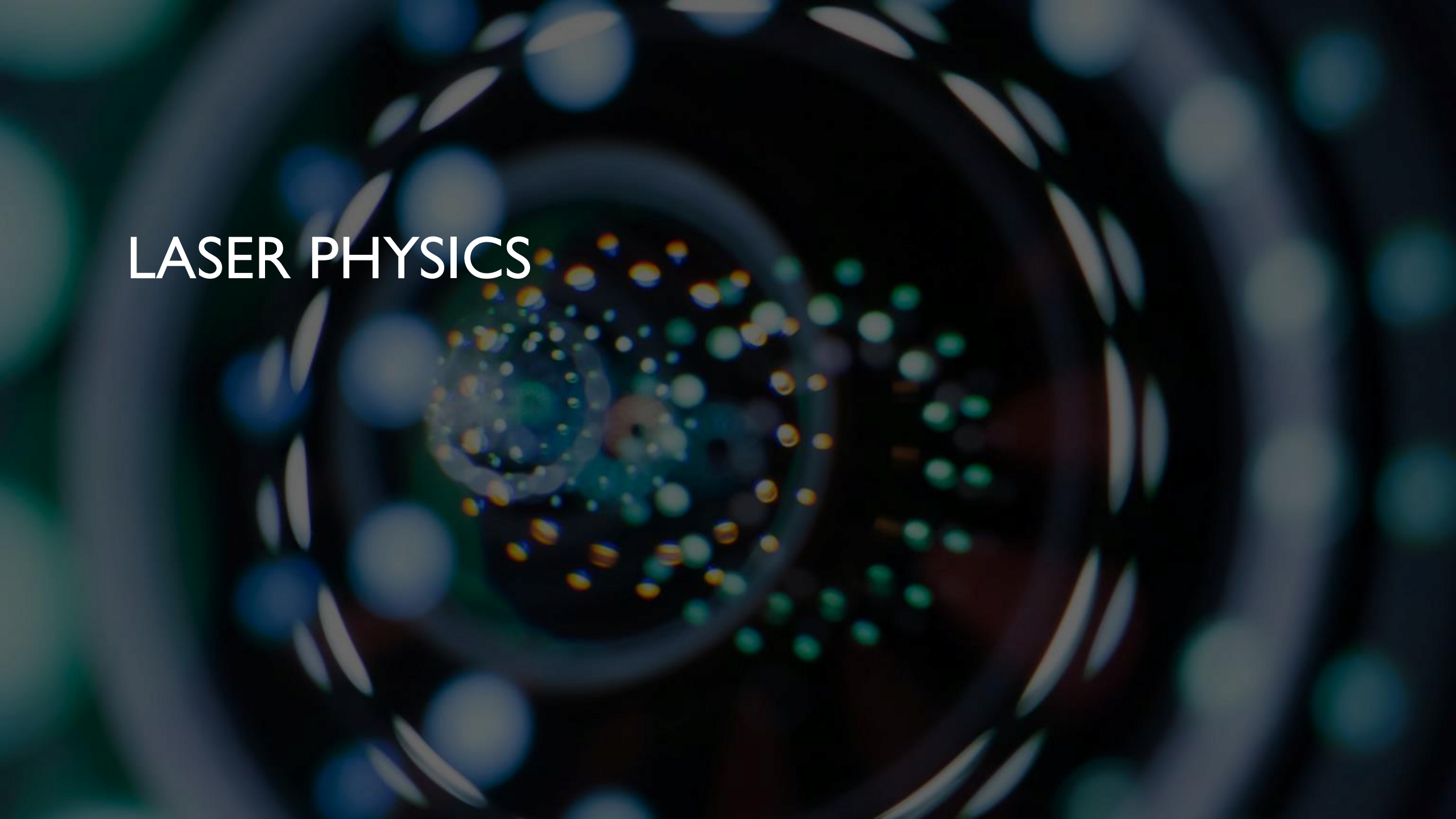
LASER PHYSICS



WHAT IS A LASER?

- Acronym for LIGHT AMPLIFICATION BY STIMULATED EMISSION OF RADIATION
- A laser is a device that emits a beam of coherent light through an optical amplification process.

Max Planck
(1858-1947)

HISTORY OF LASERS

The discovery of lasers is based on the accumulation of research of many scientists.

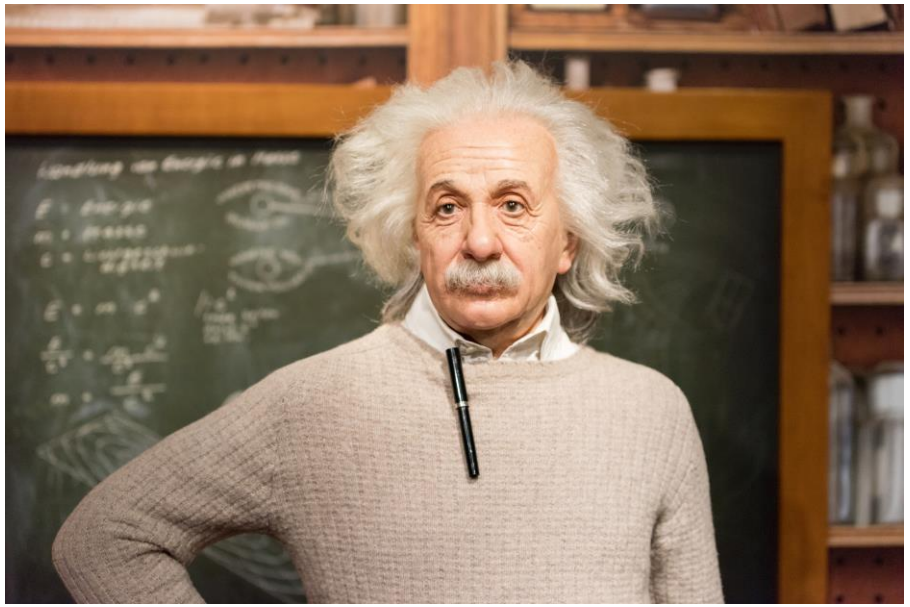
Max Carl Ernst Ludwig Plank (early1900s)

- He speculated the relationship between energy and radiation and theorized energy travels in small chunks known as quanta. His work lead the foundation for Einstein's Quantum Theory.

HISTORY OF LASERS

Einstein's Quantum Theory of Radiation (1917)

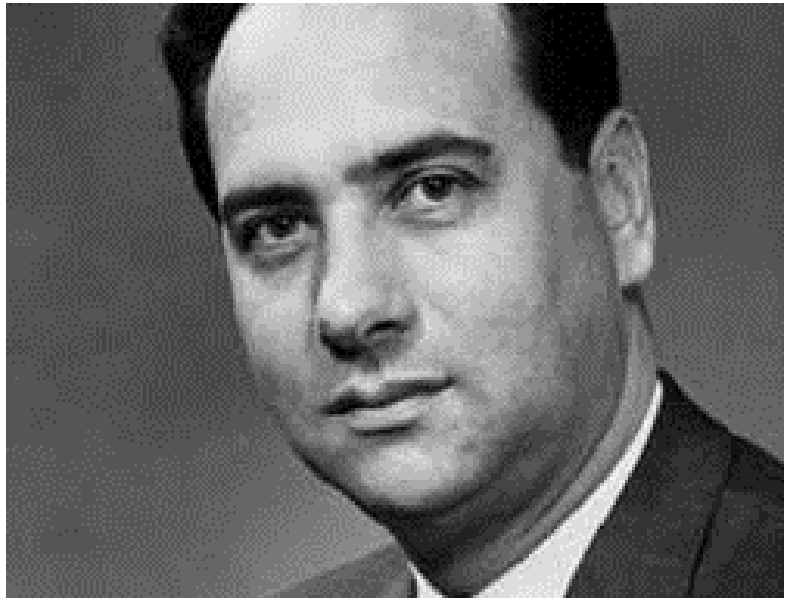
- Root of technology is based on Einstein's fundamental physics research of Stimulated Emission of radiation.
- This describes any device that creates and amplifies a narrow, focused beam of light whose photons are coherent.
- Einstein's theory of stimulated emission was a way of explaining how electricity is generated from sunlight. He did not propose the idea of lasers.



HISTORY OF LASERS

Charles Townes and Arthur Schawlow (1958)

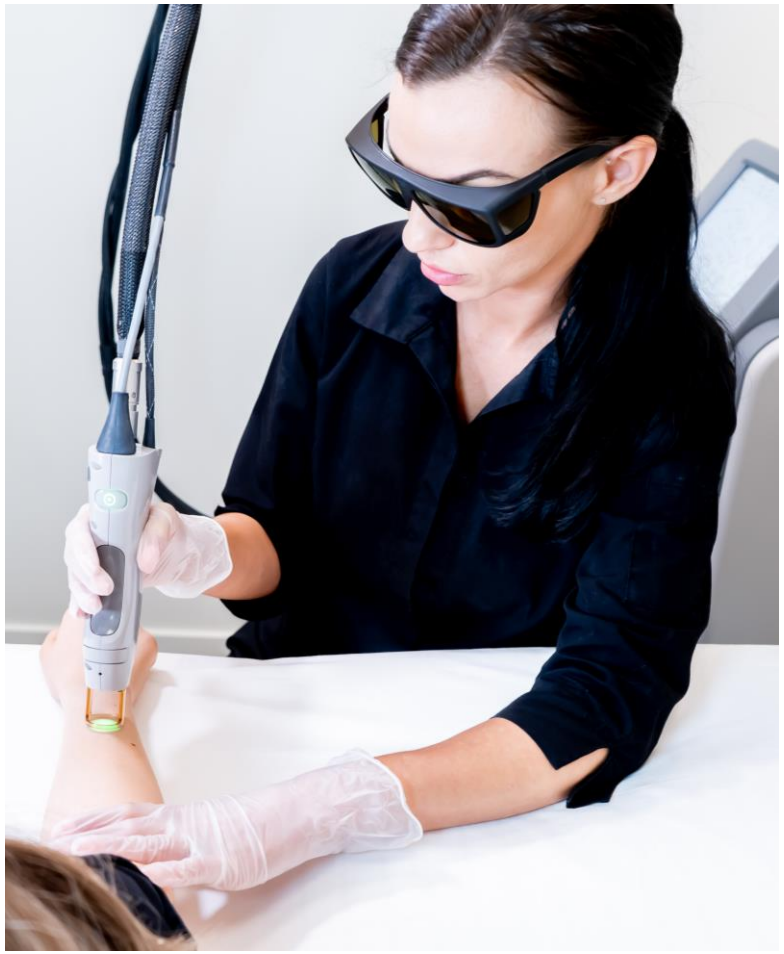
- Invented the MASER – Microwave Amplification by stimulated emission of radiation. They theorized the invention of an "Optical Masers" which would use infrared and/or visible light.



Theodore Maiman (1960)

- Developed the first laser using a synthetic ruby crystal
- His invention led to subsequent development of many other types of lasers

LASER HAIR REMOVAL

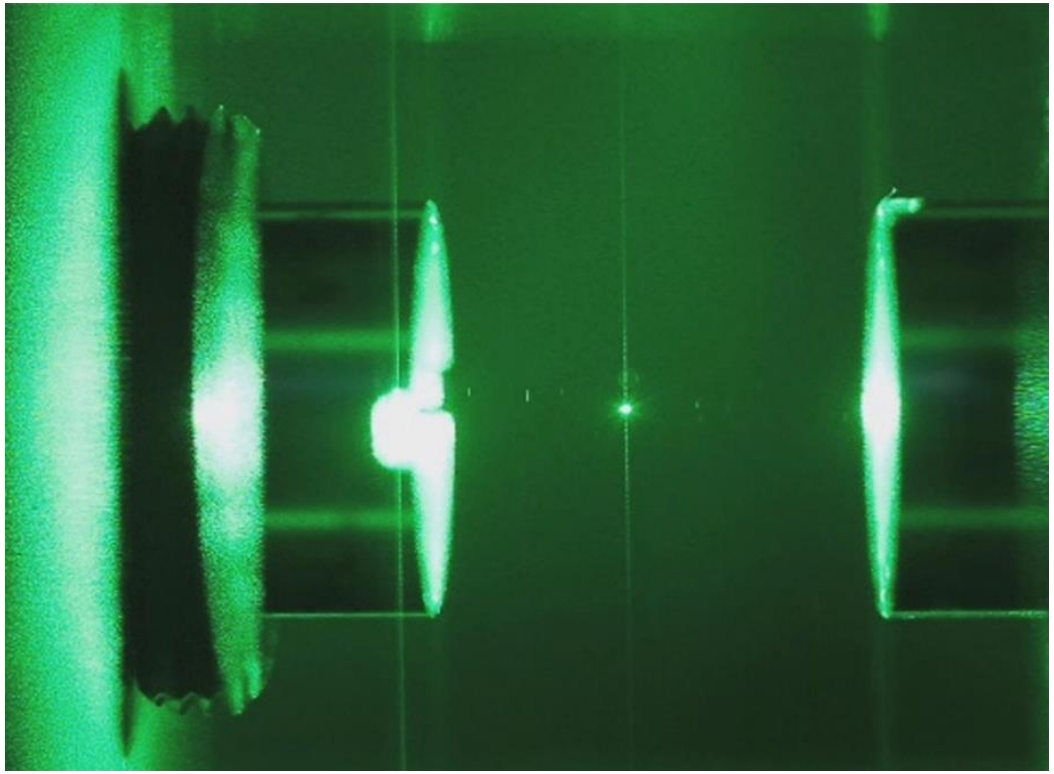


Laser hair removal is a non-invasive procedure which uses concentrated beam of light in order to remove unwanted hair. In order to achieve desired results, a series of treatments are essential followed by periodic maintenance. The number of treatments required varies from person to person. Certain areas may require more treatments compared to others.

HOW DOES A LASER WORK?

- Lasers use concentrated rays of light to destroy growth cells of the hair bulb.
- A laser beam is emitted on the skin to damage hair follicles
- Lasers for hair removal are considered Semi-Permanent because the hair bulb is not always destroyed, causing regrowth in certain areas.
- Approximately 50-60% hair reduction can be seen after 12 weeks.

LASER PHYSICS



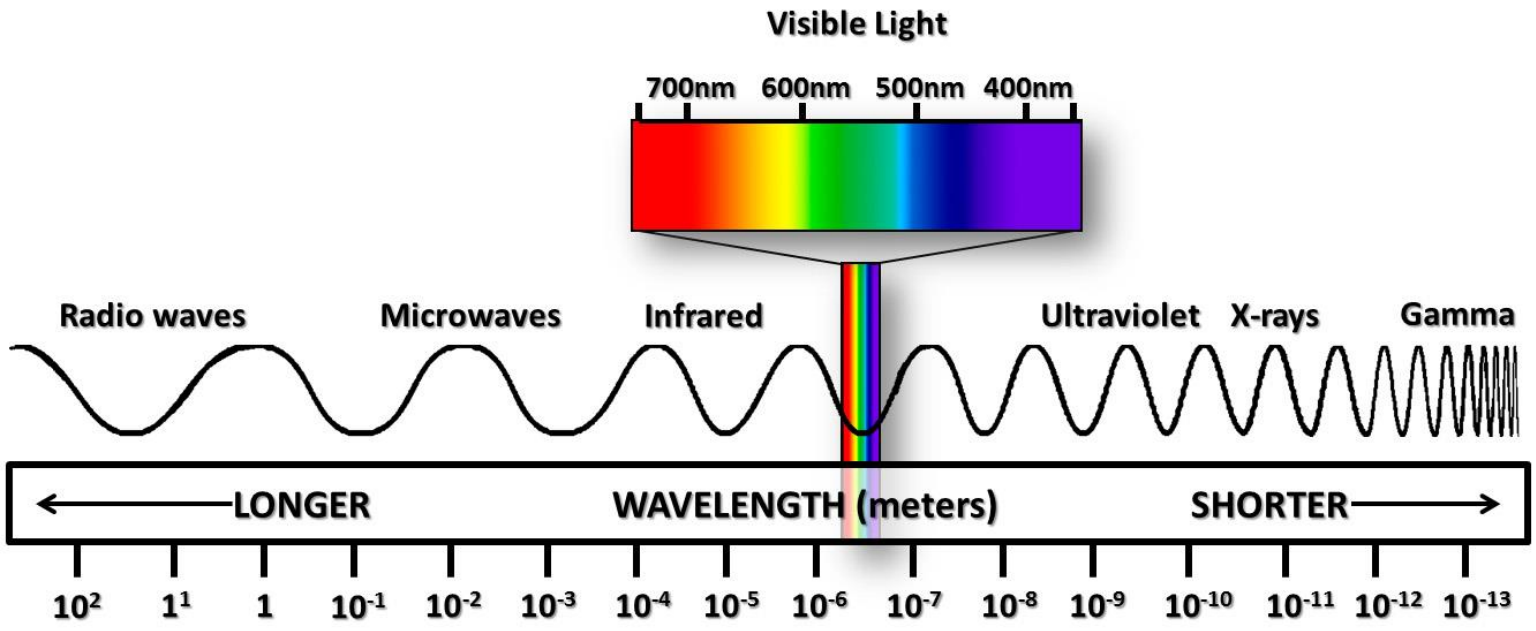
Laser physics deals with the fundamentals of laser science which includes the theory and practice of lasers. This area of study is primarily concerned with quantum electronics, laser construction, and optical cavity design. A significant understanding of lasers and light sources is required for their optimal use. A basic understanding of laser physics is also mandatory to carry out an efficient laser treatment.

