Brief outline

- Introduction.
- History.
- Laser physics.
- Classification.
- Laser tissue interactions.
- Uses – therapeutic.
  - diagnostic.
- Complications.
INTRODUCTION

LASER is an acronym for:

- L : Light
- A : Amplification (by)
- S : Stimulated
- E : Emission (of)
- R : Radiation

Term coined by Gordon Gould.

Lase means to absorb energy in one form and to emit a new form of light energy which is more useful.
1960 : The first laser was built by Theodore Maiman using a ruby crystal medium.

1963 : The first clinical ophthalmic use of laser in humans.

1968 : L Esperance developed the argon laser.

1971 : Neodymium yttrium aluminum garnet (Nd.YAG) and Krypton laser develop.

1983 : Trokel developed the eximer laser.
<table>
<thead>
<tr>
<th>LASER</th>
<th>LIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stimulated emission</td>
<td>Spontaneous emission.</td>
</tr>
<tr>
<td>Monochromatic.</td>
<td>Polychromatic.</td>
</tr>
<tr>
<td>Highly energized</td>
<td>Poorly energized.</td>
</tr>
<tr>
<td>Parallelism</td>
<td>Highly divergence</td>
</tr>
<tr>
<td>Coherence</td>
<td>Not coherent</td>
</tr>
<tr>
<td>Can be sharply focussed.</td>
<td>Can not be sharply focussed.</td>
</tr>
</tbody>
</table>
PROPERTIES OF LASER LIGHT

- Coherency
- Monochromatism
- Collimated
- Constant Phasic Relation
- Ability to be concentrated in short time interval
- Ability to produce non-linear effects
Light as electromagnetic waves, emitting radiant energy in tiny package called ‘quanta’/photon. Each photon has a characteristic frequency and its energy is proportional to its frequency.

Three basic ways for photons and atoms to interact:
- Absorption
- Spontaneous Emission
- Stimulated Emission
Continuous and pulsed lasers

- Pulsed – energy delivered in brief bursts, more power
- Examples: Nd YAG, Excimer lasers
- Continuous – Argon, krypton lasers, diode lasers, and dye lasers
CLASSIFICATION OF LASER

- **Solid State**
  - Ruby
  - Nd. Yag
  - Erbium. YAG

- **Gas**
  - Ion
  - Argon
  - Krypton
  - He-Neon
  - CO₂

- **Metal Vapour**
  - Cu
  - Gold

- **Dye**
  - Rhodamine

- **Excimer**
  - Argon Fluoride
  - Krypton Fluoride
  - Krypton Chloride

- **Diode**
  - Gallium-Aluminum Arsenide (GaAlAs)
WAVELENGTHS OF LIGHT

- 1064 nm Nd:YAG (infrared)
- 810 nm diode (near-infrared)
- 694 nm ruby-red
- 647 nm krypton-red
- 632 nm He Ne (red-orange)
- 570–630 nm dye (yellow to red)
- 532 nm 2x Nd:YAG (green)
- 514 nm argon-green
- 488 nm argon-blue
- 193 nm ArF excimer (ultraviolet)
THREE TYPE OF OCULAR PIGMENT

- **Haemoglobin:**
  - Argon Green are absorbed, Krypton yellow. These laser are found to be useful to coagulate the blood vessels.

- **Xanthophyll:**
  - Present in inner and outer plexiform layers of macula.
  - Maximum absorption is blue. Argon blue is not recommended to treat macular lesions.

- **Melanin:**
  - RPE, Choroid
  - Argon Blue, Krypton
  - Pan Retinal Photocoagulation, and Destruction of RPE
LASER SAFETY

- **Class-I**: Causing no biological damage.
- **Class-II**: Safe on momentary viewing but chronic exposure may cause damage.
- **Class-III**: Not safe even in momentary view.
- **Class-IV**: Cause more hazardous than Class-III.

