AESTHETIC TREATMENTS

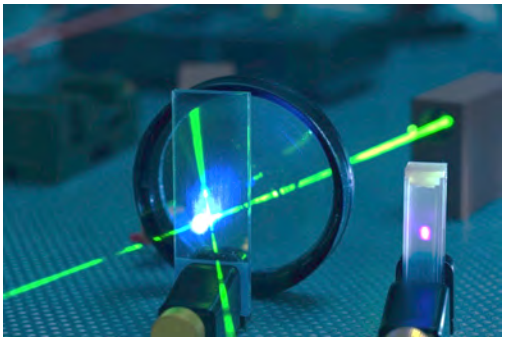
1

- What is Laser?
- Laser Physics
- Construction of a Laser
- Physical Basis for Laser Hair Removal
- Laser Hair Removal Devices

2

What is Laser?

- The term **LASER** is an acronym for Light Amplification by the Stimulated Emission of Radiation.
- Laser is a high-power light that has been harnessed to create a narrow directional beam of light.
- Laser light can be visible or invisible.
- Light can be UV light, invisible infrared light or visible light that we see.
- Light consists of many wavelengths; laser light consists of one wavelength.



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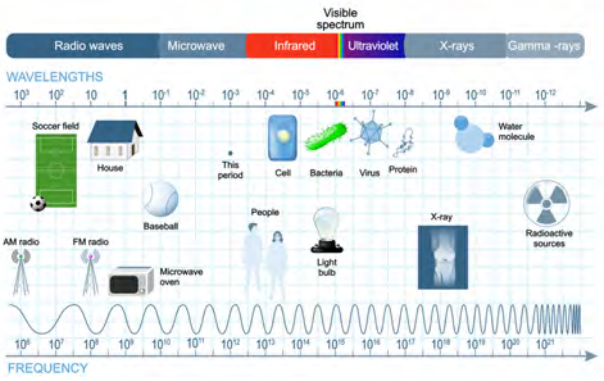
Electromagnetic Spectrum of Radiation

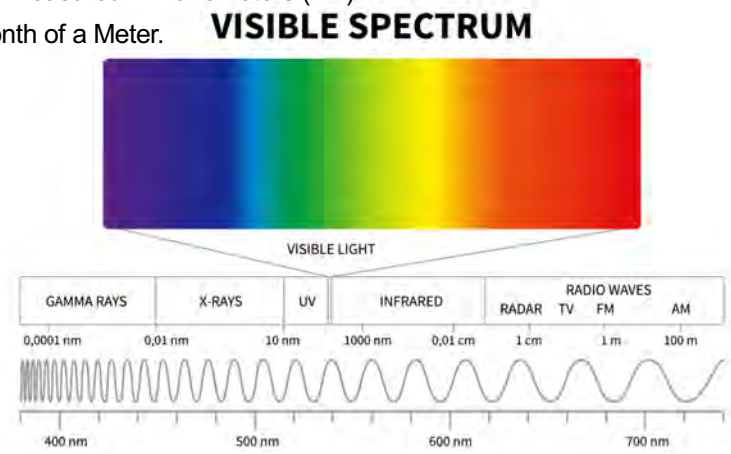
- The term light is usually referring to visible light, the light we see with our eyes, allowing us to identify the colors of blue, violet, green, yellow, orange and red.
- Visible light belongs to a much broader spectrum known as the Electromagnetic Spectrum of Radiation. The Electromagnetic Spectrum of Radiation is a vast band of energy frequencies extending from Gamma rays, X-rays, UV rays, Visible light, Microwaves, and Radio Waves.
- The spectrum is arranged by frequency of its waves, from the longest, lowest energy waves (radio waves) to the shortest, highest energy waves (gamma rays).



4

Electromagnetic Spectrum of Radiation

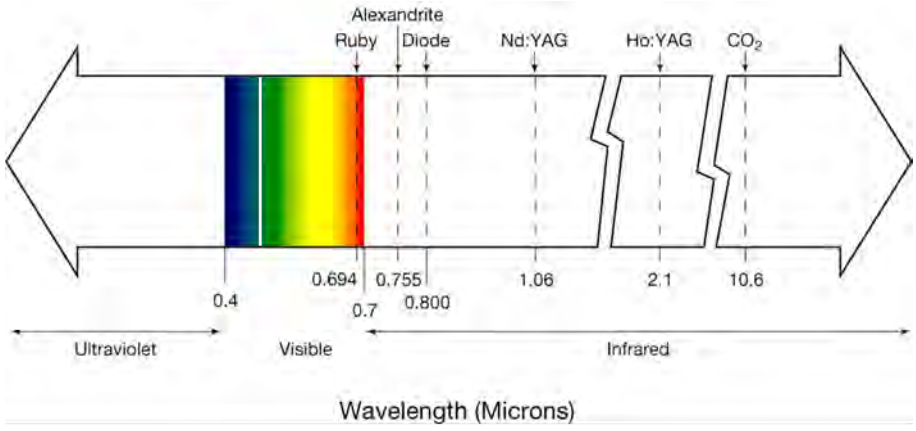
- The electromagnetic spectrum is made up of all these energies and vary by their wavelength and frequency.
- Wavelengths are often measured in Nanometers (nm).
- A Nanometer is a billionth of a Meter.



