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Light Amplification by Stimulated Emission of Radiation
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**What sort of substance can serve as the active medium in a laser?**
Lots of different sorts. It can be a gas (eg, argon), a liquid (dye), a solid (eg, Nd:YAG); it can also be a manufactured item (eg, diode).
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Are all four substances the active medium (media)? No, only neodymium is; the other substances play a supporting role.
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**tl;dr The shorter the pulse, the greater the power per pulse**
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Take-home points: One can increase the power of a laser by increasing the frequency of the emitted light, and/or by shortening the pulse-time. The shorter the pulse, the greater the power per pulse.
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Fluence = energy/area. (We will soon see that one laser procedure is known for being ‘low fluence.’)

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Lasers: Pew! Pew!

What is the essence of laser-tissue interaction?
Lasers: Pew! Pew!

What is the essence of laser-tissue interaction?
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What factors influence the transference of energy?
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With regard to wavelength: The visible spectrum runs from what to what? **About 400 to 700 nm**.
Lasers: Pew! Pew!

Tissue-related factors

Laser-related factors

Energy
Power
Fluence
Composition
Chromophore

The five modes of laser-tissue interaction:

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For purposes of understanding lasers, we can divide the visible spectrum into four color segments. What are they?

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<thead>
<tr>
<th>Wavelength (nm)</th>
<th>(Ultraviolet)</th>
<th>400</th>
<th>?</th>
<th>?</th>
<th>?</th>
<th>(Infrared)</th>
<th>700</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
<td>(Infrared)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td></td>
<td></td>
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For purposes of understanding lasers, we can divide the visible spectrum into four color segments. What are they?
Blue, green, yellow, red

<table>
<thead>
<tr>
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<th>Blue</th>
<th>Green</th>
<th>Yellow</th>
<th>Red</th>
</tr>
</thead>
<tbody>
<tr>
<td>400</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>700</td>
<td></td>
<td></td>
<td></td>
<td></td>
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(Ultraviolet) (Infrared)
Lasers: Pew! Pew!

<table>
<thead>
<tr>
<th>Tissue-related factors</th>
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<tr>
<td>Energy</td>
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Wavelength (nm)

400: Blue

Green

Yellow

Red: (Infrared)

<table>
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<tr>
<th>Wavelength (nm)</th>
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</tr>
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Which portion of the visible spectrum is well absorbed by: Hemoglobin?
Lasers: Pew! Pew!

Transferring energy from the laser to the target tissue.

Factors influencing energy transfer:
- **Tissue-related factors**
- **Laser-related factors**

Energy transfer modes:
- **Energy**
- **Power**
- **Fluence**

A chromophore absorbs light of a certain wavelength, leading to heat generation (e.g., a dye).

Two naturally-occurring chromophores in the eye:
- **Hemoglobin**
- **Melanin**

Another chromophore found in the macula:
- **Xanthophyll**

Visible spectrum colors and absorption:
- Blue, green, yellow, red
- Hemoglobin absorbs everything but red.

Wavelength ranges:
- Ultraviolet: 100-400 nm
- Infrared: 700-1400 nm
- Ultraviolet: 100-400 nm
- Infrared: 700-1400 nm
Lasers: Pew! Pew!

What factors influence the transference of energy?

There are two categories of factors affecting laser-energy transfer:
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Which portion of the visible spectrum is well absorbed by: **Melanin**?
Lasers: Pew! Pew!

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Which portion of the visible spectrum is well absorbed by: *Melanin*? Everything is absorbed fairly well.

For purposes of understanding lasers, we can divide the visible spectrum into four color segments. What are they? Blue, green, yellow, red.

Which portion of the visible spectrum is well absorbed by: *Melanin*? Everything is absorbed fairly well.

There is another *chromophore*, found only in the macula, we should mention. What is it? *Xanthophyll*.

(Note: The latest iteration of the Retina book also refers to xanthophyll as “oxygenated carotenoids, in particular lutetin and zeaxanthin”).

The wavelength (nm) range is from 400 to 700. Hemoglobin and melanin are absorbs more in blue and green wavelengths.

There is a blue dye that is absorbed by the blue wavelength and it is melanin.
Lasers: Pew! Pew!

It boils down to transferring the energy emitted by the laser to the target tissue. What factors influence the transference of energy?