LASER SAFETY REGULATION:

- Patient safety is ensured by correct positioning.
- Danger to the surgeon is avoided by safety filter system.
- Safety of observers and assistants.
LASER TISSUE INTERACTION

LASER VARIABLE:
- Wavelength
- Spot Size
- Power
- Duration

TISSUE VARIABLE:
- Transparency
- Pigmentation
- Water Content
LASER TISSUE INTERACTION

- Thermal Effect
  - Photocoagulation
  - Photodisruption
  - Photovaporization

- Photocchemical
  - Photoradiation
  - Photoablation

- Ionizing Effect
THREE BASIC LIGHT TISSUE INTERACTIONS

(1) Photocoagulation:

Laser Light
↓
Target Tissue
↓
Generate Heat
↓
Denatures Proteins
(Coagulation)

Rise in temperature of about 10 to 20 °C will cause coagulation of tissue.
THREE BASIC LIGHT TISSUE INTERACTIONS

(3) Photoablation:

- Breaks the chemical bonds that hold tissue together essentially vaporizing the tissue, e.g. Photorefractive Keratectomy, Argon Fluoride (ArF) Excimer Laser.

**Usually -**

- **Visible Wavelength**: Photocoagulation
- **Ultraviolet Yields**: Photoablation
- **Infrared**: Photodisruption, Photocoagulation
**PHOTOVAPORIZATION**

- Vaporization of tissue to CO$_2$ and water occurs when its temperature rise 60–100 °C or greater.

- Commonly used CO$_2$
  - Absorbed by water of cells
  - Visible vapor (vaporization)
    - Heat
    - Cell disintegration
  - Cauterization
  - Incision
PHOTOCHMICAL EFFECT

PHOTORADIATION (PDT):

- Also called Photodynamic Therapy
- Photochemical reaction following visible/infrared light particularly after administration of exogenous chromophore.
- Commonly used photosensitizers:
  - Hematoporphyrin
  - Benzaporphyrin Derivatives
- E.g. Treatment of ocular tumour and CNV
PHOTOCHEMICAL EFFECT

Contd. ...

Photon + Photosensitizer in ground state (S)

3S (high energy triplet stage)

Energy Transfer

Molecular Oxygen
S + O₂ (singlet oxygen)

Free Radical
Cytotoxic Intermediate

Cell Damage, Vascular Damage, Immunologic Damage
Highly energized focal laser beam is delivered on tissue over a period of nanosecond or picoseconds and produce **plasma** in target tissue.

- **Q Switching Nd:Yag**
  - Ionization (Plasma formation)
  - Absorption of photon by plasma
  - Increase in temperature and expansion of supersonic velocity
  - Shock wave production → Tissue Disruption
<table>
<thead>
<tr>
<th>Ophthalmic tissue interaction</th>
<th>Laser used</th>
<th>Clinical application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photocoagulation</td>
<td>Argon</td>
<td>Retinal photoacoagulation</td>
</tr>
<tr>
<td></td>
<td>Krypton</td>
<td>Iridotomy</td>
</tr>
<tr>
<td></td>
<td>Frequency-doubled Nd:YAG</td>
<td>Trabeculoplasty</td>
</tr>
<tr>
<td></td>
<td>Dye</td>
<td>Vitreoretinal surgery</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Choroidal/retinal tumours</td>
</tr>
<tr>
<td></td>
<td>CO₂ laser</td>
<td>Foveolar photocoagulation</td>
</tr>
<tr>
<td></td>
<td>Dye and gold vapour</td>
<td>Similar to argon</td>
</tr>
<tr>
<td></td>
<td>Nd:YAG pulsed</td>
<td>Retinal/intraretinal vascular abnormalities</td>
</tr>
<tr>
<td></td>
<td>Excimer</td>
<td>Parafoveal subretinal neovascularisation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Choroidal/retinal tumour</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Foveolar subretinal neovascularisation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Destruction of intraocular tumours like melanomas, retinoblastomas</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tissue incision, e.g. during Kronlein procedure</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Producing filtering cicatrix</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Blepharoplasty</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Debuling of large conjunctival tumours</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Capsulotomy, iridectomy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lysis of vitreous bands</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Corneal scar removal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Refractive keratoplasty</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Radial keratotomy</td>
</tr>
</tbody>
</table>
MODES OF LASER OPERATION