5

Electromagnetic Spectrum of Radiation

- Wavelengths are also measured in Microns, which is a millionth of a meter, unlike the Nanometer which is a billionth of a meter (.755 Microns converts to 755 Nanometers).



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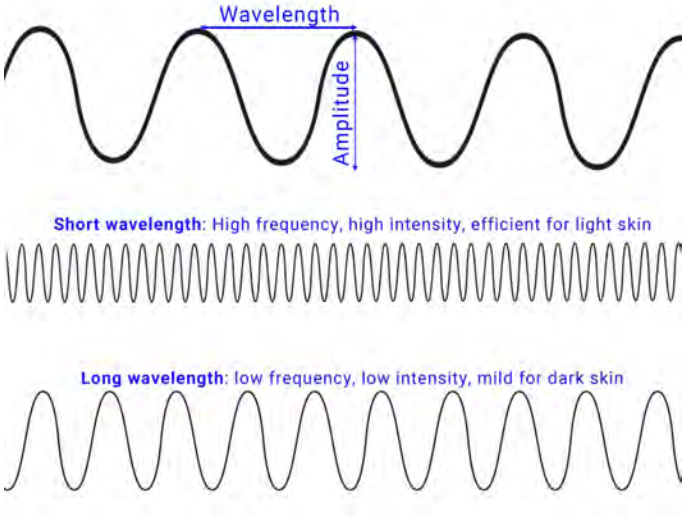
Wavelength

- A wavelength is the measurement between the distance of two consecutive peaks.



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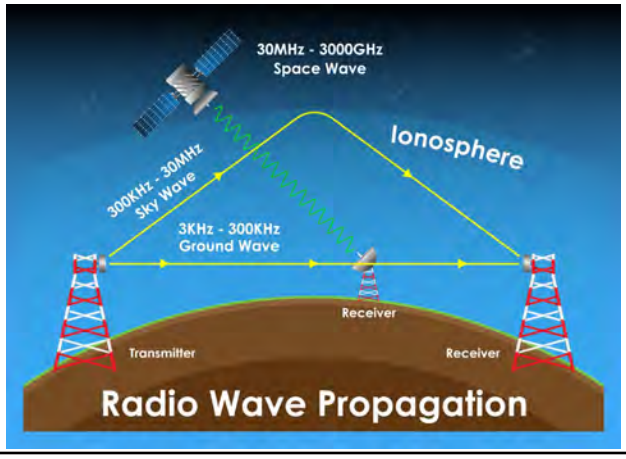
Radio Waves

- Radio Waves have the longest wavelength in the Electromagnetic spectrum.
- Radio waves can be as longer than a foot ball field to as short as a foot ball.
- Radio waves carry cell phone and television signals.



8

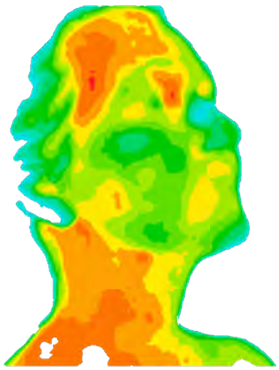
Microwaves

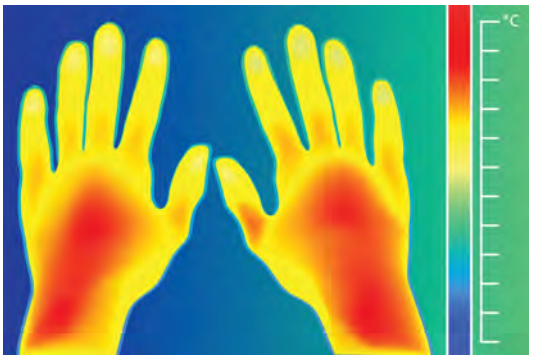
- Microwaves are higher-frequency waves lying roughly between radio and infrared waves. They have several common applications, the most familiar of which is the microwave or microwave oven used for cooking.
- Microwaves are absorbed by water and fat in food and produce heat from the inside. Microwaves are not absorbed by glass and ceramic materials and are reflected by metal.

9

Infrared Light (IR)

- Infrared energy is invisible and thermal. We experience the effects of infrared energy as heat on the skin. The sun emits infrared energy.
- Animals and humans emit infrared energy as well as heat lamps that warm food.
- Infrared energy can be captured in thermal imaging devices.