LIGHT AND WAVELENGTHS

Light - is the electromagnetic radiation of any wavelength. (light is composed of tiny particles (photons) traveling in a wave-like manner.

Electromagnetic Radiation (EMR) - is the form of energy exhibiting wave like behavior that has both electric and magnetic field components, perpendicular to each other and perpendicular to the direction of energy propagation.

ELECTROMAGNETIC SPECTRUM OF RADIATION



Electromagnetic spectrum can be defined as forms of energy that travel through space in waves consisting of both electric and magnetic properties. It includes the entire range of light that we can see and the radiation that is invisible to our eyes.

LIGHT-BASED TECHNIQUES FOR HAIR REDUCTION

- Laser and light-based techniques rely on the absorption of melanin in the hair shaft using wavelengths ranging from red, visible light, to near infrared light.
- These wavelengths range from approximately 700nm - 1100nm in the Electromagnetic Spectrum.
- The light is absorbed by the melanin in the hair causing thermal damage to the hair follicles.

ELECTROMAGNETIC RADIATION

All electromagnetic radiation consists of photons which are individual quantum packets of energy. In this course, we will mainly focus on the part of the electromagnetic spectrum specific to the use of laser for hair removal. This includes visible light and part of near infrared radiation.

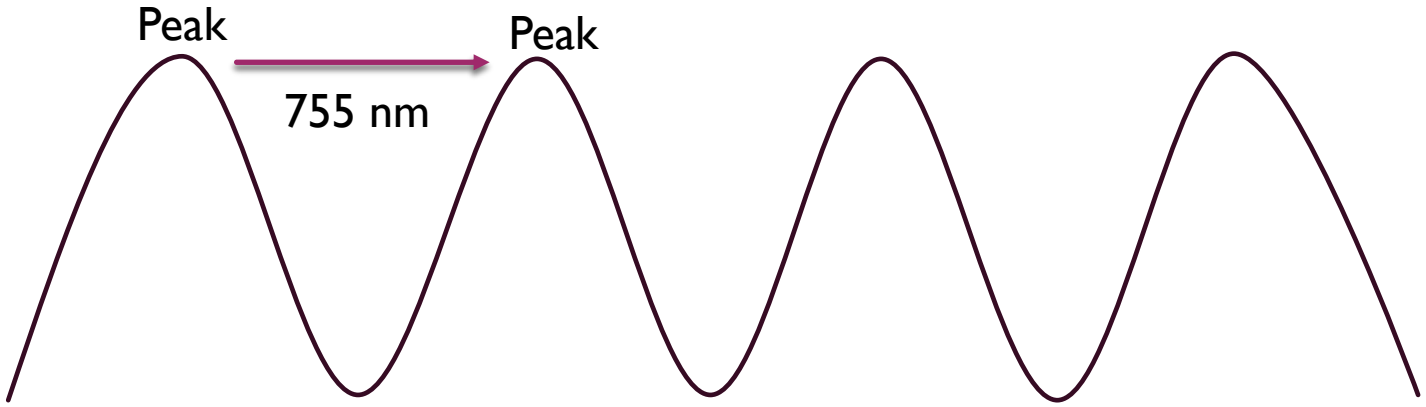
TYPE OF RADIATION	WAVELENGHT
Ultraviolet	100 nm – 400 nm
Visible light	400 nm – 750 nm
Near Infrared	750 nm – 3000 nm
Far Infrared	3000 nm – 1 mm

- Wavelength
- Frequency
- Photons

PHYSICAL PROPERTIES OF ELECTROMAGNETIC WAVES

WAVELENGTH

- Waves can vary in size. They are measured by the distance between two adjacent peaks or crest.
- Wavelength is measured in nanometers (nm).



FREQUENCY

The frequency of a wave is based on the number of cycles that will pass through space in one second.

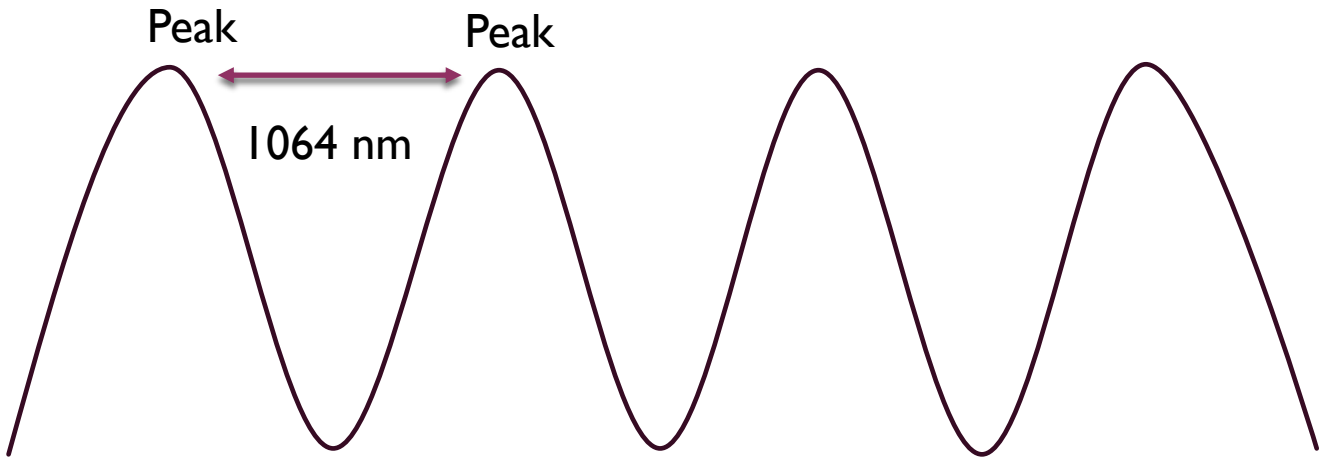
Frequency is measured in Hertz (Hz). The number of waves divided by the number of seconds.

Frequency is inversely proportional to wavelength.

(ie. longer wavelength = lower frequency)

Frequency

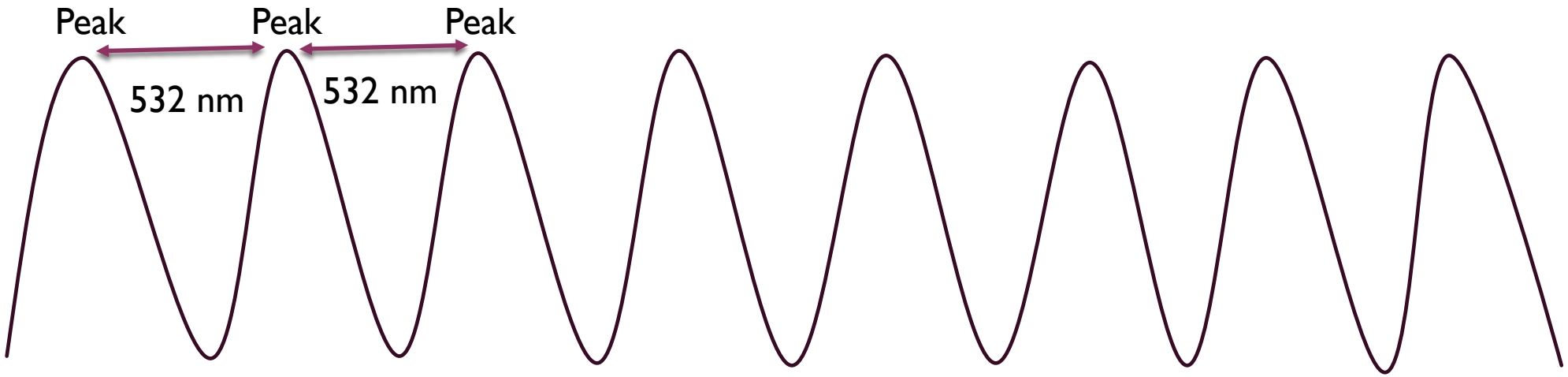
Figure A



Peak to Peak = 1 Cycle

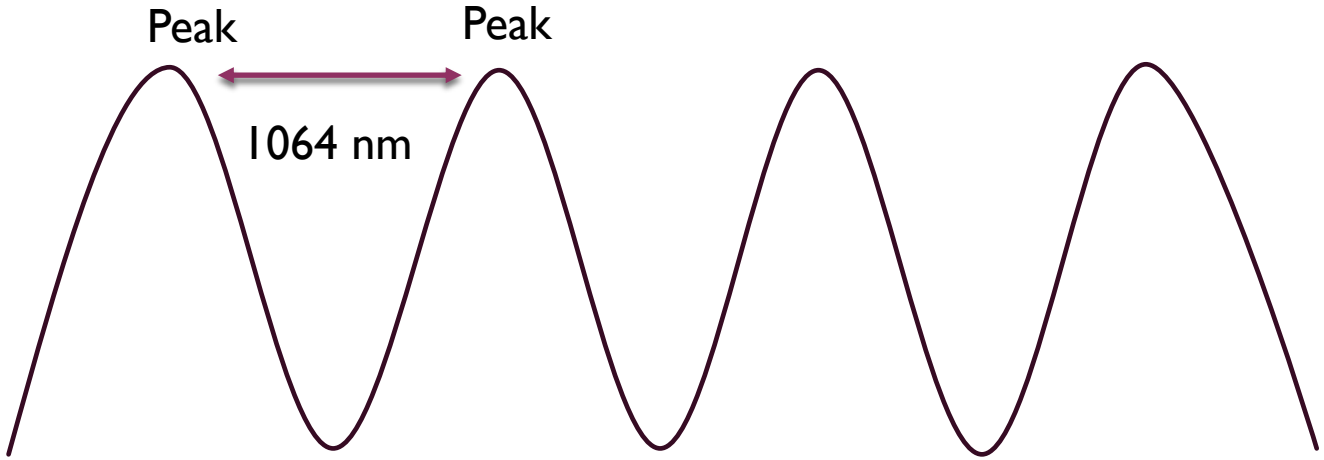
Frequency = Number of Cycles Per Second

Figure B



Frequency

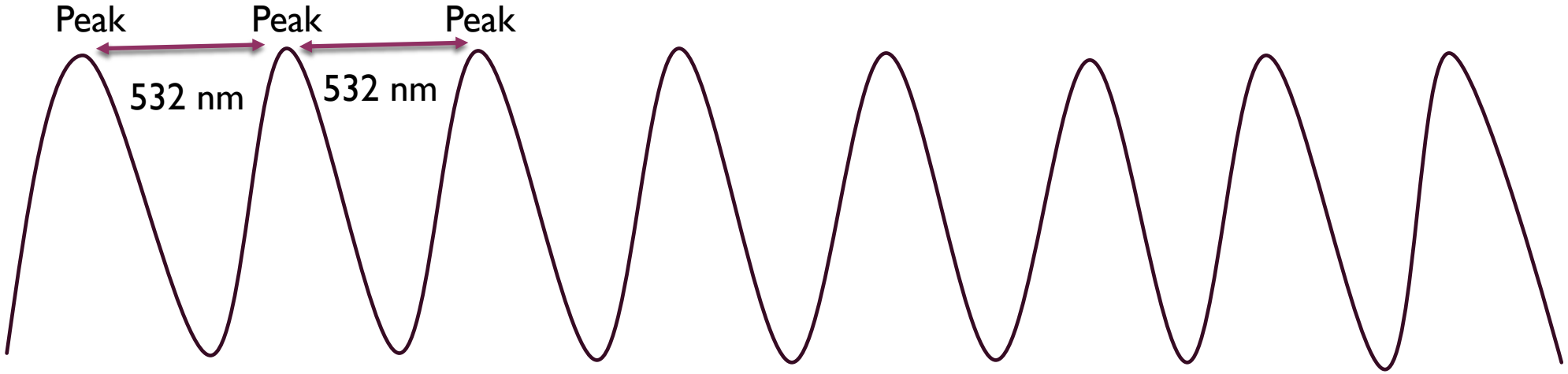
Figure A



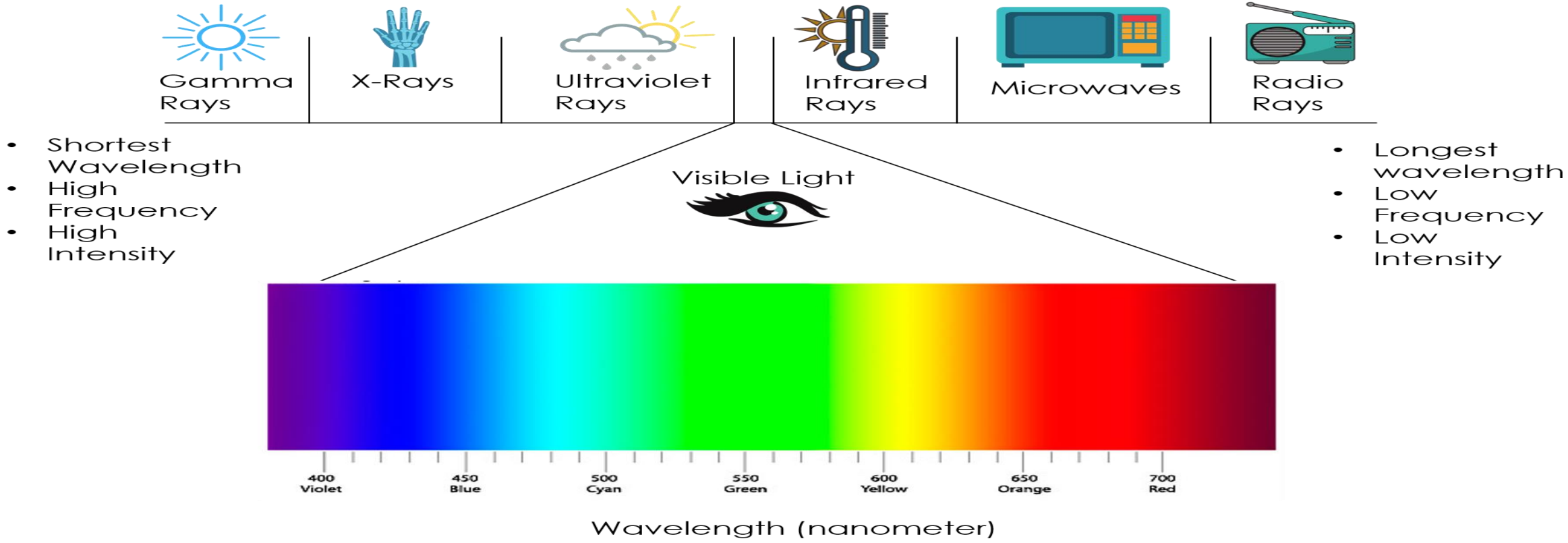
- Figure A has a longer wavelength of 1064 nm and lower frequency.

- Figure B occurs twice as frequently compared to figure A and has a shorter wavelength of 532 nm.

Figure B



ELECTROMAGNETIC SPECTRUM



Wavelengths between 400 nm – 700 nm are visible and detected by the human eye.

DEPTH OF PENETRATION

The wavelength has a major influence on the depth of penetration in the skin.

- Violet and blue light have shorter wavelengths, therefore they penetrate more superficially.
- Red light has the longest wavelength, therefore it penetrates the deepest.