- **Continuous Wave (CW) Laser:** It delivers their energy in a continuous stream of photons.
- **Pulsed Lasers:** Produce energy pulses of a few tens of microseconds to a few milliseconds.
- **Q Switches Lasers:** Deliver energy pulses of extremely short duration (nano seconds).
- **A Mode-locked Lasers:** Emits a train of short duration pulses (picoseconds).
- **Fundamental System:** Optical condition in which only one type of wave is oscillating in the laser cavity.
- **Multimode System:** Large number of waves, each in a slightly different direction, oscillate in the laser cavity.
Slit lamp biomicroscopic laser delivery

- Most commonly employed mode for anterior and posterior segment.
- ADVANTAGES:
  - Binocular and stereoscopic view.
  - Fixed distance.
  - Standardization of spot size is more accurate.
  - Aiming accuracy is good.
Laser indirect opthalmoscope.

**Advantages:**
- Wider field (ability to reach periphery).
- Better visualization and laser application in hazy medium.
- Ability to treat in supine position. (ROP/EUA)

**Disadvantage:** difficulty in focusing.
- Difficulty to standardize spot size.
- Expensive.
- Un co-operative patient.
- Learning curve.
USES

- THERAPEUTIC.
- DIAGNOSTIC.
LASER IN ANTERIOR SEGMENT

CORNEA:
Laser in Keratorefractive Surgery:
- Photo Refractive Keratectomy (PRK).
- Laser in situ Keratomileusis (LASIK).
- Laser Sub epithelial Keratectomy (LASEK).
- Epi Lasik.
Laser Thermal Keratoplasty.
Corneal Neovascularization.
Retrocorneal Pigmented Plaques.
EXCIMER LASER

- High energy UV laser.
- Excited dimer.
- Argon fluoride (193nm) most commonly applied for corneal surgeries.
- Photoablation.
EXCIMER LASER (contd...)  

- Laser removes approximately 0.25 microns of corneal tissue with each pulse.
- Amount of tissue to be ablated derived from "munnerlyn equation"
- Central ablation depth in microns = diopters of myopia \[ \times (\text{ablation zone diameter in mm})^2 \]
  \[ \frac{3}{3} \]
MYOPIC PHOTOREFRACTIVE KERATECTOMY

FIG. 15-7 Photorefractive keratectomy (PRK). After removal of the corneal epithelium, the excimer laser is used to reprofile the anterior curvature of the cornea, which changes its refractive power.

LASER-ASSISTED STROMAL IN SITU KERATOMILEUSIS

Flap lifted from eye

Lenticle removed using laser light

Flap sewn back down

FIG. 15-11 Laser-assisted stromal in situ keratomileusis. A flap with parallel sides is lifted using the microkeratome. The excimer laser is used to remove a lenticule of pre-determined power from the exposed corneal stroma. The flap, with its intact epithelium, is then folded back, and as it drapes over the modified stromal surface, the refractive power of the anterior corneal surface is modified. The dotted area in the bottom panel corresponds to the lenticule that was removed. Usually, no sutures are required.
FEMTOSECOND LASER

ADVANTAGES:
- Flap are more accurate and uniform in thickness.
- Concentration of flap is easier.
- Better adherence to underlying stroma.
- Patient are more comfortable.

