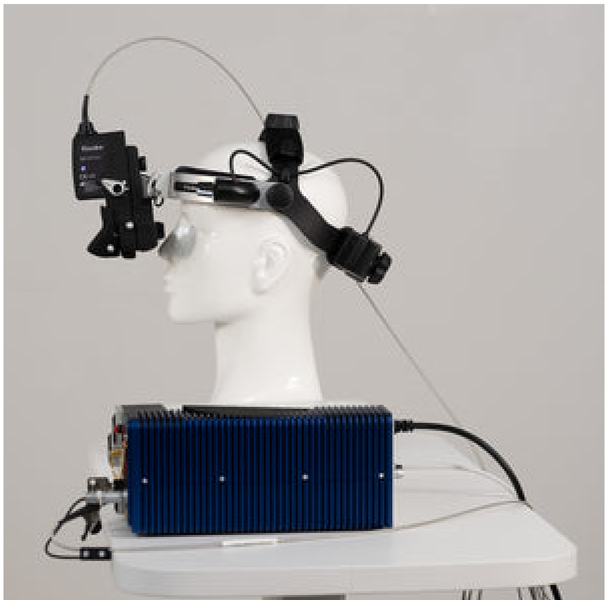
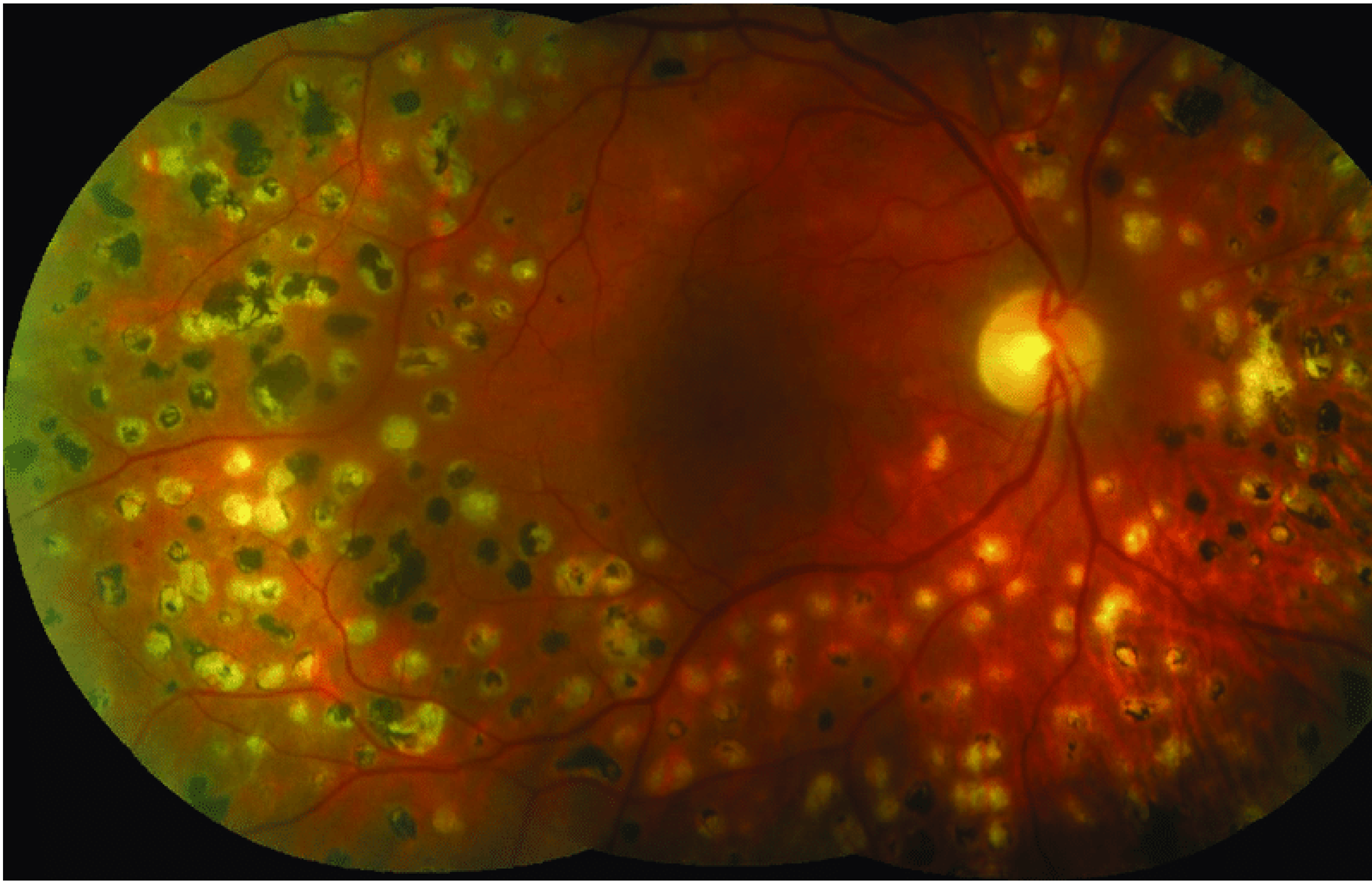
Lecture Title

