Session 4
Introduction to laser
Chinese Medicine
Department
Pre Readings


Pre Readings


Pre Readings

LASER

HAIR

TISSUE

PROBLEMS

SPECTRUM

EXPENSIVE

REGENERATION

LLLT HEALING

INFRARED THERAPY

LIGHT

GROWTH

FREQUENCIES

PHYSICS

BIOSTIMULATION

RED
General History of use

- The term LASER is an acronym for the Light Amplification by Stimulated Emission of Radiation. In simple terms, the laser can be considered a form of light amplifier.
- Lasers will behave according to the fundamental laws of light in that it travels in straight lines at a constant velocity in space.
- Light can be transmitted, reflected, refracted and absorbed.
- Electromagnetic spectrum according to its wavelength/frequency which will vary according to particular generator.

Watson, 2015
Einstein was involved

- Einstein originally outlines the principles underlying the generation of such light in the early 1900s; it wasn’t till 1960 that Theodore Maiman produced the first burst or ruby laser light.
- Various laser devices have been developed laser pointers to bar code scanners, to military laser targeting.
- In medicine surgery, “cutting” and “welding” destroying tissue has been uses.

Baxter (cited in Watson, 2008, p161)
Prof Endre Mester 1903-1984

- Pioneer of laser medicine including the use of Low-Level Laser Therapy (LLLT)
- In 1967 he started experiments with the effect on skin cancers
- He is credited with the discovery of biological effects of low power lasers
- He published over 100 articles in this area
- Developed the He-Ne laser

Baxter, 2008, p162,
Image: Swedish Laser-Medical Society
Some Basic Physics here

- Energy is everything, and everything is a form of energy
- Energy can neither be created or destroyed it merely changes forms
- Measured in joules, written as J.
- Electromagnetic radiation takes many forms and consists of photons – (packets of energy travelling at the speed of light)
- Photons can be seen a wave particles or wave packets in the shape of a wave
- This has a defined relationship to frequency and amplitude

Tunér & Hode, 2010, p2
Some Basic Physics here

- Joules is power output and is specified per point dosage or sometimes total treatment.
- It is calculated by multiplying the power output (mW) by the application time in seconds.
- So a 100mW laser applied on a point for 30 seconds could be recorded as 3J (0.10 x 30).
- Wavelength not frequency as frequency would give unmanageable high numbers, and frequency often arises discussions about pulsing.

Tunér & Hode, 2010, p2
Image: Wikimedia Commons, 2015
Electromagnetic Spectrum

Penetrates Earth's Atmosphere?

- Radio: Y
- Microwave: N
- Infrared: N
- Visible: Y
- Ultraviolet: Y
- X-ray: Y
- Gamma ray: Y

<table>
<thead>
<tr>
<th>Radiation Type</th>
<th>Wavelength (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radio</td>
<td>$10^3$</td>
</tr>
<tr>
<td>Microwave</td>
<td>$10^{-2}$</td>
</tr>
<tr>
<td>Infrared</td>
<td>$10^{-5}$</td>
</tr>
<tr>
<td>Visible</td>
<td>$0.5 \times 10^{-6}$</td>
</tr>
<tr>
<td>Ultraviolet</td>
<td>$10^{-18}$</td>
</tr>
<tr>
<td>X-ray</td>
<td>$10^{-10}$</td>
</tr>
<tr>
<td>Gamma ray</td>
<td>$10^{-12}$</td>
</tr>
</tbody>
</table>

Approximate Scale of Wavelength:

- Buildings: Radio
- Humans: Microwave
- Butterflies: Infrared
- Needle Point: Visible
- Protozoans: Ultraviolet
- Molecules: X-ray
- Atoms: Gamma ray

Frequency (Hz)

- $10^4$
- $10^8$
- $10^{12}$
- $10^{15}$
- $10^{16}$
- $10^{18}$
- $10^{20}$

Temperature of objects at which this radiation is the most intense wavelength emitted:

- 1 K: -272 °C
- 100 K: -173 °C
- 10,000 K: 9,727 °C
- 10,000,000 K: ~10,000,000 °C

Wikimedia Commons, 2015
Optical Field

Wikimedia Commons, 2015
Wavelength

- Wavelength is in nanometers nm (billionth of metres)
- Frequency is a number of times it oscillates in a second