Frequency

Figure A

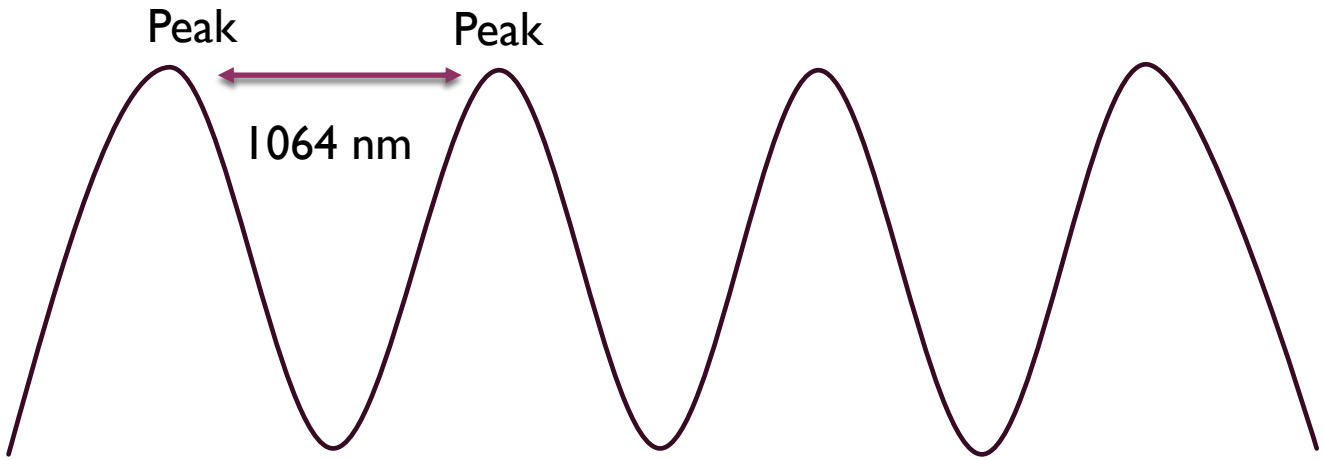
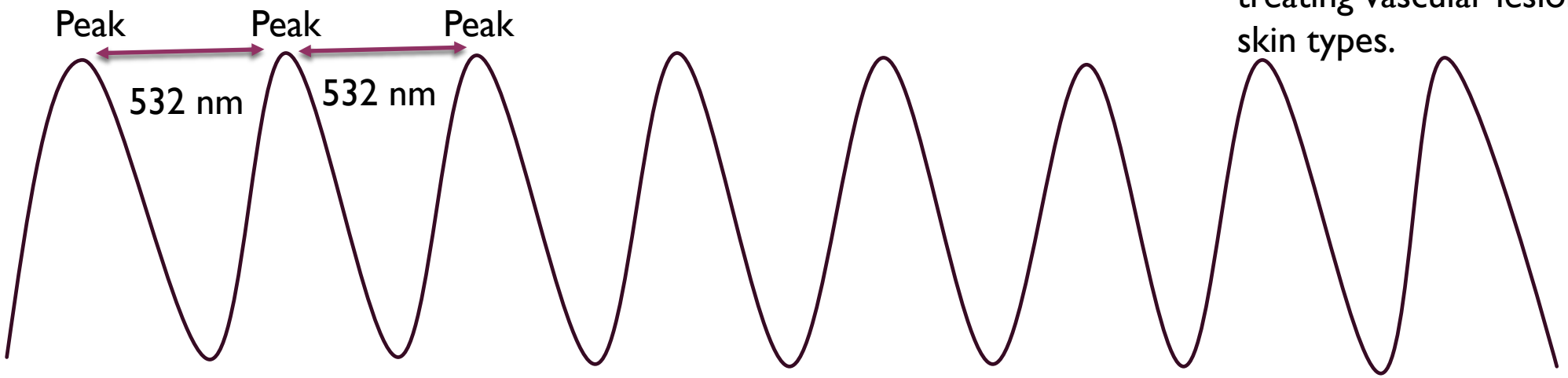


Figure B



- Figure A – 1064 nm penetrates deeper into the skin. This wavelength is ideal for laser hair removal treatments on darker skin types.
- Figure B – 532 nm is more superficial and more aggressive. These wavelengths are used for treating vascular lesions on lighter skin types.

- We know that frequency is measured in Hertz (hz).
- We use Hertz (hz) to set the pulse rate
- Pulse is a single burst of light that is emitted from a laser
- 1 hz per second = 1 pulse per second
- 2 hz per second = 2 pulses per second
- Pulse rate determines how fast or slow the treatment will be

PULSE RATE

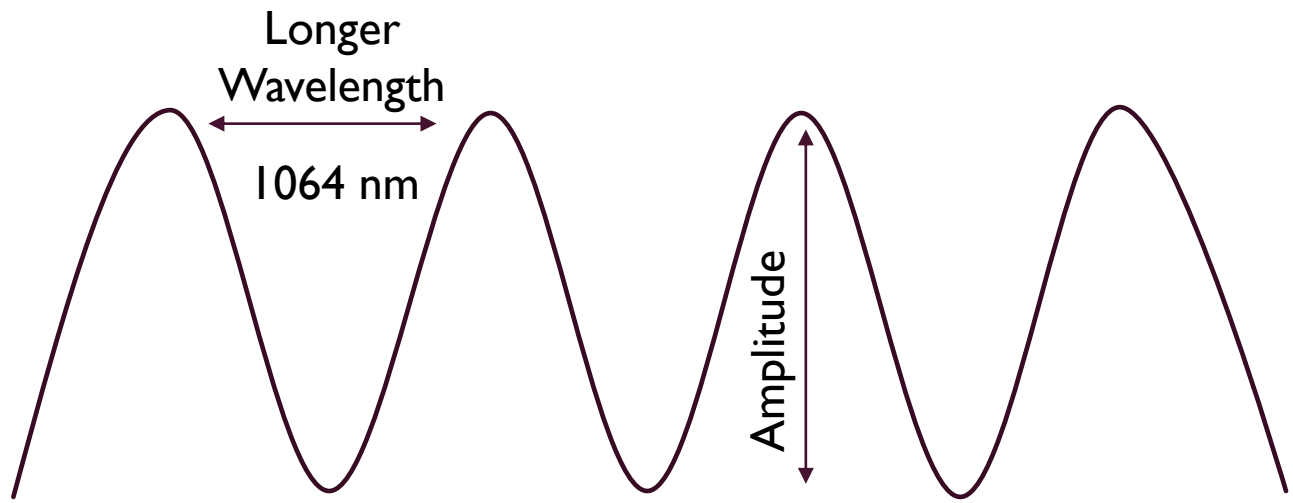
PHOTON

A photon is a particle of light which carries energy.

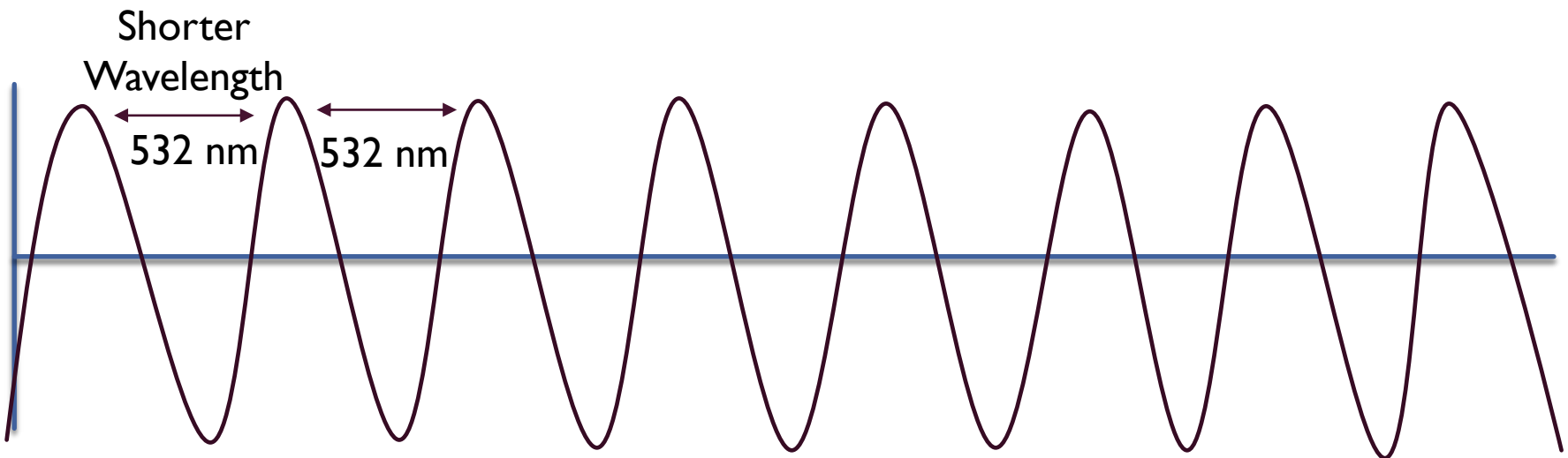
Directly proportional to frequency.

(ie. high frequency = high energy/intensity)

COMPARING WAVELENGTHS TO FREQUENCY AND ENERGY



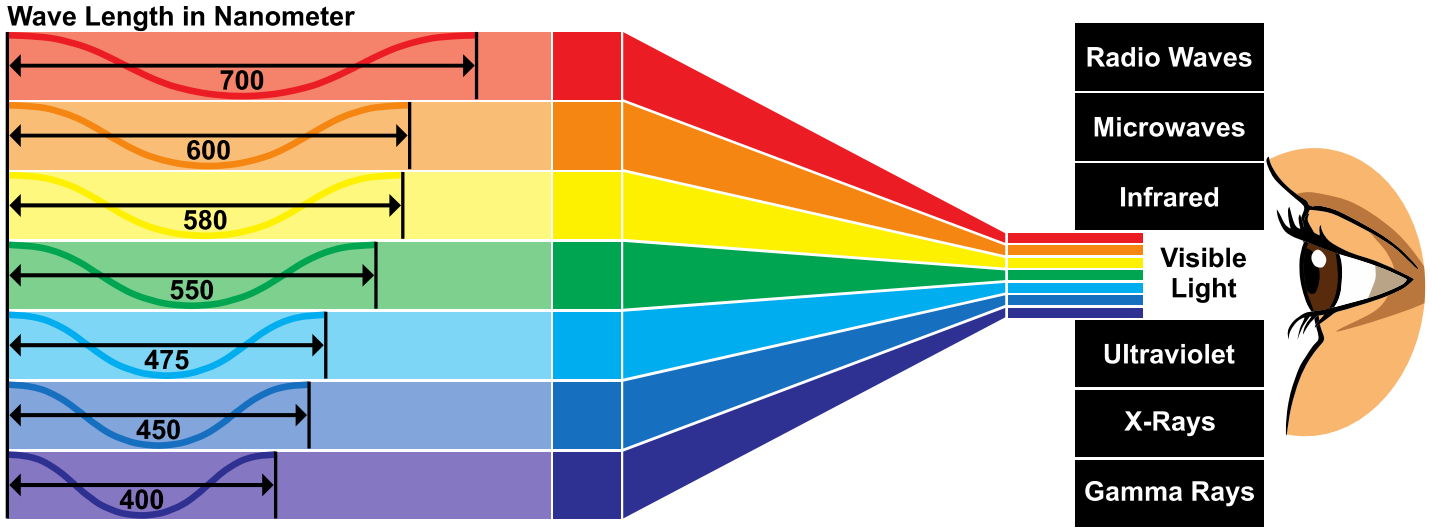
Longer wavelength
Lower Frequency
Low Energy



Shorter wavelength
Higher Frequency
High Energy

UNDERSTANDING THE ELECTROMAGNETIC SPECTRUM

- Visible light is the only part of the spectrum that can be seen with the naked eye. It ranges from approximately 400-800 nanometers (nm.). Everything else is invisible to us. In aesthetics, the goal is to pull different frequencies of energy from the spectrum in order to achieve some type of aesthetic benefit. (ie. Laser hair removal, vascular lesions, skin resurfacing, etc.)



RADIO WAVES

- Have the longest wavelength
- Lowest frequencies
- Can range from the length of a football to a size even larger than our planet
- These waves carry cell phone and television signals
- Radio waves convert electromagnetic waves into mechanical vibrations in the speaker to create the sound waves we can hear.

Microwaves

- Have slightly shorter wavelengths compared to radio waves
- Microwaves cause water and fat molecules to vibrate, which makes substances hot.
- Microwaves are commonly used by the following applications:
  - Cooking
  - Cell phones
  - Traffic speed cameras
  - Radars
  - Wi-Fi

ELECTROMAGNETIC SPECTRUM
THERE ARE 3 TYPES OF ELECTROMAGNETIC ENERGY

Visible light

This is the light we can see
35% of natural sunlight

Invisible infrared light

- Light that the naked eye cannot perceive
- Produces heat
- Longer wavelengths
- Lower frequency
- More penetrating
- 60% natural sunshine

Invisible ultraviolet radiation

- Light the naked eye cannot perceive
- Shorter wavelengths
- Higher frequencies
- Less penetrating
- 5% of natural sunshine

INFRARED LIGHT

Infrared waves are below the red light on the electromagnetic spectrum. These waves are invisible and are given off by hot objects.

Everything gives off heat:

Sun, stars, flames, lamps, and living creatures all produce infrared light. While we can't see this light, we feel it as heat.

We can use heat lamps to help heal sports injuries.

They can also be used for short range – communication such as mobile phones or night sight cameras

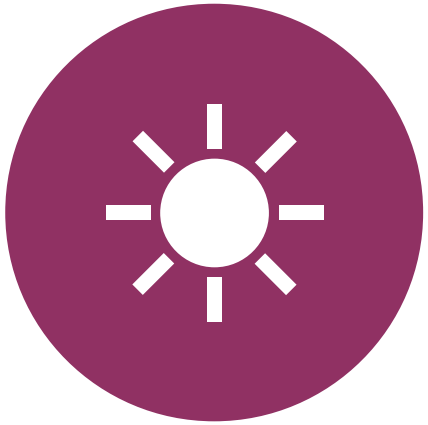
VISIBLE LIGHT

This is the tiny part of the Electromagnetic Spectrum that our eyes can see.

The violet light has the shortest wavelength.

The red light also has the longest wavelength.

ULTRAVIOLET LIGHT



ULTRAVIOLET A (UVA)

ULTRAVIOLET B

ULTRAVIOLET C

AFFECTS OF ULTRAVIOLET LIGHT

- In aesthetics, our goal is to reverse the damage from Ultraviolet exposure
- UV Radiation causes ionization, which is responsible for skin cancer
- A suntan is the body's natural defense mechanism to protect the skin from sun damage.
- When our body is exposed to the harmful rays, a pigment called melanin is produced to absorb the UV light and to dissipate it as heat. As a result, it causes our skin to darken or produce sunspots.
- Over exposure to UV radiation can damage the DNA of skin cells and produce toxic reactions causing sunburns.
- There is a higher risk for skin cancer amongst individuals who get sunburned frequently.

ULTRAVIOLET A (UVA)

- Has shorter wavelengths compared to visible light
- Penetrates directly into the dermis of the skin
- Damages the collagen and elastin
- Known as aging ray
- Often used in tanning beds
- Causes skin cancer
- 315 – 400 nm

ULTRAVIOLET B (UVB)

- Known as the burning ray- associated with sunburns
- Causes skin cancer
- 280 – 315 nm

ULTRAVIOLET C (UVC – 180 – 280NM)

Blocked by the ozone layer

This could literally destroy the earth

180 – 280 nm

X-RAYS

Very high frequency waves that carry a lot of energy.

X-rays have shorter wavelengths compared to Ultraviolet Rays.

How X-rays work: A beam of electrons are fired at a target. The x-rays pass easily through tissue, not bone. Therefore, X-rays pass through a patient onto a film and produce white patches on areas that are bone and black patches to areas without bone.

GAMMA RAYS

Gamma rays have the shortest wavelengths and are the most powerful and energetic photons.

They come from radioactive sources. They can be created through nuclear explosions using atomic bombs or be emitted by lightening on earth.

They naturally occur in outer space due to exploding supernovas, black holes, and radio active decay.

Due to advancement in technology, high doses of gamma radiation is used to kill cancerous cells.

IONIZING VS. NON-IONIZING RADIATION

Ionizing Radiation – carries an immense amount of energy capable of ionizing atoms or molecules. This means that this type of radiation causes cell destruction and is responsible for cell mutation which leads to cancer.

Ultraviolet light	X-rays	Gamma rays	Radio-active decay

Non-Ionizing Radiation – does not produce enough energy to breakdown molecular bonds or ionize atoms.

