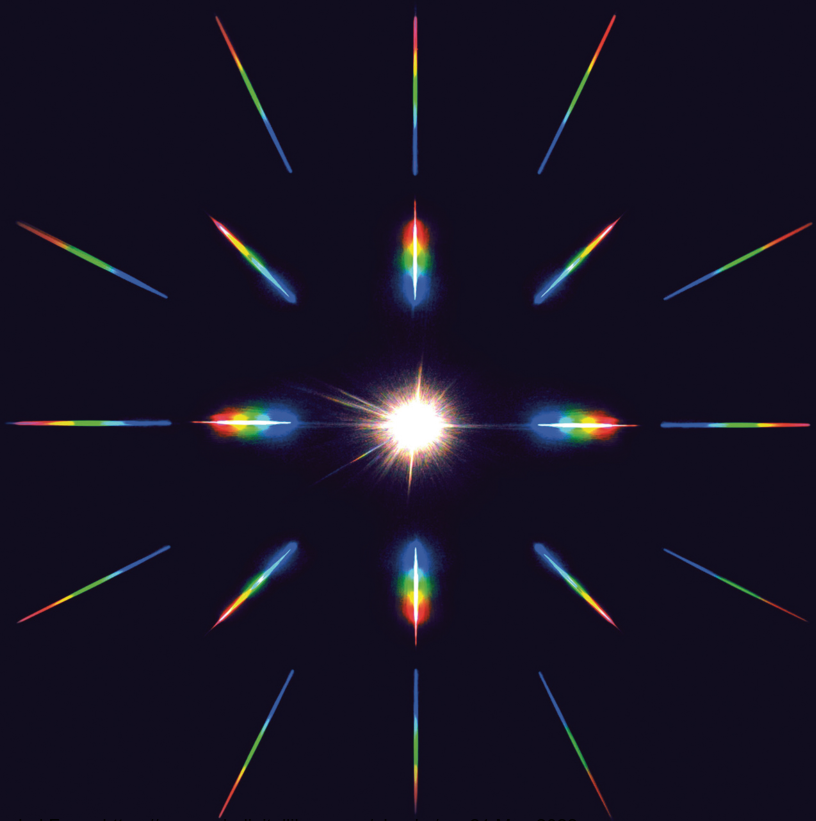
PHOTONICS

Technical applications of light

INFOGRAPHICS



A very warm thank you to all the companies and institutes that made this publication possible:

Edmund optics | worldwide

FISBA Innovators in Photonics

Fraunhofer ILT

HAMAMATSU
PHOTON IS OUR BUSINESS

IMT
PRECISION ON GLASS

LASER COMPONENTS

rofin

TOPTICA PHOTONICS

TRUMPF

PHOTONICS

Technical applications of light

INFOGRAPHICS

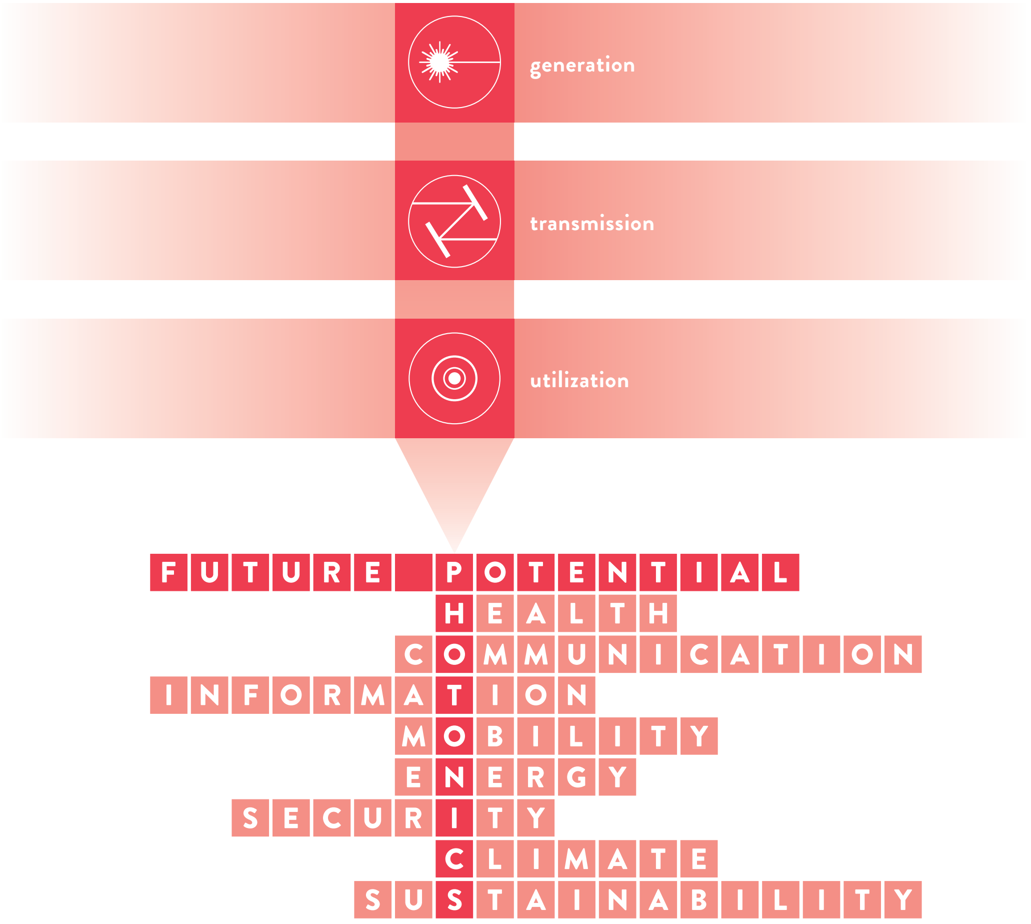
CONTENTS

BASICS

01

WHAT IS PHOTONICS?

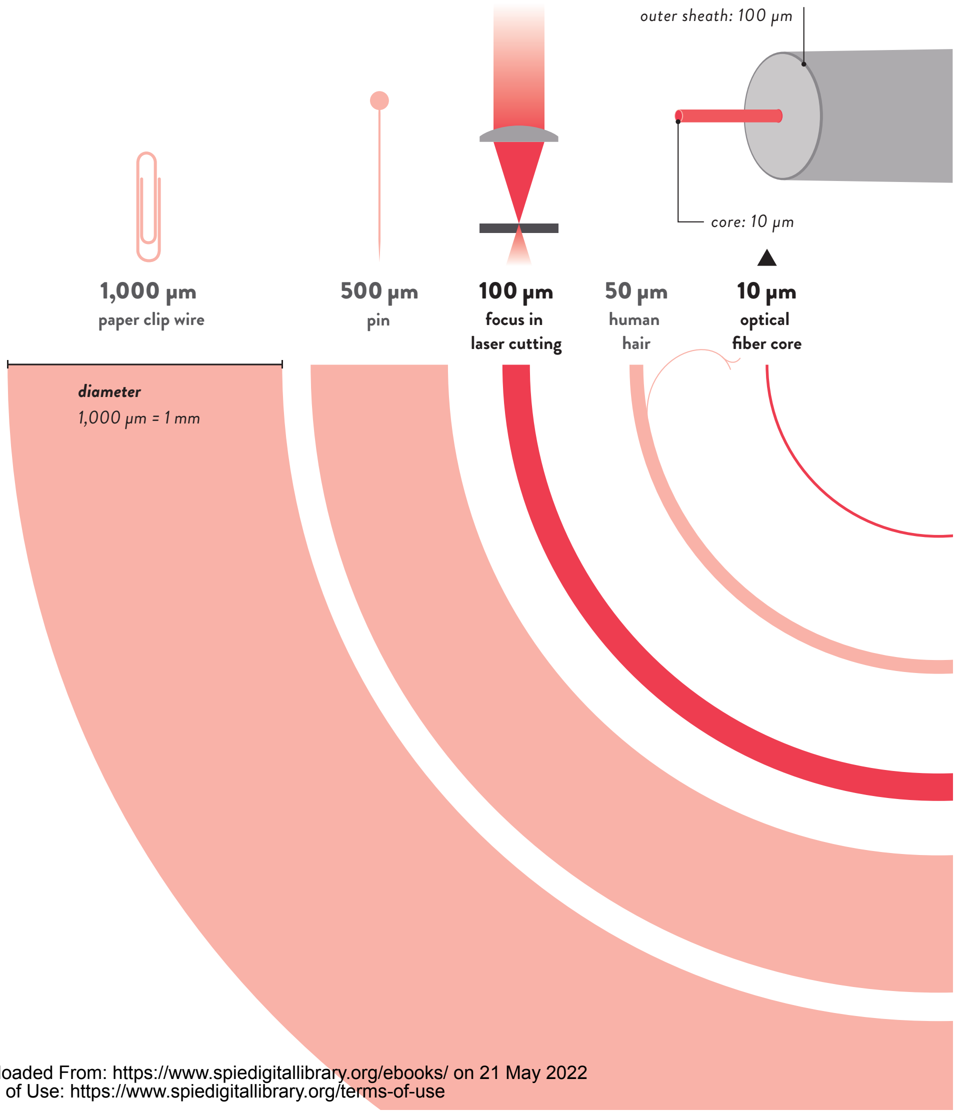
Photonics is the generation, transmission, and utilization of light and other electromagnetic radiation. Photonics offers solutions to the global challenges of our time.



02

SMALLEST POINTS

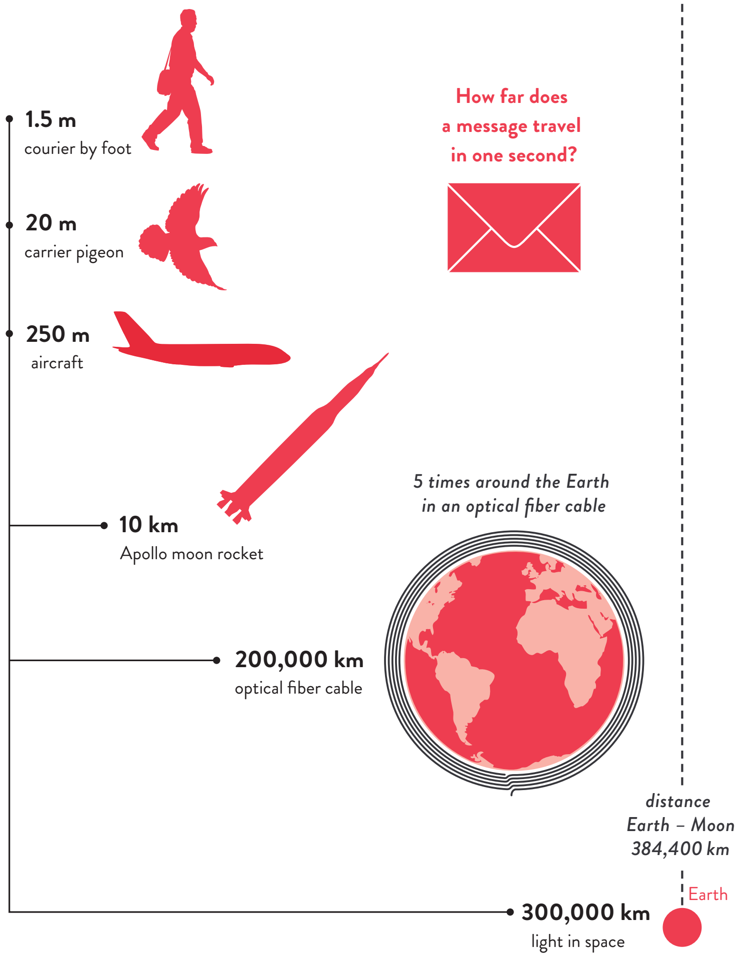
Light can be focused on extremely small diameters.



03

HIGHEST VELOCITY

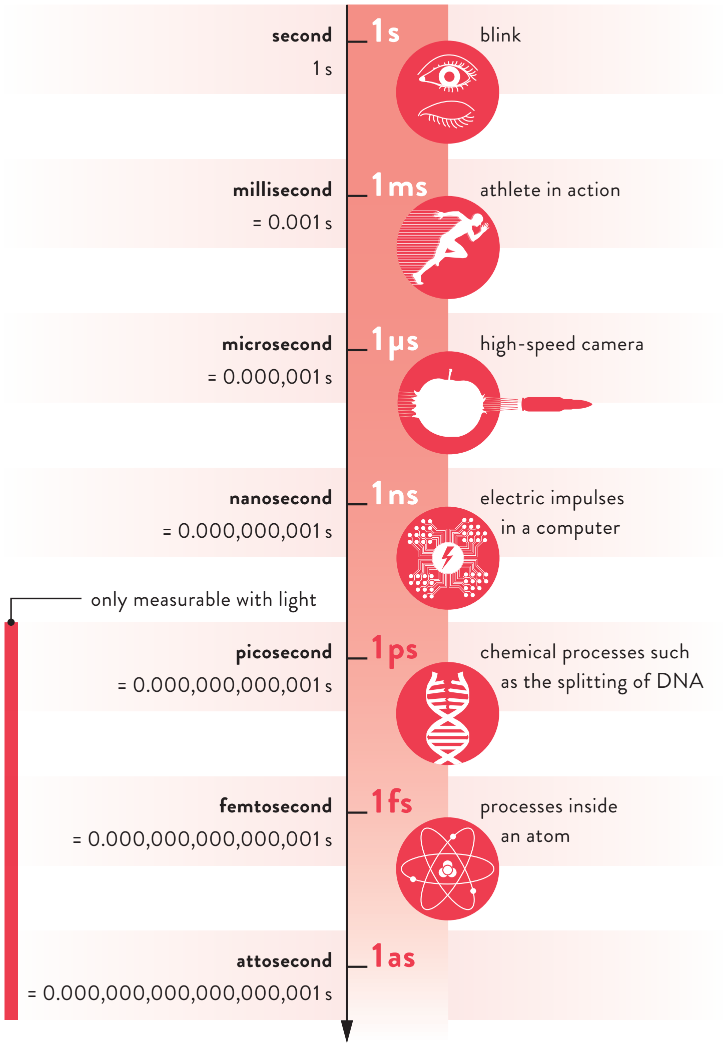
Nothing is faster than light.
The speed of light is 299,792,458 m/s.



04

SHORTEST TIMES

Light makes even the fastest events measurable.



05

HIGHEST POWER

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

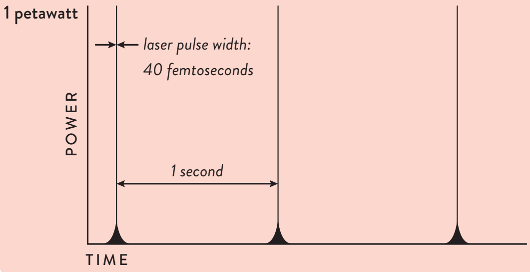
Worldwide power generated by electric power plants

2.6 terawatts = 2,600 gigawatts

Generated power of the Berkeley Lab Laser Accelerator

1 petawatt = 1,000,000 gigawatts

around 400 times

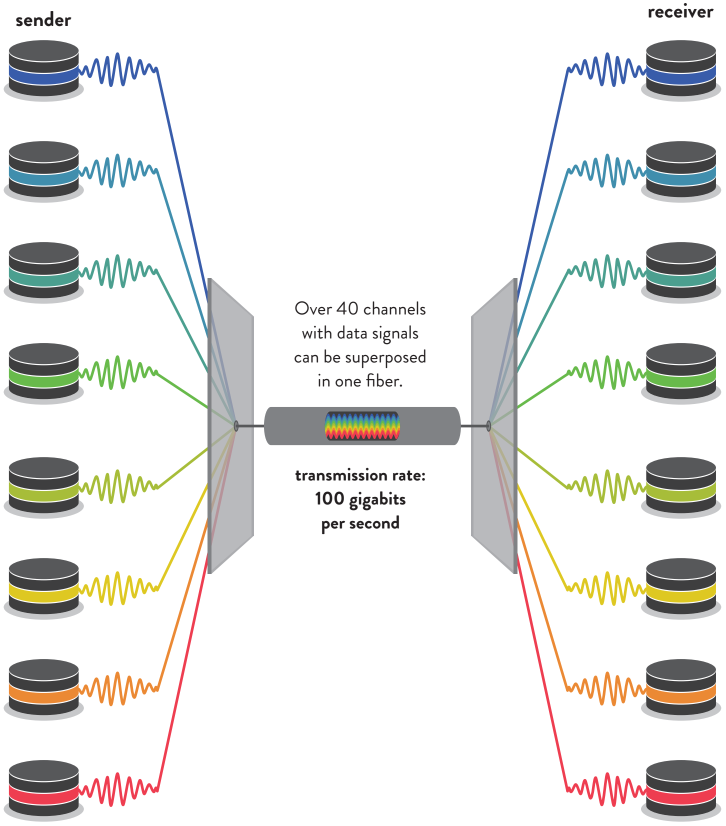


Peak powers are reached periodically for very short time intervals.