There are two categories of factors affecting laser-energy transfer:

- **Tissue-related factors**
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Energy transfer can be influenced by:

- **Power**
- **Fluence**
- **Composition**

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We’ve seen that power is energy per unit time, and fluence is energy per unit area. Is there any way to put this all together as a single factor?
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\text{Intensity} = \frac{\text{Power}}{\text{Area in cm}^2}
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\[
\text{Irradiance} = \frac{\text{Power density}}{\text{Intensity}} = \frac{\text{Power}}{\text{Area in cm}^2}
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Note that because power = energy/time, *intensity* can be written thusly:

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Note that because power = energy/time, intensity can be written thusly:

\[ \text{Intensity} = \frac{\text{Power}}{\text{Area in cm}^2} \]

Which can be rewritten as:

\[ \text{Intensity} = \frac{\text{Energy}}{\text{Time} \times \text{Area}} \]
**Lasers: Pew! Pew!**

What is the essence of laser-tissue interaction?

It boils down to transferring the energy emitted by the laser to the target tissue.

What factors influence the transference of energy?

There are **two categories** of factors affecting laser-energy transfer:

- **Tissue-related factors**
  - Composition
  - Chromophores

- **Laser-related factors**
  - Energy
  - Power = Energy/time
  - Fluence = Energy/area

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\text{Intensity} = \frac{\text{Power}}{\text{Area in cm}^2} = \frac{\text{Energy}}{\text{Time} \times \text{area}}
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This formulation neatly illustrates how intensity can be increased by:

- Increasing pulse energy, or
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*So commit this to memory!*
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PRP laser

Why doesn't the PDT laser cause thermal damage like, say, a PRP laser does?

Because the PDT laser is a low fluence laser, whereas PRP employs a high fluence laser.

Fluence = Energy/area

The tx area (ie, spot size) in PRP is measured in microns, whereas the tx area in PDT is measured in centimeters. Thus, for a given amount of energy delivered, the fluence of PRP is orders of magnitude higher than the fluence of PDT.

Before the next PDT question…What does PRP stand for in this context?

Panretinal photocoagulation

In the briefest of manners, describe the PRP procedure.

Several thousand laser burns are placed throughout the retinal periphery.

What is the most common indication for PRP?

Proliferative diabetic retinopathy (PDR) or severe nonproliferative dz (severe NPDR)

What is the goal, ie, what are we trying to do to the retina?

The goal is to kill most of the cells in the peripheral retina.

Finally (and also briefly): What is the therapeutic rationale?

Why kill the peripheral retina?

DM retinopathy renders the peripheral retina hypoxic. Hypoxic cells release VEGF, which leads to the development of PDR, which leads to severe vision loss (SVL). OTOH, dead cells do not release VEGF, so by euthanizing the hypoxic retina, the intraocular VEGF burden is reduced, neovascularization is halted, and SVL is avoided.
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In the briefest of manners, describe the PRP procedure.
Several thousand laser burns are placed throughout the retinal periphery

Briefly: What is the most common indication for PRP?
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2. **Photo-disruption** aka plasma-induced disruption
3. **Photochemical ablation**
4. **Photochemical Thermal ablation**
5. **Photo-alteration**

**Briefly, what steps are involved in a photochemical laser procedure?**

1. A photosensitizing dye is injected intravenously, and time sufficient to allow concentration of the dye in the target lesion is allowed to pass
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**Intraocular tumors.**

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**Of course, another reason PDT doesn’t produce thermal effects like PRP is because the PDT laser is a low power laser, whereas PRP employs a high power laser.**

\[ \text{Power} = \frac{\text{Energy}}{\text{Time}} \]

The tx time in PRP is measured in ms, whereas the tx time in PDT is measured in seconds. Thus, for a given amount of energy delivered, the power of PRP is orders of magnitude higher than the power of PDT.

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Note: All PDT is of low fluence compared to most other laser procedures. However, there is a PDT variant called low- or half-fluence PDT in which the amount of energy delivered is half of the standard PDT dose (there is some evidence that half-fluence PDT is more effective than full-fluence).

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\text{half-fluence} = \frac{\text{Energy}}{\text{area}}^2
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**half-fluence PDT?**

$$\text{half-fluence} \equiv \text{Half-fluence} = \frac{\text{Energy}}{\text{Area}} \times 2$$

**Could you produce half-fluence by doubling the denominator instead of halving the numerator?**

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Why couldn’t you produce half-fluence by doubling the denominator instead of halving the numerator?

