WHAT IS PHOTONICS?

Photonics is the generation, transmission, and utilization of light and other electromagnetic radiation. Photonics offers solutions to the global challenges of our time.
SMALLEST POINTS

Light can be focused on extremely small diameters.

1,000 µm paper clip wire
500 µm pin
100 µm focus in laser cutting
50 µm human hair
10 µm optical fiber core

outer sheath: 100 µm
core: 10 µm

1,000 µm = 1 mm
HIGHEST VELOCITY

Nothing is faster than light. The speed of light is $299,792,458 \text{ m/s}$.

- 1.5 m courier by foot
- 20 m carrier pigeon
- 250 m aircraft
- 10 km Apollo moon rocket
- 200,000 km optical fiber cable
- 300,000 km light in space

Distance Earth – Moon: 384,400 km
Light makes even the fastest events measurable.

- **Second** (1 s) - Blink
- **Millisecond** (1 ms) - Athlete in action
- **Microsecond** (1 µs) - High-speed camera
- **Nanosecond** (1 ns) - Electric impulses in a computer
- **Picosecond** (1 ps) - Chemical processes such as the splitting of DNA
- **Femtosecond** (1 fs) - Processes inside an atom
- **Attosecond** (1 as) - Only measurable with light
With the pulsed operation of lasers, a power orders of magnitude greater than anything we have known so far can be achieved. This is made possible through the concentration of laser power to very short femtosecond pulses.

**Generated power of the Berkeley Lab Laser Accelerator**

1 petawatt

= 1,000,000 gigawatts

Worldwide power generated by electric power plants

2.6 terawatts = 2,600 gigawatts

around 400 times

Peak powers are reached periodically for very short time intervals.

laser pulse width:

40 femtoseconds

1 second
Dozens of data signals can be coupled into one single optical fiber and be separated again at the receiver’s end. The signals can be very finely distinguished based on their wavelength (spectral color), polarization, and phase.

Over 40 channels with data signals can be superposed in one fiber. 
transmission rate: 
100 gigabits per second
Light is the very small part of the electromagnetic spectrum visible to the human eye in the wavelength range of 380 to 780 nanometers.
Photonic applications use a broad portion of the electromagnetic spectrum that is predominantly not visible to humans.

### Nuclear Technology vs. Photonics

<table>
<thead>
<tr>
<th>Cosmic Radiation</th>
<th>Gamma Radiation</th>
<th>X-Ray</th>
<th>Ultraviolet</th>
<th>Infrared</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 femtometer</td>
<td>1 picometer</td>
<td>1 nanometer</td>
<td>1 zettahertz</td>
<td>1 exahertz</td>
</tr>
</tbody>
</table>

- High frequency
- Short wave

- Radiocarbon dating
- Material testing
- X-ray machines
- Ultraviolet lamp
- Heat lamp
- Visible light
Photonic applications use a broad portion of the electromagnetic spectrum that is predominantly not visible to humans.

<table>
<thead>
<tr>
<th>TERAHertz</th>
<th>MICROWAVES</th>
<th>RADIO WAVES</th>
<th>ALTERNATING CURRENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 terahertz</td>
<td>1 gigahertz</td>
<td>1 megahertz</td>
<td>1 kilohertz</td>
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<tr>
<td></td>
<td>1 millimeter</td>
<td>1 meter</td>
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</tbody>
</table>

**Frequency**
- Low frequency
- High frequency
- Long wave
- Short wave

**Applications**
- Radar
- Broadcasting
- Electronics
- Nuclear technology
- Cell phone network
- Identification system
- Television
- Power line
- Full-body scanner
- Wireless LAN
- Lamp
- X-ray machines
- Radiocarbon dating
- Visible light
- Lamp material testing

**Units**
- 1 meter
- 1 megameter
- 1 millimeter
- 1 kilometer

**Frequencies**
- 1 terahertz
- 1 gigahertz
- 1 megahertz
- 1 kilohertz
**SHORTER WAVELENGTHS**

Wavelength has a great influence on the performance of optical systems. Shorter wavelengths can produce smaller focus diameters making greater recording densities possible on optical storage media.

**WAVELENGTHS USED TO READ OPTICAL DISCS**

<table>
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<tr>
<th></th>
<th>CD</th>
<th>DVD</th>
<th>Blu-Ray Disc</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wavelength</strong></td>
<td><strong>infrared</strong></td>
<td><strong>red</strong></td>
<td><strong>violet</strong></td>
</tr>
<tr>
<td><strong>nm</strong></td>
<td>780</td>
<td>650</td>
<td>405</td>
</tr>
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</table>

*Increasing recording density*
WINDOW GLASS vs OPTICAL FIBER

Glass is the most important component of optical systems. However, common window glass and glass used in photonics applications are worlds apart.

LIGHT TRANSMISSION OF GLASS

How thick can different glass types be so that 1% of the emitted light is still transmitted?

**WINDOW GLASS**
- Glass thickness: 80 cm
- 1% of light

**OPTICAL GLASS**
- Glass thickness: 29 m
- Example: camera lens

**OPTICAL FIBER**
- Glass thickness: 100 km
- (only valid for infrared light)
MIRRORS vs LASER MIRRORS

Many optical components can be found in their basic forms in the home. The components used in photonics, however, are characterized by the highest accuracy and technical finesse.

HOUSEHOLD MIRROR CONSTRUCTION

1. glass plate
2. back silver coating
3. protective layer
Many optical components can be found in their basic forms in the home. The components used in photonics, however, are characterized by the highest accuracy and technical finesse.

**HOUSEHOLD MIRROR CONSTRUCTION**
- glass plate
- back silver coating
- protective layer

**LASER MIRROR CONSTRUCTION**
- glass substrate
- layers of varying materials
- 99.9% reflectance

Usually, at least 20 to 50 layers of 100 to 200 nanometers thickness are applied on the front of a substrate. The result is an extremely high reflectance.

**Laser mirror in kinematic mount**
Lasers are the central component of many photonics applications. The numerous laser types always consist of the same basic elements although their shape strongly varies.

**basic elements**

- active medium = excited atoms or molecules
- energy supply = pump
- resonator (end mirror or output coupler)
- laser beam

**LASER TYPES**

- Diode Laser
- Fiber Laser
- Disk Laser
- Gas Laser
LASERS vs THE SUN

While conventional light sources emit their energy in all directions, lasers bundle the emitted light very efficiently into almost parallel light beams of small diameters.

**PERFORMANCE COMPARISON**

**Sun**
- 174 petawatts
- Solar radiation intensity on the Earth (central European summer)

**Earth**
- Button hole Ø1.5 mm
- 700 watts per m²

**LASER POINTER**
- 5 milliwatts (max.)

**Lasers vs The Sun**
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