DISADVANTAGES:
- Suction break
- Costly
**FEMTOSECOND LASER**

**INTRALASE FEMTOSECOND LASER: HOW IT WORKS**

**INTRALASE FS Laser**

1. IntralASIK software directs the INTRALASE FS Laser to optically focus its beam into a tiny, 2 micron spot of energy that passes harmlessly through the outer layers of the cornea until reaching its exact focal point within the stroma (central layer of the cornea).

2. In an “inside out” process, the laser beam creates a dissection plane by forming an interconnected series of bubbles (made of carbon dioxide and water vapor).

**Eye anatomy at a glance**

- The cornea is a dome-like structure of transparent tissue that extends over the lens, pupil, and iris. The cornea’s curvature affects the way incoming light rays are bent so that they focus optimally onto the retina for maximum visual acuity.

3. The laser beam stacks a pattern of bubbles along the periphery of the ablation plane, leaving an uncut section of tissue to act as a hinge. As with a traditional LASIK approach, the surgeon then folds the tissue back to expose the underlying corneal layer to prepare for the excimer laser treatment that will re-shape the cornea.
LASER IN GLAUCOMA

- Laser Iridotomy.
- Laser Trabeculoplasty (LT)
- Selective Laser Trabeculoplasty
- Trabecular ablation
- Gonioplasty (Iridoplasty, Iridoretraction)
- Pupiloplasty
- Sphincterotomy
- Iridolenticular Synechiolysis
- Goniophotocoagulation
- Goniotomy
Laser Iridotomy in Glaucoma

Preferred sites for laser iridotomy in PACG
PUPILLOPLASTY

2-3 rows of burns circumferentially 1mm away from the pupillary margin.

Innermost row: 8 spots, 200 micron size, 200-400mW.

Outer row: 10-12 spots, 400 micron size, 300-500mW
Mechanism of action: Mechanical.

Biological.
Argon laser trabeculoplasty

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Argon laser trabeculoplasty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spot size (μm)</td>
<td>50</td>
</tr>
<tr>
<td>Spot duration (seconds)</td>
<td>0.1</td>
</tr>
<tr>
<td>Power (mW)</td>
<td>200–800</td>
</tr>
<tr>
<td>Number of spots per quadrant</td>
<td>20–25</td>
</tr>
<tr>
<td>Wavelength</td>
<td>Argon green</td>
</tr>
<tr>
<td>Contact lens</td>
<td>Goldmann</td>
</tr>
<tr>
<td>Anesthetic</td>
<td>Topical</td>
</tr>
<tr>
<td>Pretreatment</td>
<td>Apraclonidine or brimonidine</td>
</tr>
</tbody>
</table>
Selective laser trabeculoplasty versus argon laser trabeculoplasty treatment. (Courtesy of M. Berlin, MD.)
LASER IN GLAUCOMA

Contd. ...

- Laser Filtration Procedures (sclerostomy):
  - Ab Externosclerostomy (Holmium)
  - Ab Internosclerostomy (Nd.YAG)
    - Contact
    - Non-contact

- Cyclodestructive Procedures (cyclophotocoagulation)
  - Transscleral Cyclophotocoagulation
  - Transpupillary Cyclophotocoagulation
  - Diode Laser Endophotocoagulation
Transmission of laser light through the sclera. The laser beam is focused on the ciliary processes.
Noncontact ab interno sclerostomy. Laser energy is directed internally via a goniolens. No conjunctival dissection is required.

Contact ab interno sclerostomy. Laser energy is delivered internally via a laser probe. No conjunctival dissection is required.
LASER IN LENS

- Posterior capsulotomy
- Laser phacoemulsification
- Phacoablation.

- Laser in Lacrimal Surgery:
  - Laser DCR.

LASER IN VITREOUS

- Vitreous membranes
- Vitreous traction bands
LASER TREATMENT OF FUNDUS DISORDERS

- Diabetic Retinopathy
- Retinal Vascular Diseases
- Choroidal Neovascularization (CNV)
- Clinical Significant Macular Edema (CSME)
- Central Serous Retinopathy (CSR)
- Retinal Break/Detachment
- Tumour
LASER TREATMENT OF FUNDUS DISORDERS

Contd. ...