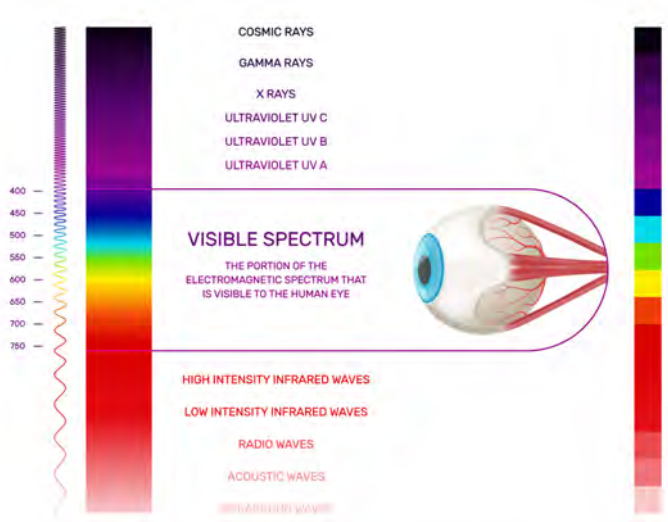




10

Visible Light

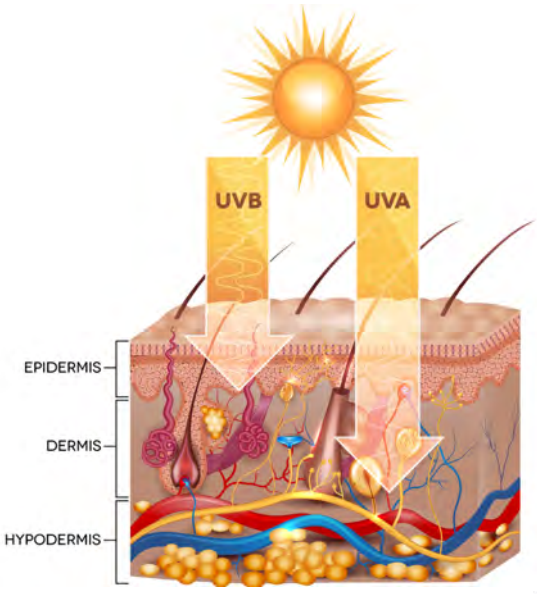
- Visible light is the part of the Electromagnetic Spectrum that we can see with our eyes. Violet light has the shortest wavelength as red light has the longest.
- Some laser hair removal devices are in the red light and some laser hair removal devices are in the near infrared part of the Electromagnetic Spectrum.



11

Ultraviolet Light

- The Ultraviolet (UV) light that penetrated our skin is made up of two types of radiation: UVA rays and UVB rays.
- UV Light is highly energetic with shorter wavelengths than visible light.
- UV energy is broken down into UVA, UVB and UVC. UVC is absorbed by the ozone layer and does not reach the earth.
- UVA rays count for 95% of the UV radiation that reaches the earth's surface. UVA rays penetrate the skin more deeply. UVA rays are the dominant tanning rays. UVA rays cause photoaging and skin cancer.
- UVB rays cause skin burns and effect the epidermis, also causing skin cancer and photoaging.



12

X-Rays

- X-rays are high energy with shorter wavelengths than UV or Visible light and are located between UV and Gamma Rays.
- X-ray wavelengths are between .01-10 nanometers
- When the Sun shines on us at a certain angle, our shadow is projected onto the ground. Similarly, when X-ray light shines on us, it goes through our skin, but allows shadows of our bones to be projected onto and captured by film.

13

Gamma Rays

- Gamma-rays have the shortest most powerful wavelengths and the most energetic form of light.
- They are produced by violent events as supernova explosions or the destruction of atoms, or by the decay of radioactive material in space. Supernova explosions, neutron stars and pulsars, and black holes are all sources of celestial gamma-rays.
- Gamma-rays can kill living cells, which medicine uses to its advantage, using gamma-rays to kill cancerous cells.
- Gamma-ray bursts can release more energy in 10 seconds than the Sun will emit in its entire 10 billion-year lifetime.

14

How Laser is Created

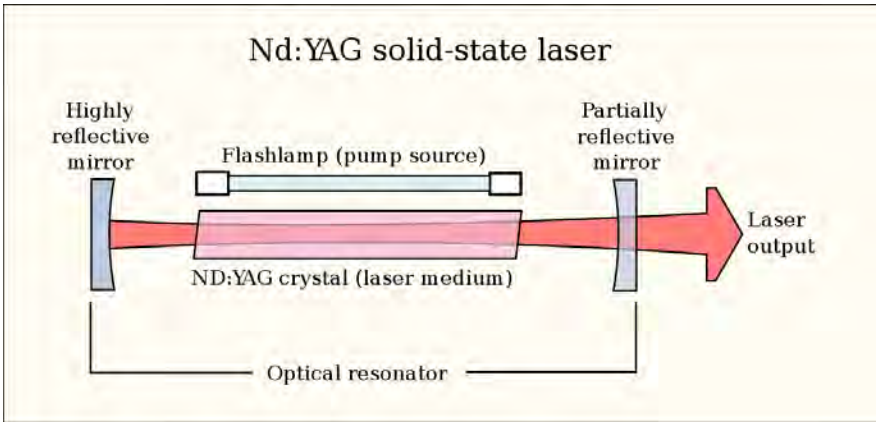
- The term **LASER** is an acronym for Light Amplification by the Stimulated Emission of Radiation.
- A device that creates and amplifies electromagnetic radiation of a specific frequency through the process of **stimulated emission**.
- The radiation emitted by a laser consists of a coherent beam of photons, all in phase and having the same polarization.
- Lasers have many uses, such as cutting hard or delicate substances, reading data from compact disks and other storage devices, and establishing straight lines in geographical surveying.

