Intense Pulsed Light (IPL) in Aesthetic Photomedicine

By Matthew Redding

Light plays a critical role in the well being and lifestyle of all living creatures. It is therefore hardly surprising that people since the early ages have tried to produce and manipulate light to enhance their life experience. From simple illumination allowing social interaction to continue beyond nightfall to the present day when precise application of light assists the body to heal itself and improve appearance.

Since the advent of lasers in the 1960's and IPL systems in the 1990's the technology has been available to selectively treat specific structures within the skin. In recent years there has been a great deal of clinical research into the efficacy of Intense Pulsed Light (IPL) Systems for the treatment of a variety of skin conditions. Very good results have been achieved in the following areas:

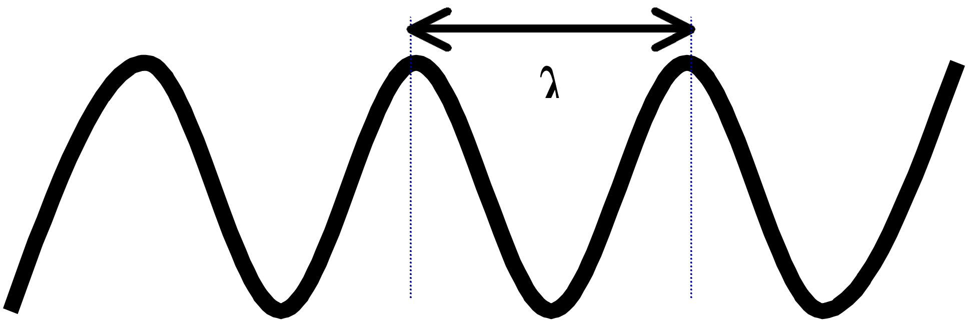
- ✓ Resolution of superficial vascular lesions, including Rosacia.
- ✓ Removing superficial pigmented lesions (e.g. sun spots).
- ✓ Permanent hair reduction.
- ✓ Skin Rejuvenation

Other clinical and aesthetic applications are continually being developed including treatment of inflammatory acne and more complex vascular lesions such as Port Wine Stain.

This article is the first in a series that will look at the theory and application of Intense Pulsed Light (IPL) in Aesthetic Practice and concentrates on the theory of Photomedicine.

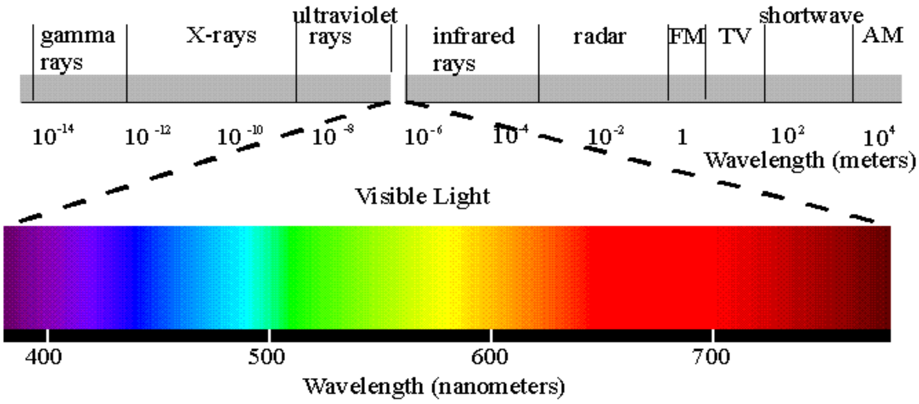
What Is Light?

Light represents a small part of the electromagnetic spectrum and is made up of Photons. Photons can be thought of as "wave packets" of energy. These photons are propagated along a waveform which travels at nearly 300,000 km/sec and has a number of properties.



The **wavelength (l)** is the distance between two points on the wave which are separated by one complete cycle. Wavelength is measured in metres, but for light we often talk in terms of nanometres where a nanometre is one billionth (10^{-9}) of a metre.