<table>
<thead>
<tr>
<th>Type</th>
<th>Wavelength</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>HeNe</td>
<td>633nm</td>
<td>Gas laser</td>
</tr>
<tr>
<td>InGaAlP</td>
<td>633-700nm</td>
<td>Semiconductor</td>
</tr>
<tr>
<td>GaAlAs</td>
<td>780nm-890nm</td>
<td>Semiconductor</td>
</tr>
<tr>
<td>GaAs</td>
<td>904nm</td>
<td>Semiconductor</td>
</tr>
</tbody>
</table>

- HeNe lasers not used, much anymore and InGaAlP are often referred to as GaAlAs in literature

Tunér & Hode, 2010, p45
Image: Wikimedia Commons, 2015
So what’s special about laser?

- Laser light differs from “normal” light
- It’s very narrow bandwidth
- High level of coherence – well-ordered photons

<table>
<thead>
<tr>
<th>White Light</th>
<th>Laser Light</th>
<th>LED Light</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple wavelengths</td>
<td>Single wavelength</td>
<td>Monochromatic but Non coherent</td>
</tr>
<tr>
<td>Non coherent</td>
<td>Coherent</td>
<td>Non coherent</td>
</tr>
</tbody>
</table>

- Myths – Parallel beams and high intensity
- Neither has to be present for LLLT
- However, these are important to surgical lasers

Tunér & Hode, 2010, p12
Image: Watson, 2015
Continuous Vs Pulse

- A light source emits light at a constant intensity (continuous wave)
- Possible to make a laser or lamp have varying intensity
- Think of a dimmer on a light or a more extreme example turning the light on and off manually
- Or running a fan in front of a light source “chopping.”
- The laser has this feature built in and has an effect on the tissue penetration level
- Around 70-80% pulse rate has been shown to be the most effective

Tunér & Hode, 2010, p17
Image: Denegar, Saliba & Saliba, 2010, p201
Pulsing is important

- Pulsing a laser generates less tissue heating at the surface to the desired depth of tissue is harder to reach.
- The “quench period” (pulse off times) reduces tissue heating and potentially much higher peak power densities.
- Higher peak power can allow the laser to penetrate deeper tissues.
- Possible other mechanisms brain waves, voltage-gated ion channels and how NO is released from its binding site may all be linked to pulsing rather than continuous wave.

Hashmi, J, et al., 2010
So how do they work?

- Locally – a great deal happens
- Individual cell functions are stimulated – the cell condition is of great importance
- Singlet oxygen molecules are released this influences the production of ATP (cell energy)
- NO and H\textsubscript{2}O\textsubscript{2} act as secondary messengers in small dosages in a cascade following laser irradiation
- This leads to secondary effects of increased cell metabolism and collagen synthesis in fibroblasts
- Increased action potential of nerve cells
- Stimulation of DNA and RNA synthesis

Tunér & Hode, 2010, p72

Image: Wikimedia Commons
So how do they work?

- Local effects on the immune system
- Increased formation of capillaries by the release of growth factors
- Increase activity of leukocytes
- Transformation of fibroblasts to myofibroblasts
- Increases in superoxide dismutase (SOD)
  Antioxidant

Tunér & Hode, 2010, p71-2
Image: Wikimedia Commons
Secondary Mechanisms

- Effects on pain
- Pain itself is complex concept
- Studies have demonstrated effects on the transmitter substances such as:
  - Endorphins
  - Nitric oxide (NO)
  - Bradykinins
  - Serotonin
  - Decreased C-Fibres action potentials (in the Nervous system)
- Increased blood flow measured by temperature changes of between 1 - 4 degrees

Tunér & Hode, 2010, p557-8
Image Wikimedia Commons
Laser Mechanisms

Primary Mechanisms
- Absorption of polarised light in cytochrome molecules (e.g. porphyrines) stimulates the creation of singlet oxygen
- In points of high intensity the probability is higher for multi-photon effects. The electrical field across the cell membrane creates a dipole moment on the bar-shaped lipids
- Local differences in intensity create temperature and pressure gradients across cell membranes

Secondary Mechanisms
- Increase of ATPase and activation of cAMP and enzymes
- Triggers an immunological chain reaction
- Increase of procollagen synthesis in fibroblasts
- Increase of endothelial cells and keratinocytes