Well, you could, but doing so wouldn’t be prudent. In PDT, we’re treating a lesion of a certain size/extent. It would make no therapeutic sense to reduce fluence by doubling the treatment area, because this would entail ‘treating’ the healthy tissue surrounding the lesion.
Lasers: Pew! Pew!

The five modes of laser-tissue interaction:

- **Photo-chemical**
  aka *photoactivation*
  Very-low-power laser energy causes a photosensitive dye to undergo chemical rxn

- **Thermal**

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PDT

No question—proceed when ready
Lasers: Pew! Pew!

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- **Thermal**
- Photo-chemical
  - Photo-chemical thermal ablation
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PDT

Thermal effects on tissue exist on a continuum. What are the five degrees (see what I did there?) of tissue effects?

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**Thermal**

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--Hypertermia
--Coagulation
--Vaporization
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Which thermal effect is employed most frequently?
Lasers: Pew! Pew!

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What does it mean to say that tissue has ‘coagulated’?

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PDT

What does it mean to say a protein has been ‘denatured’?

It means the protein has been forced out of its native conformation by some sort of applied stress (in this case, heat).

Because a protein’s function is inextricably tied to its shape, denatured proteins do not behave as they do in their native form.

Can you give an example of protein denaturation?

Consider egg albumin. In its native state, it’s a clear liquid. But if sufficient heat is applied, it becomes a white solid. (And if sufficient salsa is applied to the white solid, it becomes delish.)
### Lasers: Pew! Pew!

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Very-low-power laser energy causes a photosensitive dye to undergo chemical rxn

**Photo-chemical**
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PDT

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**The five modes of laser-tissue interaction:**

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(No question yet—proceed when ready)
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Very-low-power laser energy causes a photosensitive dye to undergo chemical reaction, aka photoactivation, aka plasma-induced disruption.

The tissue effects based on thermal energy exist on a continuum. What are the five degrees of tissue effects?

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Argon

What color is the light produced by an argon laser?

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(As noted earlier in the slide-set)
The five modes of laser-tissue interaction:

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- **Photo disruption**

Very-low-power laser energy causes a photosensitive dye to undergo a chemical reaction, aka photoactivation, aka plasma-induced disruption.

The five degrees (see what I did there?) of tissue effects:

- Hyperthermia
- Coagulation
- Vaporization
- Carbonization
- Melting

Which thermal effect is employed most frequently?

Coagulation

What does it mean to say that tissue has 'coagulated'?

It means the proteins have been denatured.

OK, what does it mean to say a protein has been 'denatured'?

It means the protein has been forced out of its native conformation by some sort of applied stress (in this case, heat). Because a protein's function is inextricably tied to its shape, denatured proteins do not behave as they do in their native form.

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What wavelength of light is readily absorbed by hemoglobin and melanin? (It's a range, BTW.)

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At one time, only one substance was used as the active medium to produce light in the 500-580 range. (Other substances are now available.) What was that original substance?

Argon

What color is the light produced by an argon laser?

Green

Another commonly-employed thermal laser uses solid-state semiconductor technology. By what name is this laser known?

Diode laser

What is the most common usage of the diode laser in ophthalmology?

Cyclophotocoagulation (CPC) of the aqueous-producing epithelium of the ciliary body (CB) in refractory glaucoma

During CPC, the diode laser probe is held against the conjunctiva. Why doesn't the laser energy burn the conj and sclera en route to the CB epithelium?

The laser's wavelength is set so as to be absorbed by melanin, which isn't encountered until the energy has passed through the conj/sclera and reached the pigmented epithelium of the CB.
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Two categories of tissue-related factors:

- Composition
- Chromophore

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### Lasers: Pew! Pew!

**The five modes of laser-tissue interaction:**

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*PDT*  
*Argon, diode*

*No question—proceed when ready*
Lasers: Pew! Pew!

The five modes of laser-tissue interaction:

- Photo-chemical
- Thermal
- Photo-physical
- Plasma-induced ablation
- Photo-disruption

Are the laser intensities (power densities; irradiiances) employed during photoablation greater than those employed during thermal laser?

Very-low-power laser energy causes a photosensitive dye to undergo a chemical reaction. Laser energy is absorbed → transforms into heat → local thermal damage.

PDT (Argon) aka photoactivation aka plasma-induced disruption.