Diode Laser (≈ 810 nm) in Ophthalmology: Principles, Applications & Clinical Practice

1. Introduction & Background





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- Laser treatment is a cornerstone in ophthalmology (diagnostic and therapeutic) — mechanisms include photothermal/photocoagulation, photodisruption, photoablation, etc.
- The diode laser refers to a semiconductor laser medium (commonly GaAlAs/GaAs) operating in the near-infrared region (≈ 720–890 nm) with a common ophthalmic wavelength ~810 nm.
- The 810 nm (near-infrared) diode laser has particular advantages and tissue-interaction characteristics which make it distinct from visible-wavelength lasers (e.g., green 532 nm, argon lasers).

2. Physics & Tissue Interaction of the 810 nm Diode Laser

2.1 Wavelength & absorption

- At ~810 nm, the light is in the near-infrared region. Absorption by hemoglobin is **poor**, whereas absorption by melanin (in the retinal pigment epithelium [RPE] and choroid) remains significant.
- Because hemoglobin absorption is low, direct coagulation of small retinal vascular lesions (microaneurysms) is more difficult with 810 nm compared to green/yellow lasers.
- The longer wavelength penetrates deeper through retina and choroid, and is less scattered by opacities, cataractous lens or vitreous haze.

2.2 Mechanism of effect: photocoagulation

- The primary mechanism is **thermal coagulation**: laser energy is absorbed, converted to heat → tissue temperature rises sufficiently (commonly ~60–70 °C) → coagulative necrosis of pigmented structures and adjacent tissue.
- Because of deeper penetration, the 810 nm laser can reach the choroid and RPE more effectively, but one must be cautious not to overtreat and cause damage to outer retinal/choroidal structures.

2.3 Device/Delivery

- Typically used via slit-lamp delivery with contact lens (for posterior segment) or via indirect ophthalmoscope for peripheral retina.
- The aiming/preview beam may be visible (often 635 nm red), whereas the therapeutic 810 nm beam is near-infrared (often less visible to the patient), thus improving patient comfort (less bright flash) in some cases.

3. Main Clinical Applications in Ophthalmology

Clinical Applications of the 810 nm Diode Laser

3.1 Retinal Photocoagulation

3.1.1 Proliferative Diabetic Retinopathy (PDR)

The 810 nm laser is used for **pan-retinal photocoagulation (PRP)** to induce regression of neovascularization.

Evidence:

- Short-pulse (20 ms) and standard-pulse (100 ms) PRP result in **similar neovascular control (~75–77%)**, with reduced pain and lower fluence in short durations (Yusran et al., 2015).

3.1.2 Diabetic Macular Edema (DME)

Although anti-VEGF therapy dominates modern management, 810 nm lasers remain useful for **focal/grid treatment** in selected cases.