15

Construction of a Laser

A Laser has several components

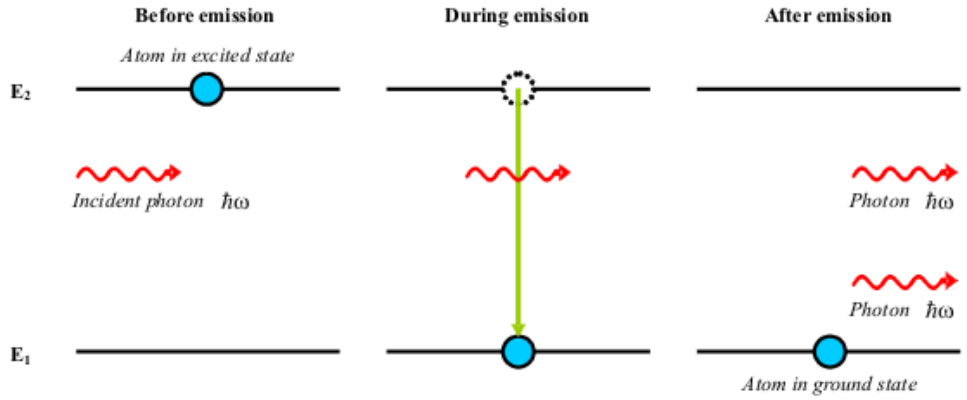
- An active medium (gas, crystal etc.)
- Laser tube/Resonator
- Power Supply
- Software
- Microprocessor
- Delivery System
- Cooling System



16

Stimulated Emission

- Occurs when an already excited electron absorbs a newly created photon of equal energy. Upon descending back to its resting state, two identical photons are now released.



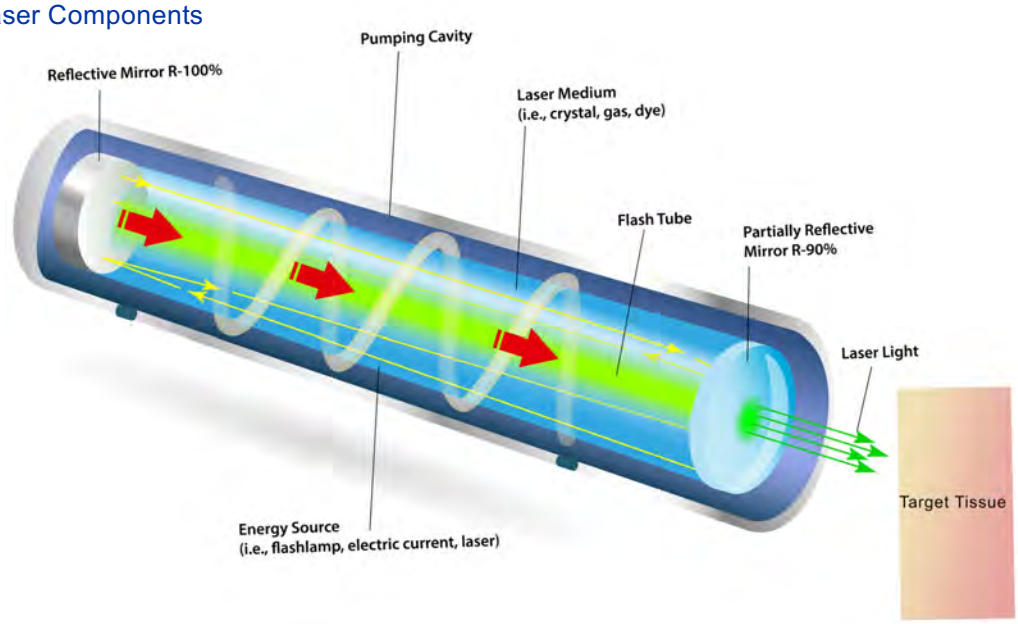
17

Laser Components

- The **pump source** is the part that provides energy to the laser system. Examples of pump sources include electrical discharges, flashlamps, arc lamps, light from another laser, chemical reactions and even explosive devices. The type of pump source used principally depends on the **gain medium**, and this also determines how the energy is transmitted to the medium. A helium-neon (HeNe) laser uses an electrical discharge in the helium-neon gas mixture, a Nd:YAG laser uses either light focused from a xenon flash lamp or diode lasers, and excimer lasers use a chemical reaction.
- The **gain or active medium** is a gas, liquid or solid that is stimulated to create laser light. Common gases are argon, C02, or helium. Liquids may be dyes, and solids tend to be synthetic crystals made of yttrium-aluminum garnet (YAG) particles that are doped with certain elements such as holmium, neodymium or erbium electrons.
- Different laser systems are named for their active mediums. Diode lasers emit light when an electrical current passes through a semiconductor chip.

18

Laser Components



19

Laser Energy I

- **Coherent Energy**: Laser light is considered coherent because the laser photons travel through space both temporally and spatially. Each wavelength of light is composed of photons that are traveling in both time and space as a single unit of energy. Coherent light waves travel in perfect unison. They are parallel and in the same direction; "in phase" or "in step".
- **Monochromatic Energy**: Laser light that is composed of one wavelength and one color whether visible or invisible.
- **Collimated Energy**: The photons are parallel to each other in diameter of the beam to produce a focused spot by using a lens. Collimated light is a very thin beam of light which all rays run parallel.