The five modes of laser-tissue interaction:

Are the laser intensities (power densities; irradiiances) employed during photoablation greater than those employed during thermal laser?

Yes, significantly so. Given this, it would seem that photoablation must cause even greater heat-mediated damage than does thermal laser. Is this the case?

You’d think so, but no—photoablation involves essentially no energy transfer in the form of heat.

How is it possible to have greater intensity but less thermal damage?

The pulse durations are too brief to induce molecular motion (which is what heat is).

If not via thermal effects, how does photoablation alter tissue?

By breaking covalent carbon-carbon bonds and carbon-nitrogen bonds.

What therapy is the classic example of photoablation?

Photoablative keratorefractive surgery (eg, LASIK).
Lasers: Pew! Pew!

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The five modes of laser-tissue interaction:

**Photo-chemical**

Laser energy causes a photosensitive dye to undergo chemical reactions.

**Photo-thermal**

Laser energy is absorbed and transformed into heat, leading to local thermal damage.

**Photo-ablation**

Greater laser intensities (power densities) are employed during photoablation than during thermal laser. Given this, it would seem that photoablation must cause even greater heat-mediated damage than does thermal laser. Is this the case? You'd think so, but no—photoablation involves essentially no energy transfer in the form of heat.

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What sort of laser is used to ablate the corneal tissue?

- **Photoablative keratorefractive surgery** (e.g., LASIK)

What is the origin of the word *excimer*?

- It is a portmanteau of the term *excited dimer*.

What is the wavelength of light employed?

- **193 nm**

Is 193 nm in the UV range, or the infrared range?

- **UV**

Does light of this wavelength penetrate tissue?

- Hardly at all (which makes it perfect for surface ablation).

Is this wavelength mutagenic?

- No
Lasers: Pew! Pew!

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- Plasma-induced ablation
- Photo-disruption

Do the laser intensities (power densities; irradiances) employed during photoablation differ significantly from those employed during thermal laser?

Yes, significantly so. Given this, it would seem that photoablation must cause even greater heat-mediated damage than does thermal laser. Is this the case?

You'd think so, but no—photoablation involves essentially no energy transfer in the form of heat.

How is it possible to have greater intensity but less thermal damage?

The pulse durations are too brief to induce molecular motion (which is what heat is).

How does photoablation alter tissue?

By breaking covalent carbon-carbon bonds and carbon-nitrogen bonds.

What therapy is the classic example of photoablation?

Photoablative keratorefractive surgery (eg, LASIK).

What sort of laser is used to ablate the corneal tissue?

An excimer laser.

What is the origin of the word excimer?

It is a portmanteau of the term excited di-mer.

What is the wavelength of light employed?

193 nm.

Is 193 nm in the UV range, or the infrared range?

UV.

Is this wavelength mutagenic?

No.
Lasers: Pew! Pew!

The five modes of laser-tissue interaction:

- Photochemical ablation
- Thermal ablation
- Plasma-induced ablation
- Photo-disruption
- Photoablative keratorefractive surgery

What sort of laser is used to ablate the corneal tissue? An excimer laser.

What is the origin of the word excimer?

Is 193 nm in the UV range, or the infrared range? UV.

Does light of this wavelength penetrate tissue? Hardly at all (which makes it perfect for surface ablation).

Is this wavelength mutagenic? No.
Lasers: Pew! Pew!

The five modes of laser-tissue interaction:

1. Photochemical ablation
2. Thermal ablation
3. Plasma-induced ablation
4. Photo-disruption
5. Photo-disruption

What sort of laser is used to ablate the corneal tissue? An excimer laser.

What is the origin of the word excimer? It is a portmanteau of the term ‘excited di-mer’.

What therapy is the classic example of photoablation? Photoablative keratorefractive surgery (e.g., LASIK).

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Lasers: Pew! Pew!