Near ultraviolet	Visible light	Infrared light	Microwaves	Radiowaves

All laser devices used in aesthetics produce non-ionizing radiation

RECAP OF ELECTROMAGNETIC SPECTRUM

THE USE OF LASERS

MEDICINE:

CARPENTRY

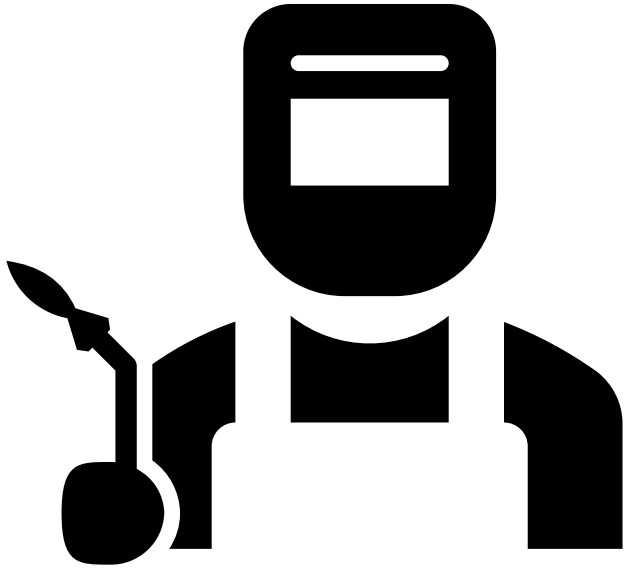
WEAPONS

HOUSEHOLD AND TECHNOLOGY

MEDICINE:

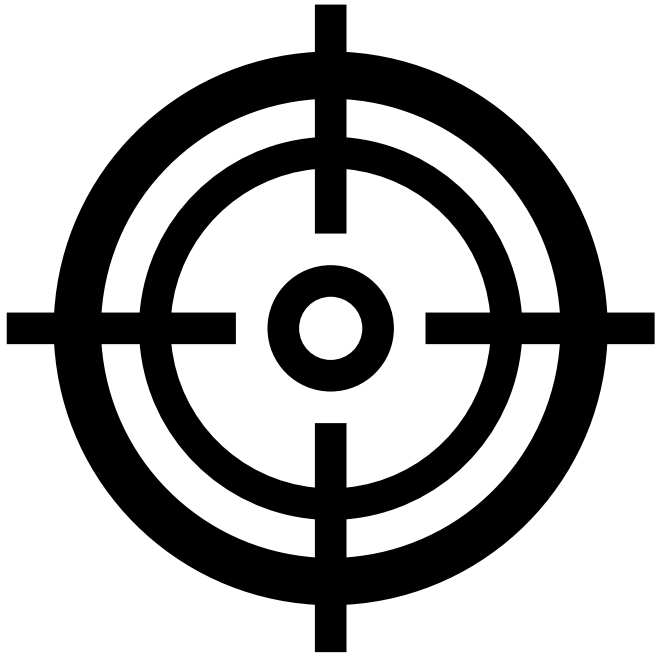
- Remove damaged tissue
- Removal of unwanted imperfections of the skin including hair, tattoos, birthmarks, and scars.
- Dental surgery and stain removal
- Eye surgery

CARPENTRY



- Used for cutting through metal and glass

WEAPONS



- Used in guns to improve aim

HOUSEHOLD AND TECHNOLOGY

- Telecommunication
- Cd players
- Laser scanners

A process called Stimulated Emission is used to create a laser light.

1

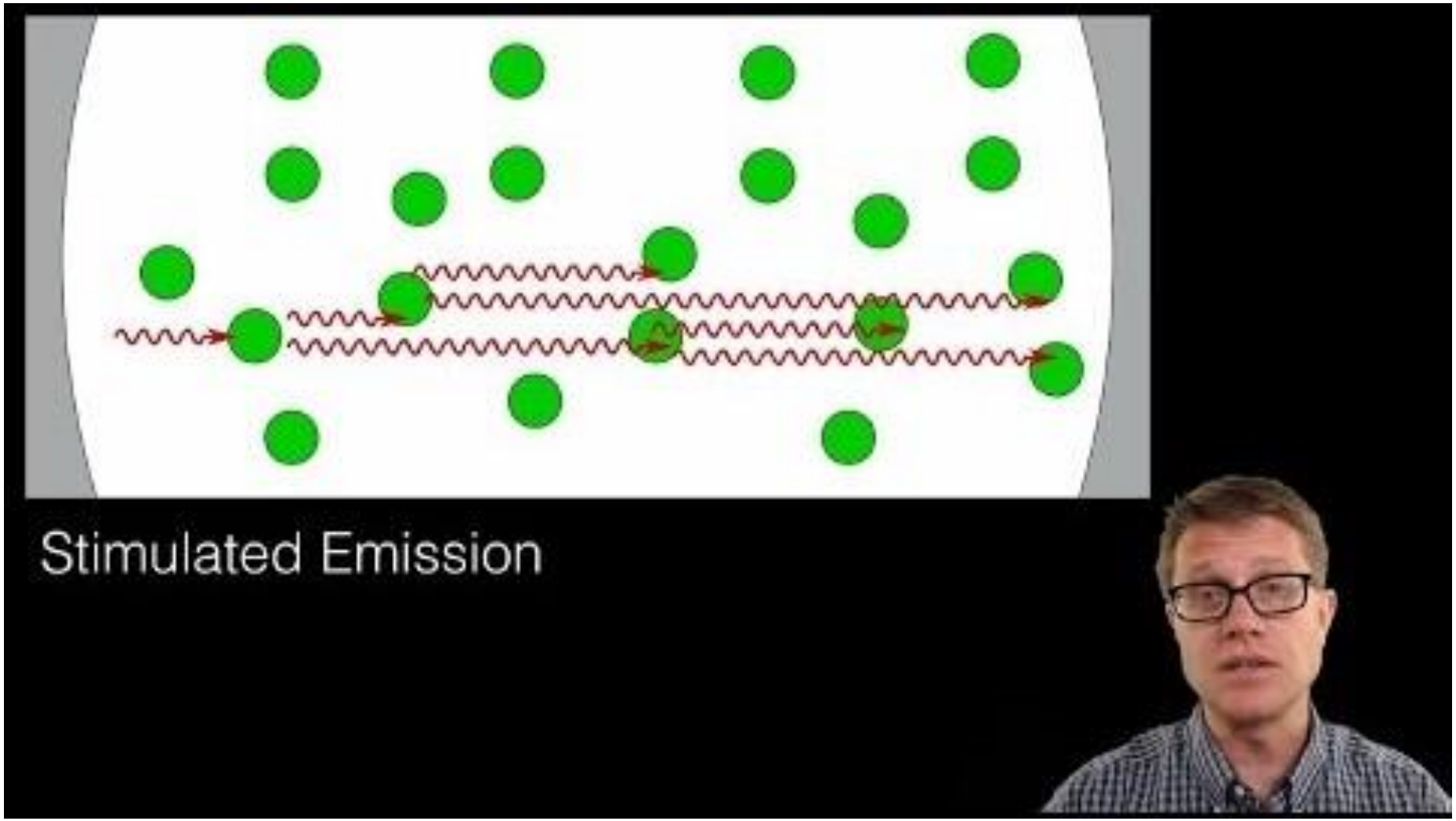
A laser is created when the electrons in atoms absorb energy from an electrical current and become excited.

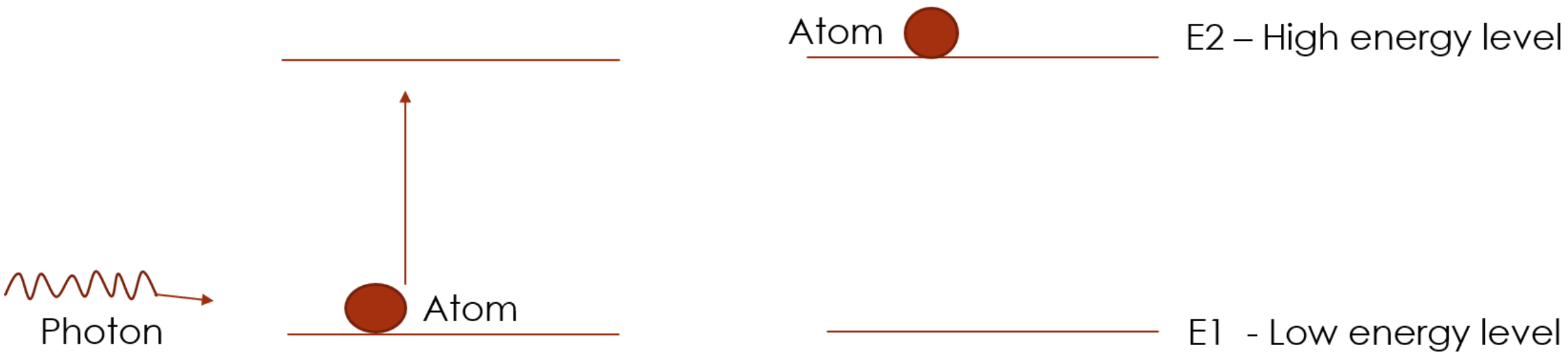
2

The excited electrons move from low energy to high energy and then back to low energy while emitting photons (particles of light).

HOW LASERS WORK

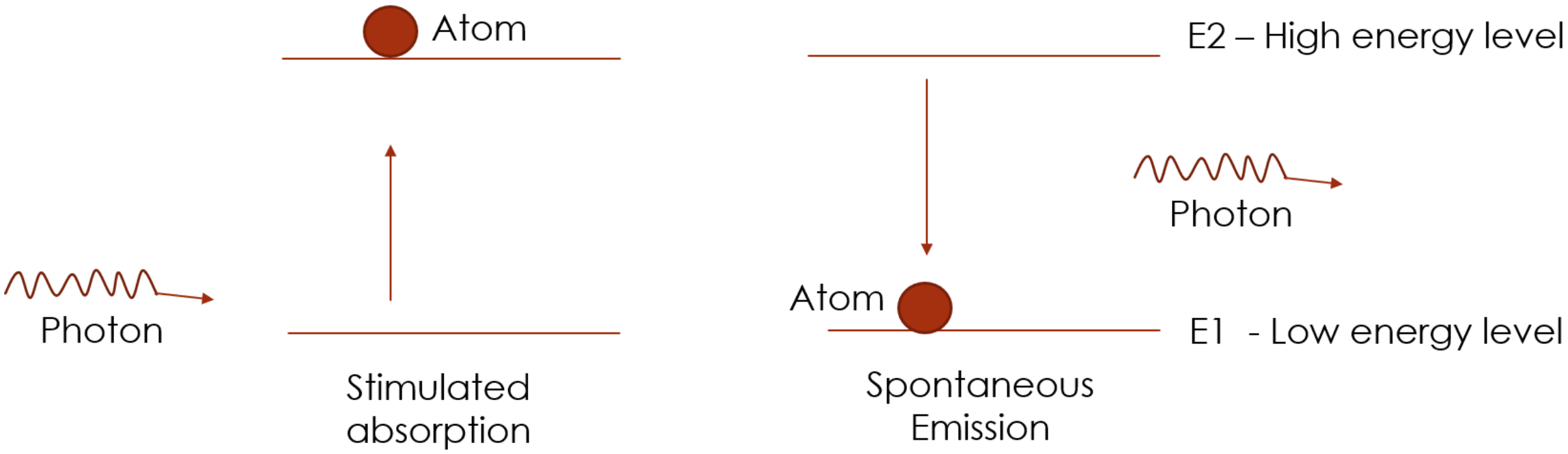
HOW LASERS WORK





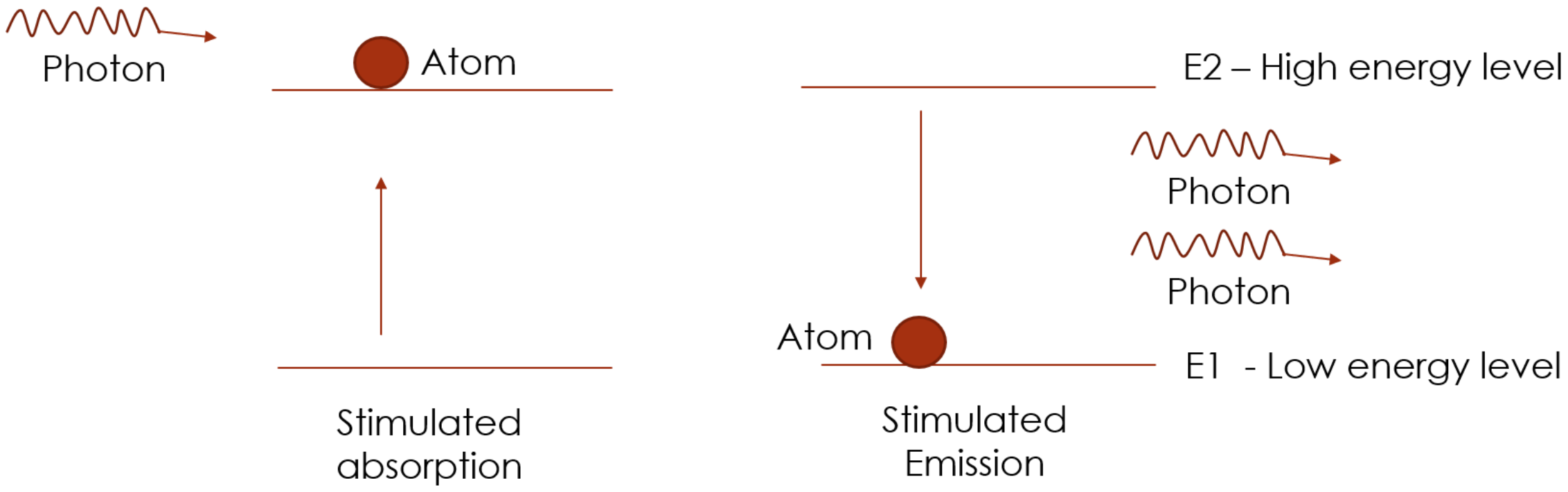
STIMULATED ABSORPTION

- Stimulated absorption – When an atom at a low energy level is hit with a photon, it takes the energy of the photon and moves to a higher energy level. In this case, the atom is absorbing the energy of that photon.



SPONTANEOUS EMISSION

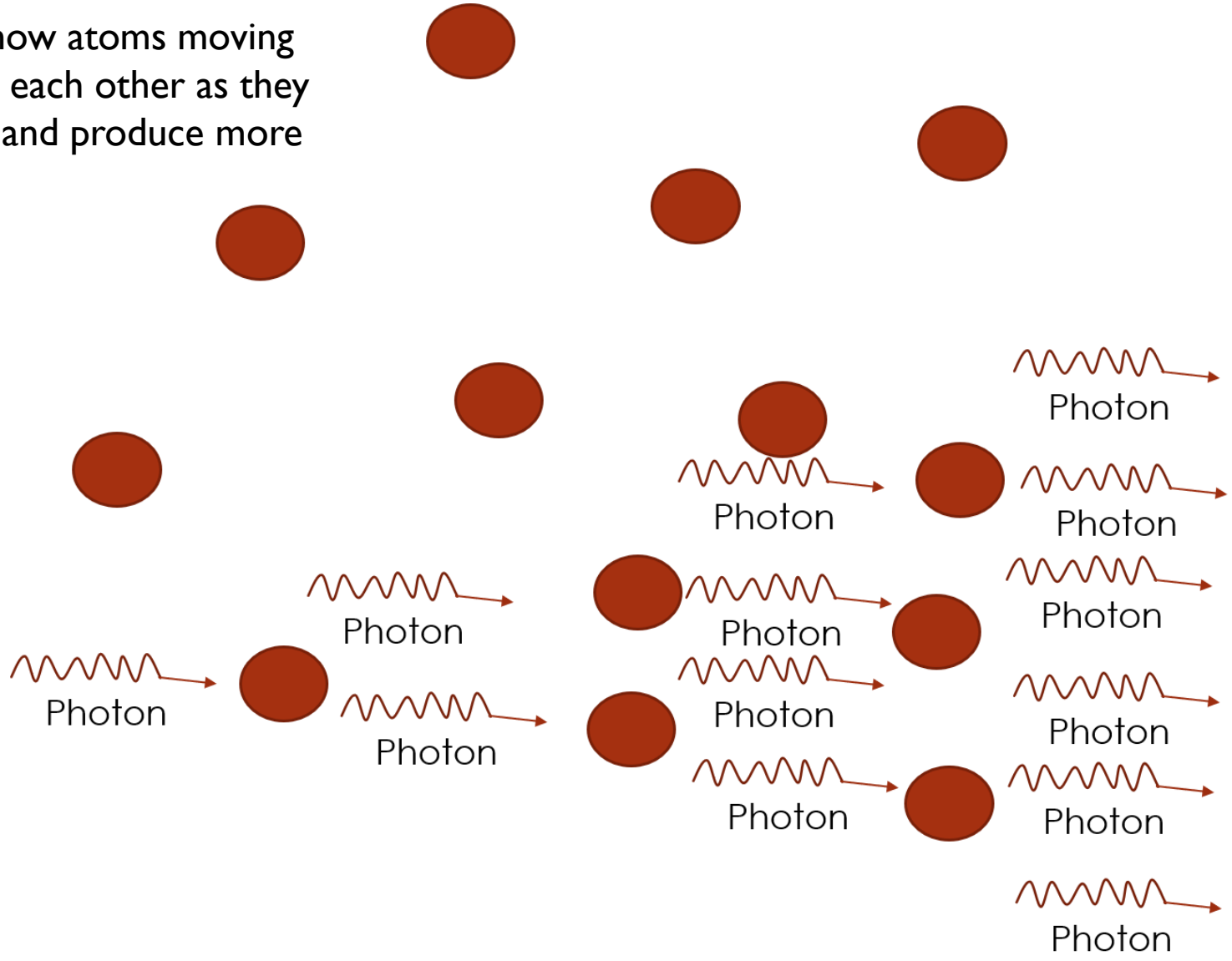
- Spontaneous Emission – When the atom falls back down to the low energy level, it releases the same photon.