- **LASER - Collimated: Monochromatic, Coherent**

- **FLASHLIGHT - Non- Collimated: Scattered, Polychromatic**

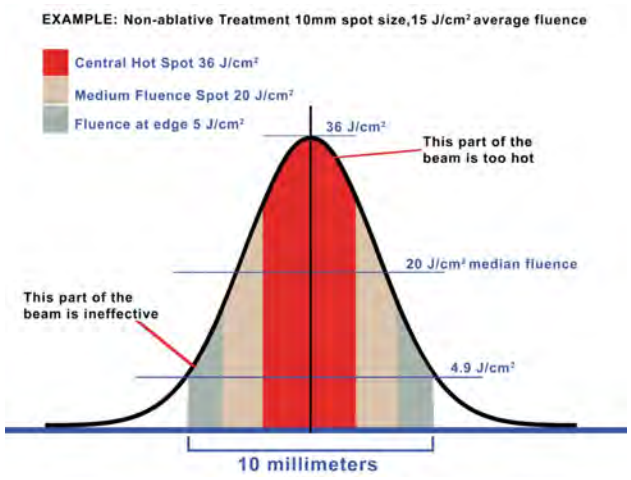
20

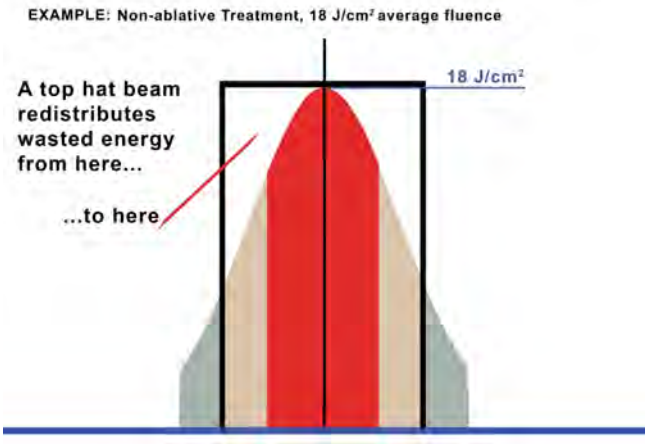
Laser Energy II

- Fluence refers to the energy of the pulsed laser beam. It is expressed in joules per cm2. Most esthetic lasers are pulsed to minimize thermal damage while destroying the target medium.
- Joule is a unit of energy or work
- Watt is a unit of power.
- Millijoules (mJ) is 1/1000 of a Joule. 820mJ = 82J
- Optical Energy is determined by the laser's power, spot size and the pulse duration or pulse width.
- Pulse duration or width is measured in nanoseconds, microseconds, or milliseconds.
- Spot Size is the measurement of the diameter of the beam that is in contact with the tissue.

21

Laser Energy II





22

Laser Properties

- Absorption is the physical process in which light energy is converted by the tissue that is targeted and the response to the energy. With laser hair removal the light energy is converted to heat.
- Reflection is the amount of energy that is reflected off the skin or any shiny surfaces. The reflected thermal properties of the light can cause surface burns, fire or eye damage.
- Transmission is the penetration into the epidermis and dermis.
- Scatter is the physical process of the skin that causes the beam to be deflected into some other direction. Scattering decreases with longer wavelengths.

Selective Photothermolysis

- The theory of Selective Photothermolysis governs today's laser & light practices and was introduced in 1983 and described the selective absorption of a specific light by a targeted chromophore.
- By selection of a specific wavelength unique to one target chromophore, heat can be delivered rapidly enough to the target before it can be diffused to the surrounding area leading to the thermal damage being confined to the target.
- The chromophores melanin, hemoglobin, and water are the most common molecular targets.

23

Photo / Thermo / Lysis
"Light" / "Heat" / "Death"

Thermal Relaxation Time

- To achieve Selective Photothermolysis you must be aware of the TRT of the target.
- TRT is the amount of time necessary for the target to lose 50% of the heat.
- Limiting laser light to a time shorter than the TRT the energy is contained to the selected target preventing damage to the surrounding tissue.
- The larger the object the longer the TRT.
- Tattoo particles have a TRT of 2-3 nanoseconds where some leg veins have a TRT of 300 milliseconds.
- Larger targets slowly absorb heat, longer pulse durations, small targets are the reverse needing shorter pulse durations.

