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Light Amplification by Stimulated Emission of Radiation
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**tl;dr** The greater the frequency of the light, the greater the energy.

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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 (e.g., argon), a liquid (e.g., dye), a solid (e.g., Nd:YAG), or it can also be a manufactured item (e.g., diode).

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Neodymium: Yttrium-Aluminum-Garnet

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**tl;dr The shorter the pulse, the greater the power per pulse**
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The greater the frequency of the light, the greater the energy. This is proportional to the frequency of the light, as per the following formula: $E = h\nu$.

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.
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We saw that power is ‘energy over time.’ Now we’re talking about ‘energy over area.’ What is the name for this variable? **Fluence** = energy/area. (We will soon see that one laser procedure is known for being ‘low fluence.’)

What can be done to get more ‘bang for the buck’ from a laser? By releasing the energy over a very brief period of time, the laser’s power (power = energy/time) can be ramped up.
Lasers: Pew! Pew!

What is the essence of laser-tissue interaction?
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- Tissue-related factors
- Laser-related factors

Composition

Chromophores
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The five modes of laser-tissue interaction:

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**With regard to wavelength: The visible spectrum runs from what to what?** About 400 to 700 nm.
Lasers: Pew! Pew!

<table>
<thead>
<tr>
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<th>Laser-related factors</th>
</tr>
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<tbody>
<tr>
<td>Chromophore</td>
<td>Energy</td>
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<tr>
<td></td>
<td>Power</td>
</tr>
<tr>
<td></td>
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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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(Infrared)
Lasers: Pew! Pew!

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- **Tissue-related factors**
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**Energy**
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The five modes of laser-tissue interaction are:

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**Which portion of the visible spectrum is well absorbed by:**

**Hemoglobin**?

A molecule that absorbs light of a certain wavelength in a manner that results in the generation of heat (i.e., a dye).
Lasers: Pew! Pew!

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The five modes of laser-tissue interaction: What is the essence?

A molecule that absorbs light of a certain wavelength in a manner that results in the generation of heat (i.e., a dye) is called a **chromophore**. What are the two naturally-occurring chromophores found in the eye that are exploited in ophthalmic laser procedures? **Hemoglobin** and **melanin**. 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 lutein and zeaxanthin”)

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: **Hemoglobin**? Everything but red

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---

**Question:**

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

---

**Diagram:**

- **Blue**
  - Hemoglobin

- **Green**
  - Melanin

- **Yellow**

- **Red**
  - (Infrared)

---

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**Melanin? Everything is absorbed fairly well**

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Energy transfer involves:

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

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Which portion of the visible spectrum is well absorbed by: **Xanthophyll**?

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Which portion of the visible spectrum is well absorbed by: **Xanthophyll**? Only **blue**.

What is the essence of this diagram? It illustrates the absorption spectrum of various chromophores across the visible spectrum, showing which wavelengths are absorbed by hemoglobin, melanin, and xanthophyll.

There are four color segments in the visible spectrum: **Blue**, **green**, **yellow**, and **red**.
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Intensity = \( \frac{\text{Power}}{\text{Area in cm}^2} \)

This formulation neatly illustrates how intensity can be increased by:

- Increasing pulse energy, or
- Decreasing pulse time, or
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Note that because power = energy/time, intensity can be written thusly:

\[
\text{Intensity} = \frac{\text{Energy}}{\text{Time} \times \text{Area}}
\]

This formulation neatly illustrates how intensity can be increased by:
- Increasing pulse energy, or
- Decreasing pulse time, or
- Decreasing pulse area.

So commit this to memory!
Lasers: Pew! Pew!

What are the five modes of laser-tissue interaction?
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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.

Briefly: What is the most common indication for PRP?

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

Again, briefly: 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 VRGF burden is reduced, neovascularization is halted, and SVL is avoided.
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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.
The five modes of laser-tissue interaction:

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

Briefly: What is the most common indication for PRP?
Proliferative diabetic retinopathy (PDR) or severe nonproliferative dz (severe NPDR)

Again, briefly: 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
**Lasers: Pew! Pew!**

The five modes of laser-tissue interaction:

1. **Light**
2. **Heat**
3. **Chemistry**
4. **Thermooptics**
5. **Photochemical**

The classic example of photochemical laser is **Photodynamic therapy (PDT)**.

What is PDT used to treat?

Prior to the development of intravitreal anti-VEGF therapy, PDT was the tx of choice for choroidal neovascular membranes. While it has been largely supplanted for this indication, it is still employed in the tx of central serous chorioretinopathy, as well as for some intraocular tumors.

The five modes of laser-tissue interaction:

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

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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.