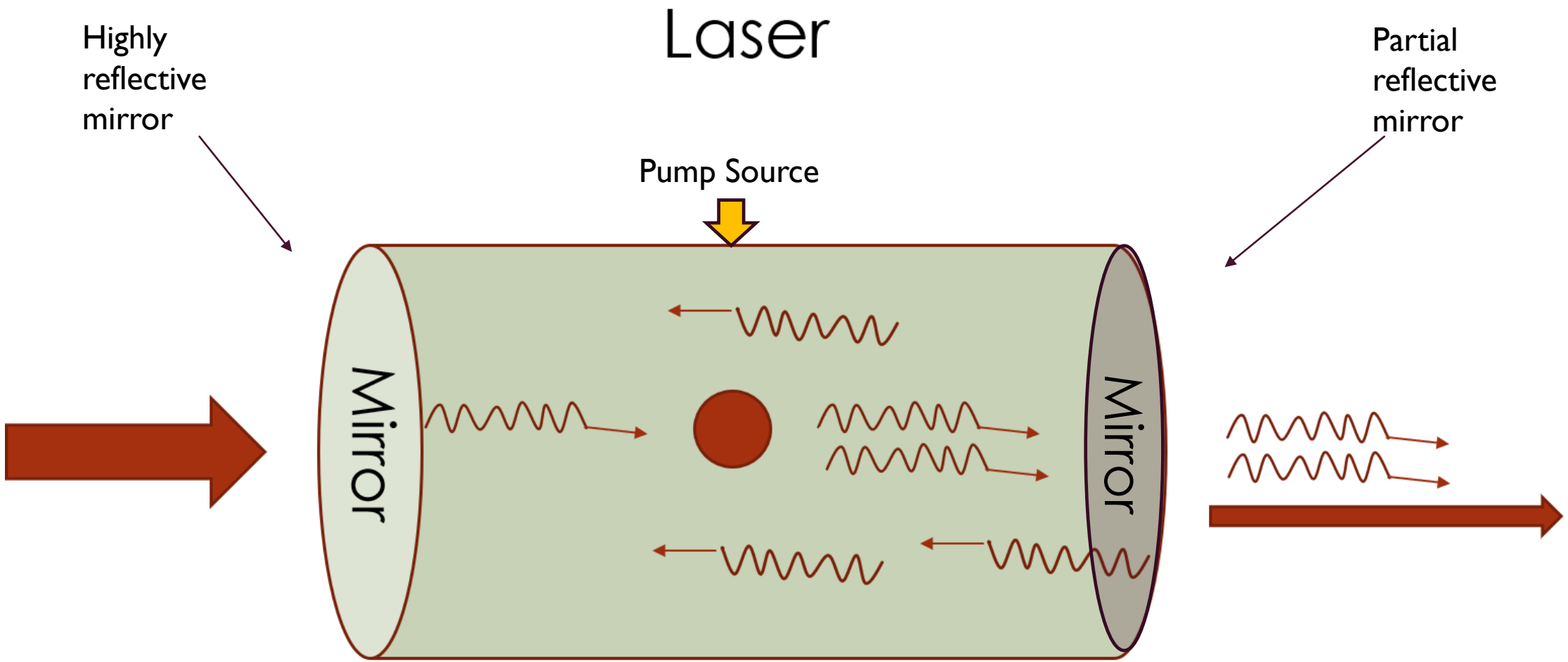
STIMULATED EMISSION

- When an atom has already been stimulated and is at a higher energy level and it gets stimulated again. Instead of moving to an even higher energy level, a second photon is released identical to the first.

Demonstration of how atoms moving coherently build on each other as they become stimulated and produce more photons.



Laser

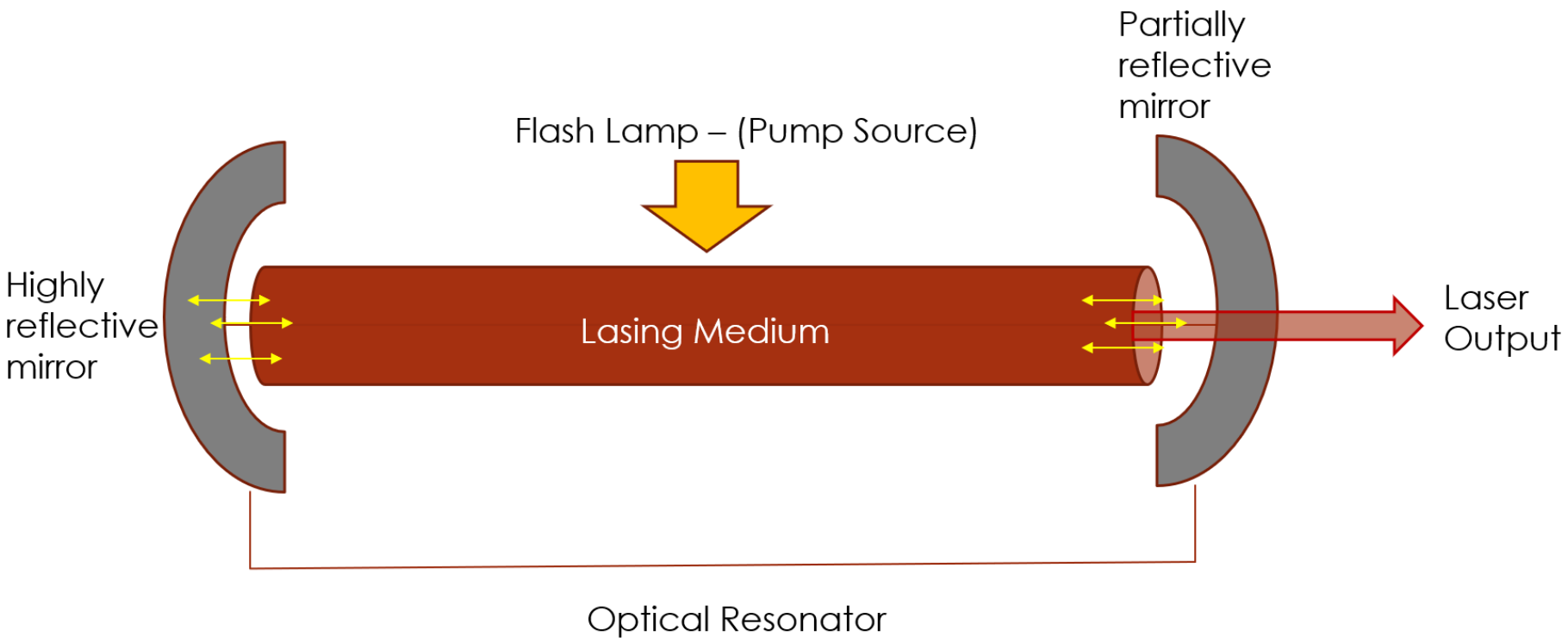


Photons bouncing back and forth from the mirrors on each side as they are pumped with more energy using a flash lamp or a pump source. As the reflectivity is lowered on the right, the photons move out coherently as light.

COMPONENTS OF A LASER

- Active Medium – solid state, gas, semiconductor, liquids, etc
- Energy Source – refers to the pump source - Flash lamp, electric current, laser
- Optical Resonator – mirrors
- Software
- Microprocessor
- Delivery System
- Cooling System

COMPONENTS OF A LASER



TYPES OF LASERS ACTIVE MEDIUM

Solid State Lasers:

- These lasers contain solid pieces of insulators that serves the excitable medium.
- Reflective mirrors contain this medium in a chamber
- Example: Holmium Yag used in dentistry and for destroying kidney stones
- Includes Ruby Crystal Lasers

Dye Lasers:

- Uses an organic liquid dye as a lasing medium which can be very toxic
- Example: Pulsed Dye Lasers used to treat scars and lesions

Gas Lasers:

- Contain gas, sealed in a tube with mirrors at its ends.
- Example: Barcode scanning lasers and holographs

Semiconductor Lasers:

- The light generated bounces back and forth to give the stimulated emission.
- Example: Compact disk players, laser pointers, diode lasers

ABLATIVE VS. NON-ABLATIVE

- Ablative lasers work to remove the top layer of the skin while non-ablative systems heat up the underlying tissue without harming the surface of the skin.

ABLATIVE SYSTEMS

Includes CO_2 and Erbium Lasers

Used for skin resurfacing to treat:

- Fine lines and wrinkles
- Scars
- Age spots
- Uneven skin tone

Longer recovery time

- 3 to 4 weeks

Risks:

- Redness, swelling, itching
- Acne
- Infection
- Scaring
- Change in pigmentation of skin

NON-ABLATIVE SYSTEMS

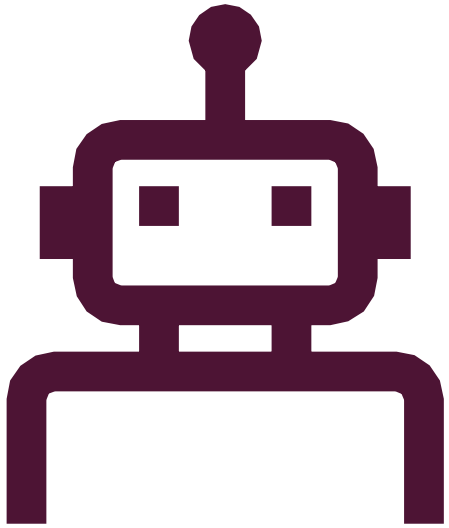
Can be used for skin resurfacing or laser hair removal

Less invasive and shorter recovery time

Less effective compared to ablative lasers for skin resurfacing

Risks:

- Mild swelling (edema) or redness (erythema)
- Infection
- Blistering
- Scarring
- Changes in pigmentation



TYPES OF LASERS

PAIRING FREQUENCIES WITH TECHNOLOGY

- 420 nm – BLUE LIGHT THERAPY
- 532 nm – KTP
- 585 nm – PULSED DYE LASER
- 694 nm– RUBY LASER
- 755 nm – ALEXANDRITE LASER
- 810 nm – DIODE LASER
- 1064 nm – ND-YAG LASER
- 1540 nm – ER-YAG
- 2490 nm– ER-YAG
- 10,000 nm – CO2
- Radio Frequency

BLUE LIGHT THERAPY – 420 NM

Used to treat the following conditions:

- Acne
- Sun-spots
- Texture
- Scars
- Precancerous skin lesions
- Cancerous skin lesions that haven't spread
- Depression

Method of treatment:

- When treating acne, a topical application known as ALA is applied 30 min prior to treatment. Blue light is applied directly on to the affected area for approximately 15 minutes. This procedure is repeated 2 times a week for 4 weeks. The results are equivalent to Accutane which does have more side effects, yet a more practical option, cost effective, and less time-consuming compared to Blue Light Therapy.

More Information

- Non-Ablative
- Appropriate for skin type

KTP- 532 NM GREEN LIGHT

Used to treat the following conditions:			
Pigmentation	Vascular lesions	Rosacea	Tattoo Removal

Target Chromophore:		
Melanin for pigmentation	Oxyhemoglobin contained within blood vessels	Red pigment for tattoo removal

Method of Treatment:
Hand piece is pressed against the surface of skin to activate light with a forced air-cooling modality to protect the skin.

More Information:	
Non-Ablative	Appropriate for skin type: 1-3

PULSED DYE LASERS – 585 NM

Used to treat the following conditions:

- Vascular lesions
- Port wine stains
- Warts
- Cherry angioma
- Keloid scars
- psoriasis

Target Chromophore

- Oxyhemoglobin

Method of Treatment

- This is a Non-Ablative laser which emits high energy yellow light that is absorbed by red blood cells within the blood vessels.

RUBY LASERS

- First laser developed in 1960 for laser hair removal.
- Non-Ablative Laser
- Solid-state laser that uses a ruby crystal as its gain medium.
- Generates pulses at a wavelength of 694 nm
- Limited to skin types 1-2
- No longer used for hair removal in the United States
- Primarily used for tattoo removal

ALEXANDRITE LASERS

- Least comfortable laser hair removal system with cooling modalities
- Non-Ablative Laser
- Solid state laser- uses crystal as a lasing medium
- Fastest laser system - downside – More painful from fast laser repetition
- Operates at a SHORTER wavelength of 755nm
- Ideal for individuals with light to olive skin color

DIODE LASERS

- Popular laser system
- Non-Ablative Laser
- Generally safe on darker skin types with coarse hair
- Operates at LONGER wavelengths of 800 – 810 nm.
- Only used for hair removal

ND-YAG

- Solid State laser – uses crystal as a lasing medium and a flashlamp for the pump source
- Operates at a LONGER wavelength of 1064 nm
- Non-Ablative Laser
- The frequency can be doubled to treat rosacea with 532 nm
- Used for hair removal, spider veins, laser facials, varicose lesions, rosacea, skin tightening.
- Safe for all skin types
- NOT used for TATTOO REMOVAL

ND-YAG – Q-SWITCH TATTOO REMOVAL

- Operates at a SHORTER wavelength of 532 nm
- Non-Ablative Laser
- Used for tattoo removal, vascular lesions, and pigmented lesions
- Safe for all skin types

LASER AND ENERGY CONCEPTS

- Irradiance
- Power
- Energy
- Fluence
- Spot Size
- Wavelength

IRRADIANCE

Irradiance – also referred to as POWER DENSITY

Shows the concentration of power in space (Spot size of the beam)

This is the intensity of the delivered beam

When you add the time component (i.e. a 20 millisecond pulse) it is converted into the treatment parameter of Joules/cm2. – These settings are generated automatically by the laser device.

IRRADIANCE (POWER DENSITY)

- Spot Size and Power (Watts/cm2)
- The most rapid changes are created by the Spot Size
- Altering the spot size is what primarily changes the Power Density – depends on the delivery system
- If Power Density is too high, it leads to burns and blistering
- If power Density is too low, there is no harm, but the treatment is ineffective

FLUENCE

- The proper term for Fluence is Radiant Exposure also known as Energy Density
- It is the "dose" of light in energy delivered per surface area of the laser spot – measured in Joules/cm2
- More energy is required for larger spots
- Parameters are set by the manufacturing companies with guidelines for treatment settings
- Joules /cm2 = Fluence

FIVE PARAMETERS FOR UNDERSTANDING LASER SETTINGS

- Wavelength
- Power
- Spot Size
- Pulse Width
- Cooling

WAVELENGTH

Wavelength is determined by the target chromophore

Water	Hemoglobin	Melanin

Two basic principles in light tissue interaction: absorption and scatter

The higher the absorption the less the scattering.

****Chromophore** – material present either in the tissue or brought from outside the tissue which absorbs particular wavelengths depending on its absorption coefficient.

LASER TISSUE INTERACTION

Transmission – Photons will pass through tissue if no chromophore is present.