24

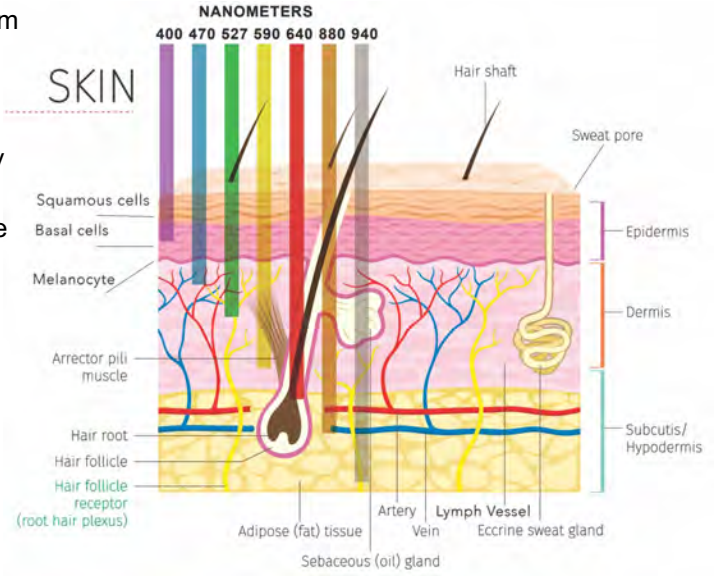
Physical Basis of Laser and Light-Based Hair Removal

- **Wavelength**
- **Intense Pulse Light**
- **Pulse Width**
- **Target Characteristics**

25

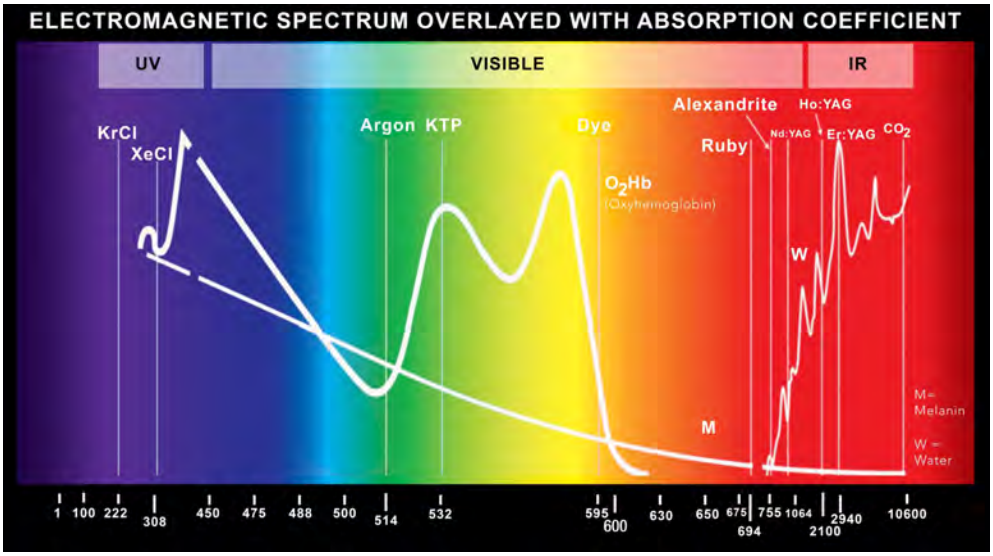
Physical Basis of LHR I: Wavelength

- Available wavelengths from 600-1100 nm
- Melanin absorption decreases with increasing wavelength
- Shorter wavelengths (i.e, 694 nm) have greater absorption, but delivered energy limited by epidermal melanin
- Longer wavelengths (i.e, 1064 nm) have much less absorption by epidermal melanin, but higher energies can be delivered



26

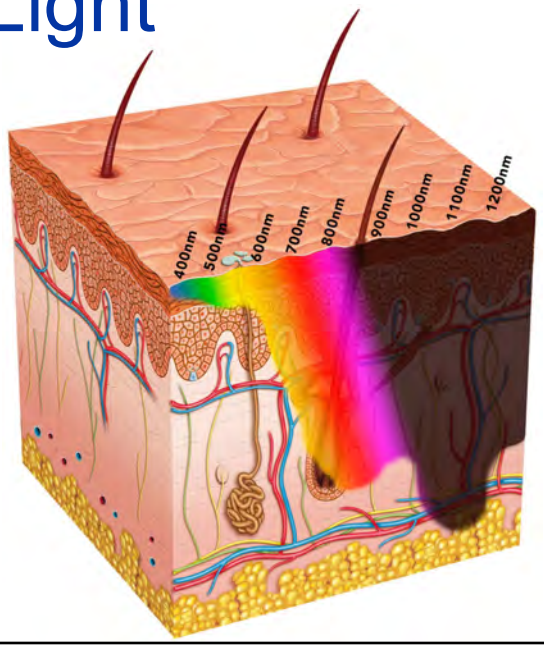
Physical Basis of LHR II: Wavelength



27

Intense Pulsed Light

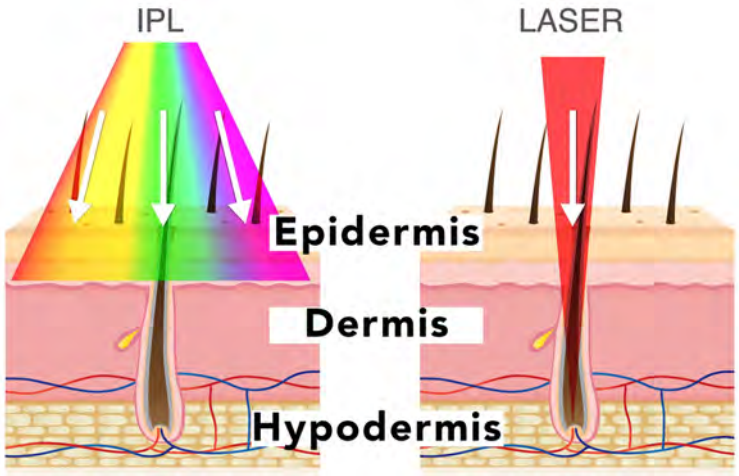
- Intense pulsed light was FDA approved for cosmetic use in the mid 1990's and is based on emitting high intensity pulses of light to penetrate the skin to treat various cosmetic defects including pigmented and vascular lesions as well as hair.
- Intense pulsed light uses full spectrum, non-coherent, broadband light. These lights include blue, yellow, red and infrared appearing as a white light with low-range infrared-radiation spectrum of approximately 400-1200 nm. The lower wavelengths are filtered out to allow a specified range of wavelengths to be used, those that will be most effective in removing hair.