06

UNDISTURBED SUPER-POSITION

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.

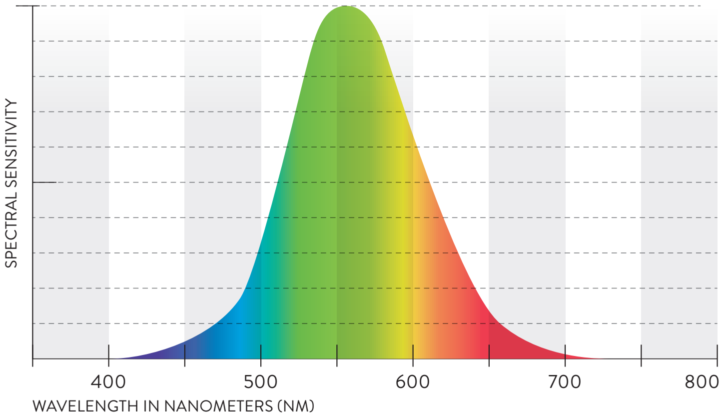


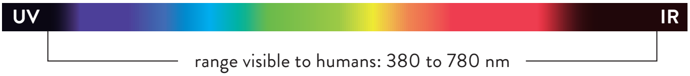
07

LIGHT SPECTRUM

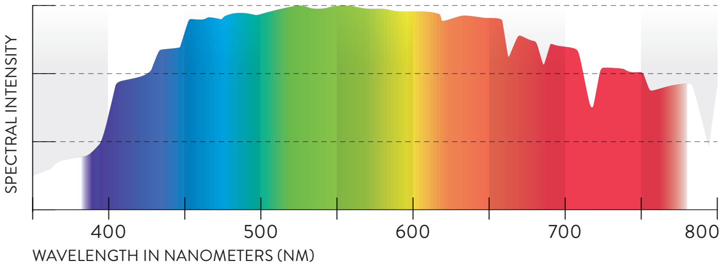
Light is the very small part of the electromagnetic spectrum visible to the human eye in the wavelength range of 380 to 780 nanometers.

SPECTRAL SENSITIVITY OF THE EYE AT DAYTIME





SPECTRAL DISTRIBUTION OF SUNLIGHT ON EARTH



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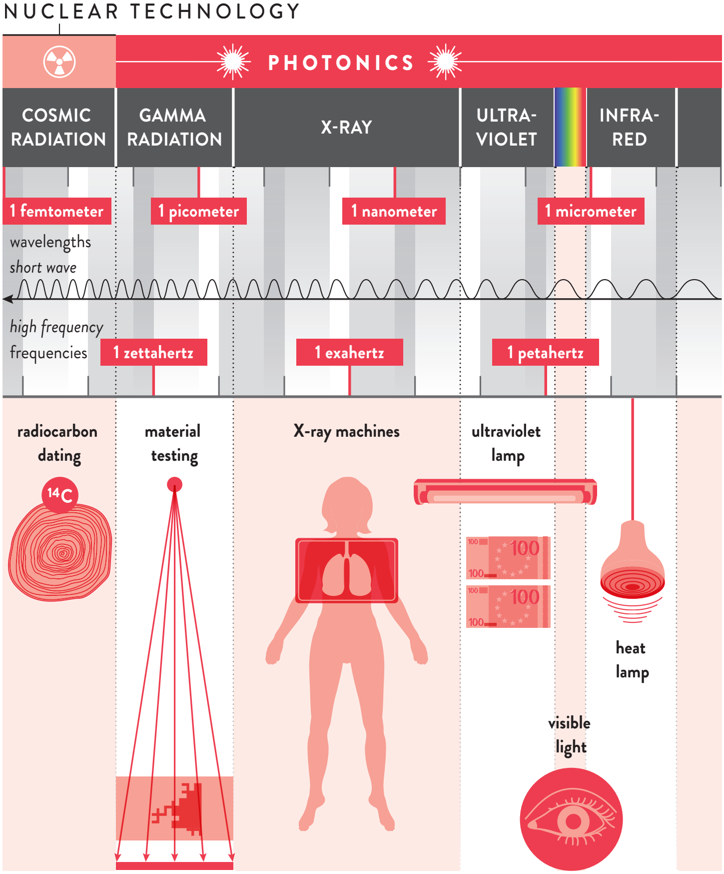
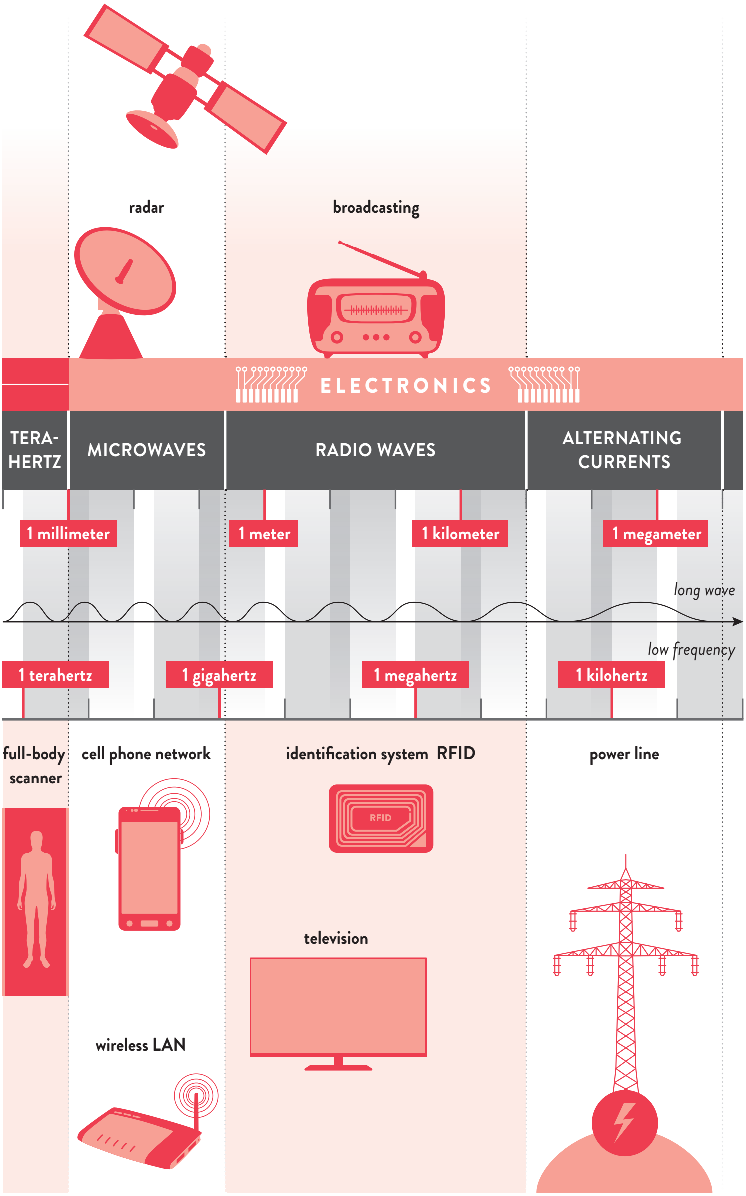
HIDDEN REALM OF PHOTONICS

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



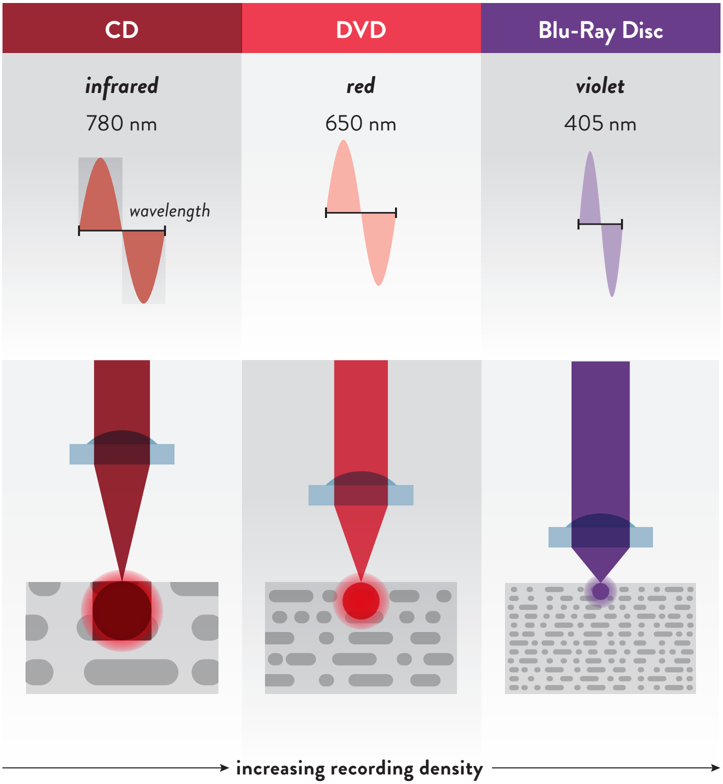

radar
broadcasting
ELECTRONICS
TERA-
HERTZ
MICROWAVES
RADIO WAVES
ALTERNATING
CURRENTS
1 millimeter
1 meter
1 kilometer
1 megameter
long wave
low frequency
1 terahertz
1 gigahertz
1 megahertz
1 kilohertz
full-body
scanner
cell phone network
identification system RFID
power line
RFID
television
wireless LAN

09

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 DICS



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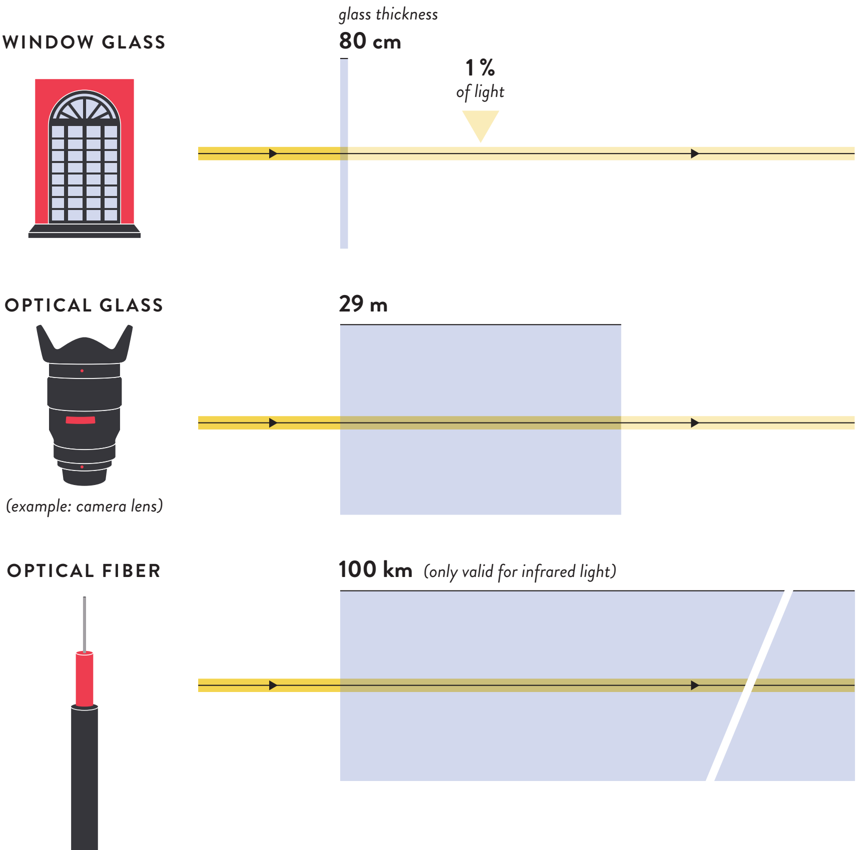
WINDOW GLASS vs OPTICAL FIBER

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?



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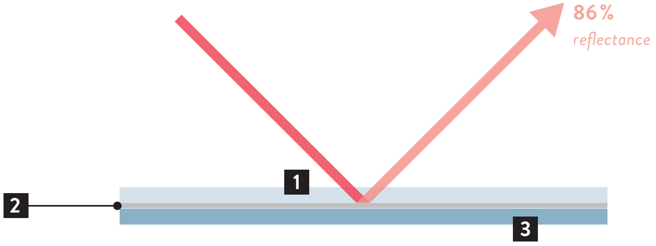
MIRRORS vs LASER MIRRORS

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

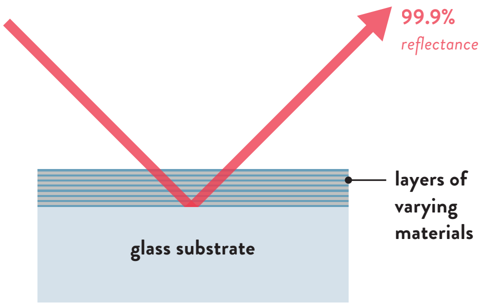


1 glass plate

2 back silver coating

3 protective layer

LASER MIRROR CONSTRUCTION



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

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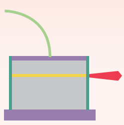
LASER TYPES

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.