Influences
- Wound healing
- Acceleration of the inflammatory process
- Pain influence

Diffuse scattering of laser light in tissue: gives interference and speckle formation

Volumes of partially polarised light are formed

Points of high laser light intensity appear

Areas of high difference in light intensity levels

Influences the permeability of cell membranes, which affects Ca^{2+}, Na^{+} and K^{+} as well as the proton gradient over the mitochondria membranes

Increased receptor activity on cell membranes

Increased synthesis of endorphine

Bradykinine decrease

Decreased C-fiber activity

Increased nerve cell action potential

Enhancement of S.O.D. levels

Enhancement of S.R.F.

Increase in number of mast cells

Increase of procollagen synthesis in fibroblasts

Tunér & Hode, 2010, p563
# Major Mechanisms

<table>
<thead>
<tr>
<th>Mild Thermal $&lt;$40°C)</th>
<th>Biochemical</th>
<th>Bioelectric</th>
<th>Bioenergetic</th>
</tr>
</thead>
<tbody>
<tr>
<td>↑ Nerve conduction</td>
<td>(Mitochondrial events)↑ ATP Production↑ Release of NO↑ very low levels of reactive oxygen species (ROS)</td>
<td>↑ Electromotive action on membrane bound ion transport mechanisms</td>
<td>↑ Rotational and vibrational changes to membrane molecule electrons</td>
</tr>
<tr>
<td>↑ Capillary dilation</td>
<td>↑ Fibroblast proliferation – collagen and elastin synthesis</td>
<td>↑ Intercellular extracellular ion gradient changes</td>
<td>↑ Stimulation of acupuncture points and vessels</td>
</tr>
</tbody>
</table>

Kim, & Calderhand, 2011
## Major Mechanisms Cont.

<table>
<thead>
<tr>
<th>Mild Thermal (&lt;40°C)</th>
<th>Biochemical</th>
<th>Bioelectric</th>
<th>Bioenergetic</th>
</tr>
</thead>
<tbody>
<tr>
<td>↑mast cell degranulation, cytokine, chemokine and trophic factor release</td>
<td>↑depolarisation of synaptic cleft – closure of synaptic gate</td>
<td>↑biophotonic activity</td>
<td></td>
</tr>
<tr>
<td>↑macrophage activity</td>
<td>↑activation of DRG control mechanism</td>
<td></td>
<td></td>
</tr>
<tr>
<td>↑opiate and nonopiate control (endorphins, dynorphins and enkephalins)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Kim, & Calderhand, 2011
## Depth of Penetration

<table>
<thead>
<tr>
<th>Waveband</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visible Red (630-700nm)</td>
<td>0.5-1 cm</td>
</tr>
<tr>
<td>Near Infrared (700-800nm)</td>
<td>2-3cm</td>
</tr>
<tr>
<td>Near Infrared (800-960nm)</td>
<td>3-5cm</td>
</tr>
<tr>
<td>Near Infrared (970-990nm)</td>
<td>1-2cm</td>
</tr>
<tr>
<td>Near Infrared (990-1200nm)</td>
<td>4-5cm</td>
</tr>
</tbody>
</table>

Power density, tissue type, tissue temperature, tissue condition, probe design, operating mode of the laser, treatment technique will have an effect on the penetration depth of the laser.

Dirty skin and darker skin reduce skin penetration, Adipose tissue is more transparent than muscle, highly vascular tissue absorbed more light than less vascular.

Conditions such as tendinopathies and joint pain don’t require deep penetration.

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Tunér & Hode, 2010, p118-9
Hashmi, J, et al., 2010
But working on deep structures...

- Back, hip and neck joints would require deeper level of penetration – some of these are greater than 5cm under the skin
- Postulated theory is that LLLT brings benefit by inhibiting superficial nociceptors
- Attenuating pain perception as opposed to decreasing inflammation
- Further studies are needed to confirm or refute this

Hashmi, J, et al., 2010
Image: Netter, 2014, plate 491
On the skin will give greater depth

Tunér & Hode, 2010, p119-20
Contact Vs Non contact

Baxter, 2008, p171
Not always possible

- Open wounds and ulcers are something that laser is known for, and when treating them, you don’t want to have the probe on the broken skin.
- The treatment of this is applied in two stages, contact around the wound margin and secondarily using a non-contact method.