Reflection – The amount of energy that is reflected off the skin or any surface. The reflected thermal properties of light can cause surface burns, fire, or eye damage. Reflection can be minimized by holding the hand piece exactly perpendicular to the skin's surface.

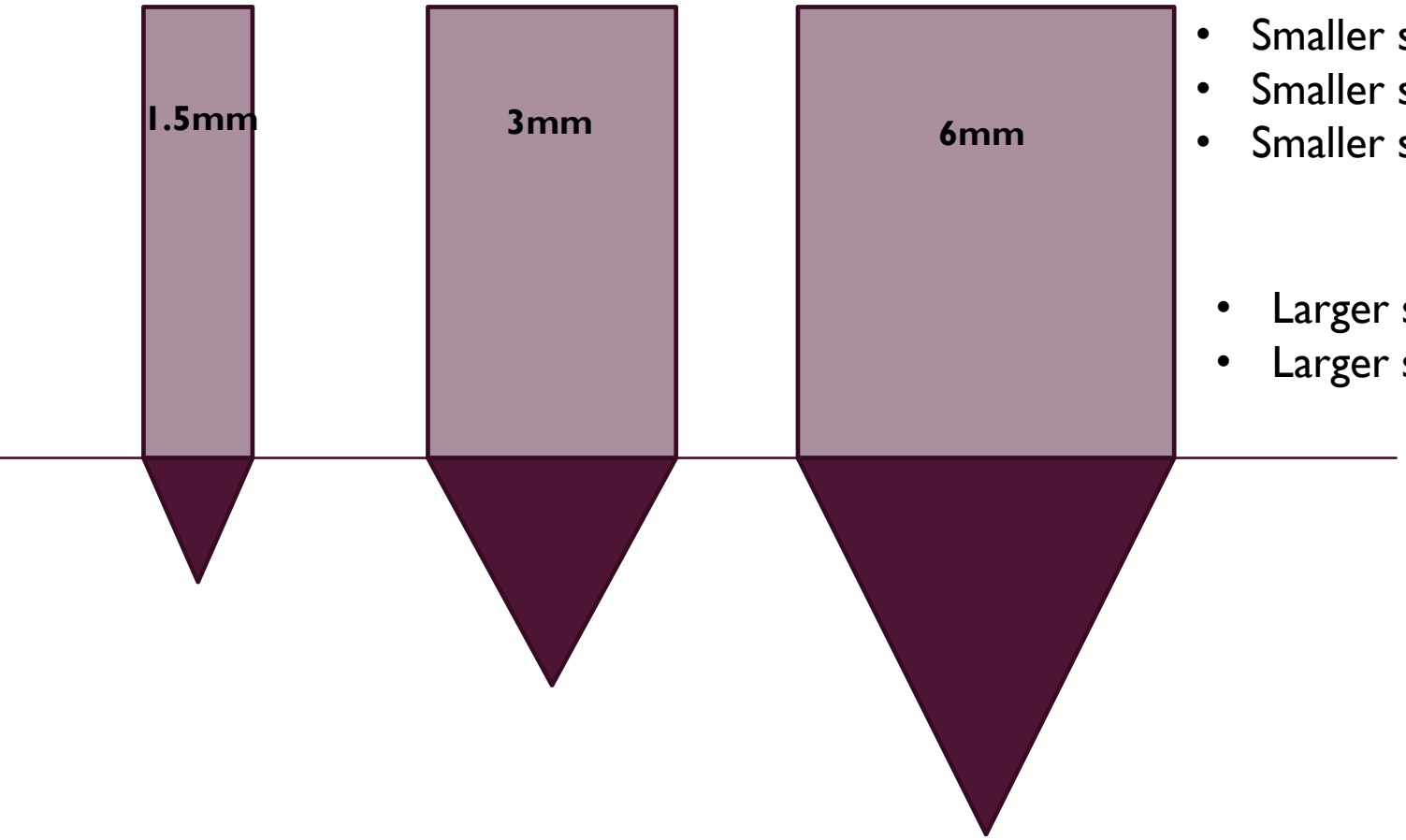
Scattering – occurs due to lack of homogeneity in the skin's structure, such as molecules, organelles, cells, or larger tissue structures. Shorter wavelengths have greater scattering. This decreases the depth of penetration and increases the possibility of absorption of the surrounding tissue (skin).

Absorption – Absorbed photons can produce thermal, mechanical, or chemical changes in and around the chromophore. For hair reduction, thermal changes are the most useful.

POWER AND SPOT SIZE

- Power and Spot Size are two separate parameters. When combined they make up Power Density
- The combination of these 2 characteristics will tell us how much energy and heat are delivered to the desired target

SPOT SIZE

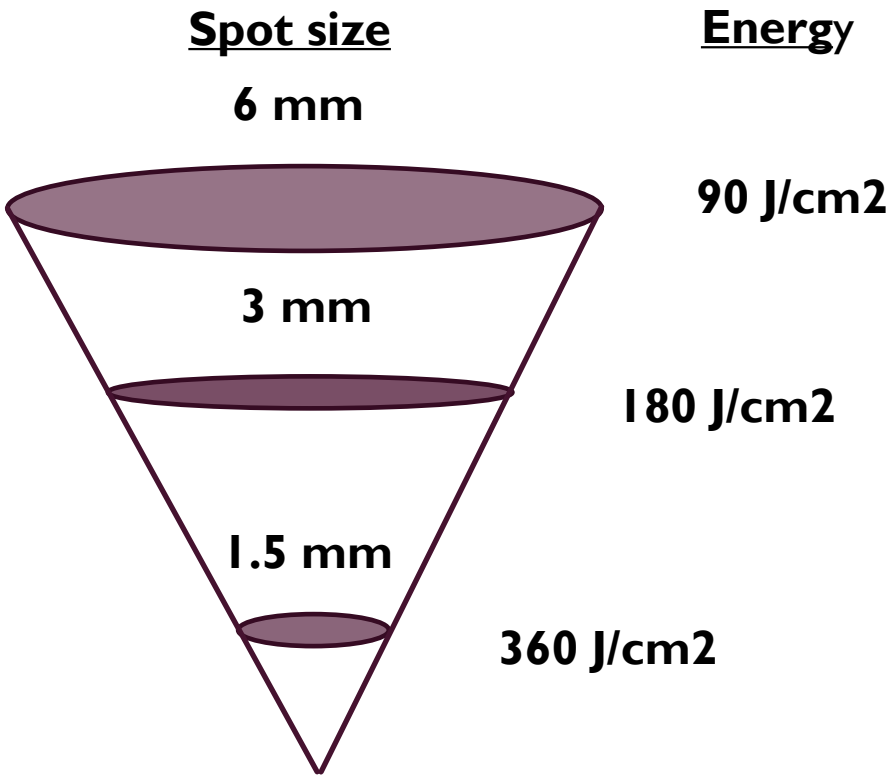


- Smaller spot size = Decreases depth of penetration
- Smaller spot size = More scattering of photons
- Smaller spot size = More superficial treatment effect

- Larger spot size = creates an inverse pyramid (dark purple)
- Larger spot size

DECREASING SPOT SIZE

When decreasing the spot size, the energy delivered should be doubled in order to create an effect similar to the treatment depth due to more scattering and decreased intensity of the incident beam.



90 J/cm2 on a 6mm spot size would be the safest and most effective setting if the target requires a deeper penetration. For a more superficial treatment, you would decrease the spot size.

Example: Imagine hitting an object with a finger with light pressure vs. hitting an object with your entire hand with the same amount of pressure, the impact will be much greater with the hand. In order to achieve the same pressure with the finger, one must hit harder. Hence, the smaller the spot size, the energy level needs to be doubled to make an impact.

PULSE DURATION (PULSE WIDTH)

This is the exposure or delivery time of selected energy to the target tissue

Smaller targets require less time to heat compared to larger targets.

Example: When boiling water, a smaller pot would heat up faster than a larger pot. Therefore, thicker, dense hair would require more energy to heat up compared to fine, thin hair.

The Thermal Relaxation Time (TRT) is defined as "a unit time for a target to release more than half of the temperature rise in the target tissue"

TRT is essential in understanding pulse width

The recommended pulse width or energy exposure time to the target is half of the TRT.

SELECTIVE PHOTO-THERMOLYSIS

It is a technique used to select specific wavelengths of light to heat and destroy targeted chromophores without damaging surrounding tissue.

Selective photo-thermolysis is achieve by limiting laser light to a time shorter than the TRT.

This allows the energy to be contained to the selected target while sparing the surrounding tissue.

THERMAL RELAXATION TIME (TRT)

- Thermal relaxation time is the amount of time it takes for a target to lose 50% of heat delivered.
- **TARGET CHROMOPHORE**: For laser hair removal, in order to effectively destroy the hair follicle, it is necessary for the pulse duration, or the delivery time of the light, to be shorter than its Thermal Relaxation Time, otherwise the heat will dissipate before causing thermal damage to the target.
- **EPIDERMIS:** In order to spare adjacent structures such as the skin, the pulse duration, or the delivery time for the light, should be longer than the Thermal Relaxation Time. This will minimize thermal injury to the skin.

UNDERSTANDING THERMAL RELAXATION TIME

- Thermal Relaxation Time (TRT) for the Epidermis is (approximately 3 – 10 milliseconds)
- Thermal Relaxation Time for the hair follicle is (approximately 40 – 100 milliseconds)
- Therefore, Pulse Duration between 10 – 40 milliseconds, should be sufficient amount of time to cause thermal damage to the hair follicle while sparing the surrounding tissue (epidermis).

REPETITION RATE

- Repetition rate (frequency) is measured in pulses per second.
- Adjusting the repetition rate determines how long each treatment will take and how well the client will be able to tolerate it. However, it does not impact the effectiveness of the treatment.
- Faster repetition rate allows for faster treatment time, yet it can be more painful and uncomfortable for clients possibly causing blisters.
- Slower repetition rate results in slower treatment time, yet less painful and more comfortable for clients.
- Heat accumulates faster when pulses are applied rapidly, even if there is not much overlapping.
- For lower fluence applications, many manufacturers require some degree of overlapping, preferably 10%, in order for heat to accumulate.
- Overlapping for high fluence applications should be avoided to prevent extreme heat generation causing burns or scarring.

COOLING MODALITIES

- Contact Cooling
- Cryogen Sprays (selective epidermal cooling)
- Ultrasound Gels
- Cold Air Chillers
- Post-Treatment cooling packs

WHY COOLING IS REQUIRED

- To protect the epidermis from burns and blisters
- Reduce swelling and inflammation
- Decrease the level of pain and discomfort associated with laser treatments
- Protect darker skin types
- Lasers generates a tremendous amount of heat. Such high levels of heat can cause severe damages to the skin if not provided appropriate cooling during the treatment. Therefore, manufacturers have added cooling mechanisms to laser systems that provide cool air or cool chillers to maintain the level of heat at certain temperatures.

CONTACT COOLING

- Contact cooling is designed to protect the epidermis by allowing water to circulate around tip of the handpiece while cooling the skin. It is important to keep the handpiece compressed against the surface of the skin before firing each pulse in order to prevent any types of burns. Condensation may build up on the surface of the tip and may require cleaning many times throughout the treatment.

CRYOGEN SPRAYS

- Burst of air is sprayed onto the skin right before exposure to laser energy. As the cryogen liquid starts to evaporate, it begins to cool down the skin.
- This method works great for shorter pulse widths, where the treatment is more aggressive. You may also be able to treat more aggressively with darker skin types.
- There may be a risk for burns if the cryogen spray is not aligned correctly with the laser beam.
- "Freezer burns" may result from excessive cryogen pulse times.

PULSED LASER EMISSION

Pulsed lasers emit light in very short pulse durations at very high peak powers.

These are bursts of energy that are emitted in short intervals (usually in microseconds or nanoseconds)

The time it takes to emit the energy is called Pulse Width

CONTINUOUS WAVE (CW)

- Continuous Wave is a constant delivery of laser energy.
- Its maximum powers are lower than pulsed lasers but can emit immense amount of energy.
- Despite the time frame involved, the amount of power delivered is constant.
- In a Continuous Wave mode there is a limit to the amount of power that can be produced.
- The laser resonator can only store a limited number of atoms or molecules to produce the light.

PULSING TERMINOLOGY

- Q-Switch : Maximum peak power pulse delivered in nanoseconds
- Pulse Width : Term used when referring to pulsed lasers
- Exposure Duration : Term used when referring to continuous wave lasers
- Pulse Repetition Rate (PRR) : times per second
- Hertz (Hz) : Times per second

SHORT PULSED LASERS

- Short pulsed lasers are also called Q-switch lasers
- They are primarily used for tattoo removal and can also be used for vascular and pigmented lesions.
- Short pulsed lasers produce a photo-mechanical effect.
- If a short pulsed laser was used for hair removal, it would temporarily remove hair, but the hair would grow back within a month like it would with any other hair removal modality.
- A short pulsed laser doesn't heat up the skin because it does not release energy long enough to cause a thermal injury. The energy is administered in a very short period of time. The energy gets released as it is being absorbed by the target.
- The reason why we use short pulsed for tattoo removal is because it breaks the pigmentation apart, which is then suctioned by the lymphatic system. The body treats the ink as a foreign object and tries to get rid of it as waste or transfers it to the lymph nodes.
- You may wonder why a tattoo doesn't fade in the first place if the lymphatic system tries to attack the ink and get rid of it. Initially when someone gets a tattoo, the body does attempt to get rid of it, however, the ink molecules used for tattoos are so large that it isn't able to. Sometimes when you see the tattoo fading, its due to your body trying to get rid of it. Once the body fails at its attempts, it creates a macule around the tattoo, recognizes it as part of the body, and leaves it alone.

LONG PULSED LASER

Long pulsed lasers are used for laser hair removal

They produce a photo-thermal effect (causing a thermal injury to the target)

Long pulsed lasers hold the pulsed for a longer period of time, while heating up the desired target in order to cause a thermal injury.

If a long pulsed laser was used for tattoo removal, then you would cause a potential 3rd degree burn.

Remember, the goal for tattoo removal is to break apart the pigment, not to burn it.

LONG PULSED VS. SHORT PULSED

Recap:

- Long pulsed is used for hair removal while short pulsed is used for tattoos.
- Alexandrite produces exactly 755nm of light (visible red light)
- There are two types of Alexandrite lasers which both emit 755 nm of light
  - Long pulsed laser – used for laser hair removal
  - Short pulsed laser – used for tattoo removal
- It is important to note that these two lasers are completely different from one another and should only be used for the purpose they were designed for.

OPTICAL ENERGY

- Optical Energy, also known as Optical Power, is the strength of a lens.
  - The higher the optical power, the wider the range of view, covering a shorter focal distance.
  - The lower the optical power, the longer the focal distance but with limited range of view.
- Optical Energy is determined by the following:
  - Laser's power
  - Spot size
  - Pulse duration/pulse width
- Pulse duration or width:
  - Can be measured in nanoseconds, microseconds, or milliseconds
- Spot size:
  - Measurement of the diameter of the beam that is in contact with the tissue.

TERMINOLOGY

- **IPL** – Intense Pulsed Light – where peak optical pulse power is up to 20,000 watts achieved with capacitor banks.
  - Wavelengths emitted range from 400nm – 1200 nm and the lower wavelengths can be eliminated by cut off filters which range from 515nm to 755 nm.
- **Chromophore** – material present either in the tissue or brought from outside the tissue which absorbs particular wavelengths depending on its absorption coefficient.
  - Endogenous chromophore – melanin, hemoglobin, water, protein, peptide bonds, amino acids, nucleic acid, urocanic acid, and bilirubin.
  - Exogenous compounds- color of tattoo ink

OTHER POPULAR DEVICES USED IN AESTHETICS

- Intense Pulsed Light (RF)
- Radio Frequency (RF)

INTENSE PULSED LIGHT (IPL)

- Intense Pulsed Light (IPL) devices are FDA approved and provide a broad range of wavelengths that are noncoherent and absorbed by various chromophores within the skin.
- These devices emit high intensity pulses of light to treat various skin conditions such as pigments and vascular lesions as well as hair reduction.
- Majority of the energy is absorbed by smaller, more superficial targets on the surface of the skin. Therefore, it can be challenging to obtain enough energy to destroy deeper targets such as hair follicles.
- Deeper targets require higher levels of energy, which in turn can lead to adverse effects such as burning or hyper-pigmentation.
- The broadband wavelength ranges approximately between 400-1200nm.
- Has cut off filters to achieve different wavelengths of light.