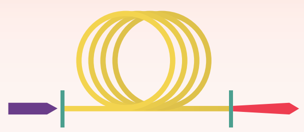
basic elements

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

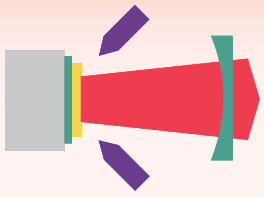
DIODE LASER



FIBER LASER



DISK LASER



GAS LASER

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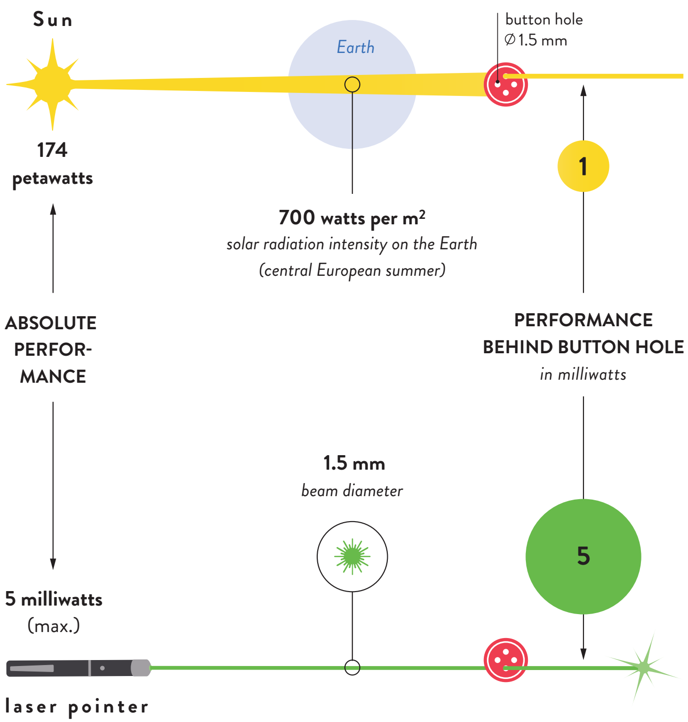
LASERS vs THE SUN

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



PRODUCTION TECHNOLOGY

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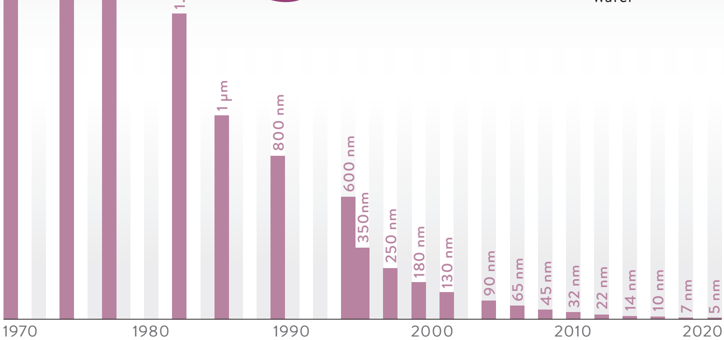
IMAGE OF SMALLEST STRUCTURES

Modern technology requires efficient electronics in the smallest spaces. Thanks to optical technologies it is possible to organize increasingly smaller electronic components on semiconductor chips.

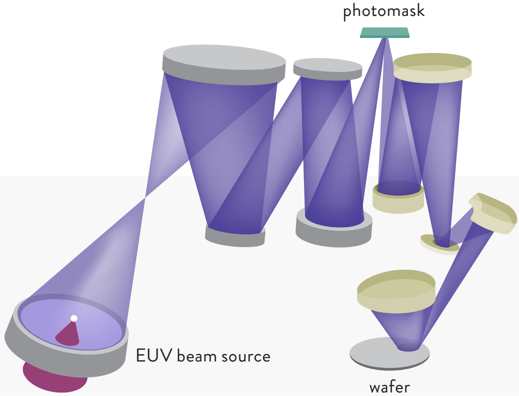
DEVELOPMENT OF SEMICONDUCTOR PRODUCTION PROCESSES

The image of increasingly smaller structures requires light sources with very short wavelengths.



OPTICAL BEAM PATH

Extreme ultraviolet (EUV) light, which is already in use and which has a wavelength of only 13.5 nanometers, requires the application of purely reflective optics with extremely accurate geometry.



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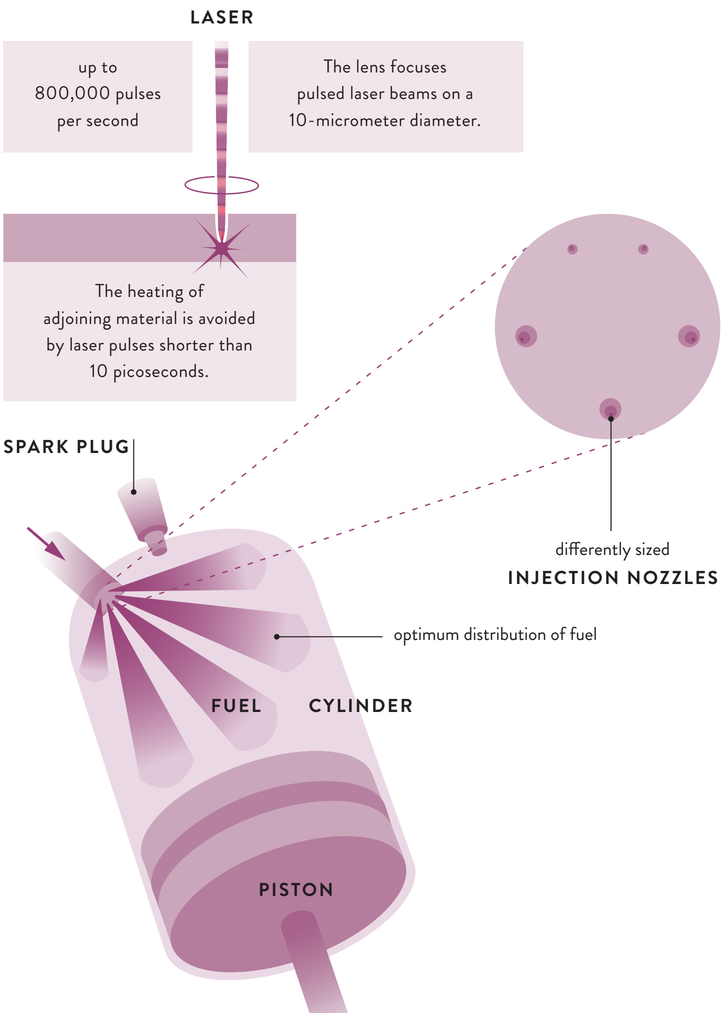
PRECISE LASER DRILLING

Ultrashort pulse lasers drill differently sized, accurately shaped injection nozzles that distribute the fuel in the best way possible. Thanks to laser precision machining, up to 30 % of fuel can be saved.



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LASER CUTTING

Laser cutting enables very quick processing of materials with a low loss of material, which makes this method extremely energy-efficient.

EFFICIENCY AND PERFORMANCE COMPARISON OF CONVENTIONAL MILLING AND LASER CUTTING

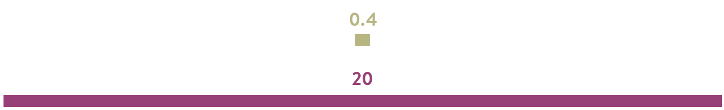
cutting a 5-millimeter-thick steel plate for one meter

CUTTING WIDTH

(millimeters)

TOOL PERFORMANCE

(kilowatts)




DURATION PER METER
14 Minutes
12 Seconds
ENERGY CONSUMPTION
(kilowatt hours)
0.10
0.07
WASTE
(grams)
390
15
TOTAL ENERGY CONSUMPTION
taking into account material savings
(kilowatt hours)
2.05
0.14

SMARTPHONES THANKS TO THE LASER

Hundreds of thousands of smartphones are manufactured daily. Quality and efficiency of production are of crucial importance to the manufacturers in this competitive market. Lasers are the key to success here.

LASER TYPES

- fiber laser
- UV solid-state laser
- solid-state laser
- CO_2 laser
- ultrashort pulse laser
- UV excimer laser
- IR diode laser

MACHINE PROCESS

- edge
- pattern
- area
- holes

Touchscreen

- cutting of extremely thin, hard cover glass
- cutting of touchscreen foil
- structuring of conducting layers

Screen

- generation of polycrystalline layers
- encapsulation of laminated glasses

Battery

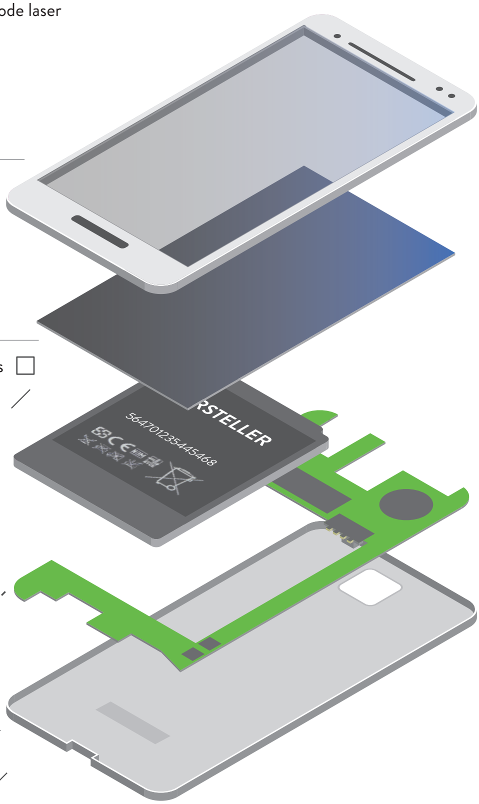
- welding of battery case
- marking logo, data-matrix-code, and serial number

Circuit board

- structuring of conductor tracks
- cutting of foil circuit boards
- drilling of contact holes

Housing

- cutting of housing
- marking logo and serial number



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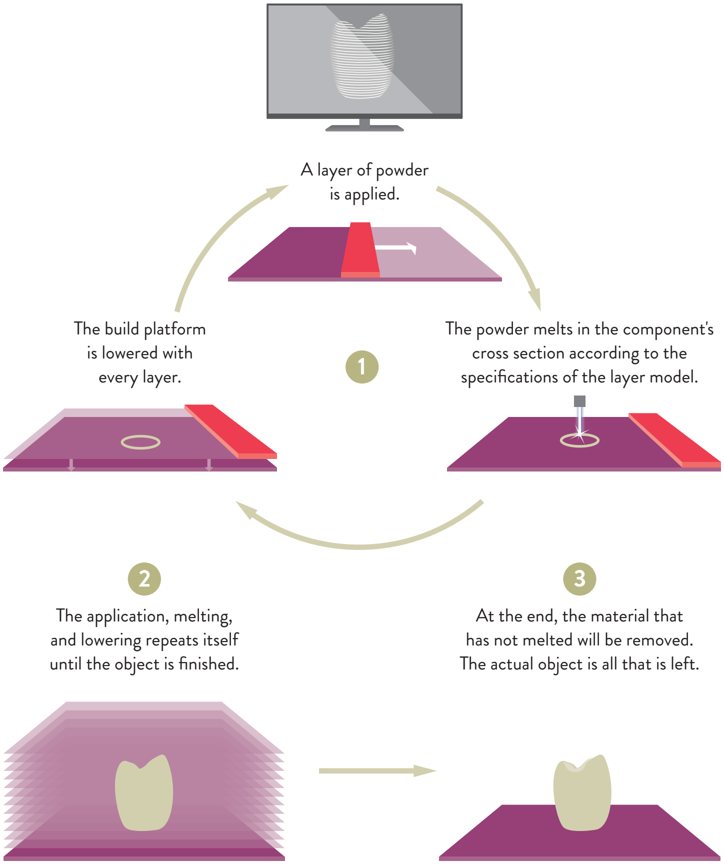
3D PRINTING

Based on a computer drawing, complex structures can be produced from plastics, ceramics, and metals with the help of selective laser melting. Dentures and implants are among the rapidly growing number of applications.

GENERAL OPERATING PRINCIPLE

The digital model of an object is transformed into a model made of a series of thin layers.



DATA TRANSFER

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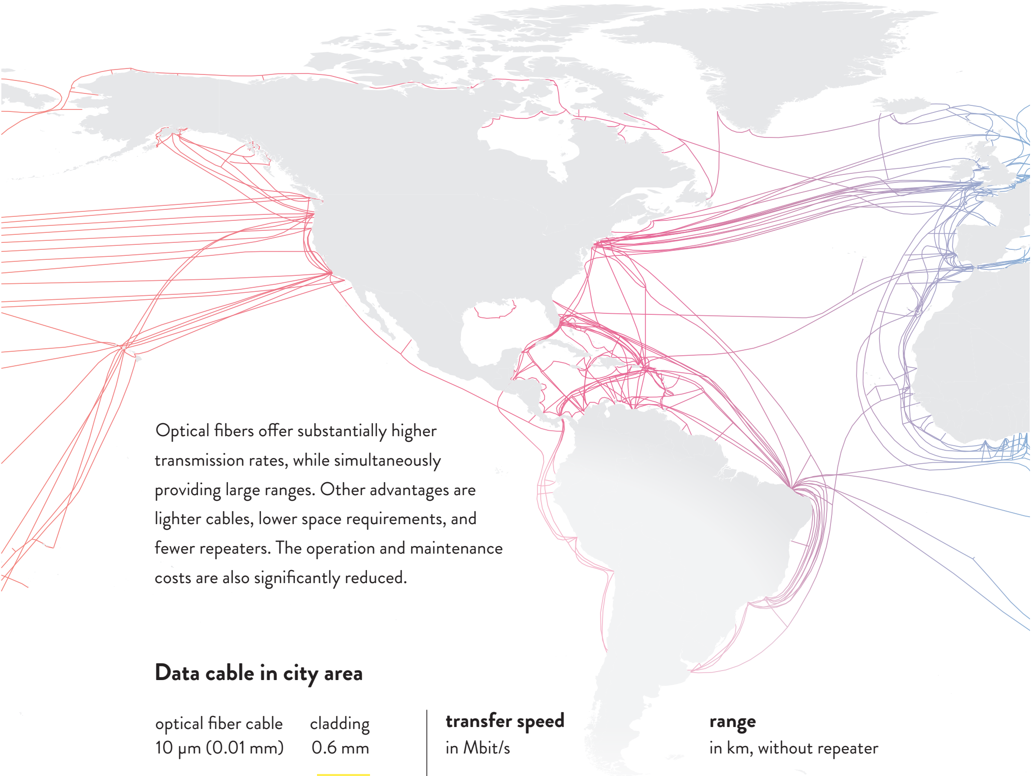
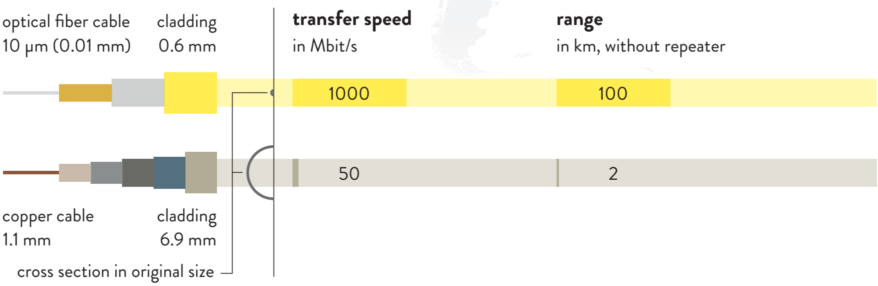
OPTICAL FIBER NETWORKS

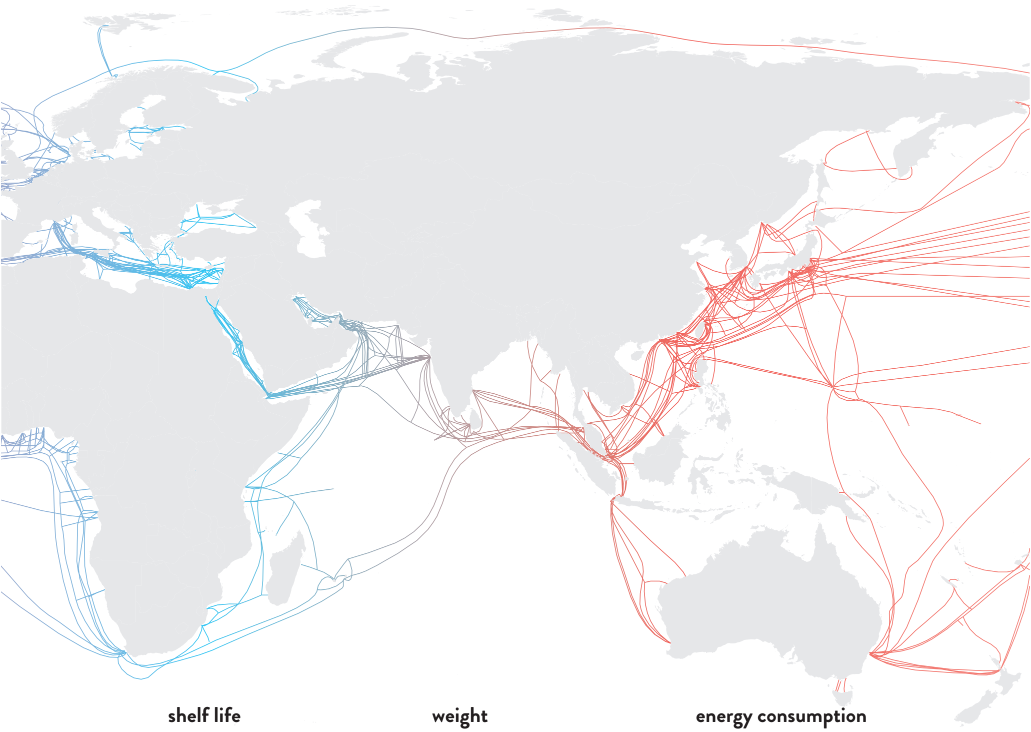
In 1988, the first transatlantic optical fiber cable, the TAT-8, went into operation. Optical fiber quickly replaced copper cables to meet the fast-growing need for greater capacity. Today, submarine cables with capacities of up to several terabytes per second connect the whole Earth.