Advantages:

- Deeper penetration
- Reduced xanthophyll absorption → potentially less inner retinal damage

3.1.3 Peripheral Retinal Pathology

- Lattice degeneration
- Retinal holes or tears
- Difficult cases with mild media opacity

3.1.4 Retinopathy of Prematurity (ROP)

Used as **trans-scleral diode photocoagulation**:

- Less bright flash → safer for infants
- Effective for avascular peripheral retina

3.2 Glaucoma: Trans-Scleral Cyclophotocoagulation (CPC)

The 810 nm diode is the **standard wavelength** for CPC in:

- Refractory glaucoma
- Neovascular glaucoma
- Post-keratoplasty glaucoma
- Eyes with poor visual potential

Mechanism: controlled destruction of the ciliary processes → reduced aqueous production → lower IOP.

4. Laser Parameters & Practical Considerations

4.1 Key parameters

For an eye-care laser procedure, the main variables are: spot size, power (mW), exposure duration (ms), and number of burns.
Example: The study using 810 nm for PDR used: spot size 200 µm, durations of 20 ms vs 100 ms, and ~1500 burns.
Because power and duration are inversely related (shorter duration → need higher power to achieve same fluence), one must adjust parameters carefully.

4.2 Burn classification & titration

- Aim for a visible mild grey-white burn (in retina) rather than heavy white scars, especially in macular region or when attempting sub-threshold treatments.
- With 810 nm diode laser, because the beam is less visible (near infrared) the operator must rely on the tissue response and, if possible, fundus visualization with contact lens and good view.
- Titrate power up gradually until a barely visible burn appears, then adjust number of burns as per protocol.

4.3 Choice of wavelength relative to lesion, media clarity, and absorption

- If there is substantial media opacity (cataract, vitreous hemorrhage) or retina is far periphery, 810 nm may offer better penetration than green/yellow lasers.
- If targeting superficial micro-aneurysms where hemoglobin absorption is key, green/yellow may be more effective given the stronger hemoglobin absorption at shorter wavelengths.

4.4 Recent approach: shorter pulse durations

- The cited study compared 20 ms vs 100 ms exposures with 810 nm and found similar success rates for PDR progression prevention but with lower fluence and potentially less collateral damage in the 20 ms group.
- This suggests that shorter duration, higher power burns may reduce energy delivered and potentially reduce pain and collateral damage.

5. Safety, Complications & Patient Considerations

5.1 Safety measures

- Proper protective eyewear specific to the wavelength must be used.

- Warning signs in the OR/laser suite, restricted access during firing, and avoiding inadvertent exposure to bystanders.
- Use of appropriate aiming beams, alignment of contact lens (if used), ensuring stable fixation.
- Document baseline vision, fundus status, media clarity; counsel patient regarding expectations and risks.

5.2 Potential complications

- Over-coagulation may cause excessive tissue damage → Bruch's membrane rupture, choroidal neovascularisation, retinal atrophy.
- Because the 810 nm beam penetrates deeper, there is a risk of choroidal damage if energy is too high.
- Pain during the procedure: in the 810 nm study, pain was present in 28.6 % in 100 ms group vs 7.1 % in 20 ms group.
- Post-laser vision changes, macular scarring, inadvertent laser to fovea if mis-directed, vitreous hemorrhage if neovascular vessels are broken.

5.3 Patient selection & counselling

- Patients with good media clarity and fundus view are ideal; for those with opacities, 810 nm may perform better.
- Inform patients of the procedure, expected outcomes (e.g., stabilization rather than improvement), potential need for additional treatments (especially in diabetic retinopathy where anti-VEGF may be adjunct).
- Consider ocular comorbidities: e.g., significant cataract may reduce view or require cataract surgery first.