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**intraocular tumors.**
**Lasers: Pew! Pew!**

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**Briefly, what steps are involved in a photochemical laser procedure?**
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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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\[ \text{half-fluence PDT} \]

Could you produce half-fluence by doubling the denominator instead of halving the numerator?
The five modes of laser-tissue interaction:

- **Photochemical**
  aka photoactivation

- Thermal

- Photo-ablation

- Plasma-induced ablation

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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-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).

**half-fluence PDT?**

**half - Fluence = Energy/area \times 2**

*Could 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**
- **Photo-ablation**
- **Plasma-induced ablation**
- **Photo-disruption**
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PDT

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

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PDT
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PDT
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
  - *PDT*

- **Thermal**
  - Photo-ablation
  - Plasma-induced ablation

  *Thermal effects on tissue exist on a continuum. What are the five degrees (see what I did there?) of tissue effects?*
  - *Hyperthermia?*
  - *Coagulation?*
  - *Vaporization?*
  - *Carbonization?*
  - *Melting?*

  *Which thermal effect is employed most frequently?*
The five modes of laser-tissue interaction:

- **Thermal**
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- Hyperthermia
- **Coagulation**
- Vaporization
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**Which thermal effect is employed most frequently?**

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

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

- Hyperthermia
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**Photo-ablation**

**Plasma-induced ablation**

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

- Hyperthermia
- Coagulation
- Vaporization
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*What does it mean to say that tissue has ‘coagulated’?*

Which thermal Coagulation

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.)
The five modes of laser-tissue interaction:

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

- It means the proteins have been denatured

**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.)
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OK, what does it mean to say a protein has been ‘denatured’?

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

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Lasers: Pew! Pew!

The five modes of laser-tissue interaction:

- Photo-chemical (aka photoactivation)
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- **Plasma-induced ablation**
  - At what temperature does retinal tissue start to coagulate?

- **Photo-disruption**
  - aka *plasma-induced disruption*

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### Lasers: Pew! Pew!

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**At what temperature does retinal tissue start to coagulate?**

65°C

**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.)
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<td>Plasma-induced ablation</td>
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**Coagulation**

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PRP
Lasers: Pew! Pew!

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Very-low-power laser energy causes a photosensitive dye to undergo photochemical reaction (PDT, aka photoactivation).

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

- Hyperthermia
- Coagulation
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- Carbonization
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(No question yet—proceed when ready)
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The five modes of laser-tissue interaction:

**Thermal**
- Hyperthermia
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- Melting

What are the five degrees of tissue effects? Hyperthermia, coagulation, vaporization, carbonization, and melting.

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

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**Lasers: Pew! Pew!**

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

- **Photo-chemical**
  - aka photoablation
  - Very-low power laser energy causes a photosensitive dye to undergo a chemical reaction (aka photoactivation or plasma-induced disruption)

- **Thermal**
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  - Coagulation
  - Vaporization
  - Carbonization
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The five degrees of tissue effects are on a continuum.

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**Tissue-related factors**

- **Composition**
- **Chromophore**

What is a **chromophore** in this context?

A molecule that absorbs light of a certain wavelength in a manner that results in the generation of heat (ie, a dye).
The five modes of laser-tissue interaction:

- **Thermal**
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What tissue-related factors exist on a continuum? What are they?

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The five modes of laser-tissue interaction:

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

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

From 400 to 580 nm. However, wavelengths below 500 nm are avoided, as they are too readily absorbed by the xanthophyll pigment found in the macula.

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

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

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

**Photo-disruption**

Very low laser energy causes a photosensitive dye to undergo chemical rxn aka **photoactivation** aka plasma-induced disruption.

The five degrees of tissue effects:

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Which thermal effect is employed most frequently?

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- **Thermal**

Photochemical and 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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A molecule that absorbs light of a certain wavelength in a manner that results in the generation of heat (ie, a dye).

What two naturally-occurring chromophores found in the eye are exploited in ophthalmic laser procedures?

Hemoglobin and melanin.
Lasers: Pew! Pew!

The five modes of laser-tissue interaction:

1. **Photothermolysis**
   - 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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   - Coagulation
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Which thermal effect is employed most frequently?
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- **Thermal**
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The five modes of laser-tissue interaction:

- **Thermal**
  - Composition
  - **Chromophore**
  - **Tissue**-related factors

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Lasers: Pew! Pew!

The five modes of laser-tissue interaction:

- Photothermal/thermal
- Photomechanical
- Photochemical
- Photoablation
- Plasma-induced ablation

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

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

--Hyperthermia--
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**Lasers: Pew! Pew!**

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

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

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 (e.g., LASIK).
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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 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.

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

Lasers: Pew! Pew!