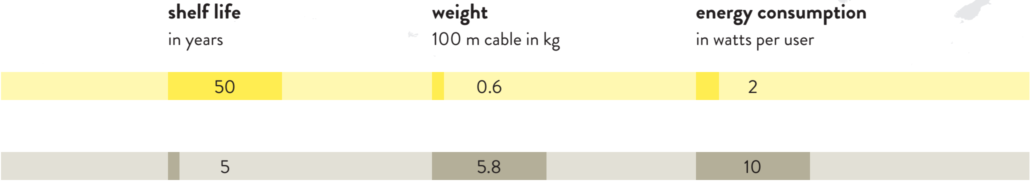


Optical fibers offer substantially higher transmission rates, while simultaneously providing large ranges. Other advantages are lighter cables, lower space requirements, and fewer repeaters. The operation and maintenance costs are also significantly reduced.

Data cable in city area







shelf life
in years
weight
100 m cable in kg
energy consumption
in watts per user
50
0.6
2
5
5.8
10

LASER COMMUNICATION IN SPACE

Free space optical communication between near-Earth and geostationary satellites enables the fast transfer of data to a ground station. Vital data during natural catastrophes or in emergencies at sea can be received almost in real time in this way.

ADVANTAGES OF THE LASER

LARGE DATA VOLUMES
1.8 gigabytes per second corresponds to around 500 songs per second

NO LIMIT
due to frequency allocations

LOWER ENERGY CONSUMPTION
expands shelf life

LESS MASS
saves costs

THE LASER AND OPTICS MEET THE HIGHEST REQUIREMENTS

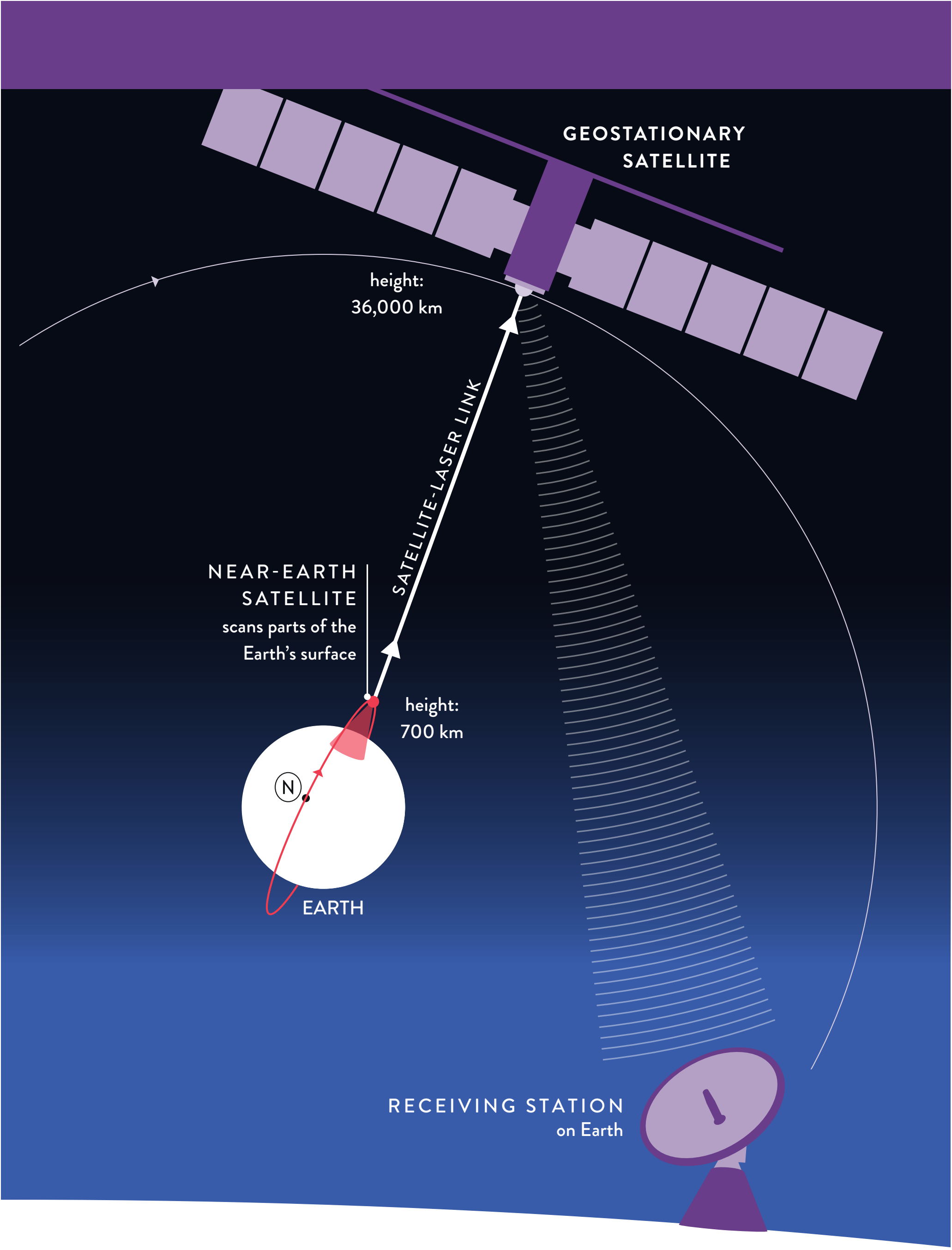
SMALLEST TOLERANCE
for generating a bundled laser beam across largest distances

stable despite great **TEMPERATURE DIFFERENCES**

survive strong **VIBRATIONS** and **ACCELERATIONS** during rocket launches

over **15** years **MAINTENANCE-FREE**

RESISTANT
against UV and gamma radiation in space


GEOSTATIONARY SATELLITE
height: 36,000 km
SATELLITE-LASER LINK
NEAR-EARTH SATELLITE
scans parts of the Earth's surface
height: 700 km
N
EARTH
RECEIVING STATION
on Earth

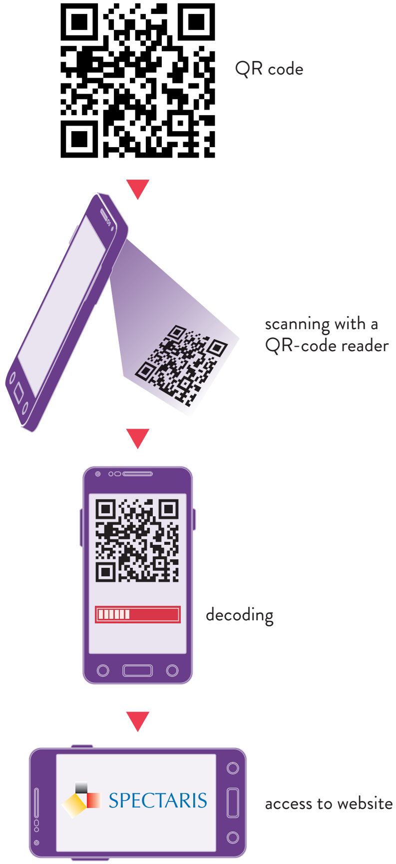
21

QR CODES

Cameras and optical sensors often work together
with intelligent image or data processing.
The QR code (Quick Response) shows this impressively.

USE OF QR CODES

QR codes are two-dimensional bar codes. A camera phone with the appropriate code reader software recognizes this information and decodes it.



QR-CODE STRUCTURE

Apart from the content, QR codes contain additional elements so that the software can recognize the data correctly. This includes:

positioning · format information · timing · version information · alignment

Up to **4,000 alphanumerical characters** fit on a QR code.

ADVANTAGES OF QR CODES

In comparison to the classic barcode, QR codes can store more information on a smaller area and make fewer requirements of reading devices.

They also function even if they are partly damaged or corrupted:

graphic/text in code · *distorted* · *blurred* · *twisted*

IMAGE CAPTURE & DISPLAY

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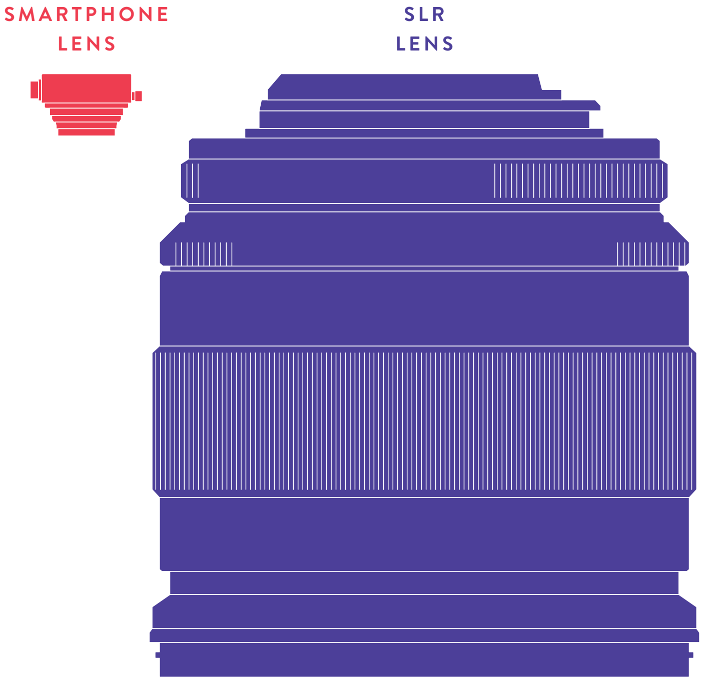
CAMERA LENSES

Today, brilliant images are possible with the smallest smartphone lenses. Why then is it still necessary to have large lenses in photography?

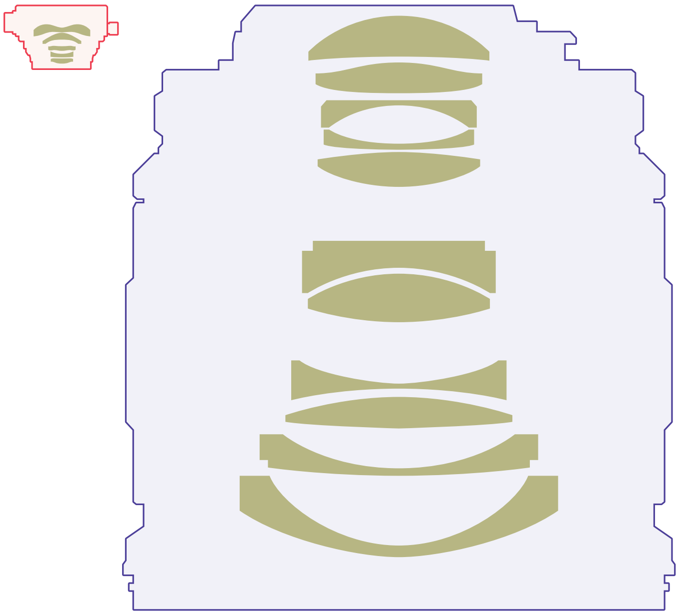
SIZE COMPARISON

(original sizes)



LENS ARRANGEMENT

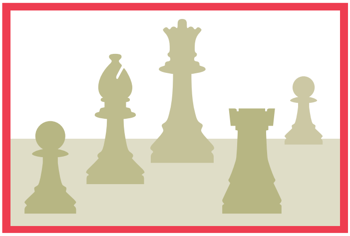
Despite their small size, smartphone lenses have sophisticated optics with complex lens arrangements.



DEPTH OF FIELD

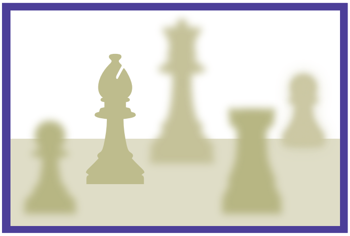
The most important consequence of the size difference is the different depths of field.

SMARTPHONE LENS



Smartphones display all objects from near to far with the same sharpness.

SLR LENS



The depth of field can be set selectively with large SLR lenses.

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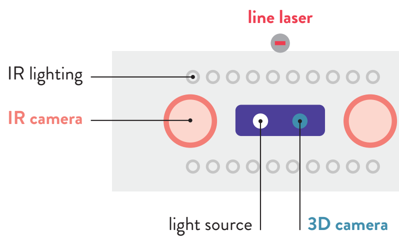
GESTURE CONTROL

Optical systems can capture and interpret hand movements contactlessly – this is ideal in sterile workplaces such as hospital operating rooms.

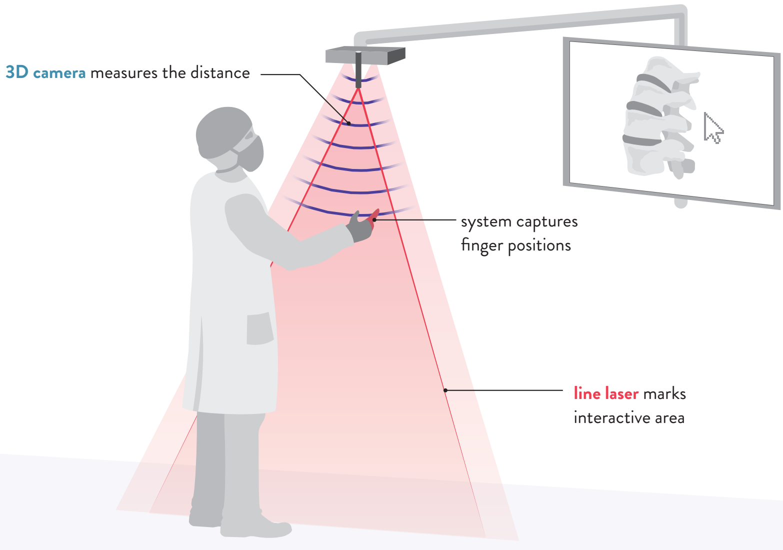
SURGICAL HAND-TRACKING SYSTEM

detailed view from below



Two **infrared (IR) cameras** capture the scene like two human eyes from slightly shifted perspectives.

A **3D camera**, which is based on the propagation time of light, verifies the distance.