6. Clinical Evidence & Comparative Data

- The pilot study of J.D.A. McHugh et al. (1989) on an infrared diode laser (≈ 810 nm) in retinal vascular disease (33 eyes) found regression of neovascularisation in ~81% of PDR eyes.
- More recently, the Indonesian study using 810 nm compared 20 ms vs 100 ms durations in PDR and showed non-progression rates of 76.9% vs 75.0% respectively, with lower fluence in the short-duration group.
- Reviews of laser physics note that the 810 nm diode laser is well-suited for deeper lesions and shows good portability and versatility.
- Comparative absorption tables show that although hemoglobin absorption drops off as wavelength increases, melanin absorption remains effective, giving 810 nm its utility for RPE/choroid targeting.
- However, there is less data specifically for focal/macular diode-810 treatments compared to anti-VEGF, and evolving technologies (e.g., micropulse, sub-threshold) may modify the role of 810 nm lasers in future.

7. Summary & Best Practice Recommendations

- The 810 nm diode laser is a valuable tool in ophthalmic laser therapy, especially for posterior segment applications requiring deeper penetration and for patients with less media clarity.
- When using 810 nm: tailor parameters (spot size, duration, power) carefully; consider shorter-duration burns to reduce fluence and complications; ensure appropriate training and safety.
- Remember that wavelength choice matters: shorter visible wavelengths (green, yellow) may still be preferred when hemoglobin absorption is critical (e.g., small retinal vessels).
- Patient counselling should emphasize that laser therapy often aims to stabilise rather than dramatically improve vision, particularly in diabetic retinopathy or macular oedema.
- Ongoing research (micropulse 810 nm, combination therapies) may expand the role for diode laser treatment modalities in the futur

Revision (Key Points Summary)

1. Wavelength & Physics

- The diode laser operates at **810 nm (near-infrared)**.
- Strongly absorbed by **melanin** (RPE, choroid) and weakly by **hemoglobin**.
- Less scattering → effective even with **media opacity** (cataract, vitreous hemorrhage).

2. Mechanism of Action

- Causes **photothermal coagulation**.
- Temperature increases to **60–70°C**, producing controlled coagulative necrosis.
- Deeper penetration compared with 532 nm green lasers.

3. Main Clinical Uses

- **PRP for PDR** (diabetic retinopathy).
- **Grid/Focal treatment** in selected DME cases.
- **Peripheral retina**: lattice degeneration, tears.
- **ROP** treatment using trans-scleral applications.
- **Glaucoma CPC** for refractory or neovascular glaucoma.

4. Laser Parameters

- Spot size ~200–500 µm.
- Duration **20 ms (short pulse)** or **100 ms (traditional)**.
- Power titrated to achieve **light grey burn**.
- Short-pulse PRP → **less pain, lower fluence**.

5. Safety & Complications

- Risks: choroidal damage, Bruch's rupture, macular burn, inflammation, vitreous hemorrhage.
- CPC risks: hypotony, pain, inflammation.
- Always use proper eye protection and correct titration.

6. Evidence

- PRP with 810 nm shows **~75–80% regression** of neovascularization.
- Short vs long pulse PRP → **similar efficacy, less pain** in short pulse.
- # Comparison Table: 532 nm Green Laser vs 810 nm Diode Laser

Feature	532 nm Green Laser	810 nm Diode Laser
Wavelength	532 nm (visible green)	810 nm (near-infrared)
Main Absorber	Hemoglobin + Melanin	Melanin (strong), Hemoglobin (weak)
Tissue Penetration	Moderate	**Deep penetration**
Effect Through Media Opacity	Reduced by cataract/vitreous haze	**Very good performance** through opacity
Use in PRP (PDR)	Gold standard	**Equally effective**, especially with poor view
Use in DME	More selective for microaneurysms	Less selective; deeper, less xanthophyll damage

Use in ROP	Less ideal (bright flash)	**Preferred** (infrared → less bright)
Use in CPC	Not used	**Standard laser for cyclophotocoagulation**
Visibility of Beam	Bright, visible	Near-invisible → more comfortable for patients
Pain During PRP	Higher	**Lower**, especially with short pulses
Risk of Choroidal Damage	Lower	**Higher if overtreatment occurs**
Cost & Portability	More expensive systems	**Cheaper, more portable units**

Sample of questions

5 MCQ (with Answers Below)

1.