Baxter, 2008, p172
Clinical Usages

- As the effects of LLLT are vast and varied many conditions can be treated with the therapy.
- Laser works by stimulating the natural cellular process; it is easy to imagine many new indications in the future.
- Typical conditions include skin problems, inflammation, Fibromyalgia, joint problems, headaches/migraines, low back pain, oedema, eye conditions, tendinopathies, wound healing, sports injuries, pain, whiplash, trigeminal neuralgia, trigger points, tinnitus, TMJ, post-op vomiting.
- Needle-phobic patients, children.
Equipment Settings

- **Power switch**
  - Make sure the unit gets charged regularly.

- **Set Time**
  - Average treatment time is 1 minute per point, 30 seconds for children.
  - There is no ability to turn the machine off; it will only run for the time selected.

- **Duty Cycle**
  - Frequency in Hz (cycles per second 145-1300Hz)
  - Most efficient is 70-80%. This is the amount of time the laser is on – stays consistent regardless of frequency.

- **Frequency**
  - This is a pulsing effect.

- **Infrared detector**
  - Laser probe goes in here.

*Imatron technologies, 2015*
More on Frequency

<table>
<thead>
<tr>
<th>Frequency Range</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>145-700Hz</td>
<td>Work best in physical conditions – stasis on joint, muscle local area</td>
</tr>
<tr>
<td>825Hz</td>
<td>Works well for general tissue healing and cellular repair</td>
</tr>
<tr>
<td>960-1300Hz</td>
<td>More effective for Qi stagnation, or to reduce a point/area. Or to reduce pain</td>
</tr>
</tbody>
</table>

Example: Frozen shoulder, local and distal approach

Lower frequencies 145Hz at distal points, e.g., GB39, ST38, 30-60s
825Hz for local specific points 30-60s
Then “paint the area” at higher frequencies 1100Hz for 3-4 minutes
How to use the Laser

Click to see how to use the Imatron Laser Therapy Device

Images: Mannix 2016
Video: Edtech at Endeavour, 2016
Cautions and Contraindications

- Active or suspected carcinoma - Contraindicated
- Direct irradiation or the uterus in pregnant women
- Irradiation of the testes
- Directly over the thyroid gland as it has sensitivity to light
- Areas of haemorrhage as it increases blood flow in the area
- Cautions – dosages in children to be reduced
- Tattoos as the pigments absorb the light and may experience a heating or even pain – start at a distance and work closer

Image: Eugene Zemlyanskiy, 2005
Laser Sign for the Door

DANGER
LASER RADIATION
AVOID EYE OR SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION
CLASS 3B LASER IN USE
PROTECTIVE EYEWARE MUST BE WORN AT ALL TIMES
Safety – It’s all fun and games until……..

- **CLASS 3B**
  - A Class 3B laser is hazardous if the eye is exposed directly, but diffuse reflections such as from paper or other matte surfaces are not harmful. These lasers are limited to 0.5W. Protective eyewear is typically required where direct viewing of a class 3B laser beam may occur.
  - Baxter “In the only reported case of an eye injury during therapeutic laser treatment, a chartered physiotherapist using a treatment unit on loan from a supplier suffered a 60% corneal abrasion from protective wings on the side of the goggles provided with the apparatus.”
  - The lasers used in eye surgery are much more powerful and capable of burning tissue.
  - The use of regular sunglasses increases the risk of eye injury due to the filtration method in the lens and the darkening of the lens open and makes the pupil dilate.

Tunér & Hode, 2010, pp20-1
Image: Erich Ferdinand, 2009
Must be worn by all
Open Wounds

- Use non-contact on the open wound and have a decreased intensity.
- This wound doesn’t have the skin to protect it, and all the energy is absorbed in the target tissue faster.
- Higher intensity and contact method around the edges and unbroken skin.
- This is because the probe is unable to be kept clean if touches the wound.