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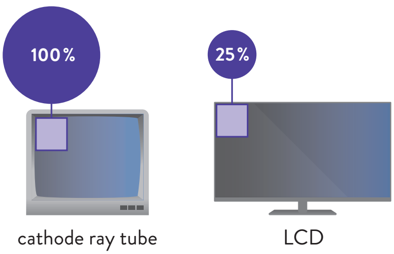
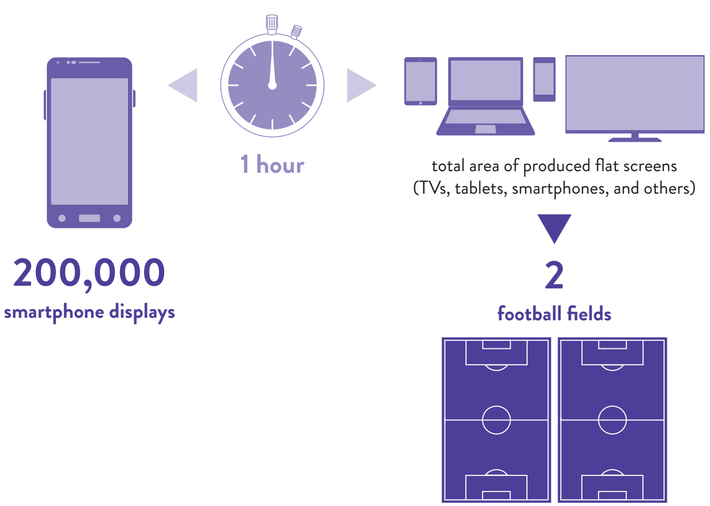
FLAT SCREENS

In contrast to early cathode ray tubes, flat screens save a great deal of energy per unit area. Impressive global production capacities meet the high demand for these displays.

ELECTRICITY CONSUMPTION AT SAME DISPLAY SIZE



PRODUCTION OF FLATSCREENS WITHIN ONE HOUR



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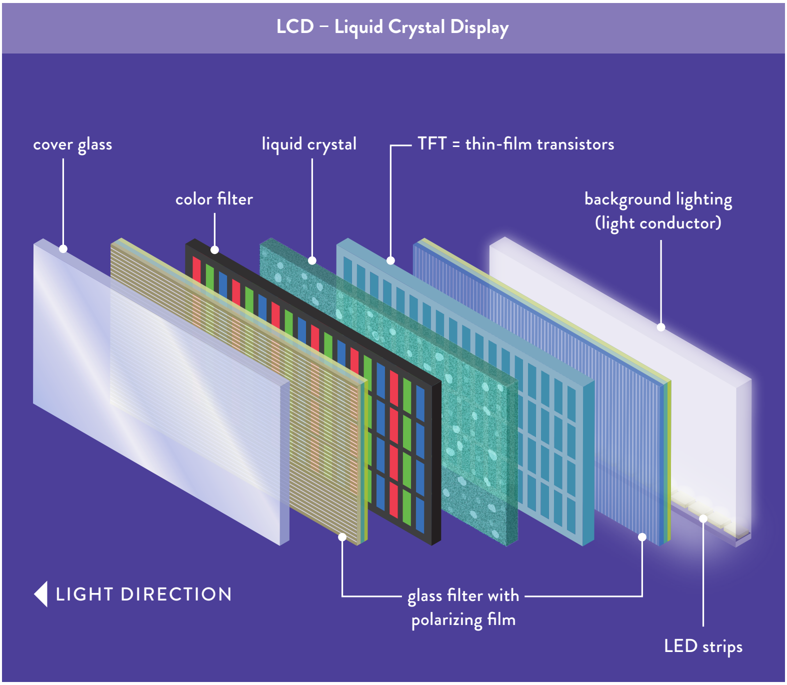
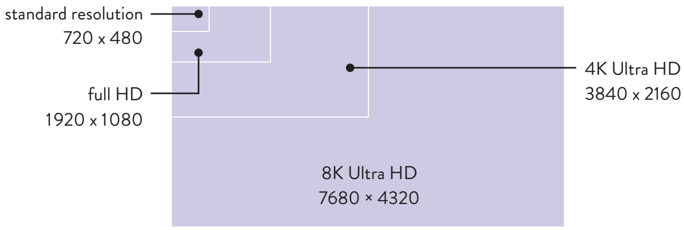
LCD vs OLED

Today, LCD displays dominate the flatscreen market, but in smartphones, organic LEDs (OLEDs) are conquering an increasingly larger market share. OLED displays are thinner, more energy-efficient, and higher in contrast but more expensive to produce.

LCD DISPLAY STRUCTURE

Today's most common type of display creates images by blocking off or letting through white light that LEDs create across the back of the display.

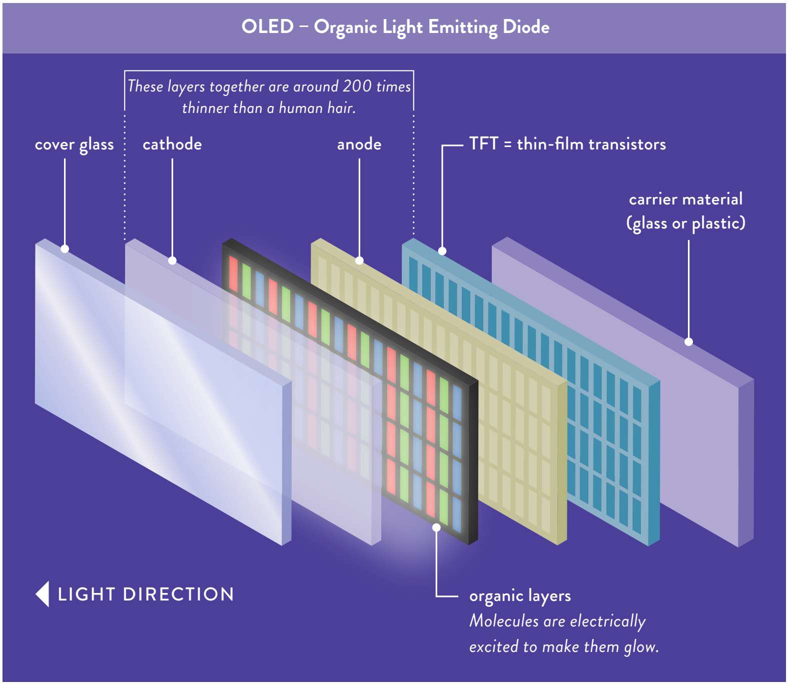




display resolutions
in pixels

OLED DISPLAY STRUCTURE

Organically luminous materials in OLED displays do not require a separate light source, which makes their construction depth much thinner.



MEDICAL TECHNOLOGY

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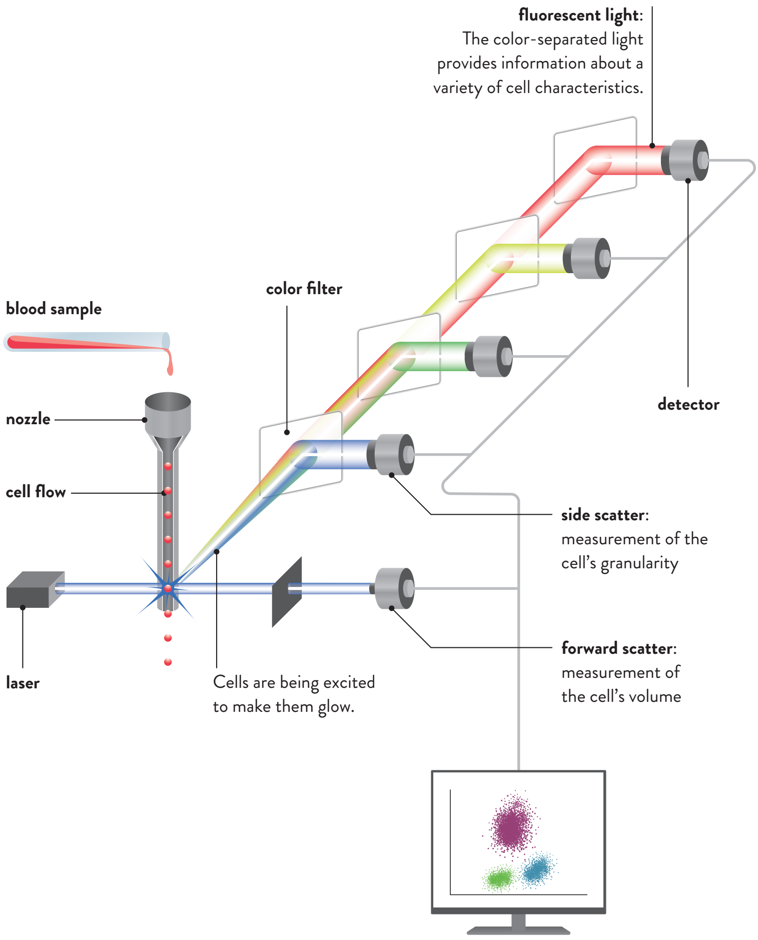
COUNTING BLOOD CELLS

Thousands of cells per second are counted and characterized in medical and biotechnical analytics with laser-based flow cytometry. This enables the fast and secure detection of blood anomalies.



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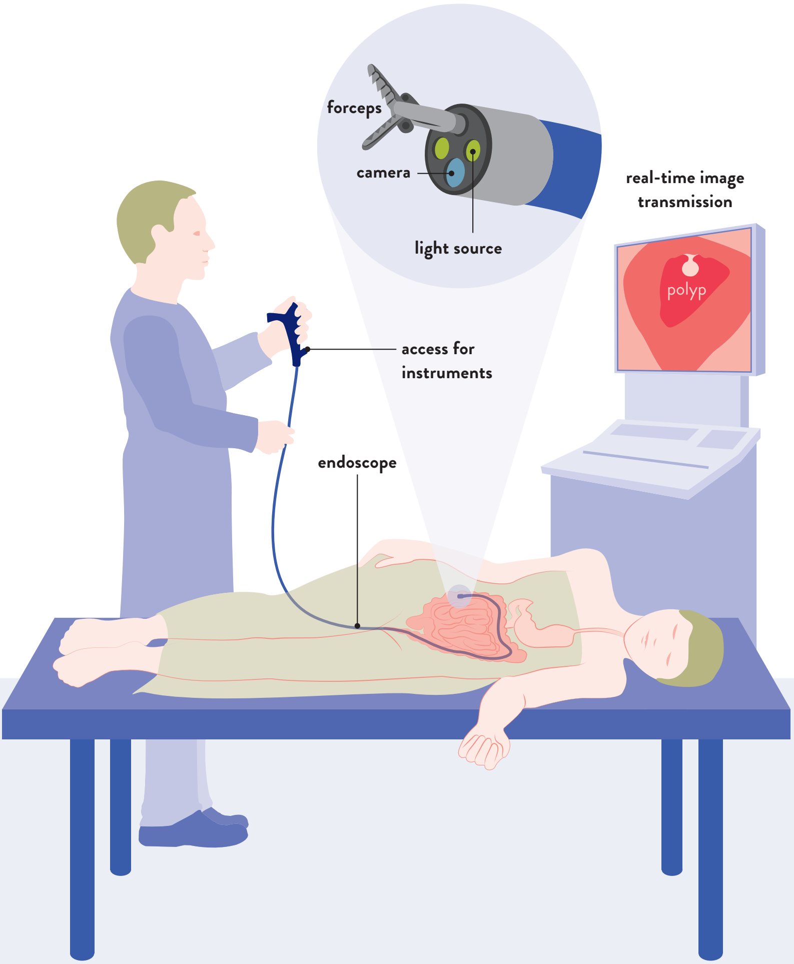
ENDOSCOPY

Endoscopes enable doctors to examine body cavities and hollow organs, detect illnesses, and treat them with minimal invasion at the same time, if required. The tubes, which are only a few millimeters thick, transfer illumination in one direction and high-resolution images in real time in the other direction.



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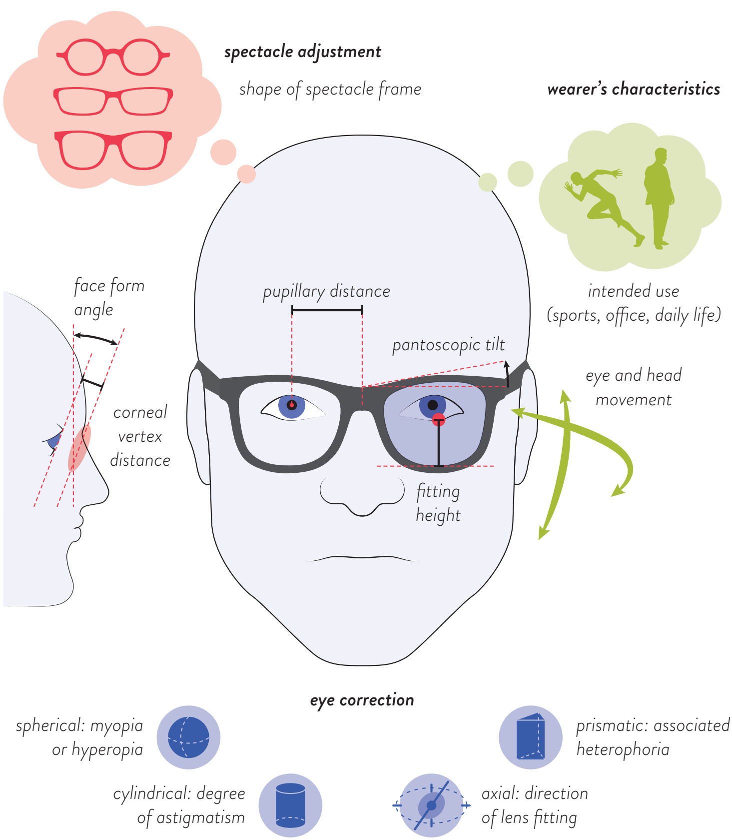
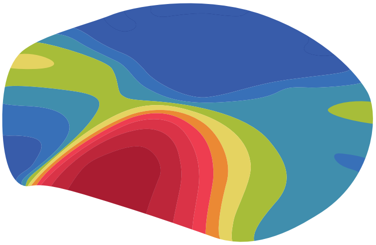
SEEING NEAR AND FAR

Individually adjusted varifocals help older people have good vision for all distances. A variety of criteria is included in the calculation for personalized and individual lens design. CNC machines are used to translate the calculated design into individual lenses with micrometer precision.

INDIVIDUAL CRITERIA

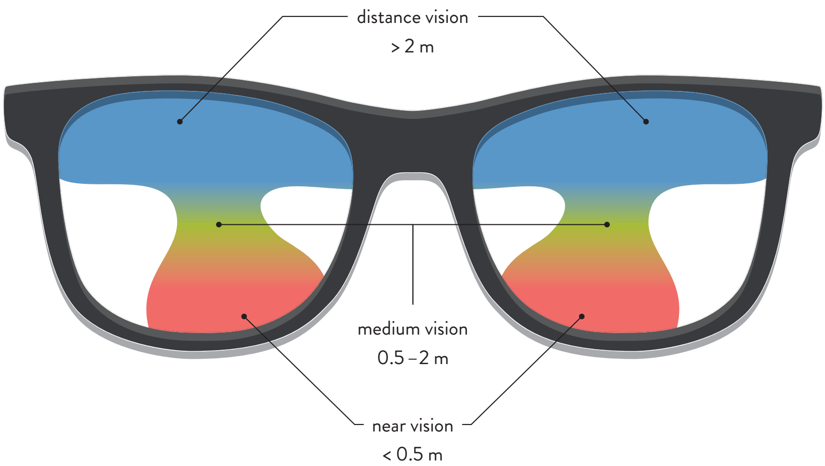


COMPUTER-CALCULATED LENS DESIGN



The different colors indicate the varying refractive power of the lens: from red (strong) to blue (weak).

