Lasers in ophthalmology

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Definition

LASER is an acronym for

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

The laser is a source of coherent, directional, monochromatic light that can be precisely focused into a small spot. The laser is a very useful tool for a wide variety of clinical **diagnostic** and **therapeutic** procedures.
• Types of ophthalmic lasers
• Absorbtion spectras of important ocular chromophores
• Laser- tissue interactions
• Laser- therapeutic applications
• Laser- diagnostic applications
Types of ophthalmic lasers

Wavelength range of ophthalmic lasers extends from 193nm to 1064nm, including the visible spectrum: approximately between 400 and 750 nm
Absorption Spectra of Important Ocular Chromophores

Extinction Coefficient (cm⁻¹)

Wavelength (nm)

400  500  600  700  800  900  1000  1100

Ar 488  515  Kr 568  Kr 647  Nd-YAG 1,064 nm

melanin

HbO₂

Deoxy-Hb

xanthophyll
Laser-Tissue Interactions

Interactions of light with biological tissues depend on it’s

- wavelength
- pulse duration
- irradiance (amount of power per unit area, W/cm²)
Laser/tissue interaction depends on power density and exposure time.
LIGHT- TISSUE INTERACTIONS
thermal effect

Photocoagulation:

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

Rise in temperature of about 10 to 20 °C (to 50-60 °C) will cause coagulation of tissue.
Photodisruption:

Laser Light

↓

Acoustic shock waves (thunderclap)

↓

Tissue ruptures as a result of the vapor bubbles

↓

Tissue Damage

(between 100 and 305 °C)
Vaporization

- With very high power of densities, lasers will quickly heat the tissues with temperature between 60—100 °C or above. Water within the tissues boils and evaporates.
- Photo-vaporization results in complete removal of the tissue.

https://www.researchgate.net/figure/Laser-tissue-interaction_fig15_258140573
Photoablation:

Breaks the chemical bonds that hold tissue together, essentially vaporizing the tissue.

- Photorefractive Keratectomy,
- Argon Fluoride (ArF)
- Excimer Laser.
PHOTORADIATION (PDT):

Also called Photodynamic Therapy

Photochemical reaction following visible/infrared light particularly after administration of exogenous chromophore.

Commonly used photosensitizers:

- Hematoporphyrin
- Benzaporphyrin Derivatives

Treatment of ocular tumour and choroidal neovascularisatin (CNV)
LIGHT - TISSUE INTERACTIONS

Ionization effect

- 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
Therapeutic application of lasers
Eye Anatomy

- conjunctiva
- ciliary body
- choroid
- retina
- macula
- iris
- lens
- pupil
- cornea
- anterior chamber
- vitreous body
- optic nerve
- optic disc
- sclera
ND: YAG laser

- Neodymium-doped-yttrium-aluminium garnet is a crystal that is used as a lasing medium for solid-state lasers
- ND: YAG lasers typically emit light with a wavelength of 1064nm in the infrared

Application:

- correct posterior capsular opacification
- peripheral iridotomy in patients with angle-closure glaucoma
- laser trabeculoplasty in open angle glaucoma
- frequency doubled ND:YAG lasers (wavelength 532nm) are used for pan-retinal photocoagulation in patients with diabetic retinopathy
Opacification of the lens (Cataract)

1. Incision: A small incision, approximately 3mm in width, is made at the corneal margin.
2. Emulsification: Phacoemulsification probe is inserted through corneal incision and ultrasound breaks cataract up into microscopic fragments, which can then be aspirated using the probe tip.
3. Intraocular Lens Implant: The artificial foldable intraocular lens is inserted and, once inside, the lens unfolds.
4. Result: The new lens is in place, the small incision heals naturally without the need for sutures, and vision is restored.

Correct posterior capsular opacification
Intraocular fluid

-- intraocular fluid: aqueous humor and vitreous humor
-- maintain intraocular pressure
Abnormal liquid drainage or liquid production result in damage to the optic nerve and cause vision loss.
Types of glaucoma

- Angle-Closure Glaucoma
- Primary Open-Angle Glaucoma
- Normal Tension Glaucoma
- Secondary Glaucoma
- childhood Glaucoma
- Pigmentary Glaucoma
- Acute Angle-Closure Glaucoma
Angle-Closure Glaucoma

Peripheral iridotomy in patients with angle-closure glaucoma
Laser trabeculoplasty

The targets are the pigmented trabecular meshwork cells in the angle of the eye.
Frequency doubled ND:YAG lasers pan-retinal photocoagulation (often termed as "green laser")

**Thermal Effects**

**Photocoagulation:**

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

Rise in temperature of about 10 to 20 °C will cause coagulation of tissue. Frequency-doubled Nd:YAG lasers (wavelength 532 nm) are used for pan-retinal photocoagulation in patients with diabetic retinopathy. Argon and krypton lasers were used previously.