Light is made up of many different wavelengths. The eye can only see wavelengths between approximately 400nm and 750nm, this range is what we refer to as **visible light.** Different colours are merely different wavelengths of light.



Selective Photothermolysis?

The process of using the properties of light to destroy or injure certain structures is **Selective***(targeted)* **Photo**(*light*)**thermo***(heat)***lysis***(disintegration or dissolution)***.**

Selective Photothermolysis is achieved clinically through the understanding and control of two properties of light in tissue, these are:

1. Selective Absorption ….and
2. Thermal Relaxation Times

Our aim is to choose a wavelength that will be **preferentially absorbed** by the target tissue, but **NOT** well absorbed by other chromophores in the skin and to deliver the light in pulses which match the **Thermal Relaxation Time** of the target.

Selective Absorption - Why Is Wavelength Important?

In Photomedicine the wavelength of light affects its behaviour in two important ways:

1. Longer wavelengths penetrate the skin more deeply, whilst shorter wavelengths are absorbed closer to the surface. Therefore to target structures deep in the skin such as hair follicles, we use longer wavelengths. Conversely to optimise absorption in superficial structures, for example lentigo senillis (age spots) shorter wavelengths are more effective.

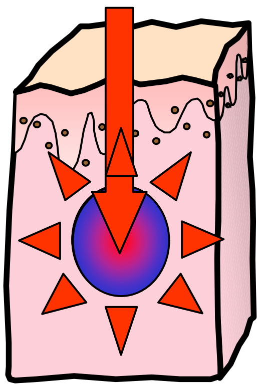
2. Anything that absorbs light is called a **chromophore**, different chromophores absorb different wavelengths (colours) of light to different degrees. This is called **selective absorption** and is one mechanism by which certain structures can be targeted within the skin whilst allowing the light to pass harmlessly through others. For example, blood absorbs green and blue light but transmits red light, hence our eye sees blood as red in colour. Melanin is a good absorber of all colours of light. When light is absorbed by a structure the photon's energy is converted to **heat** which causes damage or necrosis.

Thermal Relaxation Time

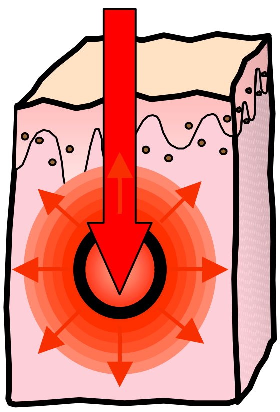
Consider an object of a certain size.

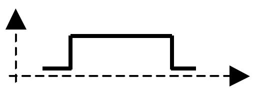
Assume an input of energy instantaneously heats the object (i.e. absorbed laser / IPL light). The object is heated such that the temperature at the centre reaches a value of T degrees.

The object cools by heat diffusion and the centre temperature eventually falls to a value of T/2.

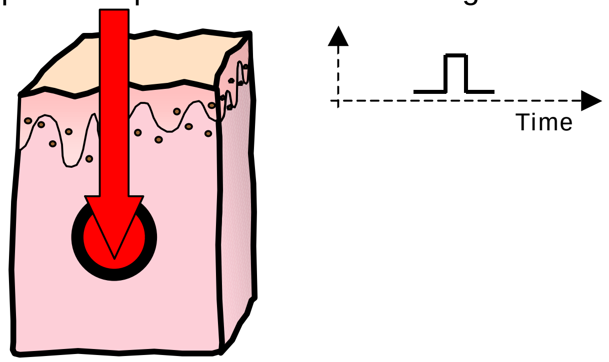


The time elapsed from the instant the object was heated to the moment when the central temperature reaches T/2 is the **Thermal Relaxation Time**
Long pulse duration allows time for heat to thermally diffuse out of target into surrounding region. This results lower peak temperatures.





Short pulse duration confines heat to target due to limited thermal diffusion. This results in higher peak temperatures within the target.



In this way it is possible to concentrate the heat energy in a certain chromophore (e.g. a hair follicle) whilst allowing surrounding structures which have shorter thermal relaxation times (e.g. the surrounding dermis) to remain undamaged.