MODEL OF VARIFOCALS

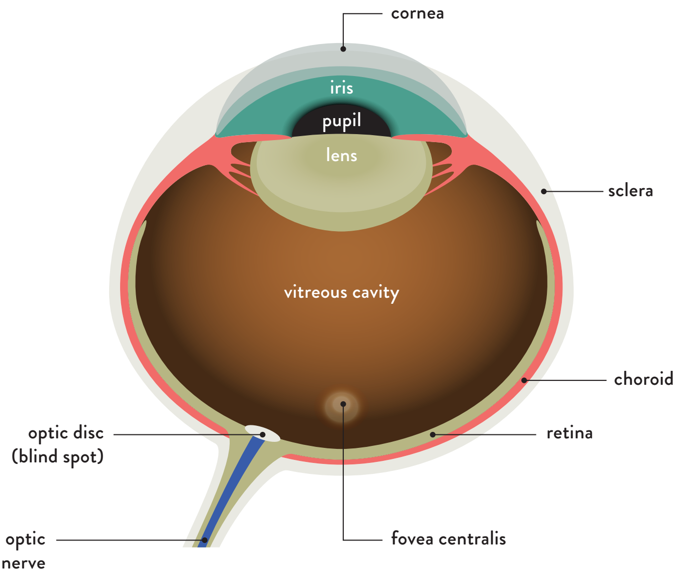


29

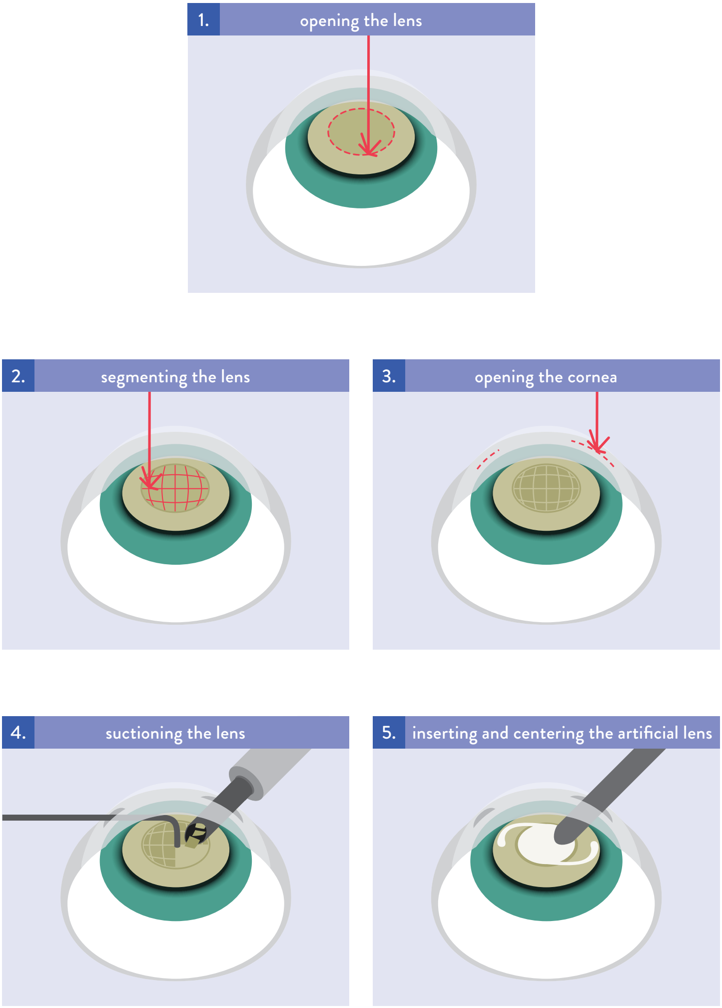
SEEING CLEARLY AGAIN

From the age of 60 onwards, most people get a slight cataract – known as the grey star. Treating cataracts is the most common operation around the world. The WHO estimates that by 2020, 32 million cataract operations will be performed. The use of the femtosecond laser with ultra-short pulses allows a precise and careful operation.

ANATOMY OF THE HUMAN EYE



SEQUENCE OF A LASER OPERATION

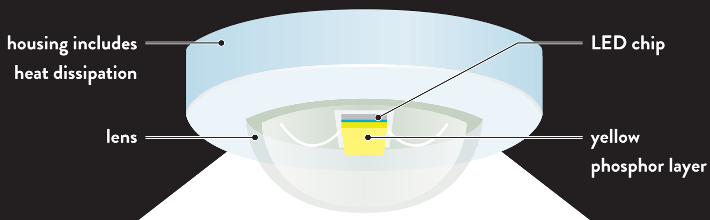


LIGHTING

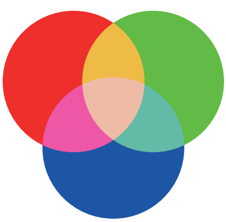
30

WHITE LED LIGHT

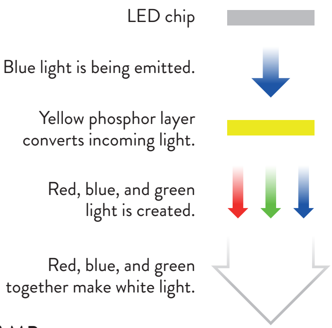
LED chips make colorful light.
White light is created by luminescence conversion.



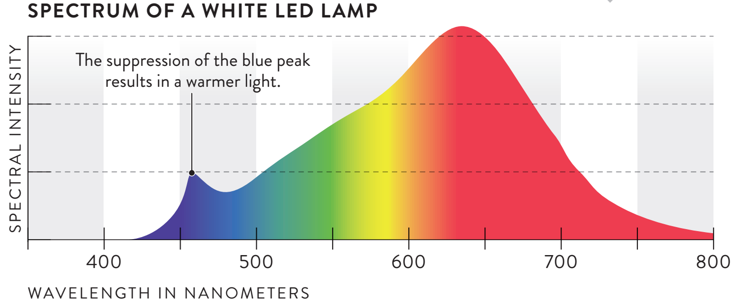
White light is a mix of red, blue and green.



Creation of white LED light through luminescence conversion:



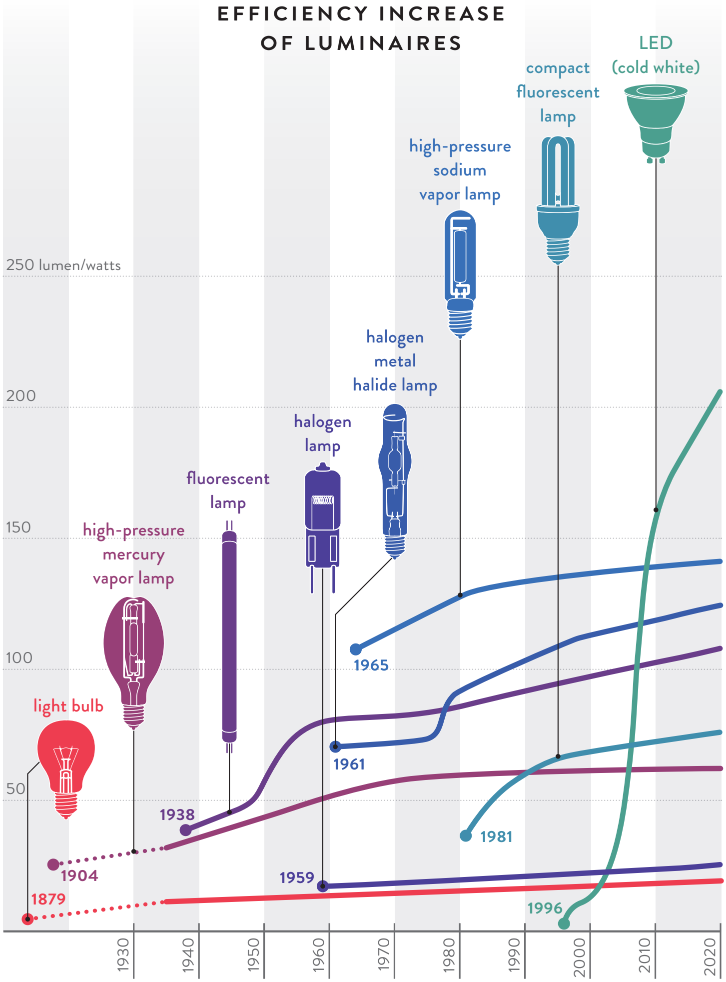
SPECTRUM OF A WHITE LED LAMP



31

BRIGHTER WITH LEDs

Since the light bulb, the light output of different types of lamps has been significantly increased. Today, white LEDs are the most efficient ones.



LAMP SPECIFICATIONS

Just a few years ago, you could find out almost everything you needed to know about the light of a domestic lamp just by looking at the number of watts. Nowadays, nearly a dozen criteria have to be considered.

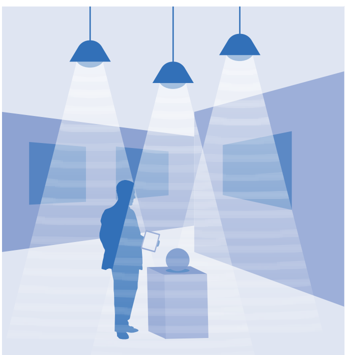
- W — **power** (watts)
  electrical connected load
- lm — **brightness** (lumens)
  how bright the lamp's light is
- T — **color temperature** (Kelvin)
  the higher the color temperature, the colder (more blue) the light
- **warm-up time**
  the time it takes for the lamp to fully light up
- **dimmability**
  lamp dimmable or not
- **shelf life**
  usage in hours
- R_a — **color rendering index**
  accuracy of color rendering
- **energy savings**
  in comparison to the conventional light bulb
- Hg — **mercury content**
  environmentally friendly without mercury
- **illumination angle**
  the scope and range of effective light

33

INTELLIGENT LUMINAIRES

LED lights can be switched on and off so quickly that it is imperceptible to the human eye. In this way, hundreds of megabytes per second can be transmitted to a mobile optical receiver as an additional function apart from the lighting – completely without electrosmog or additional cables.

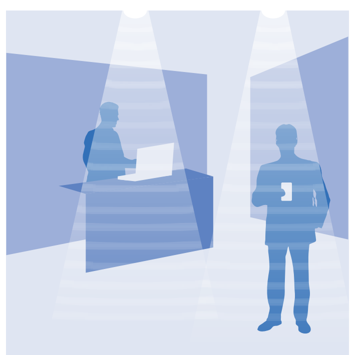
MUSEUMS



BUSES

AIRCRAFT CABINS

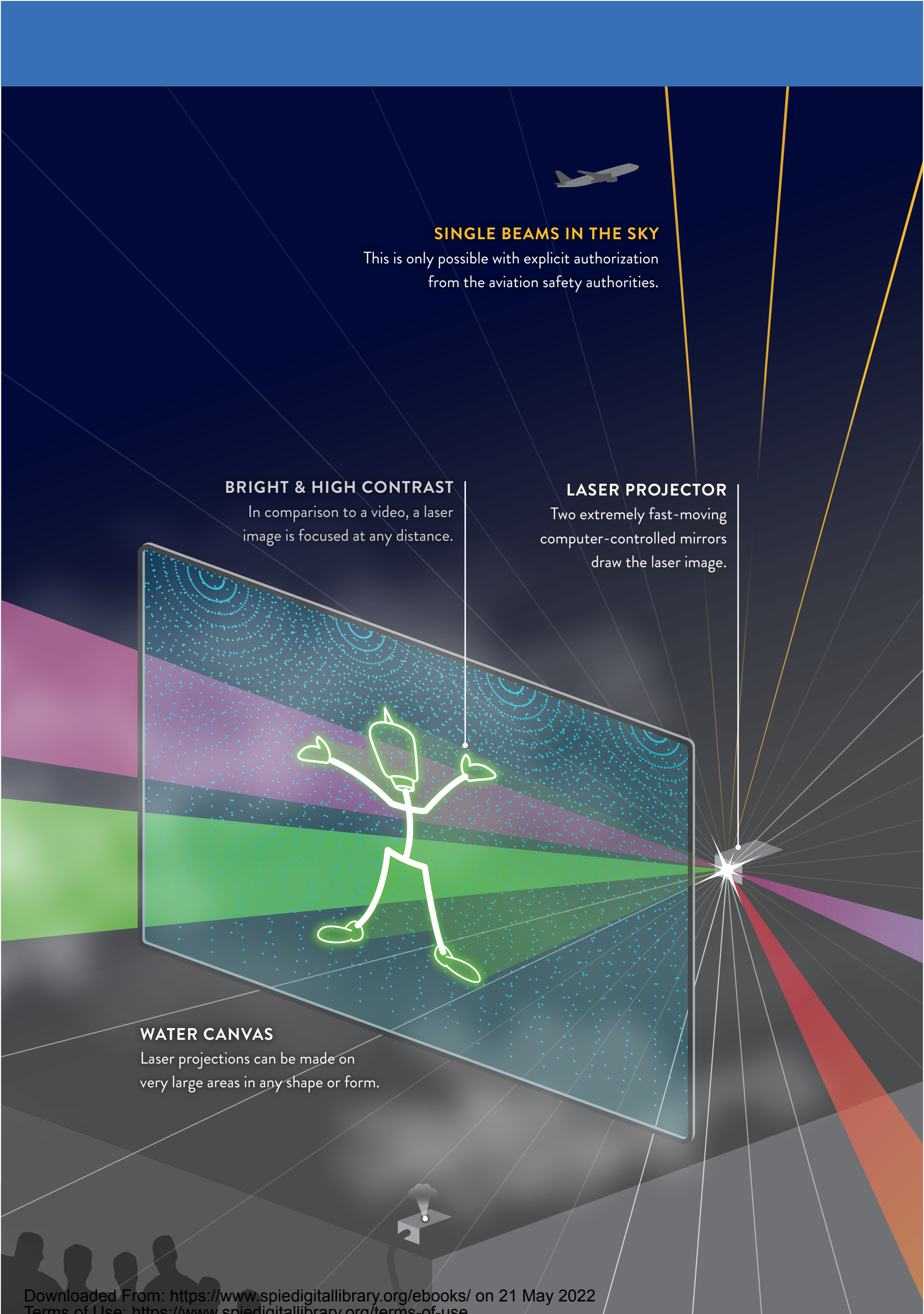
TRADE FAIR STANDS



34

LASER SHOWS

Laser shows are an impressive way of demonstrating how fascinating photonics can be.


SINGLE BEAMS IN THE SKY
This is only possible with explicit authorization from the aviation safety authorities.
BRIGHT & HIGH CONTRAST
In comparison to a video, a laser image is focused at any distance.
LASER PROJECTOR
Two extremely fast-moving computer-controlled mirrors draw the laser image.
WATER CANVAS
Laser projections can be made on very large areas in any shape or form.