28

Intense Pulsed Light

- The difference between IPL and laser is that IPL emits every wavelength of light in the visible and some invisible parts of the spectrum, as opposed to lasers that emit only one.



29

Physical Basis for LHR III: Pulse Width

- TCT = heating remains confined to target
- TRT = time for target to dissipate 50% of delivered heat
- Short TRT of epidermis vs. follicle spares epidermis (absent bulk heating)

$$t_r \approx d^2$$

$$t_c \approx \frac{d^2}{2}$$

t_r (hair follicle) ≈ 10-50 mSec

t_r (epidermis) ≈ <1 mSec

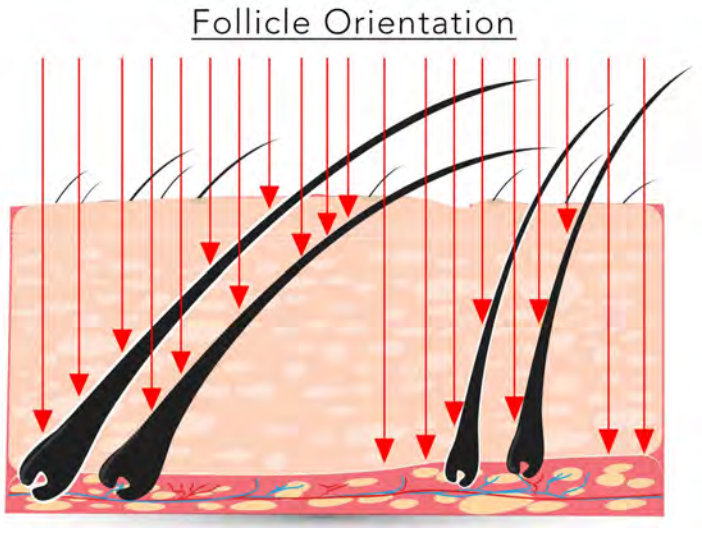
t_r = Thermal Relaxation Time

t_c = Thermal Containment Time

30

Physical Basis for LHR IV: Hair as a Target I

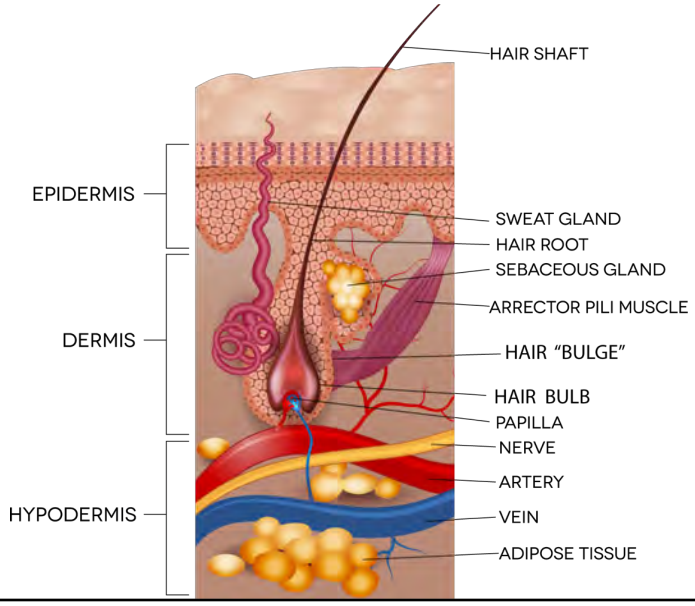
- Hair comes in a variety of color, sizes, orientations
- Vellus hairs -unpigmented, follicles <30 um diameter
- Terminal hair follicles- 50-150 um, u to 300 um at the bulb
- Depth varies from body area, stage growth cycle, and orientation
- Pigmented with brown-black eumelanin, reddish-brown pheomelanin, a mixture, or none



31

Physical Basis for LHR V: Hair as a Target II

- Hair color is determined by the amount and relative proportions of eumelanin to pheomelanin
- Eumelanin absorbs 50X better than pheomelanin
- Melanin is present in the hair shaft, melanocytes in the upper bulb and infundibular area only.



32

Physical Basis for LHR VI: Hair as a Target III

- The Bulge-regulates the hair growth cycle.
- Upper bulb and bulge contain melanocytes-both areas are targeted by LHR.
- Bulb may be too deep in anagen hairs; bulge is superficial and accessible.
- Early anagen hairs display active melanogenesis and both bulb and bulge are relatively superficial.

