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.
Light can be focused on extremely small diameters.

- **Outer sheath**: 100 µm
- **Core**: 10 µm
- **Pin human hair**
- **Optical fiber core diameter**: 1,000 µm = 1 mm
- **Paper clip wire**: 1,000 µm
- **Focus in laser cutting**: 100 µm, 50 µm, 10 µm

**BASICS 02**

**SMALLEST POINTS**
HIGHEST VELOCITY

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

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

Distance Earth – Moon: \( 384,400 \text{ km} \)
Light makes even the fastest events measurable.

<table>
<thead>
<tr>
<th>Time Unit</th>
<th>Symbol</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Second</td>
<td>s</td>
<td>Blink</td>
</tr>
<tr>
<td>Millisecond</td>
<td>ms</td>
<td>Athlete in action</td>
</tr>
<tr>
<td>Microsecond</td>
<td>µs</td>
<td>High-speed camera</td>
</tr>
<tr>
<td>Nanosecond</td>
<td>ns</td>
<td>Electric impulses in a computer</td>
</tr>
<tr>
<td>Picosecond</td>
<td>ps</td>
<td>Chemical processes such as the splitting of DNA</td>
</tr>
<tr>
<td>Femtosecond</td>
<td>fs</td>
<td>Processes inside an atom</td>
</tr>
<tr>
<td>Attosecond</td>
<td>as</td>
<td>Only measurable with light</td>
</tr>
</tbody>
</table>

Conversion:
- 1 millisecond = 0.001 second
- 1 microsecond = 0.000,001 second
- 1 nanosecond = 0.000,000,001 second
- 1 picosecond = 0.000,000,000,001 second
- 1 femtosecond = 0.000,000,000,000,001 second
- 1 attosecond = 0.000,000,000,000,000,001 second
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.

**Comparison of Power**

Worldwide power generated by electric power plants
2.6 terawatts = 2,600 gigawatts

Generated power of the Berkeley Lab Laser Accelerator
1 petawatt
= 1,000,000 gigawatts

around 400 times

Peak powers are reached periodically for very short time intervals.
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.

**SPECTRAL SENSITIVITY OF THE EYE AT DAYTIME**

Range visible to humans: 380 to 780 nm

**SPECTRAL DISTRIBUTION OF SUNLIGHT ON EARTH**
HIDDEN REALM OF PHOTONICS

Photonic applications use a broad portion of the electromagnetic spectrum that is predominantly not visible to humans.

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### Nuclear Technology

<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>
<tr>
<td>wavelengths</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>short wave</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>high frequency</td>
<td>1 zettahertz</td>
<td>1 exahertz</td>
<td>1 petahertz</td>
<td></td>
</tr>
<tr>
<td>frequencies</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **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.

- **Terahertz (THz)**: 1 THz to 1000 THz
- **Gigahertz (GHz)**: 1 GHz to 1 THz
- **Zettahertz (ZHz)**: 1 ZHz to 1 EHz
- **Exahertz (EHz)**: 1 EHz to 1 ZHz
- **Petahertz (PHz)**: 1 PHz to 1 EHz
- **Picometer (pm)**: 1 pm to 1 nm
- **Femtometer (fm)**: 1 fm to 1 pm
- **Micrometer (μm)**: 1 μm to 1 mm
- **Nanometer (nm)**: 1 nm to 1 μm
- **Meter (m)**: 1 m to 1 km
- **Kilometer (km)**: 1 km to 1 Mm
- **Megahertz (MHz)**: 1 MHz to 1 GHz
- **Kilohertz (kHz)**: 1 kHz to 1 MHz

**GAMMA RADIATION**

**COSMIC RADIATION**

**X/RAY ULTRA VIOLET**

**INFRARED**

**RED TERA/ZET HERTZ MICROWAVES RADIO WAVES ALTERNATING CURRENTS**

**ELECTRONICS**

- **Frequencies**: low frequency, high frequency
- **Wavelengths**: short wave, long wave

**NUCLEAR TECHNOLOGY**

- **Materials**: testing, radiocarbon dating
- **Systems**: cell phone network, wireless LAN, identification system (RFID), television, power line, full-body scanner

**RADAR**

**BROADCASTING**

**TELEVISION**

**LAMP**

**ULTRAVIOLET LAMP**

**MATERIAL TESTING**

**RADIATION**

**CELL PHONE NETWORK**

**WIRELESS LAN**

**IDENTIFICATION SYSTEM (RFID)**

**TELEVISION**

**FULL-BODY SCANNER**

**POWER LINE**

**RADAR**

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**POWER LINE**
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>
<thead>
<tr>
<th>CD</th>
<th>DVD</th>
<th>Blu-Ray Disc</th>
</tr>
</thead>
<tbody>
<tr>
<td>infrared</td>
<td>red</td>
<td>violet</td>
</tr>
<tr>
<td>780 nm</td>
<td>650 nm</td>
<td>405 nm</td>
</tr>
</tbody>
</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

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

86% reflectance
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

LASER MIRROR

CONSTRUCTION

glass plate
back silver coating
protective layer

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.

99.9% 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

**ABSOLUTE PERFORMANCE**

- **Sun**: 174 petawatts
- **Earth**, solar radiation intensity on the Earth (central European summer): 700 watts per m²

**PERFORMANCE BEHIND BUTTON HOLE** in milliwatts

- **Laser pointer**: 5 milliwatts (max.)
- **Button hole Ø1.5 mm**: 1.5 mm beam diameter

5 milliwatts