Which chromophore absorbs the 810 nm diode laser most strongly?
A. Xanthophyll
B. Hemoglobin
C. Melanin
D. Water

Answer: C

2.

The main mechanism of action of the 810 nm diode laser is:
A. Photodisruption
B. Photoablation
C. Photothermal coagulation
D. Electrophotostimulation

Answer: C

3.

The 810 nm diode laser is preferred in ROP mainly because:
A. It has high hemoglobin absorption
B. The beam is less bright for infants
C. It causes more superficial burns
D. It causes immediate regression of plus disease

Answer: B

4.

Short-pulse (20 ms) PRP with 810 nm diode laser is associated with:
A. Higher fluence
B. More pain
C. Lower fluence and less pain
D. Higher rate of complications

Answer: C

5.

The standard wavelength used for trans-scleral cyclophotocoagulation is:
A. 532 nm
B. 577 nm
C. 690 nm
D. 810 nm

Answer: D

5 Fill in the Blank

1. The diode laser commonly used in ophthalmology operates at a wavelength of approximately **_______ nm**.
   (Answer: 810)
2. The primary absorbing pigment for the 810 nm wavelength is **_______**.
   (Answer: melanin)
3. The mechanism of tissue effect produced by diode laser is **_______ coagulation**.
   (Answer: photothermal)
4. In PRP, the desired retinal lesion is a **_______ grey-white burn**.
   (Answer: light / barely visible)
5. Trans-scleral cyclophotocoagulation lowers IOP by reducing **_______ production**.
   (Answer: aqueous)

5 Definitions

1. **Photothermal Coagulation**
   A laser-tissue interaction where absorbed light energy is converted to heat, producing controlled coagulative necrosis of pigmented structures.
2. **Cyclophotocoagulation (CPC)**
   A diode laser procedure targeting the ciliary body through the sclera to reduce aqueous humor production in refractory glaucoma.
3. **Pan-Retinal Photocoagulation (PRP)**
   A retinal laser treatment applying multiple peripheral burns to reduce ischemia and induce regression of neovascularization.
4. **Pulse Duration**
   The time over which a laser pulse is delivered, influencing tissue heating and depth of coagulation.
5. **Media Opacity**
   Any reduction in clarity of ocular media (cornea, lens, vitreous) that interferes with visualization and laser delivery.

3 Enumerate (Short List Questions)

1. Enumerate three clinical uses of the 810 nm diode laser.

- PRP for proliferative diabetic retinopathy

- Cyclophotocoagulation for refractory glaucoma
- Peripheral retinal treatment (lattice, tears, holes)

2. Enumerate three advantages of the 810 nm diode laser.

- Good penetration through media opacity
- Strong melanin absorption
- Lower patient discomfort compared with visible lasers

3. Enumerate three complications of diode laser PRP.

- Choroidal damage or effusion
- Bruch’s membrane rupture
- Worsening of macular edema or accidental macular burn

3 Clinical Cases (with Answers)

Case 1

A 58-year-old diabetic patient presents with vitreous hemorrhage and neovascularization. Fundus view is hazy.
Which laser wavelength is most suitable and why?

Answer:
The 810 nm diode laser because it penetrates well through media opacities and provides effective PRP in reduced visibility.

Case 2

A child with ROP requires urgent peripheral retinal ablation.
Why is diode laser preferred over green laser?

Answer:
The diode laser's near-infrared beam is less bright and more comfortable for infants, and provides effective trans-scleral or indirect delivery.

Case 3

A patient with neovascular glaucoma has very high IOP despite maximum medications. Vision is poor.
What diode-laser procedure is indicated?

Answer:
Trans-scleral cyclophotocoagulation (CPC) using the 810 nm diode laser to reduce aqueous production.