- At least two responses to treatment seem to be present:
  - Sublethal injury to the bulge with induction of a long term or permanent regression to a vellus hair ("miniaturization").
  - Sufficient energy is delivered to the bulb and bulge to completely and selectively destroy the follicle.

33

Laser Hair Removal Devices I: Ruby Laser

- Long Pulse Ruby Laser @ 694 nm
- Original device for LHR
- Highest melanin absorption
- Most superficial depth
- Use limited to skin types I-III
- Often marketed as dual mode
- Obsolescent, replaced by Alexandrite l

Sharplan EpiTouch


Aesclepion


Novalis

34

Laser Hair Removal Devices II: Alexandrite Laser

- Alexandrite Laser @ 755 nm
- Less absorption by melanin
- May be used on skin types I - III
- Reliable, capable of high powers, large spot sizes, high repetition rates

Epicare - Zenith

Candela GentleLase

Cynosure Apogee

35

Laser Hair Removal Devices III: Diode Laser

- Diode laser @ 800-810 nm
- Longer wavelength with slightly less melanin absorption then Alex
- Less effective on fine, light, red hair
- May be used on skin types I-VI
- Spot size, rep rate limited
- Treatment is less comfortable than 694 and 755 nm

Venus Velocity

Soprano Ice

LightSheer

36

Laser Hair Removal Devices IV: Nd:YAG Laser

- Nd:YAG @ 1064 nm
- Low melanin absorption, safe for all skin types and tanned patients
- Less effective for fine, light hair- high fluences needed
- Deep penetration due to lack of competing chromophores
- Capable of high power, rep rates


Sciton Profile


Cooltouch Viara


Cutera CoolGuide


Laserscope Lyra

37

Laser Hair Removal Devices V: Dual Wavelength Devices

- Laser Hair Removal Devices V: Dual Wavelength Devices


Candela Gentlemax


Cynosure Elite

Light Based Devices for Hair Removal: ELOS

- IPL/diode light combined with bipolar RF
- Optical heating facilitates RF flow through tissue
- Marketed as effective for all hair types including white and gray hair


Syneron Comet

Light Based Devices for Hair Removal: IPL

- Broadband light with cut-off filters (>640 nm)
- Lamp may be weighted toward NIR,
- Large rectangular spot with contact cooling
- Best suited for lighter skinned patients
- Primary advantage of IPL is multifunctionality
- Problematic for Type IV-VI

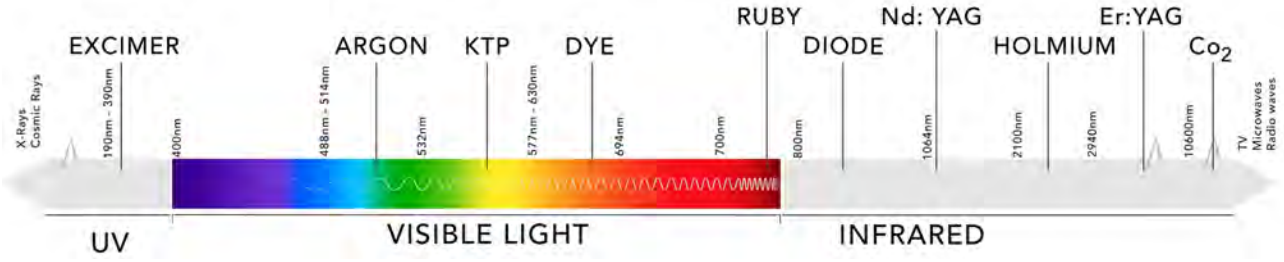

Sciton BBL


Palomar MaxG

38

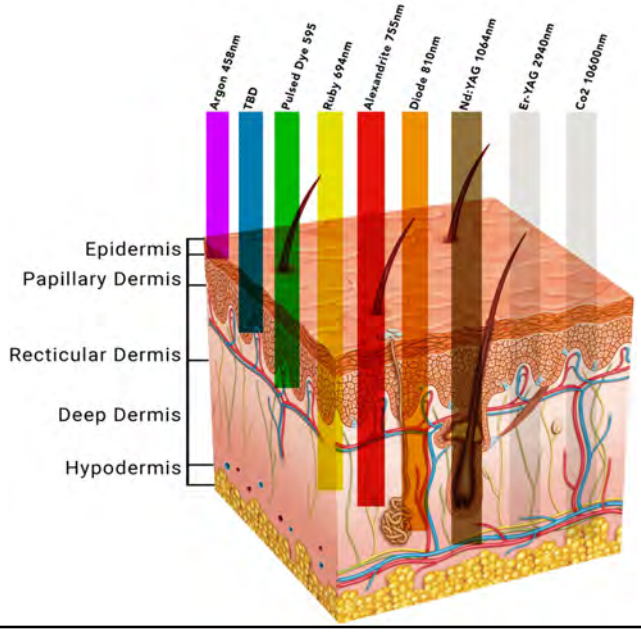
Laser Device Wavelengths

- Various commonly used laser wavelengths are identified below:



39

Laser Device Penetration Depth



40