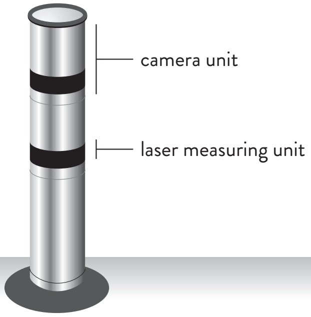
TRAFFIC

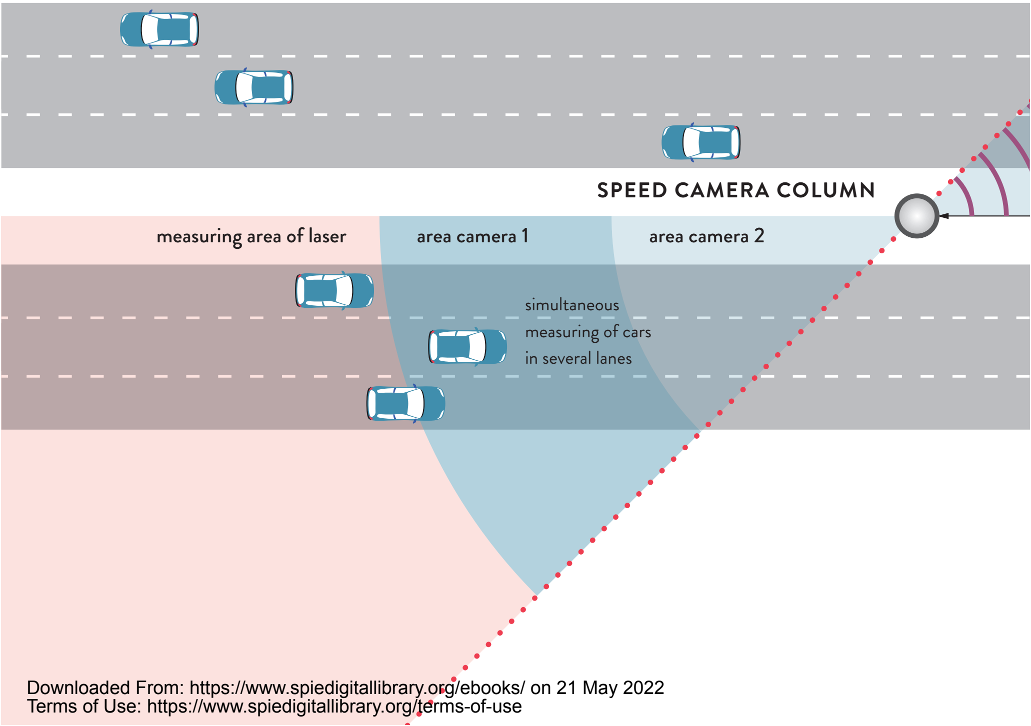
35

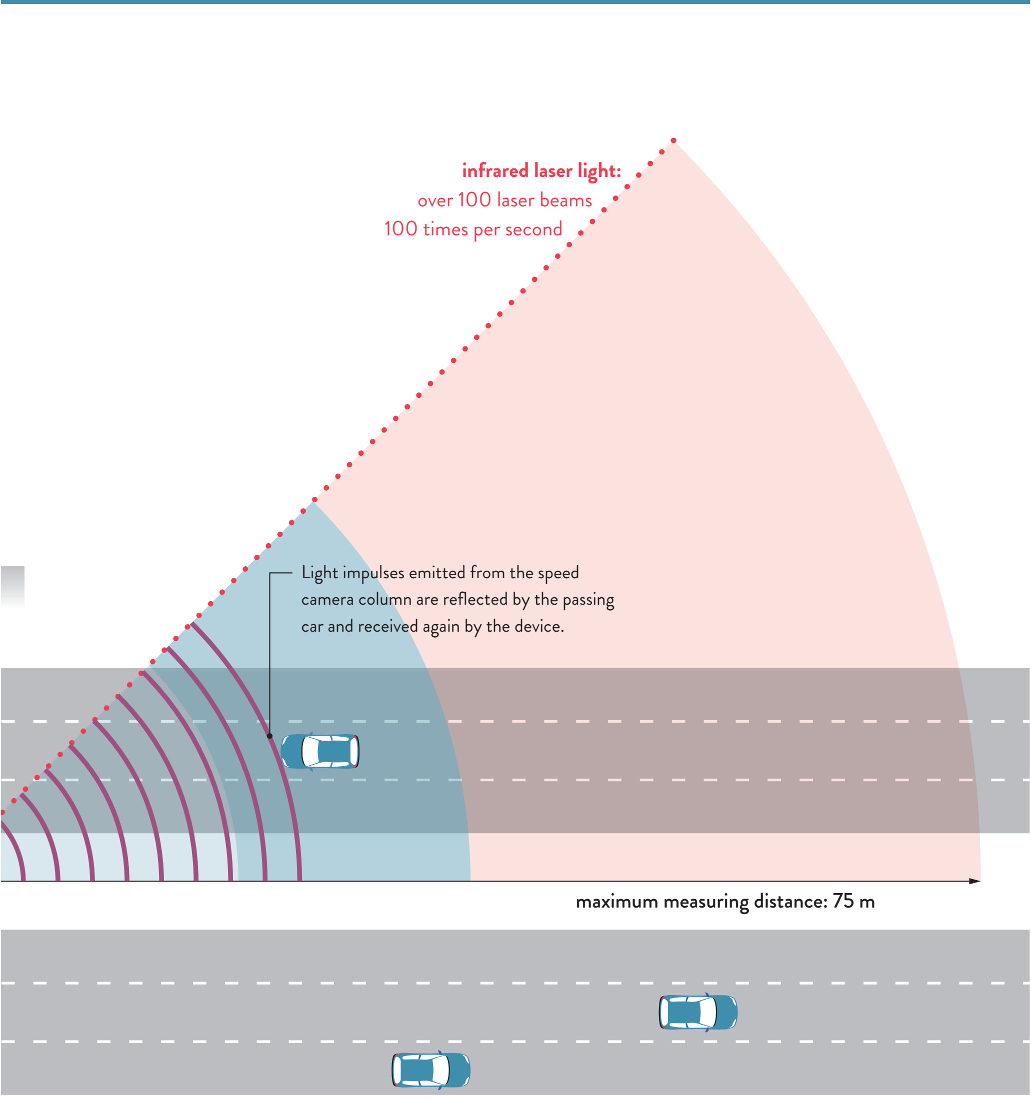
TRAFFIC ENFORCEMENT

Measuring systems based on the roundtrip time of emitted and reflected infrared laser beams can calculate the speed of vehicles precisely. Cameras take pictures of the vehicle and driver if they have committed a traffic offence.

SPEED CAMERA COLUMN UNIT





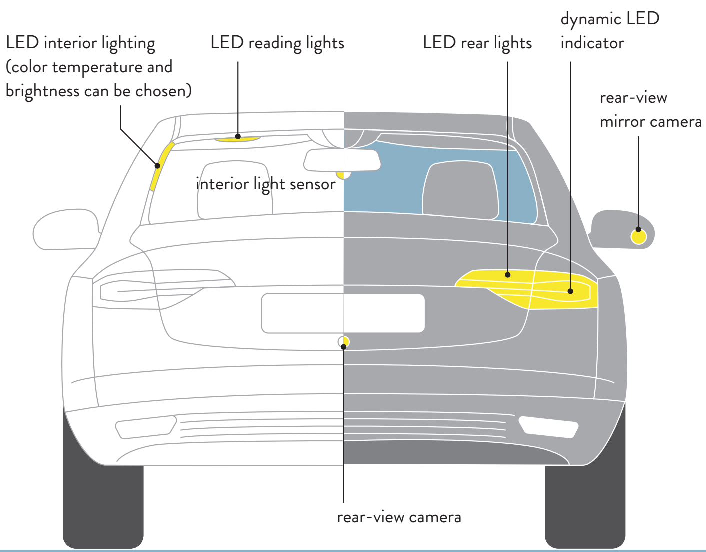

infrared laser light:
over 100 laser beams
100 times per second
Light impulses emitted from the speed camera column are reflected by the passing car and received again by the device.
maximum measuring distance: 75 m

36

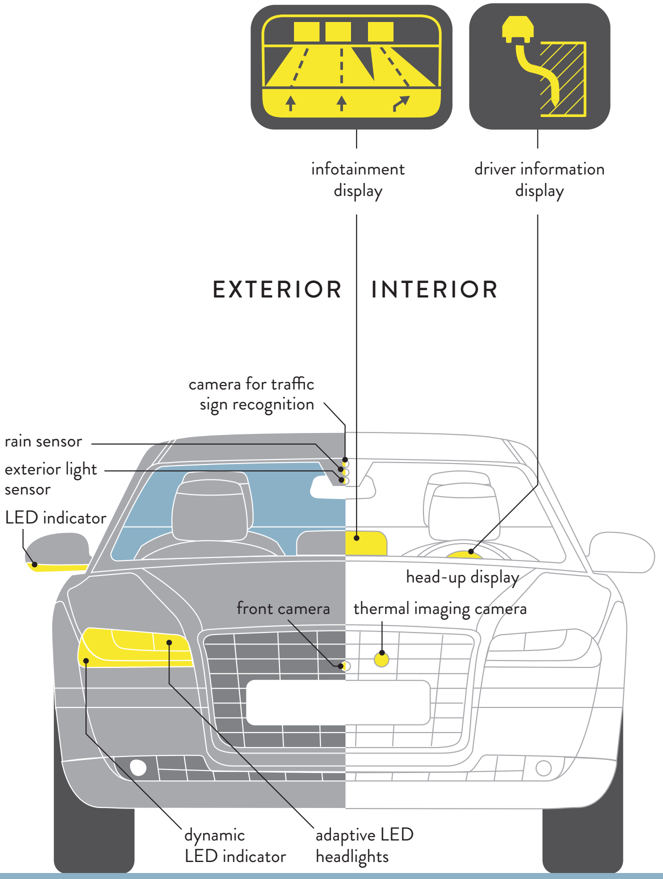
LIGHT ON AND IN THE CAR

Intelligent LED lights, camera-based assistance systems, and information displays ensure a greater security in all driving situations.

INTERIOR EXTERIOR



REAR VIEW


infotainment display
driver information display
EXTERIOR
INTERIOR
camera for traffic sign recognition
rain sensor
exterior light sensor
LED indicator
head-up display
front camera
thermal imaging camera
dynamic LED indicator
adaptive LED headlights

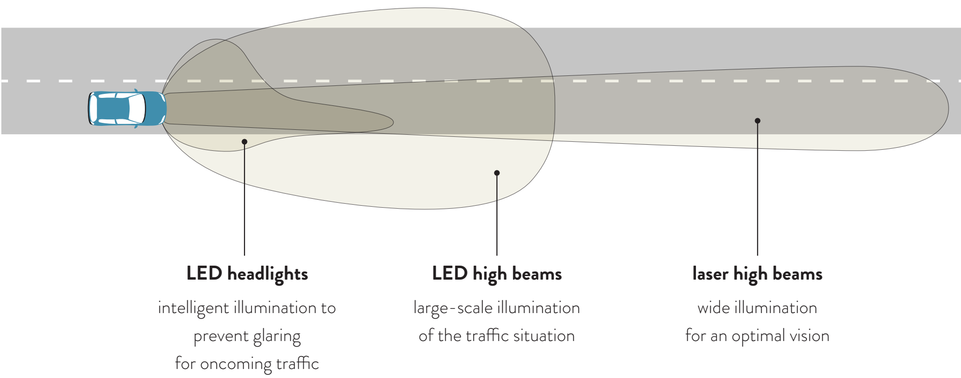
FRONT VIEW

37

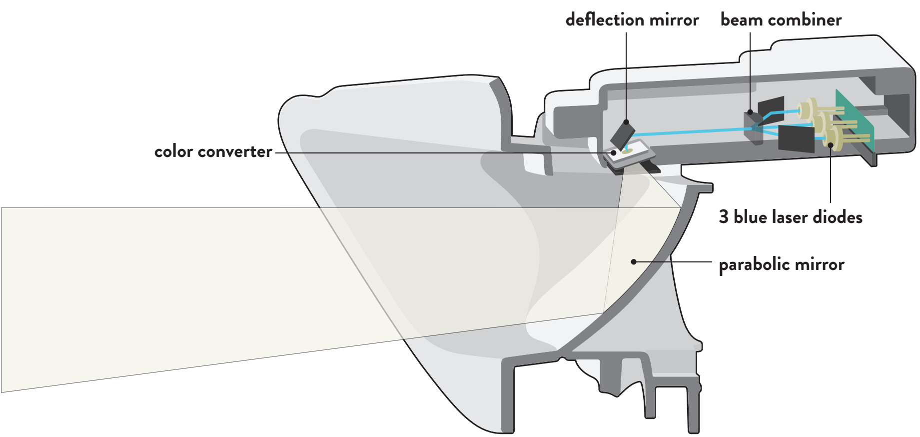
CAR HEADLIGHTS

Seeing further ahead: the combination of LED and laser light sources enables an optimum for roadway illumination in every traffic situation.

LIGHT CONE OF HEADLIGHTS



LASER HIGH BEAMS



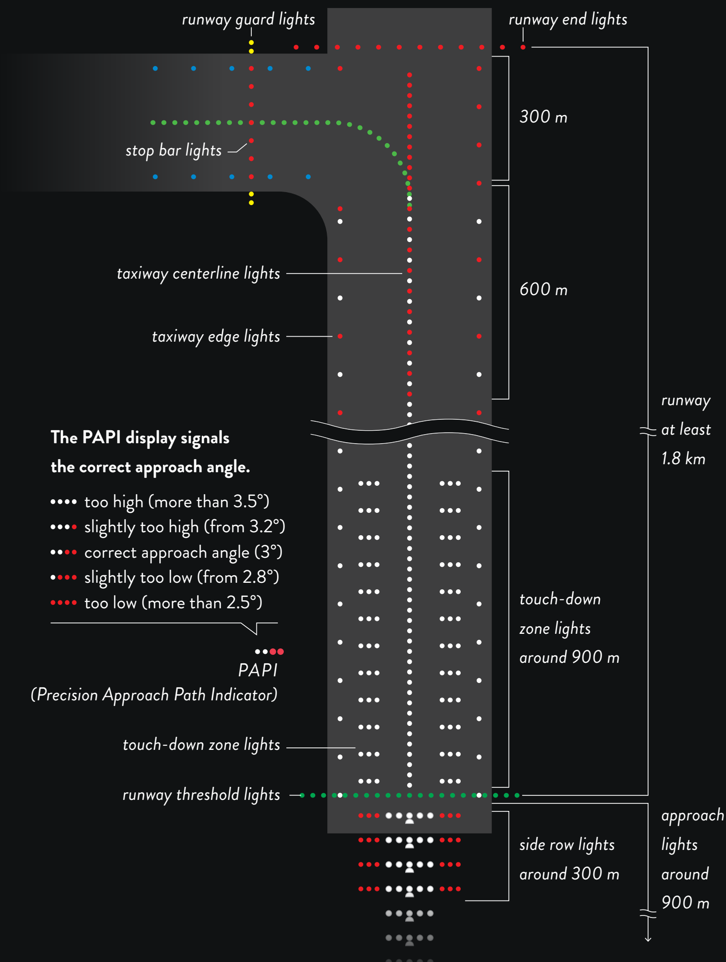
38

AIRPORT LIGHTING

Millions of new LED lamps lower the operation and maintenance costs of airports around the globe.

LED vs Halogen

	LED	Halogen
hours shelf life	60,000	2,500
typical connected load per lamp (W)	18	65

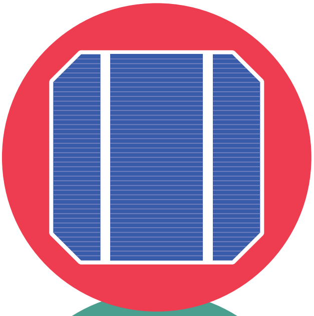


PHOTOVOLTAICS

SOLAR CELLS

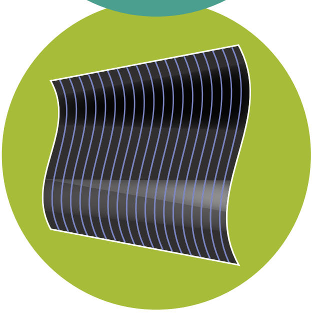
Solar cells can transform sunlight directly into electricity. An efficiency of around 45% has already been achieved under laboratory conditions. In commercial use, efficiency has to be weighed against acquisition costs.

BASIC COMMERCIAL TYPES



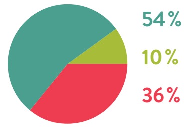
Monocrystalline silicon cells
are cut out from a round silicon crystal. The missing corners of the squares are characteristic. This form is created because the round cross section of the raw material is exploited in the best possible way.