The five modes of laser-tissue interaction:

- **Photo-chemical**
- **Thermal**
- **Photo-ablation**
- **Plasma-induced ablation**
- **Photo-disruption**

**Photoablation**

What sort of laser is used to ablate the corneal tissue? An **excimer laser**

What is the origin of the word excimer? It is a portmanteau of the term ‘**excited di-mer**’

**To what does excited dimer refer in this context?**

**Photoablative keratorefractive surgery**

- **Photochemical**
- **Thermal**
- **Photoablation**
- **Plasma-induced ablation**
- **Photo-disruption**

Are the laser intensities (power densities; irradiances) employed during photoablation greater than those employed during thermal laser? Yes, significantly so

Given this, it would seem that photoablation must cause even greater heat-mediated damage? You'd think so, but no—photoablation involves essentially no energy transfer in the form of heat

How is it possible to have greater intensity but less thermal damage? The pulse durations are too brief to induce molecular motion (which is what heat is)

If not via thermal effects, how does photoablation alter tissue? By breaking covalent carbon-carbon bonds and carbon-nitrogen bonds

What therapy is the classic example of photoablation? **Photoablative keratorefractive surgery** (eg, LASIK)

What sort of laser is used to ablate the corneal tissue? An **excimer laser**

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**Photoablative keratorefractive surgery**
The five modes of laser-tissue interaction:

- **Photo-chemical**
- **Photo-ablation**
- **Plasma-induced ablation**
- **Photo-disruption**

What sort of laser is used to ablate the corneal tissue? An excimer laser.

What is the origin of the word excimer? It is a portmanteau of the term 'exci-ted di-mer'.

To what does excited dimer refer in this context? The active medium in an excimer consists of a diatomic combination of two elemental gases.

What therapy is the classic example of photoablation? Photoablative keratorefractive surgery (e.g., LASIK).

What is the wavelength of light employed? 193 nm.

Is 193 nm in the UV range, or the infrared range? UV.

Does light of this wavelength penetrate tissue? Hardly at all (which makes it perfect for surface ablation).

Is this wavelength mutagenic? No.
The five modes of laser-tissue interaction:

- **Photo-chemical**
  - What sort of laser is used to ablate the corneal tissue? An **excimer** laser.
  - What is the origin of the word excimer? It is a portmanteau of the term ‘**exci-ted di-mer**’.
  - To what does excited dimer refer in this context? The active medium in an excimer consists of a diatomic combination of two elemental gases.
  - Which gas combo is most commonly used in ophthalmic excimer lasers? **Argon-fluoride**.

- **Photo-ablation**
  - What therapy is the classic example of photoablation? **Photoablative keratorefractive surgery**.

- **Plasma-induced ablation**
- **Photo-disruption**
The five modes of laser-tissue interaction:

- **Photochemical**
  - What sort of laser is used to ablate the corneal tissue? An excimer laser
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  - Which gas combo is most commonly used in ophthalmic excimer lasers? Argon-fluoride

- **Photoablation**

- **Plasma-induced ablation**
  - What therapy is the classic example of photoablation? Photoablative keratorefractive surgery (eg, LASIK)

- **Photo-disruption**

- **Thermal**
  - Are the laser intensities (power densities; irradiances) employed during photoablation greater than those employed during thermal laser? Yes, significantly so
  - Given this, it would seem that photoablation must cause even greater heat-mediated damage? You'd think so, but no—photoablation involves essentially no energy transfer in the form of heat
  - How is it possible to have greater intensity but less thermal damage? The pulse durations are too brief to induce molecular motion (which is what heat is)
  - If not via thermal effects, how does photoablation alter tissue? By breaking covalent carbon-carbon bonds and carbon-nitrogen bonds

- **Photo-disruption**
The five modes of laser-tissue interaction:

| Photo-chemical | Thermal | Photo- | Plasma-induced ablation | Photo- | Photo-
|----------------|---------|-------|--------------------------|-------|--------|
| Photo- | ablation | disruption | ablative | tion | disrup-
| Photo- | ablation | disruption | ablative | tion | disrup-

### What sort of laser is used to ablate the corneal tissue?
An **excimer** laser

### What is the origin of the word excimer?
It is a portmanteau of the term ‘**exci**-ted di-**mer**’

### What is the wavelength of light employed?
**193 nm**

This wavelength is in the **UV** range and hardly penetrates tissue, making it perfect for **surface ablation**.

### Is this wavelength mutagenic?
No.
Lasers: Pew! Pew!

The five modes of laser-tissue interaction:

1. Photo-chemical ablation
   - Very-low-power laser energy causes a photosensitive dye to undergo chemical reaction.
   - Laser energy is absorbed → transforms into heat → local thermal damage.