USES OF INTENSE PULSED LIGHT

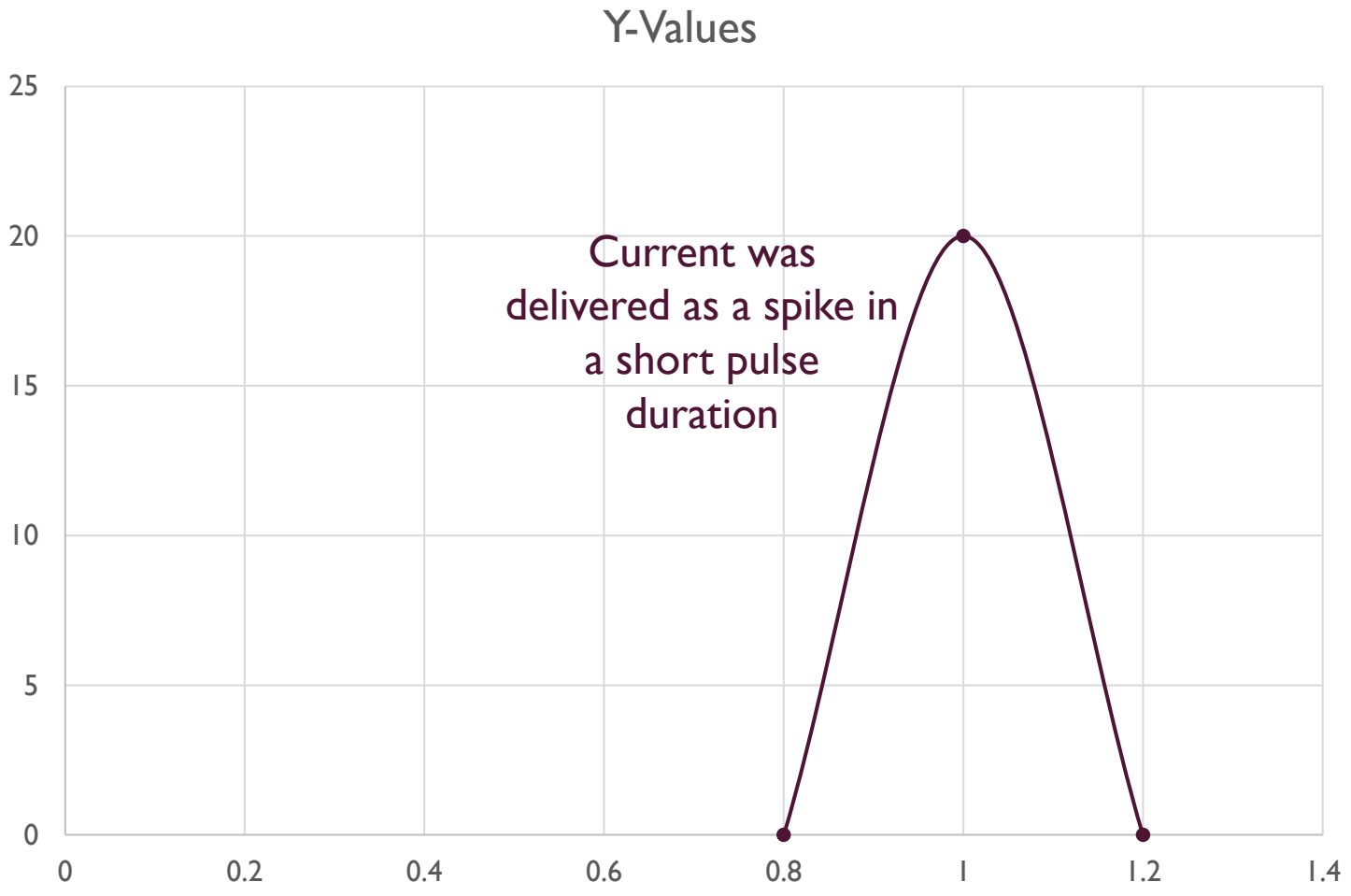
- **IPL devices are mainly used to treat the following:**
  - Skin discoloration
  - Freckles
  - Brown spots
  - Vascular lesions
  - Rosacea
  - Hair removal (less effective)
- **Candidates:**
  - Individuals with light skin tones with blonde or red hair are good candidates for this procedure
  - Darker skin types are at risk for burns and hyper-pigmentation

IMPORTANT PARAMETERS FOR UNDERSTANDING IPL SETTINGS

- Pulse Shape
- Pulse configuration
- Pulse Duration
- Maximum Energy Fluence
- Cooling Modalities

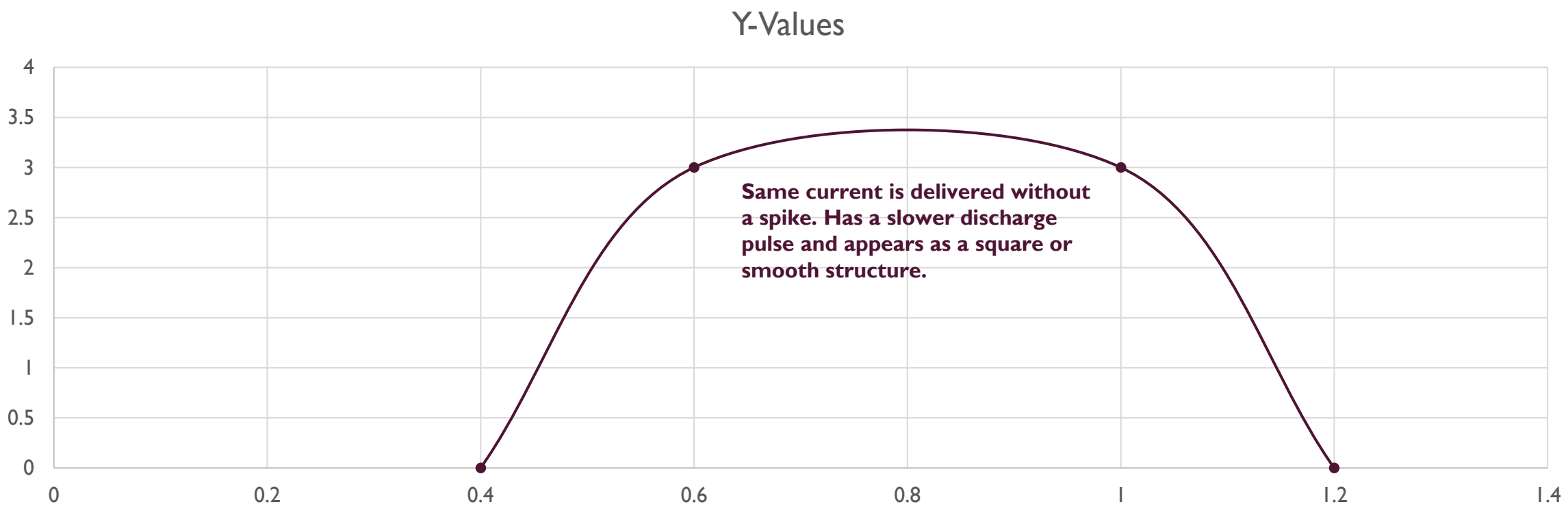
PULSE SHAPE

- Pulse shape determines the level of efficacy and risks involved when energy is delivered to tissue.



PULSE SHAPE 1

Increased risk for side effects when energy is delivered too quickly in a short period of time. This method of delivery would be more painful and higher occurrence of side effects.



PULSE SHAPE 11 –

Treatment is much less painful and has a lower chance of side effects.

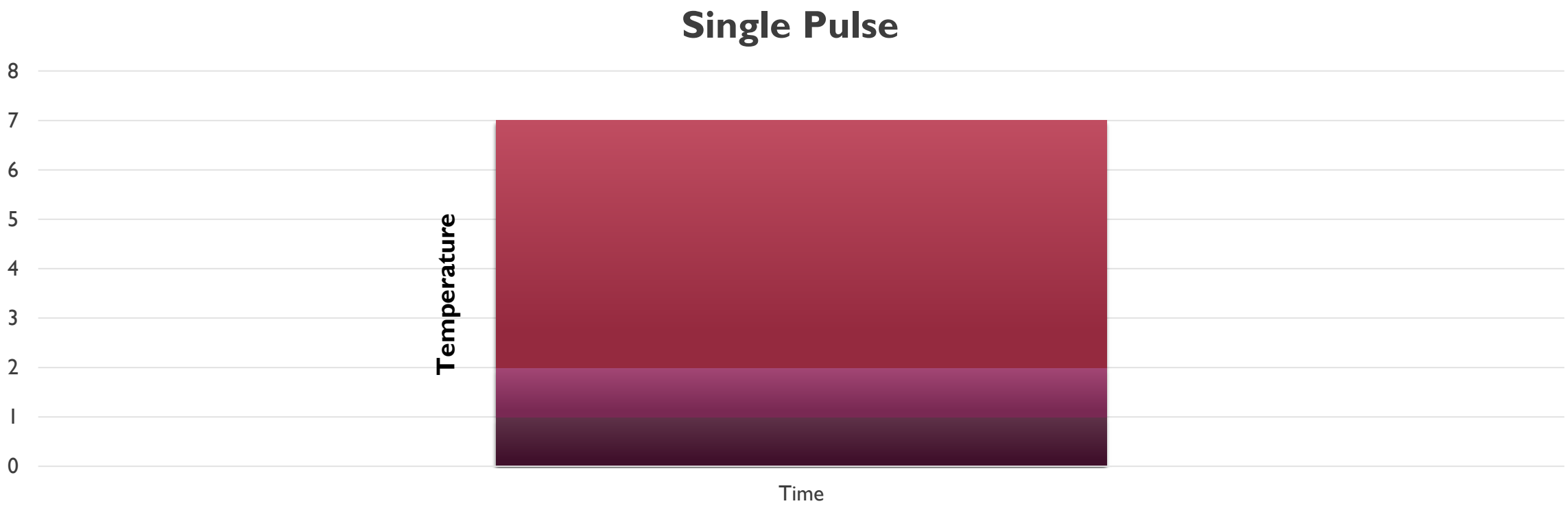
PULSE SHAPE CONT.

- In accordance to the Theory of Selective Photothermolysis, the square and closed pulse stacking systems are safer and more effective for laser hair removal, since an optimal dose of energy is delivered to induce sufficient thermal damage to the target.

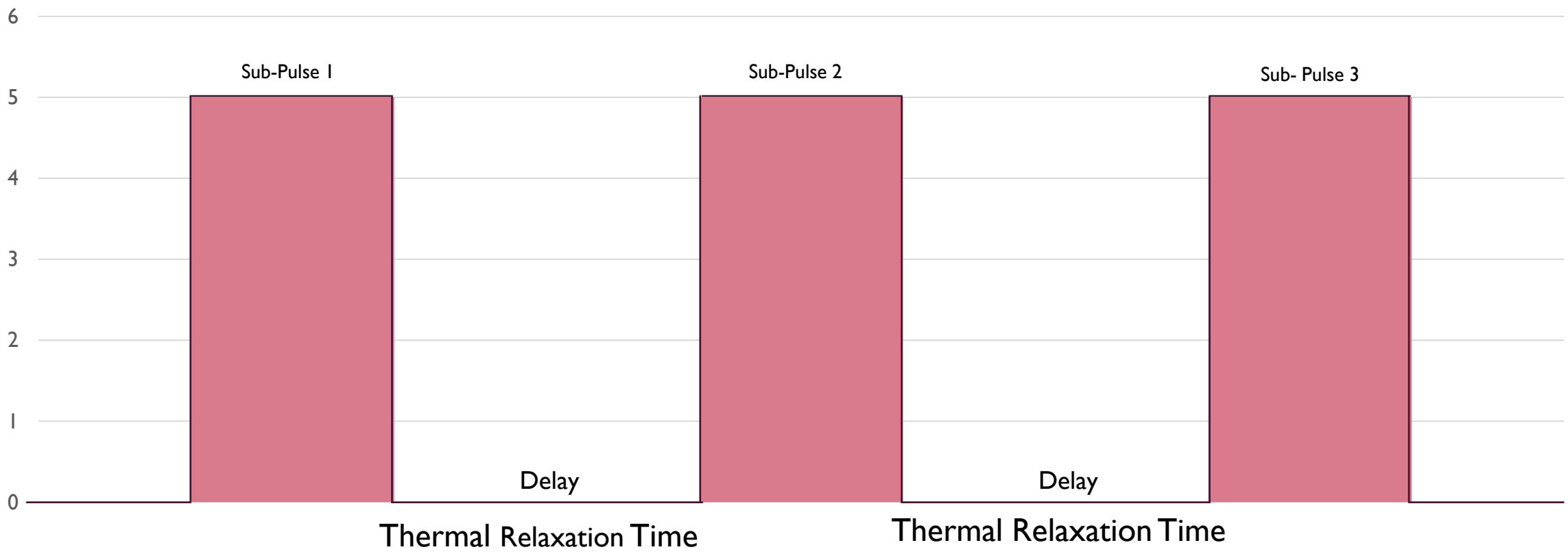
PULSE CONFIGURATION

- Pulse Configuration is the ability to control the pulse algorithm.
- Single Pulse Configuration vs. Multiple Pulse Configuration
  - **Single Pulse:**
    - When choosing the energy fluence: Increasing the energy fluence could lead to a positive endpoint with great results, however, you would be taking a huge risk for possible side effects such as superficial burns.
    - Lowering the energy fluence leads to a safer outcome, however, doing so will make the treatment less effective.
    - **Multiple Pulse Configuration:**
    - Allows the delivery of high energy fluence within a safer profile
    - The pulse is divided into 3 sub-pulses with delays in between to allow release of energy
    - The treatment is more effective

SINGLE PULSE CONFIGURATION



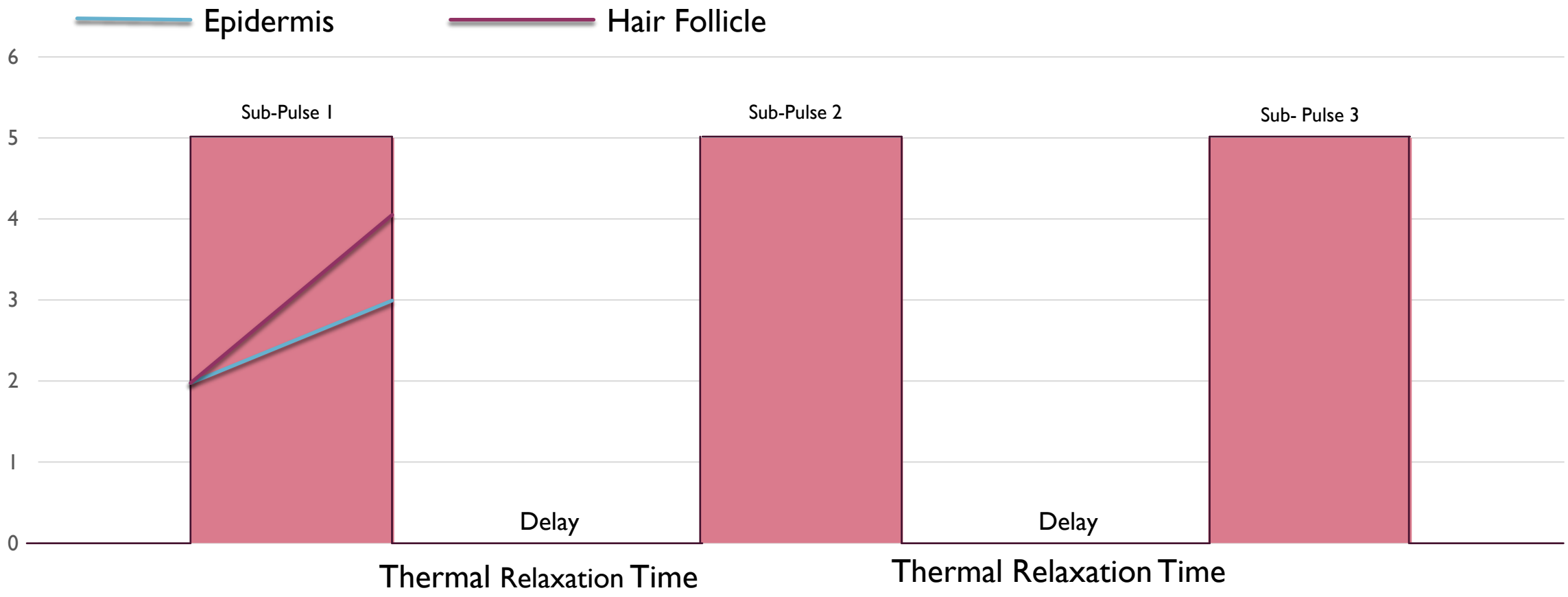
MULTIPLE PULSE CONFIGURATION



UNDERSTANDING MULTIPLE PULSE CONFIGURATION

- Scenario 1: Let's say you're doing a laser hair removal procedure using an IPL device
- During the first sub-pulse, the temperature of the melanin will increase in both the epidermis and the hair follicle. However, since there is more melanin in the hair follicle, the increase in temperature will be much higher in the hair compared to the epidermis. (refer to illustration on the next slide)