5 True or False

1. The 810 nm diode laser is strongly absorbed by hemoglobin.
   False
2. Short-pulse PRP (20 ms) causes less pain than long-pulse PRP.
   True
3. Diode laser can be reliably used through mild cataract or vitreous haze.
   True
4. Cyclophotocoagulation increases aqueous outflow facility.
   False (it reduces aqueous production)
5. 810 nm diode laser produces more superficial burns compared with green 532 nm.
   False (it penetrates deeper)

6. Discuss Briefly

1. Discuss briefly the advantages of using the 810 nm diode laser in eyes with media opacity.

The 810 nm diode laser has a near-infrared wavelength that undergoes minimal scattering as it passes through ocular structures. Because of this property, it maintains good energy delivery even when the cornea, lens, or vitreous are partially opaque—such as in early cataract, corneal edema, or vitreous hemorrhage. This makes it especially useful in urgent PRP cases where visualization is compromised but treatment must not be delayed, such as proliferative diabetic retinopathy with vitreous hemorrhage.

2. Discuss briefly why short-pulse (20 ms) PRP reduces patient discomfort compared to traditional 100 ms burns.

Short-pulse PRP delivers energy in a very brief period, resulting in lower total thermal load (fluence) while still achieving a therapeutic retinal burn. Because less heat spreads to surrounding tissues, the patient experiences less pain during treatment. The shorter exposure time also reduces collateral damage to inner retinal layers and choroid while maintaining similar efficacy in inducing regression of neovascularization.

3. Discuss briefly the role of diode laser cyclophotocoagulation (CPC) in refractory glaucoma.

Cyclophotocoagulation targets the ciliary processes through the sclera using the 810 nm diode laser. By partially destroying the ciliary epithelium, aqueous humor production decreases, leading to a sustained lowering of intraocular pressure. CPC is indicated in advanced or neovascular glaucoma where medical therapy and filtration surgery have failed or are not feasible. It is especially useful in eyes with poor visual potential, painful blind eyes, or eyes with a history of multiple surgeries.

Match Question 1: Wavelength & Absorption

Column A Column B

1. 810 nm | A. Strongly absorbed by hemoglobin
2. Melanin | B. Near-infrared wavelength
3. Hemoglobin | C. Weak absorber of 810 nm
4. Xanthophyll | D. Minimal absorption at 810 nm
5. Water | E. Primary absorber of 810 nm laser

Correct Matches:

1–B, 2–E, 3–C, 4–D, 5–D

Match Question 2: Mechanisms & Effects

Column A Column B

1. Photothermal effect | A. Tissue vaporization
2. Photodisruption | B. Shock-wave–mediated tissue breaking
3. Photoablation | C. Heating pigmented tissue to 60–70°C
4. Coagulative necrosis | D. Removal of tissue by molecular fragmentation
5. Thermal diffusion | E. Spread of heat into adjacent layers

Correct Matches:
1–C, 2–B, 3–D, 4–C, 5–E

Match Question 3: Clinical Uses

Column A Column B

1. PRP for PDR | A. Refractory glaucoma
2. CPC | B. Peripheral ablation in infants
3. ROP | C. Regression of neovascularization
4. Focal/Grid DME | D. Deep penetration reduces xanthophyll damage
5. Retinal breaks | E. Treating lattice or holes through haze

Correct Matches:
1–C, 2–A, 3–B, 4–D, 5–E

Match Question 4: Parameters & Delivery

Column A Column B

1. 20 ms pulse | A. Visible red aiming beam
2. 100 ms pulse | B. Higher total fluence
3. 635 nm beam | C. Lower fluence, less pain
4. 200–500 µm | D. Spot size for retinal burns
5. Indirect ophthalmoscopy | E. Peripheral laser delivery

Correct Matches:
1–C, 2–B, 3–A, 4–D, 5–E

Match Question 5: Complications

Column A Column B

1. Choroidal damage | A. CPC complication
2. Macular burn | B. Excess energy near fovea
3. Hypotony | C. Excessive penetration
4. Vitreous hemorrhage | D. Treatment of fragile neovascularization
5. Bruch's membrane rupture | E. Very intense PRP burn

Correct Matches:
1–C, 2–B, 3–A, 4–D, 5–E