2. Photo-ablation
   - Are the laser intensities (power densities; irradiances) employed during photoablation greater than those employed during thermal laser?
   - Yes, significantly so.
   - Given this, it would seem that photoablation must cause even greater heat-mediated damage than does thermal laser. Is this the case?
   - You'd think so, but no—photoablation involves essentially no energy transfer in the form of heat.
   - How is it possible to have greater intensity but less thermal damage?
   - The pulse durations are too brief to induce molecular motion (which is what heat is).

3. Plasma-induced disruption
   - If not via thermal effects, how does photoablation alter tissue?
   - By breaking covalent carbon-carbon bonds and carbon-nitrogen bonds.

4. Photo-disruption
   - What therapy is the classic example of photoablation?
     - Photoablative keratorefractive surgery (eg, LASIK).

5. Photo-disruption
   - What sort of laser is used to ablate the corneal tissue?
     - An excimer laser.
   - What is the origin of the word excimer?
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   - What is the wavelength of light employed?
     - 193 nm.
   - Is 193 nm in the UV range, or the infrared range?
     - UV.
   - Does light of this wavelength penetrate tissue?
     - Hardly at all (which makes it perfect for surface ablation).
   - Is this wavelength mutagenic?
     - No.
The five modes of laser-tissue interaction:

**Photo-chemical**

What sort of laser is used to ablate the corneal tissue? An **excimer** laser

What is the origin of the word excimer? It is a portmanteau of the term ‘**exci**-ted di-**mer**’

What is the wavelength of light employed? 193 nm

Is 193 nm in the UV range, or the infrared range?

**Photo-ablation**

What therapy is the classic example of photoablation? **Photoablative keratorefractive surgery** (e.g., LASIK)

**Plasma-induced ablation**

**Photo-disruption**

**Lasers: Pew! Pew!**

Are the laser intensities (power densities; irradiances) employed during photoablation greater than those employed during thermal laser? Yes, significantly so

Given this, it would seem that photoablation must cause even greater heat-mediated damage than does thermal laser. Is this the case? You’d think so, but no—photoablation involves essentially no energy transfer in the form of heat

How is it possible to have greater intensity but less thermal damage? The pulse durations are too brief to induce molecular motion (which is what heat is)

Is 193 nm in the UV range, or the infrared range? UV

Is this wavelength mutagenic? No

What does it mean to alter tissue? By breaking covalent carbon-carbon bonds and carbon-nitrogen bonds
The five modes of laser-tissue interaction:

- **Photo-chemical**
- **Photo-ablation**
- **Plasma-induced ablation**
- **Photo-disruption**

What sort of laser is used to ablate the corneal tissue? An **excimer** laser.

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What therapy is the classic example of photoablation? **Photoablative keratorefractive surgery** (e.g., LASIK).
The five modes of laser-tissue interaction:

### Photo-chemical
- What sort of laser is used to ablate the corneal tissue? An **excimer** laser.
- What is the origin of the word **excimer**? It is a portmanteau of the term ‘**excit**-ted di-**mer**’.
- What is the wavelength of light employed? 193 nm.
- Is 193 nm in the UV range, or the infrared range? UV.
- Does light of this wavelength penetrate tissue?

### Photo-thermal
- How is heat generated? Laser energy is absorbed → transforms into heat → local thermal damage.
- Are the laser intensities (power densities; irradiances) employed during photoablation greater than those employed during thermal laser? Yes, significantly so.
- Given this, it would seem that photoablation must cause even greater heat-mediated damage than does thermal laser. Is this the case? You’d think so, but no—photoablation involves essentially no energy transfer in the form of heat.
- How is it possible to have greater intensity but less thermal damage? The pulse durations are too brief to induce molecular motion (which is what heat is).
- Does light of this wavelength alter tissue? By breaking covalent carbon-carbon bonds and carbon-nitrogen bonds.

### Plasma-induced ablation
- What therapy is the classic example of photoablation? **Photoablative keratorefractive surgery** (e.g., LASIK).
- What sort of laser is used to ablate the corneal tissue? An **excimer** laser.
- What is the origin of the word **excimer**? It is a portmanteau of the term ‘**excit**-ted di-**mer**’.
- What is the wavelength of light employed? 193 nm.
- Is 193 nm in the UV range, or the infrared range? UV.
- Does light of this wavelength penetrate tissue?
Lasers: Pew! Pew!

The five modes of laser-tissue interaction:

- Photochemical
- Thermal
- Photoablation
- Plasma-induced ablation
- Photo-disruption

**Photoablation**

What sort of laser is used to ablate the corneal tissue? An **excimer** laser.