It is important that the wavelength and pulsing sequence of the light can be controlled to achieve selective Photothermolysis.

Lasers and Light Sources

In order to take advantage of the selective absorption of target chromophores in Aesthetic Photomedicine, we need to produce light within a specific wavelength range. Traditionally this was achieved using a laser. More recently, filtered broad band (or IPL) light sources have been utilised for some of these applications.

So what is the difference between the two?

Lasers

Laser is an acronym for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation. It is not within the scope of this paper to delve into Laser physics. In summary, laser light is produced when energy is added to certain substances under controlled conditions and within a precisely aligned set of optics. The wavelength of a laser beam is a function of the lasing medium which may be a solid, as in the case of an ND:YAG or Ruby laser or a gas such as Carbon Dioxide or Argon. Alternatively, diode lasers utilise the unique emission characteristics of certain semi-conductors.

Laser light has a number of important characteristics:

1. Laser light is **monochromatic**, that is each laser emits light in a single wavelength or colour.
   Some lasers can be **frequency doubled**, for example the native wavelength of an ND:YAG laser is 1064nm, when the frequency is doubled the wavelength halves to 532nm. **Pulsed Dye** lasers can have their output adjusted within a limited range.

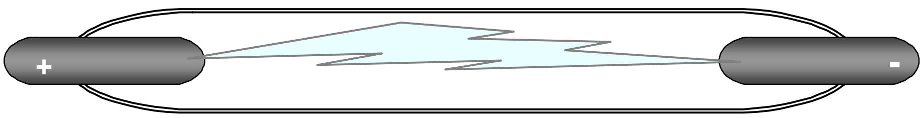
2. Laser light is **Non Divergent**, that is the beam of light does not get larger as it moves further away from the source.

3. Laser light is **Coherent**, that is the peaks and troughs of all the waves align.

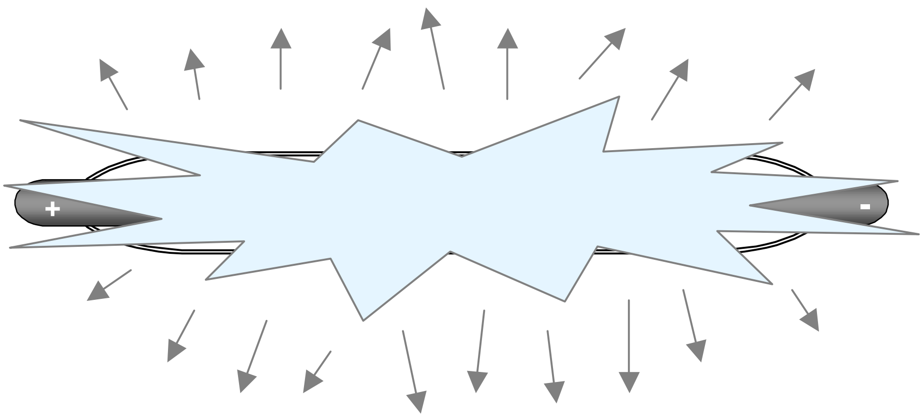
Whilst Lasers have proven their place in Aesthetics, they are relatively expensive to manufacture and maintain. By their monochromatic nature lasers are limited in application. A clinic that wishes to offer a wide range of treatments needs to invest in a number of lasers of different wavelengths. This high level of investment is a cost entry barrier to most clinics.

IPL Broadband Light Sources

An IPL system utilises a filtered broad band light source. The light is produced in a Flashlamp in the treatment hand piece. A typical Flashlamp comprises a clear quartz envelope containing pressurised gas, with tungsten electrodes at each end.



Electrical current passing through the gas forms a plasma which irradiates light. When the lamp simmers, this is seen as a bright narrow line (arc).



During a pulse the arc expands emitting an intense pulse of light. Unlike a laser an IPL Flashlamp produces an intense pulse of white light, that is light with many wavelengths. The light is not coherent and is emitted in all directions.