Highly absorbed by the hemoglobin and the melanin pigment.
Frequency doubled ND:YAG or Argon blue-green lasers pan-retinal photocoagulation

‘Lasers essentially destroy tissue in order to have a beneficial effect on the eye’

Argon blue-green laser (70% blue (488 nm) and 30% green(514nm))
LASER VARIABLE:

- Wavelength
- Spot Size
- Power
- Duration
Pattern scan laser (PASCAL)

- The PASCAL Photocoagulator is an integrated semi-automatic pattern scan laser photocoagulation system designed to treat ocular diseases using a single shot or multiple shots at a single click to predetermined pattern array.
- Laser source: Nd:YAG laser (green or yellow)
- Delivery device: slit lamp or laser indirect ophthalmoscope (LIO)
- It has Control system for selecting power, duration and spot size
- It also has micropulse technology to deliver sub threshold burns by reducing the duty cycle and thus less damage to tissue & less heat production in macular area
- Used for PRP and macular lasers

https://www.slideshare.net
Retinopathy prematurity (ROP)

- birth of a baby at fewer than 37 weeks gestation age
- disorganized growth of retinal blood vessels
- new vessel formation

Dioda laser (805-810 nm)

- well absorbed by melanin
- near infrared spectrum
- very deep penetration
Transpupillary thermotherapy (TTT)

- Transpupillary thermotherapy is proven and medically necessary for treating the following tumors:
  - Retinoblastoma
  - Choroidal melanomas

- Diode laser to raise the temperature within treated tumor tissue, causing heat-induced 
  *sclerosis* of vascular channels and eventually 
  *tumor regression* and resolution of 
  *subretinal fluid*.
Main components and different delivery systems of a laser

- Laser console
- Foot pedal
- Operating microscope
- Fibre optic cable
- Slit lamp
- Endoprobe
- Indirect ophthalmoscope
An **excimer laser** is a powerful kind of **laser** which is nearly always operated in the **ultraviolet** (UV) spectral region (→ **ultraviolet lasers**) and generates nanosecond **pulses**.
Refractive surgery

- **Refractive eye surgery** is an **eye surgery** used to improve the refractive state of the **eye** and decrease or eliminate dependency on **glasses** or **contact lenses**.
- This can include various methods of surgical remodeling of the **cornea** (**keratomileusis**).
- The most common methods today use **excimer lasers** to reshape the curvature of the cornea.
- Successful refractive eye surgery can reduce or cure common vision disorders such as **myopia**, **hyperopia** and **astigmatism**, as well as degenerative disorders like **keratoconus**.
Refractive Surgeries

- Photorefractive keratectomy
- Laser subepithelial keratomileusis (LASEK)
- Laser-assisted in situ keratomileusis (LASIK)
Diagnostic application of lasers
• Optical coherence tomography OCT
  - anterior segment
  - posterior segment

• Optical coherence tomography angiography OCTA
• Optomap system
How does OCT work?

OCT is a non-invasive, sub-surface imaging technique capable of providing high resolution cross sectional images of biological tissues such as retina.

OCT empowers you with the details of “What lies beneath the fundus image?”
Anterior segment of the eye
Anterior OCT image

Measurements: cornea thickness, cornea anterior radius, anterior chamber depth, irido corneal angle
Time domain and Spectral domain
OCT
Retinal labeled layers
What conditions can OCT help to diagnose?

OCT is useful in diagnosing many eye conditions, including:

- macular hole
- macular pucker
- macular edema
- age-related macular degeneration
- glaucoma
- central serous retinopathy
- diabetic retinopathy
- vitreous traction
Macular hole
Macular oedema
Age related macular degeneration
Age related macular degeneration
Optic nerve analyser
Central serous chorioretinopathy
Diabetic retinopathy
Vitreo-macular traction
How does OCT-A work?

OCT image is a structural, cross-sectional, B-scan image.

OCT works by sending a **long-wavelength light**, then detecting changes that occurred on the tissue-reflected light; thereby, it converts the reflected light into an image.
Optical Coherence Tomography Angiography (OCTA)
OCTA diabetic retinopathy
**Optomap** technology incorporates low-powered laser wavelengths that scan simultaneously.

- **Green laser** (532 nm) scans from the sensory retina to the pigment epithelial layers
- **Red laser** (633 nm) scans from the RPE to the choroid
- **Blue laser** (488 nm) used in fluorescein angiography procedures
- **Infrared laser** (802 nm) used in indocyanine green angiography procedures
Thank you for your attention