What is the origin of the word excimer? It is a portmanteau of the term ‘exci-ted di-mer’.

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Is 193 nm in the UV range, or the infrared range? UV.

Does light of this wavelength penetrate tissue? Hardly at all (which makes it perfect for surface ablation).

What therapy is the classic example of photoablation? **Photoablative keratorefractive surgery** (eg, LASIK).

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The five modes of laser-tissue interaction:

Photo-chemical

Thermal

Photo-ablation

Plasma-induced ablation

Photo-disruption

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Photoablative keratorefractive surgery (eg, LASIK)
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Is this wavelength mutagenic? No.

What therapy is the classic example of photoablation? Photoablative keratorefractive surgery (e.g., LASIK).
### Lasers: Pew! Pew!

**The five modes of laser-tissue interaction:**

<table>
<thead>
<tr>
<th>Photo-chemical aka photoactivation</th>
<th>Thermal</th>
<th>Photo-ablation</th>
<th>Plasma-induced ablation</th>
<th>Photo-disruption aka plasma-induced disruption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very-low-power laser energy causes a photosensitive dye to undergo chemical rxn</td>
<td>Laser energy is absorbed $\rightarrow$ transforms into heat $\rightarrow$ local thermal damage</td>
<td>Laser energy disrupts covalent bonds</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**PDT**

| Argon, diode | Excimer |

**No question—proceed when ready**
**Lasers: Pew! Pew!**

The five modes of laser-tissue interaction:

<table>
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<tr>
<th>Photo-chemical ablation</th>
<th>Thermal ablation</th>
<th>Photo-ablation</th>
<th><strong>Plasma-induced ablation</strong></th>
<th>Photo-disruption ablation</th>
</tr>
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</table>

Are the laser intensities (power densities; irradiances) employed during plasma-induced ablation greater than those employed during ‘regular’ photoablation?
Lasers: Pew! Pew!

The five modes of laser-tissue interaction:

<table>
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<th>Thermal ablation</th>
<th>Photo-disruption</th>
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<tr>
<td>Photo-chemical ablation</td>
<td>Thermal ablation</td>
<td>Photo-disruption</td>
</tr>
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</table>

**Plasma-induced ablation**

Are the laser intensities (power densities; irradiances) employed during plasma-induced ablation greater than those employed during ‘regular’ photoablation? Indeed they are.

How does plasma-induced ablation alter tissue?

In addition to breaking covalent bonds, the laser 'strips' electrons from molecules (thereby transforming the molecules into ions) and accelerates them. The accelerated electrons fly off and smash into other molecules, in turn ionizing them and accelerating their electrons. This cascade ionization process results in the transformation of tissue into plasma (a gas composed of ions and free electrons). In this manner, the tissue sort of 'goes away.'

What therapy is the classic example of plasma-induced ablation?

The femtosecond laser
Lasers: Pew! Pew!

The five modes of laser-tissue interaction:

<table>
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<th>Mode</th>
<th>Description</th>
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<td>Photo-chemical ablation</td>
<td>Laser energy is absorbed → transforms into heat → local thermal damage</td>
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<td>Thermal ablation</td>
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<tr>
<td>Photo-ablation</td>
<td>Photo-sensitive dye undergoes chemical rxn</td>
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<tr>
<td>Plasma-induced ablation</td>
<td>Laser energy disrupts covalent bonds, strips electrons from molecules, ions</td>
</tr>
<tr>
<td>Photo-disruption</td>
<td>Causes tissue to transform into plasma</td>
</tr>
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Are the laser intensities (power densities; irradiances) employed during plasma-induced ablation greater than those employed during ‘regular’ photoablation? Indeed they are.

Are the pulse durations short enough to preclude thermal effects?
Lasers: Pew! Pew!

The five modes of laser-tissue interaction:

- Photochemical ablation
- Thermal ablation
- Photoablation
- Plasma-induced ablation
- Photo-disruption

**Plasma-induced ablation**

Are the laser intensities (power densities; irradiances) employed during plasma-induced ablation greater than those employed during ‘regular’ photoablation?
Indeed they are

Are the pulse durations short enough to preclude thermal effects?
Yes (in fact, the durations are significantly shorter than are those of photoablation)
Lasers: Pew! Pew!