In this form the light is not useful, however in the IPL handpiece the light is captured and reflected through a filter into the skin. The filtering system only allows the desired range of wavelengths to pass. Eliminated are those wavelengths that are significantly absorbed in water (~>1100nm) as they only serve to created generalised heating of the skin. At the lower end the filter will cut out wavelengths below a chosen level, depending on the clinical application. Typically IPL systems use wavelength ranges between 500nm – 1100nm (yellow / orange / red light).

IPL systems are less complex than Lasers and by changing the filters in the handpiece an IPL system can treat a wide range of conditions. This makes IPL a cost effective and versatile investment.

It is important to note however that IPL is **NOT** a panacea for all conditions. There are conditions that IPL will treat equally as well or better than a laser (Hair Reduction, Rosacia), however there are other treatments that can only be performed effectively with a laser (Tattoo's, larger deeper blood vessels).

Terminology

As with all technology there are some terms that you will come across when investigating IPL systems. A brief definition of the most pertinent of these is detailed here. The clinical, physiological and economic implications of these variables will be discussed in more detail in future papers.

ENERGY

Every photon has a certain amount of energy, therefore the light given out by a laser or IPL must carry all this energy. We measure this energy in **JOULES (J)** and we usually only talk about the energy given out in a pulse of light. When light is given out continuously (CW) then we talk about measuring POWER

SPOT SIZE

When a laser beam falls onto a surface (for example the patients skin) then a small dot of light is seen. The diameter of this spot can be measured in millimetres and this is called the spot size. A 5.0 mm spot size actually covers an area of only 0.2 cm^2

Most IPL's use a rectangular light guide to deliver light to the skin. A light guide 1cm x 5cm (5cm^2) is an area 25 times larger than a typical; 5mm laser spot. This makes treatment of larger areas of the body quicker and more cost effective.

FLUENCE or ENERGY DENSITY

Fluence is the energy per area, measured in Joules per square centimetre. For example if an IPL delivers 100J over a spot size of $5cm^2$ then the fluence is $20J/cm^2$. Typically IPL treatments are performed between15-30 J/cm^2

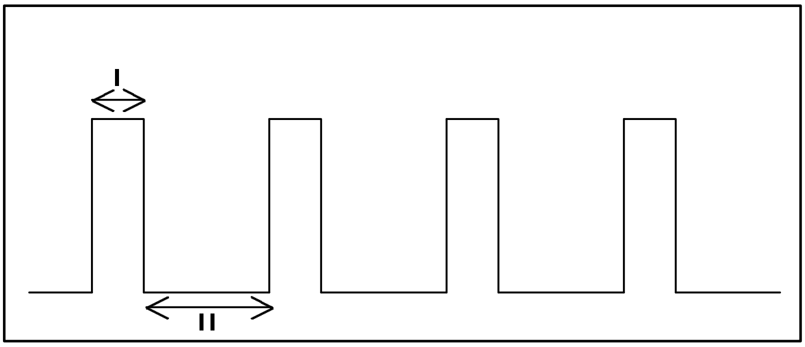
$$Fluence(J/cm^2) = \frac{Energy(J)}{Area(cm^2)}$$

PULSE TRAIN

In order to control the application of energy in relation to the Thermal Relaxation Times of the target chromophore and surrounding tissue, most IPL's deliver the energy to the skin in a **Pulse Train**. For example if 24 J/cm^2 is set and the total pulses is 4 then each press of the IPL button will deliver a series of 4 pulses and the total energy delivered will equal 24 J/cm^2 .

The **Light Pulse (I)** heats both chromophore and epidermis. The **Pulse Delay (II)** is the period between pulses, usually set in milliseconds. This time is selected to allow the epidermis to cool, but is too short to allow cooling of the chromophore as it has a longer thermal relaxation time.

During subsequent pulses the chromophore continues to heat until permanent damage occurs, whilst the epidermis remains below the temperature required to cause permanent thermal damage. The Pulse sequence is adjusted depending on the chromophore being targeted.



In the next issue we will discuss specific clinical applications, in particular Permanent Hair Reduction, Vascular Lesions, Pigmentation and Skin Rejuvenation.

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