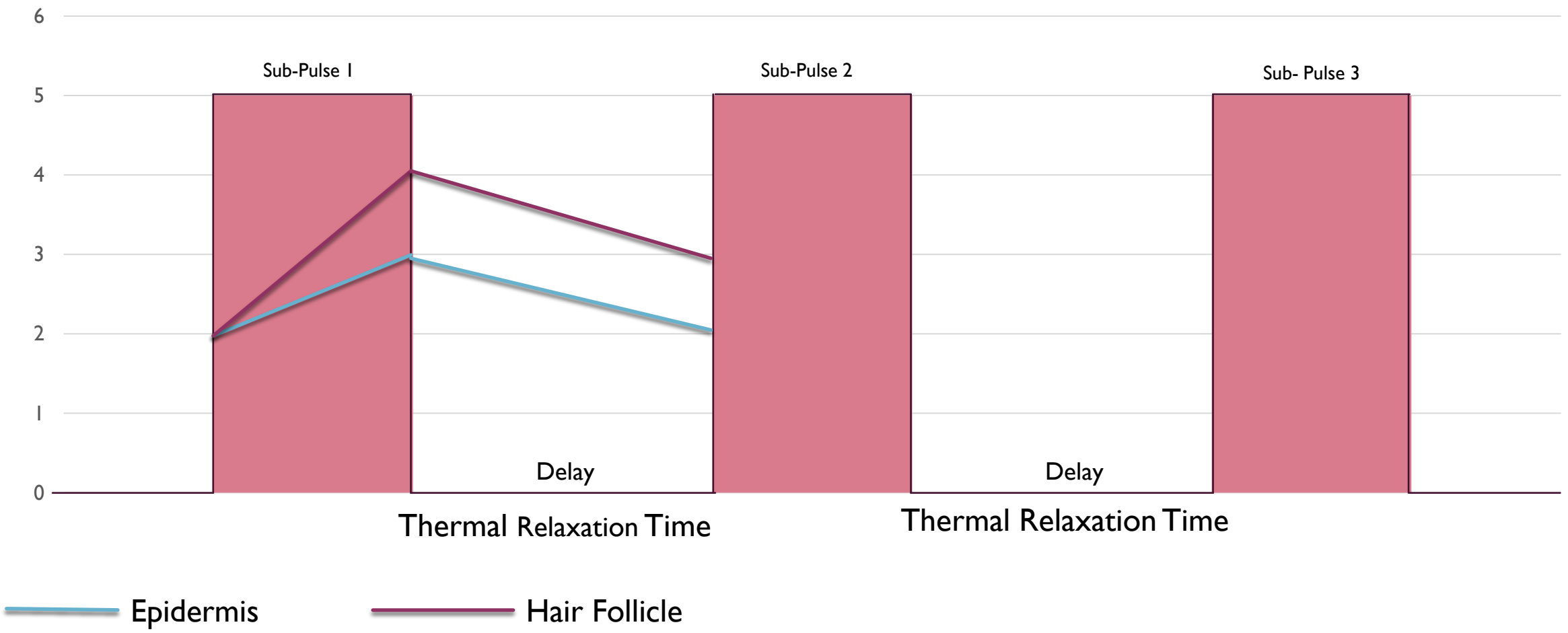
MULTIPLE PULSE CONFIGURATION



UNDERSTANDING MULTIPLE PULSE CONFIGURATION

- During the first "Delay" the temperature of the melanin in the epidermal will drop back to its initial temperature, because the pulse duration of the sub-pulse was longer than the epidermal thermal relaxation time.
- The temperature of the melanin in the hair follicle does not drop back to the initial temperature since the pulse duration of sub-pulse was much shorter than the thermal relaxation time. (refer to illustration on next slide)

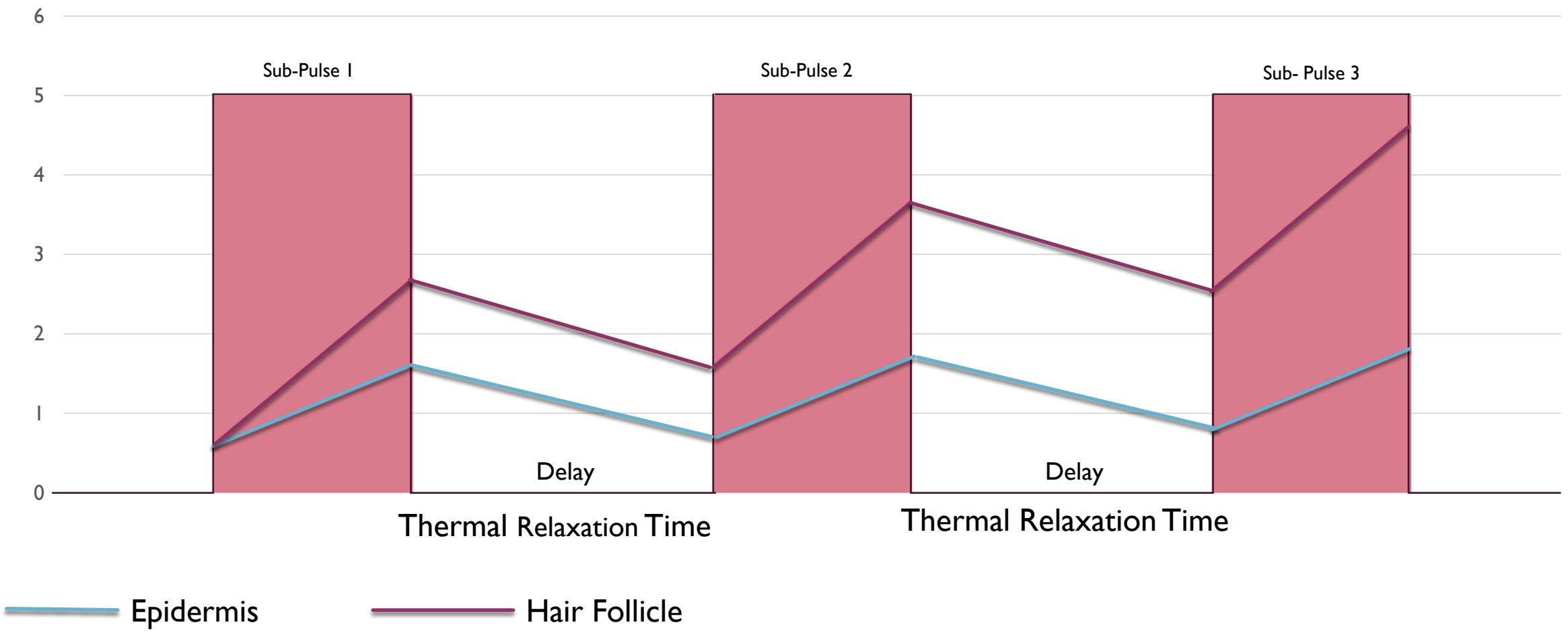
MULTIPLE PULSE CONFIGURATION



UNDERSTANDING MULTIPLE PULSE CONFIGURATION

- The cycle continues for the following sub-pulses. The temperature of both types of melanin continue to rise and drop during the thermal relaxation time. However, the temperature in the epidermis remains relatively consistent while the temperature in the melanin of the hair follicle increases to reach the coagulative response of the hair bulb. (refer to slide 99)

MULTIPLE PULSE CONFIGURATION



PULSE DURATION

- Pulse duration is also known as the pulse width.
- It refers to how long the light is delivered during each pulse
- Can be measured in Milliseconds, Microseconds, Nanoseconds or Pico-seconds
- Pulse duration can be modified by the clinician based on the Thermal Relaxation Time of the target chromophore and the surrounding tissue.
- Influences the level of thermal absorption
- Longer pulse duration – Heat delivered is more gentle to the target
- Shorter pulse duration– Heat delivered is more aggressive for the target

TARGET SIZE

- Pulse duration shorter or equal to Thermal Relaxation Time produces thermal damage to target chromophore.
- Pulse duration longer than the Thermal Relaxation Time of 3-10 ms, helps prevent the surrounding tissue from being damaged.
- Larger targets (thick hair)
  - Have a large heat capacity, meaning they heat slowly and cool slowly.
    - Have a longer thermal relaxation time, therefore a longer pulse duration will be more effective.
- Smaller targets (fine hair)
  - Have a small heat capacity, meaning they heat faster and cool faster.
    - Have shorter thermal relaxation time, therefore a shorter pulse duration will be more effective.

ENERGY FLUENCE

- As mentioned earlier, this is how much energy is delivered per area (cm2) measured in Joules/cm2. The higher the energy, the greater the damage to the target chromophore.
- When selecting energy level, it is important to refer to the Fitzpatrick skin type:
  - Darker skin types will receive a lower energy fluence in order to protect the epidermis.
    - Higher energy fluence in darker skin type can cause burns and hyperpigmentation.
- Energy level is based on the type of treatment:
  - For instance, higher energy fluence is used for pigmented lesions and lower energy fluence for acne clearance.
  - This is determined by the target chromophore, the concentration of each application, and the cut off filters used for the type of treatment.

COOLING MECHANISMS

- There are 2 types of cooling mechanisms for IPL systems:
  - External Cooling
    - Ultrasound Gel (most often used)
    - Cryogen Spray
  - Systems Cooling
    - Water or air cooling modalities incorporated into the laser system.

WHAT IS RADIO FREQUENCY?

- A type of electromagnetic radiation which consists of both electrical and magnetic waves
- Unlike Lasers and Intense Pulse Light, Radio Frequency is in the form of electrical currents
- Compared to other devices, radio frequency can be used to deliver heat energy to the tissue without being dependent on a target chromophore.

THE SCIENCE BEHIND RADIO FREQUENCY (RF)

- When RF energy is applied to the tissue, it produces electromagnetic fields. The electromagnetic field is absorbed by polar molecules and ions. This absorption causes rapid movement of molecules within the tissue resulting in a generation of heat. The amount of heat we can produce depends on how much energy we are going to deliver along with the electrical conductivity of the tissue. Tissue with high blood and water content has the highest level of electrical conductivity. Bone has the lowest level of electrical conductivity with no penetration of the RF current. Dry skin also has a very low electrical conductivity. Therefore, it is necessary to keep the skin hydrated in order to enhance the conductivity before the RF treatment. That's why, clients are asked to drink at least

RADIO FREQUENCY (RF) APPLICATION IN AESTHETICS

- A type of electromagnetic radiation which consists of both electrical and magnetic waves
- Unlike Lasers and Intense Pulse Light, Radio Frequency is in the form of electrical currents
- Both Ablative and Non-Ablative procedures are used for skin tightening, fat reduction, and skin rejuvenation.
- Multiple treatments are required to see results in non-ablative procedures
- Compared to other devices, radio frequency can be used to deliver heat energy to the tissue without being dependent on a target chromophore.
- Depending on the type of treatment, radio frequency can penetrate in all three layers of the skin.
- When rf energy is applied to the tissue, it produces
- Tissue with high blood and water have the highest level of electrical conductivity.
- The effects of Radio Frequency are based on producing thermal damage to the underlying network of collagen and elastin fibers to stimulate new collagen in the deep layers of the skin and subcutaneous tissue. Due to the production of new collagen, the skin appears firmer and has more elasticity.

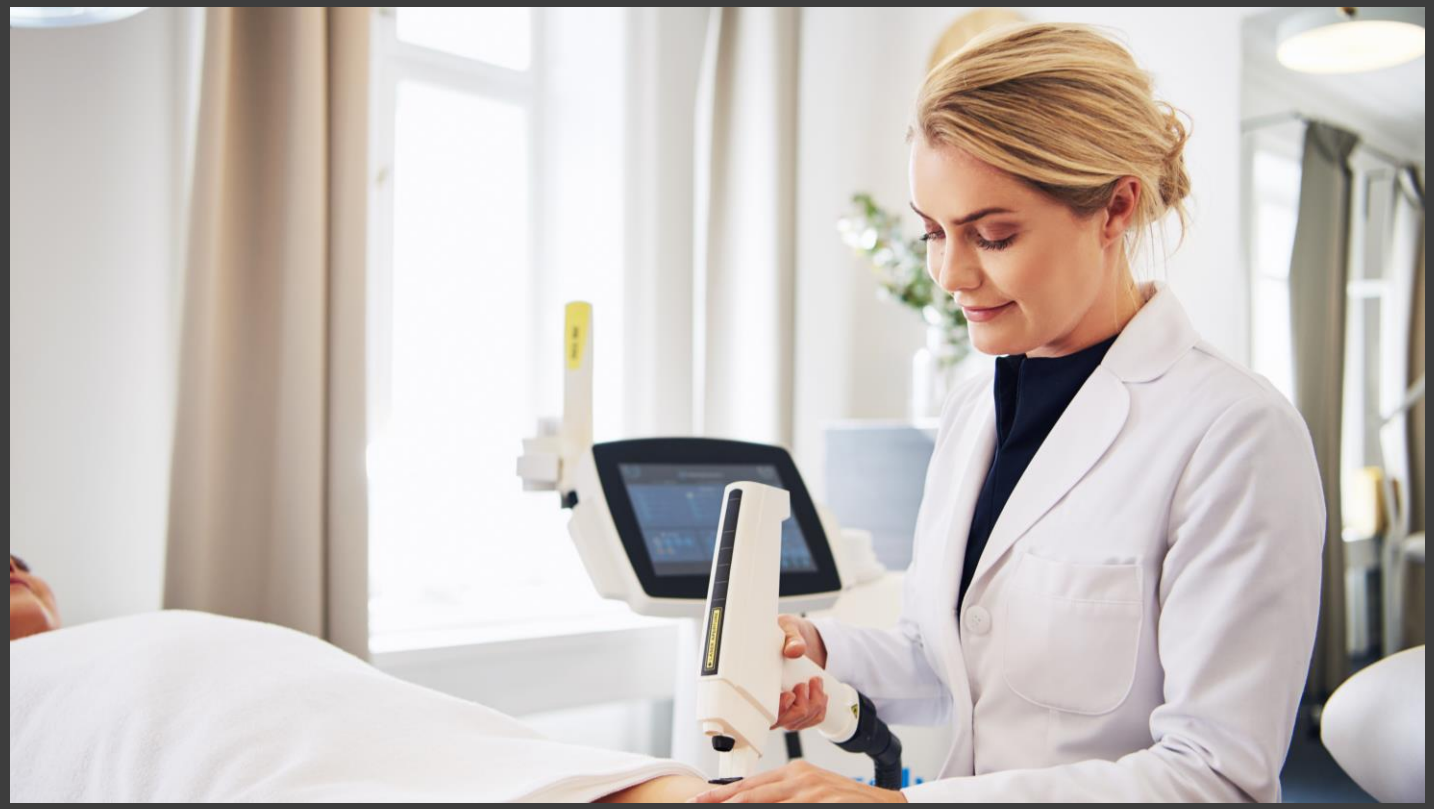
CAREER OPPORTUNITIES

- Laser Hair Removal is a popular noninvasive procedure which has grown by 51% since the year 2000. It is ranked as one of the top 5 nonsurgical procedures and is anticipated to grow in the year 2020 by $1.35B

- As the cosmetic field is increasing with new treatments, a laser technician can earn anywhere from 30k to 60k average salary. Many places offer opportunities to earn commission. Salaries are based on experience and there's potential for growth.

WORK ETHICS

- Keep a Positive Attitude in the work place
- Treat clients and co-workers with respect
- Maintain a professional appearance and dress for success
- Schedule enough time between clients to allow time to prepare for the upcoming procedures.
- Be on time to all appointments and meetings.



WORK ETHICS CONT.

Work towards gaining trust and respect of patients, making sure all the patient's needs are being fulfilled.

Work to gain trust, and respect of the patient, making sure the all the patients needs are being fulfilled