The five modes of laser-tissue interaction:

- Photochemical ablation
- Thermal ablation
- Plasma-induced ablation
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The five modes of laser-tissue interaction:

- Photochemical
- Thermal
- Photoablation
- Plasma-induced ablation
- Photo-disruption (aka plasma-induced disruption)

Are the laser intensities (power densities; irradiances) employed during plasma-induced ablation greater than those employed during ‘regular’ photoablation? Indeed they are.

Are the pulse durations short enough to preclude thermal effects? Yes (in fact, the durations are significantly shorter than are those of photoablation).

How does plasma-induced ablation alter tissue? In addition to breaking covalent bonds, the laser ‘strips’ electrons from molecules (thereby transforming the molecules into ions) and accelerates them. The accelerated electrons fly off and smash into other molecules, in turn ionizing them and accelerating their electrons.
### Lasers: Pew! Pew!

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**Plasma-induced ablation**

Are the laser intensities (power densities; irradiances) employed during plasma-induced ablation greater than those employed during ‘regular’ photoablation? Indeed they are

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How does plasma-induced ablation alter tissue? In addition to breaking covalent bonds, the laser ‘strips’ electrons from molecules (thereby transforming the molecules into ions) and accelerates them. The accelerated electrons fly off and smash into other molecules, in turn ionizing them and accelerating their electrons. This *cascade ionization* process results in the transformation of tissue into plasma (a gas composed of ions and free electrons). In this manner, the tissue sort of ‘goes away.’
Lasers: Pew! Pew!

The five modes of laser-tissue interaction:

- Photochemical
- Thermal
- Photoablation
- Photo-disruption
- Plasma-induced ablation

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What therapy is the classic example of plasma-induced ablation?
Lasers: Pew! Pew!

The five modes of laser-tissue interaction:

- Photochemical ablation
- Thermal ablation
- Photo-ablation
- Plasma-induced ablation
- Photo-disruption

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What therapy is the classic example of plasma-induced ablation? The femtosecond laser.
### Lasers: Pew! Pew!

#### The five modes of laser-tissue interaction:

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<td></td>
</tr>
<tr>
<td>PDT</td>
<td>Argon, diode</td>
<td>Excimer</td>
<td>Femtosecond</td>
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</tr>
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</table>
Lasers: Pew! Pew!

The five modes of laser-tissue interaction:

- Photo-chemical Thermal Photo-ablation
- Plasma-induced ablation
- Photo-disruption

Very-low-power laser energy causes a photosensitive dye to undergo chemical reaction. Laser energy is absorbed → transforms into heat → local thermal damage.

PDT Argon
aka photoactivation
aka plasma-induced disruption

Like plasma-induced ablation, photodisruption involves the creation of plasma. How do they differ in that regard?

In plasma-induced ablation, a modest amount of energy is used, resulting in the production of a relatively small amount of plasma. In contrast, photodisruption employs much more energy, resulting in the creation of a great deal more plasma.

OK, so photodisruption involves substantially more plasma. Why does this justify classifying it as a separate mode of laser-tissue interaction?

Because the increased plasma creation results in the production of mechanical forces (shock waves; acoustic waves) that propagate well beyond the laser spot, causing tissue to be torn apart remote from the area of laser application.

What therapy is the classic example of photodisruption?

YAG capsulotomy
The five modes of laser-tissue interaction:

- Photochemical Thermal
- Photoablation
- Plasma-induced ablation
- Photo disruption
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Plasma-induced ablation aka plasma-induced disruption
Lasers: Pew! Pew!

The five modes of laser-tissue interaction:

- Photo-chemical
- Thermal
- Photo-
disruption
- Plasmainduced

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Lasers: Pew! Pew!

The five modes of laser-tissue interaction:

Photo-

chemical Thermal Photo-

ablation Plasma-induced Photo-

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Lasers: Pew! Pew!

The five modes of laser-tissue interaction:

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What therapy is the classic example of photodisruption?
YAG capsulotomy
**Lasers: Pew! Pew!**

The five modes of laser-tissue interaction:

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<td>Laser energy is absorbed $\rightarrow$ transforms into heat $\rightarrow$ local thermal damage</td>
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<td>Laser energy produces large amount of plasma, causing mechanical disruption of tissue</td>
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- Very-low-power laser energy causes a photosensitive dye to undergo chemical rxn
- PDT
- Argon, diode
- Excimer
- Femtosecond
- YAG cap

No question—review slide