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

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

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

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.

What are the processes involved in photoablation? Breaking covalent carbon-carbon bonds and carbon-nitrogen bonds.

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 tissue 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).

What is the wavelength of light employed? 193 nm.

Is 193 nm in the UV range, or the infrared range? UV.
### The five modes of laser-tissue interaction:

<table>
<thead>
<tr>
<th>Mode</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photochemical</td>
<td>chemical rxn of photosensitive dye transformed into heat</td>
<td>Lasers: Pew! Pew!</td>
</tr>
<tr>
<td>Thermal</td>
<td>laser energy absorbed and transformed into heat</td>
<td>Lasers: Pew! Pew!</td>
</tr>
<tr>
<td>Photoablation</td>
<td>laser energy absorbed and transforms into local thermal damage</td>
<td>Lasers: Pew! Pew!</td>
</tr>
<tr>
<td>Plasma-induced ablation</td>
<td>energy employed during photoablation is significantly greater than thermal</td>
<td>Lasers: Pew! Pew!</td>
</tr>
<tr>
<td>Photo-disruption</td>
<td>extremely brief pulse durations prevent molecular motion</td>
<td>Lasers: Pew! Pew!</td>
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**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**-ited 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.

**What therapy is the classic example of photoablation?**

Photoablative keratorefractive surgery (eg, LASIK).
The five modes of laser-tissue interaction:

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

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

What is the wavelength of light employed? 193 nm. Is this wavelength UV or infrared? **UV**.

Is this wavelength penetrative? Hardly at all (which makes it perfect for **surface** ablation).

Is this wavelength mutagenic? **No**.

Must cause even greater heat-mediated damage? No, 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).

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

Photoablation involves essentially no energy transfer in the form of heat.
The five modes of laser-tissue interaction:

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<td>Photoablation</td>
</tr>
<tr>
<td>Photo-disruption</td>
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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? The active medium in an excimer consists of a diatomic combination of two elemental gases.

What gas combo is most commonly used in ophthalmic excimer lasers? Argon-fluoride.

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.

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

The five modes of laser-tissue interaction:

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

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 terms ‘excited dimer’.

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).

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

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

- Photo-chemical
- Photo-ablation
- Laser energy
- Photochemical rxn
- Photosensitive dye
- Local thermal damage
- Plasma-induced disruption
- Laser energy
- Transforms into heat
- Very-low-power laser energy causes a photosensitive dye to undergo chemical rxn

Lasers: Pew! Pew!

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

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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:

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- **Plasma-induced ablation**
- **Photo-disruption**
- **Lasers: Pew! Pew!**
Lasers: Pew! Pew!

The five modes of laser-tissue interaction:

- Photo-chemical ablation
- Thermal 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’.

What is the wavelength of light employed? 193 nm, in the UV range.

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

Why must cause even greater heat-mediated damage? If not via thermal effects, how does photoablation alter tissue?

By breaking covalent carbon-carbon bonds and carbon-nitrogen bonds.
The five modes of laser-tissue interaction:

- Photochemical
- Thermal
- Photoablation
- 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 ‘excited di-mer’

What is the wavelength of light employed?
193 nm

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

What laser is used to ablate the corneal tissue?
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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
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**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’
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- 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)
The five modes of laser-tissue interaction:

**Photochemical**

Photochemical effects involve the absorption of laser energy by a photosensitive dye, which then undergoes a chemical reaction. The energy is transformed into heat, leading to local thermal damage.

**Thermal**

Thermal effects occur when laser energy is absorbed by tissue and converted into heat. The intensity of laser energy employed during photoablation is significantly greater than that employed during thermal laser. Given this, it would seem that photoablation must cause even greater heat-mediated damage than does thermal laser. However, this is not the case. Photoablation involves essentially no energy transfer in the form of heat.

**Photoablation**

Photoablation is a process where the laser energy is absorbed by tissue and transformed into heat. However, the pulse durations are too brief to induce molecular motion (which is what heat is). Therefore, the energy is not transferred to the tissue in the form of heat. Instead, photoablation involves the breaking of covalent carbon-carbon bonds and carbon-nitrogen bonds.

**Plasma-induced ablation**

Plasma-induced ablation occurs when laser energy leads to the formation of plasma, which can alter the tissue.

**Photo-disruption**

Photo-disruption is a process where laser energy is absorbed by tissue and transformed into heat. However, the pulse durations are too brief to induce molecular motion (which is what heat is). Therefore, the energy is not transferred to the tissue in the form of heat. Instead, photo-disruption involves the breaking of covalent carbon-carbon bonds and carbon-nitrogen bonds.