Tunér & Hode, 2010, p521
Image: Tunér & Hode, 2010, p521
“While most lasers are harmless, some lasers certainly can cause eye injury. The most dangerous types combine power (>100mW) with a collimated beam and have a wavelength in the interval 700nm-1400nm. So-called laser pointers are harmless. A divergent beam can be quite strong and still carry a small risk; the more divergent, the less risk.”
Practice

- Practice with the laser
- Use it on different conditions, various skin conditions and different people and record your experiences
References

- Gustavo Ciancio, 2009, Laser thread, viewed 18th August 2015, https://www.flickr.com/photos/tattoo/4116523055/in/photolist-7gLtTr-5XREN3-9m1bWK-cEWgsJ-bjMG63-dUqFHM-9JTjh4-dbFaU5-nZYY1L-2hK6LE-4foS7Y-nypZqtx-51qFjz-cl9RCA-9dsYia-egFSEA-7C6qwz-nQFNgv-oR3gsM-eaJTX-daGRUG-9JHSBE-7ocsE9-7etree-ajuuph-2k8cho-9bHvny-rZbDvt-dq7g8B-oFTtvj-5rM3Ym-9Sbodc-8wKjJJ-pF9ZWX-d1rwKyr-nYNUG-66mqzi-nZlQPz-9oQxS-YBNADm-hvkU6b-kgi9er-mgn3y-7cgBhn-8xSrYu-2FzT1K-fa9l5Y-UTLPz-5GJM3R-r3Cxe4
- "EM Spectrum Properties edit" by Inductiveload, NASA - self-made, information by NASABased off of File:EM_Spectrum3-new.jpg by NASAThe butterfly icon is from the P icon set, P biology.svgThe humans are from the Pioneer plaque, Human.svgThe buildings are the Petronas towers and the Empire State Buildings, both from skyscrapercompare.svg, viewed 19th August 2015, Licensed under CC BY-SA 3.0 via Commons - https://commons.wikimedia.org/wiki/File:EM_Spectrum_Properties_edit.svg#/media/File:EM_Spectrum_Properties_edit.svg
- Eugene Zemlyanskiy, 2005, Caution Tape, viewed 6th August 2015, https://www.flickr.com/photos/pictureperfectpose/76138988/in/photolist-7Jebt-5FiyMN-56GqVey-6QqHps-fSxR8-8zJron-6v6Iza-qWVRv4-5muY3t-6tBHit-8wAmRaz-dPxzM-31pTMH-9pUdtk-urBo-8nwpqi-abucilK-69cohS-5xueAnU-dzTfgR-6cbsUC-6c7bko-frBeUY-8yBsqM-hbSqww-4zZcET-siUnQs-c378Dd-fgrnXw-w7aCg-4QdSaZ-6c7yBe-aDMbMw-MwxTe-abcfQ-aCrMYo-bnEDf5-bk2RYc-pbj3jW8-8Mvpq-8z2YgQ-JBMp6-fQ6Vca-5HsJgj-8zuips-dfg8Fy-rFj6Kr-hbQsc-367fch-vq3GvQ
- Focus Clinic, 2011, Focus as featured in Men's Health Magazine, March 2011, viewed 21st August 2015, https://www.flickr.com/photos/focuslaservision/5509304603/in/photolist-9oQxS-YBNADm-hvkU6b-kgi9er-mgn3y-7cgBhn-8xSrYu-2FzT1K-fa9l5Y-UTLPz-5GJM3R-r3Cxe4
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- Erich Ferdinand, 2009, Patched Up Boys, viewed 21st August 2015, https://www.flickr.com/photos/erix/3217395417/in/photolist-5UIzY-M-dJk175-4HFVov-5x45EB-5x8xky-5x8v3C-5x4aGh-5x44Kx-5x8vHJ-5x48MR-5x8umm-5x49iz-5Vv7D-6NuJz6-ac8cQz-5Exzyh-e853k5-nn7pU8-8vY8Has-5dGAF-pV5Ds1-rWShi1-739z5y-1R8GB-6BPZeJ-eDp4vq-9NEdXe-9NFVNX-9NBMMn-fs2je5-9NEtYQ-9N9Krb-9NAsCc-GMBPW-edMn9C-oizGJe-khg2cg-5vjHbL-9K5f1e-683Eq8-8Bj11q-593un8-axhfmf-cfZeNL-dPJZ9r-fscCmE-iuWN6E-7vjfaj-7XaqC-9M2DZZ
- Mannix, 2016, Using the laser on LI4, private collection
- Mannix, 2016, Blue Steel, private collection
- Mannix, 2016, Laser goggles, private collection
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