- ARMD
- Retinal Vein Occlusion
- Eale’s Disease
- Coats Disease
- Peripheral Retinal Lesion
- Retinopathy of prematurity.
Informed consent

- Patient should be explained about the possible complications to avoid legal problems to the treating physician later.
CLASSIFICATION OF CHORIORETINAL BURN INTENSITY

- Light: Barely visible retinal blanching
- Mild: Faint white retinal burn
- Moderate: Opaque dirty white retinal burn
- Heavy: Dense white retinal burn
Fig. 16.17
(a) Appropriate laser burns; (b) appearance several weeks after completion of treatment (Courtesy of C Barry – fig. b)
Pathogenesis of diabetic macular edema

- Microaneurysm OR Damaged capillary
- Exudate
- Swollen retina
- Normal capillary
- Normal retina
- Retinal pigment epithelium
LASER LIGHT ABSORBED BY MELANIN IN RPE

PHOTORECEPTOR DESTRUCTION AND DECREASED OXYGEN CONSUMPTION

OXYGEN FLUX FROM CHOROID INTO INNER RETINA
IMPROVED OXYGENATION OF INNER RETINA

- Decreased VEGF production
- Decreased permeability
- Degraded neovascularization

AUTOREGULATORY CONSTRICITION OF RETINAL ARTERIOLES AND INCREASED RESISTANCE

- Decreased hydrostatic pressure in capillaries and venules

CONSTRICITION OF RETINAL CAPILLARIES AND VENULES

- Decreased edema formation
# Diabetic Retinopathy

<table>
<thead>
<tr>
<th>Type of Retinopathy</th>
<th>Therapy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Background</td>
<td>Control of diabetes, regular review</td>
</tr>
<tr>
<td>Maculopathy</td>
<td>Focal photocoagulation</td>
</tr>
<tr>
<td>Maculopathy CSME</td>
<td></td>
</tr>
<tr>
<td>Diffuse leakage around macula</td>
<td>Grid laser</td>
</tr>
<tr>
<td>Circinate</td>
<td>Focal photocoagulation</td>
</tr>
<tr>
<td>Pre-proliferative Retinopathy</td>
<td>Frequent review</td>
</tr>
<tr>
<td>Proliferative retinopathy</td>
<td>Pan retinal photocoagulation</td>
</tr>
<tr>
<td>Advanced diabetic eye disease</td>
<td>Vitreoretinal surgery with photocoagulation</td>
</tr>
</tbody>
</table>
Retinal hemorrhage
Choroidal melanoma

- Indication:
- Photocoagulation technique.
- Initial destruction of the surrounding choroidal blood supply-1-2rows - 200-500 microns 0.5-1sec-intense burn.
- Direct tumour photocoagulation-low energy burns long duration5-30sec.
Scanning Laser Ophthalmoscopy
allows for high-resolution, real-time motion images of the macula without patient discomfort.

SLO angiography: to study retinal and choroidal blood flow.

May be used to perform microperimetry, an extremely accurate mapping of the macula’s visual field.
Optical Coherence Tomography

- Uses diode laser light in the near-infrared spectrum (810 nm) to produce high-resolution cross-sectional images of the retina using coherence interferometry.
Complications

General complications:
- Pain
- Seizures.

Anterior segment complications:
- Elevated IOP.
- Corneal damage.
- Iris burns.
- Crystalline lens burns.
- IOL and PC damage.
- Internal opthalmoplegia.
Lasers can:

- Save a child’s eye as in Retinoblastoma.
- Change a personality as in LASIK.
- Cure a middle aged person with Glaucoma.
- Restore Vn. in a person with After-Cataract.
- Preserve & Retain Vn. in pts. with DR & ARMD.
- The possibilities are endless......