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

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.
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? UV.
- Does light of this wavelength penetrate tissue?

**Photo-ablation**

- 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).

**Plasma-induced ablation**

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

**Photo-disruption**

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- What sort of laser is used to ablate the corneal tissue? An **excimer** laser.
Lasers: Pew! Pew!

The five modes of laser-tissue interaction:

Photo-chemical

Thermal

Photo-ablation

Plasma-induced ablation

Photo-disruption

What sort of laser is used to ablate the corneal tissue?
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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** (e.g., LASIK)
Lasers: Pew! Pew!

The five modes of laser-tissue interaction:

- Photochemical
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- Plasma-induced ablation
- Photo-disruption

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What therapy is the classic example of photoablation? Photoablative keratorefractive surgery (e.g., LASIK).
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- Photo-ablation
- Plasma-induced ablation
- Photo-disruption
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Hardly at all (which makes it perfect for **surface** ablation)

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No

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

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<td>Very-low-power laser energy causes a photosensitive dye to undergo chemical rxn</td>
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<td>Thermal</td>
<td>Laser energy is absorbed → transforms into heat → local thermal damage</td>
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<td>Laser energy disrupts covalent bonds</td>
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<td></td>
</tr>
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</table>

PDT, Argon, diode

Excimer

No question—proceed when ready
The five modes of laser-tissue interaction:

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<td>Lasers: Pew! Pew!</td>
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<tr>
<td>Thermal ablation</td>
<td>The five modes of laser-tissue interaction:</td>
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<td>Plasma-induced ablation</td>
<td>Are the laser intensities (power densities; irradiances) employed during plasma-induced ablation greater than those employed during ‘regular’ photoablation?</td>
</tr>
<tr>
<td>Photo-disruption</td>
<td>Are the laser intensities (power densities; irradiances) employed during plasma-induced ablation greater than those employed during ‘regular’ photoablation?</td>
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</table>

PDT Argon aka photoactivation aka plasma-induced disruption
Lasers: Pew! Pew!

The five modes of laser-tissue interaction:

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

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:

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

- Photochemical
- Thermal
- Photoablation
- Plasma-induced ablation
- Photo-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).
Lasers: Pew! Pew!

The five modes of laser-tissue interaction:

- Photochemical
- Thermal
- Photoablation
- Plasma-induced ablation
- Photo-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?
Lasers: Pew! Pew!

The five modes of laser-tissue interaction:

- Photochemical
- Thermal
- Photoablation
- Plasma-induced ablation
- Photodisruption

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.
The five modes of laser-tissue interaction:

- Photochemical
- Thermal
- 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)

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Lasers: Pew! Pew!

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

- **Photochemical**
- **Thermal**
- **Photoablation**
- **Plasma-induced ablation**
- **Photo-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. 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?**
Lasers: Pew! Pew!

The five modes of laser-tissue interaction:

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

**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).

*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:*

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<td>Very-low-power laser energy causes a photosensitive dye to undergo chemical rxn</td>
<td>Laser energy is absorbed → transforms into heat → local thermal damage</td>
<td>Laser energy disrupts covalent bonds</td>
<td>Laser energy produces minute amount of plasma, causing local vaporization of tissue</td>
<td>aka <em>photoactivation</em></td>
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**PDT** | **Argon, diode** | **Excimer** | **Femtosecond** |

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

The five modes of laser-tissue interaction:

- Photochemical Thermal Ablation
- Photothermal Ablation
- Photoablation
- Plasma-induced Ablation
- Photo-induction of 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
Lasers: Pew! Pew!

The five modes of laser-tissue interaction:

- Photochemical Thermal Ablation
- Photochemical Disruption
- Plasma-induced Ablation
- Excimer Femtosecond
- Photodisruption

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.

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

The five modes of laser-tissue interaction:

- Photo-thermal
- Photo-ablation
- Plasma-induced ablation
- Photo-chemical
- Photo-disruption

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- Photochemical
- Thermal
- Photoablation
- Photo-disruption
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<td>Laser energy produces substantial amount of plasma, mechanical forces</td>
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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.

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

The five modes of laser-tissue interaction:

- Photochemical Thermal Ablation
- Photodisruption
- Plasma-induced Ablation
- Photo-dissociation
- Plasmas-Induced Disruption

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

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

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<td>Laser energy produces minute amount of plasma, causing local vaporization of tissue</td>
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<td><strong>Photo-disruption</strong></td>
<td>Laser energy produces large amount of plasma, causing mechanical disruption of tissue</td>
</tr>
</tbody>
</table>

**PDT** — Argon, diode           

**Excimer**                       

**Femtosecond**                   

**YAG cap**                       

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*No question—review slide*