Polycrystalline silicon cells
feature a characteristic texture that comes from crystal borders that are very close together.

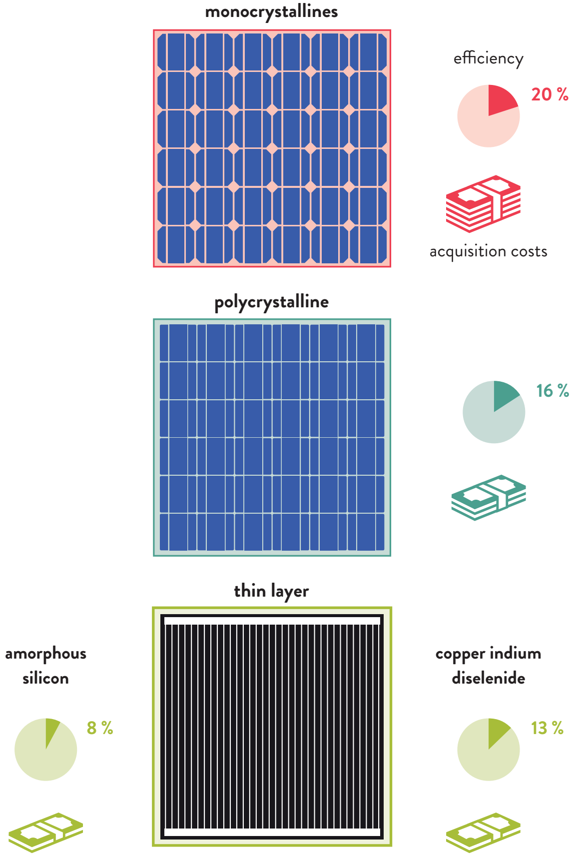


Thin-film cells
consist of amorphous silicone or other material compounds. They can be vapor deposited onto carrier materials, even onto flexible material.

GLOBAL MARKET SHARE



CHARACTERISTICS



40

SOLAR ENERGY

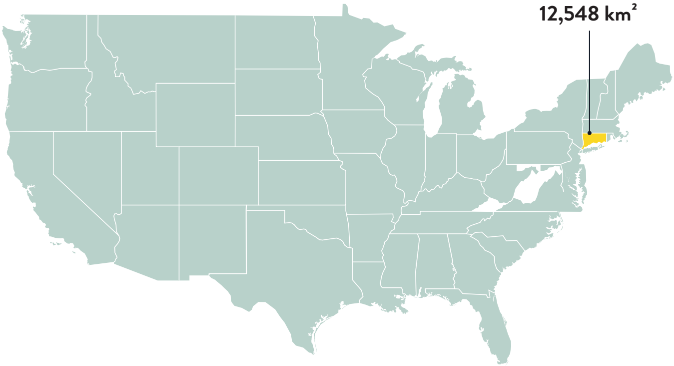
Solar energy has the potential to satisfy the world's raising appetite for electricity without polluting the environment. What total size of solar power plants would be needed to run the United States on solar electricity?

US electricity consumption per year: 4093 TWh (2014)

Area of solar cells needed to supply this energy:

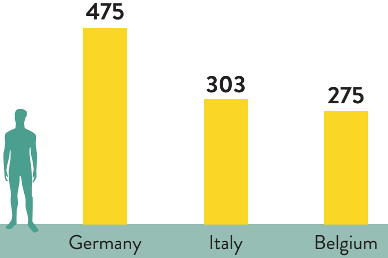
12,800 km²

This roughly equals the land area of the US state of Connecticut.



TOP PRODUCERS

installed power 2014 per capita in watts



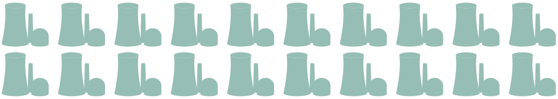
PRODUCTION COMPARISON 2014

World photovoltaic energy per year

180 Terawatt hours
= 180,000,000,000 kilowatt hours

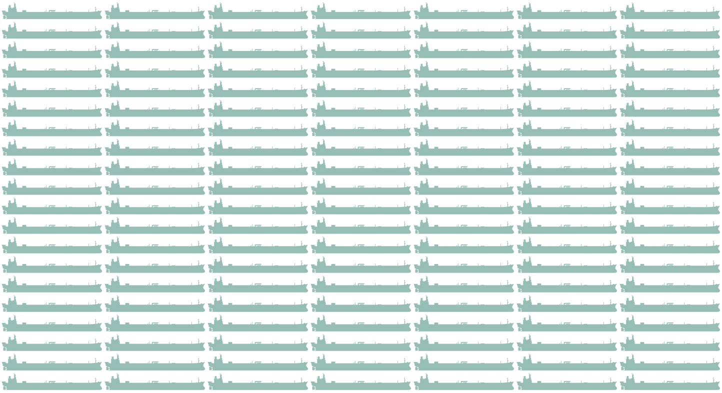
Nuclear energy

The photovoltaic energy produced corresponds to the electricity volume of 20 nuclear power stations.



Crude oil

With regard to petroleum, the equivalent is 42 million tons. This amount corresponds to 140 oil tankers with a capacity of 300,000 GRT each.*



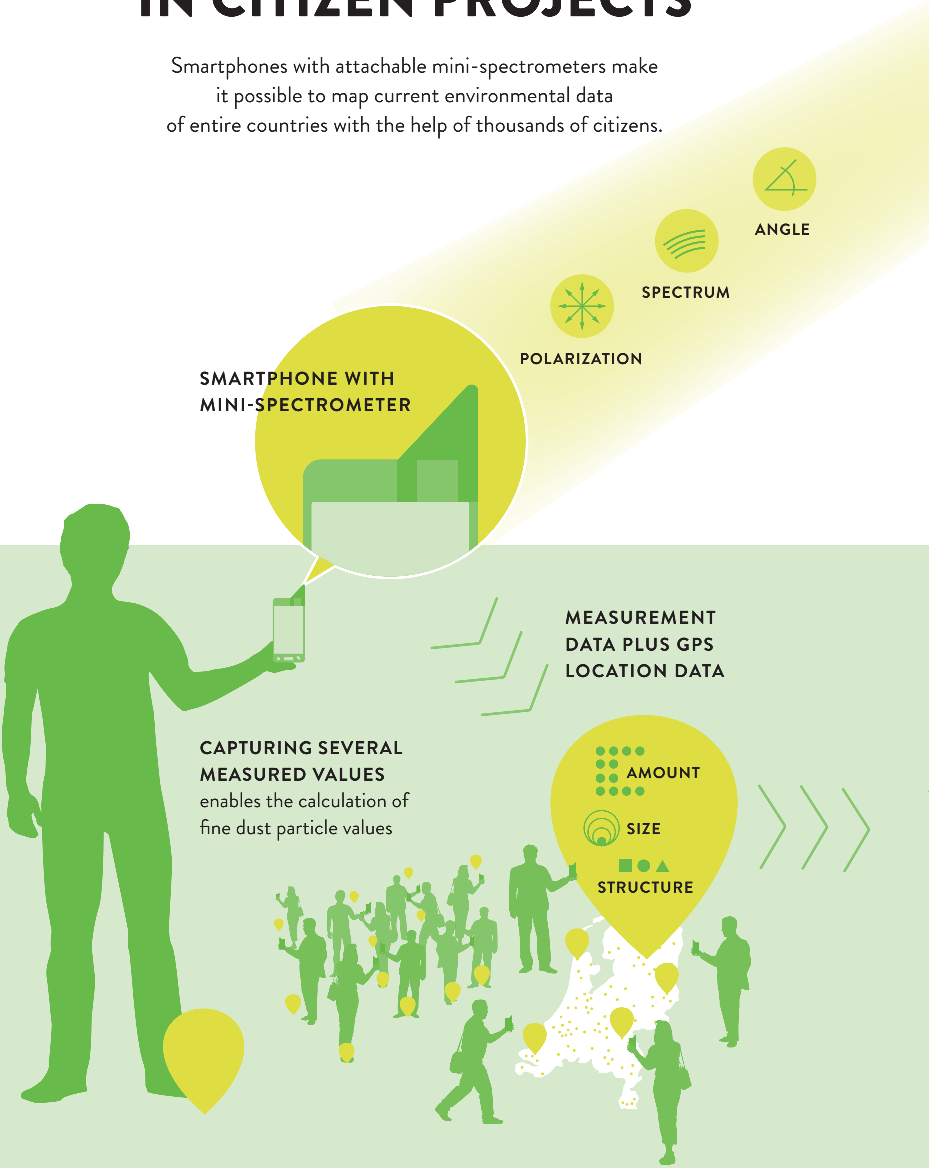
* *gross register tons*

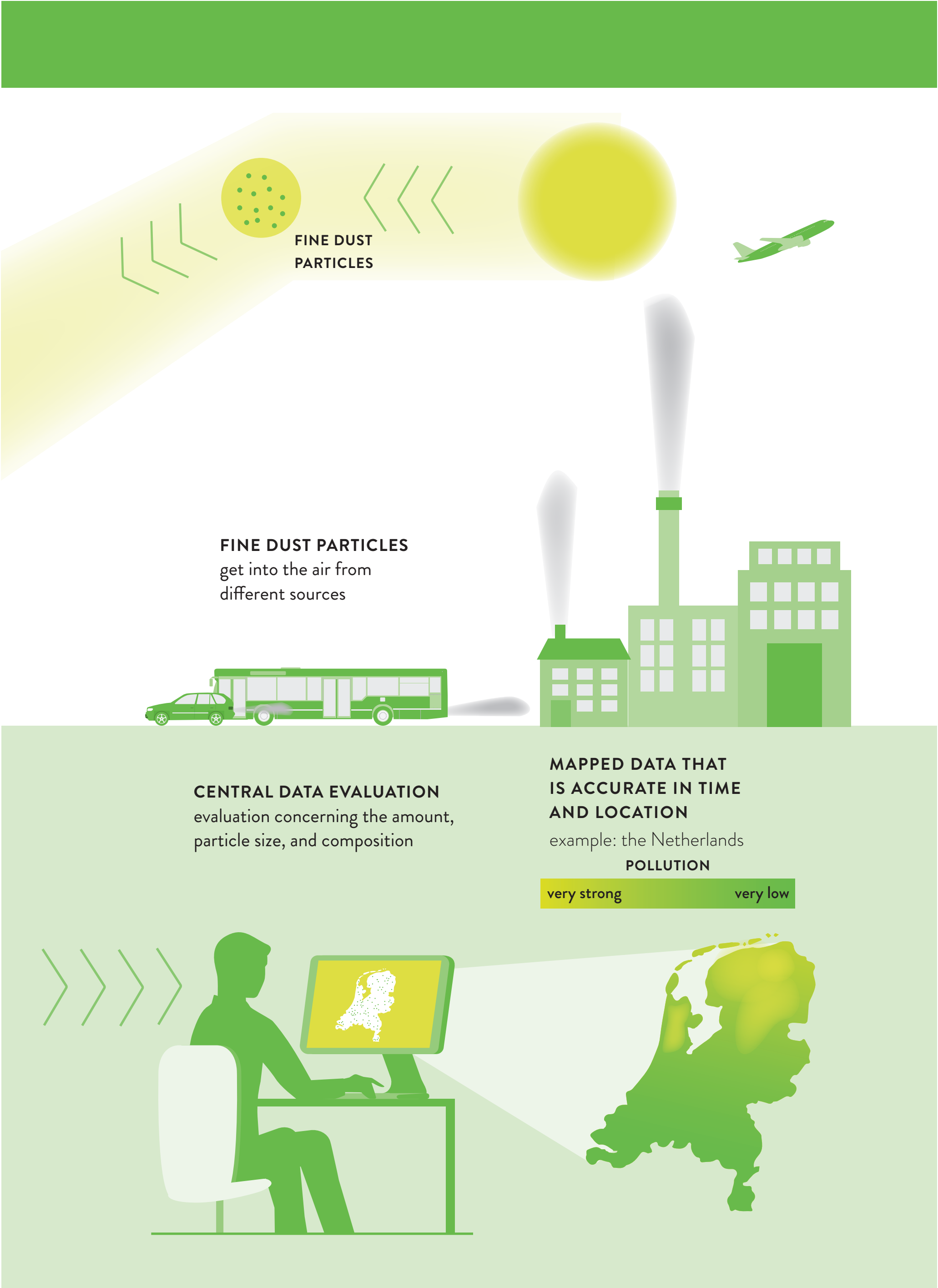
ENVIRONMENT

41

OPTICAL MEASUREMENTS IN CITIZEN PROJECTS

Smartphones with attachable mini-spectrometers make it possible to map current environmental data of entire countries with the help of thousands of citizens.



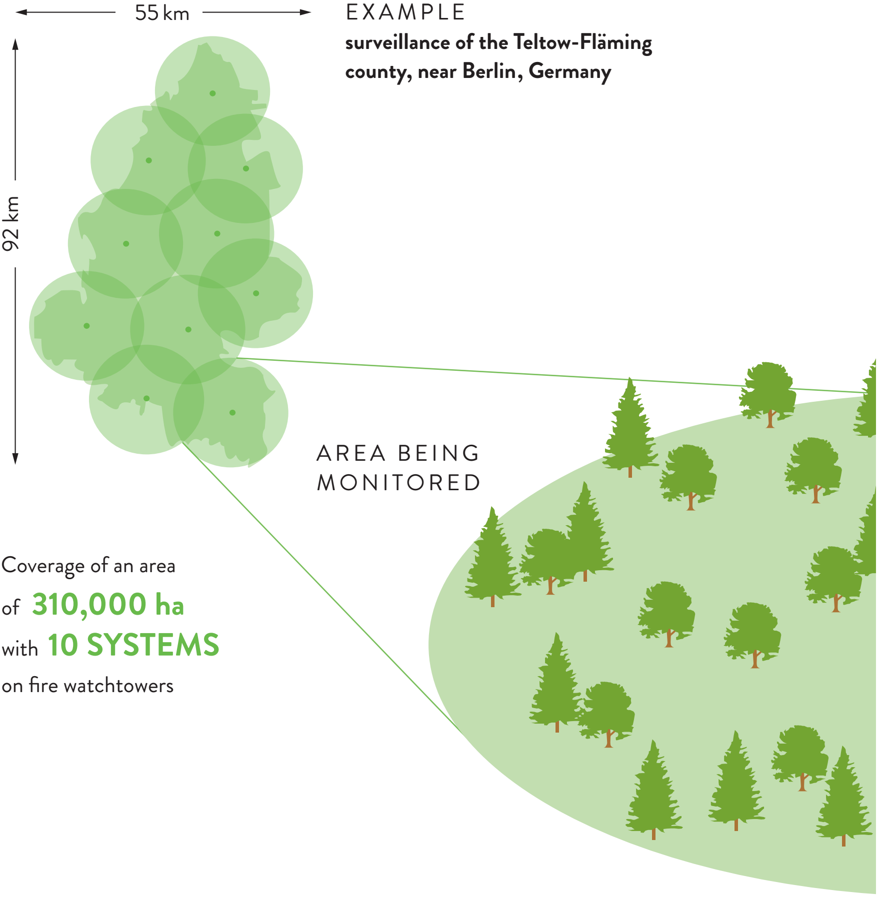

FINE DUST
PARTICLES
FINE DUST PARTICLES
get into the air from
different sources
CENTRAL DATA EVALUATION
evaluation concerning the amount,
particle size, and composition
MAPPED DATA THAT
IS ACCURATE IN TIME
AND LOCATION
example: the Netherlands
POLLUTION
very strong
very low

42

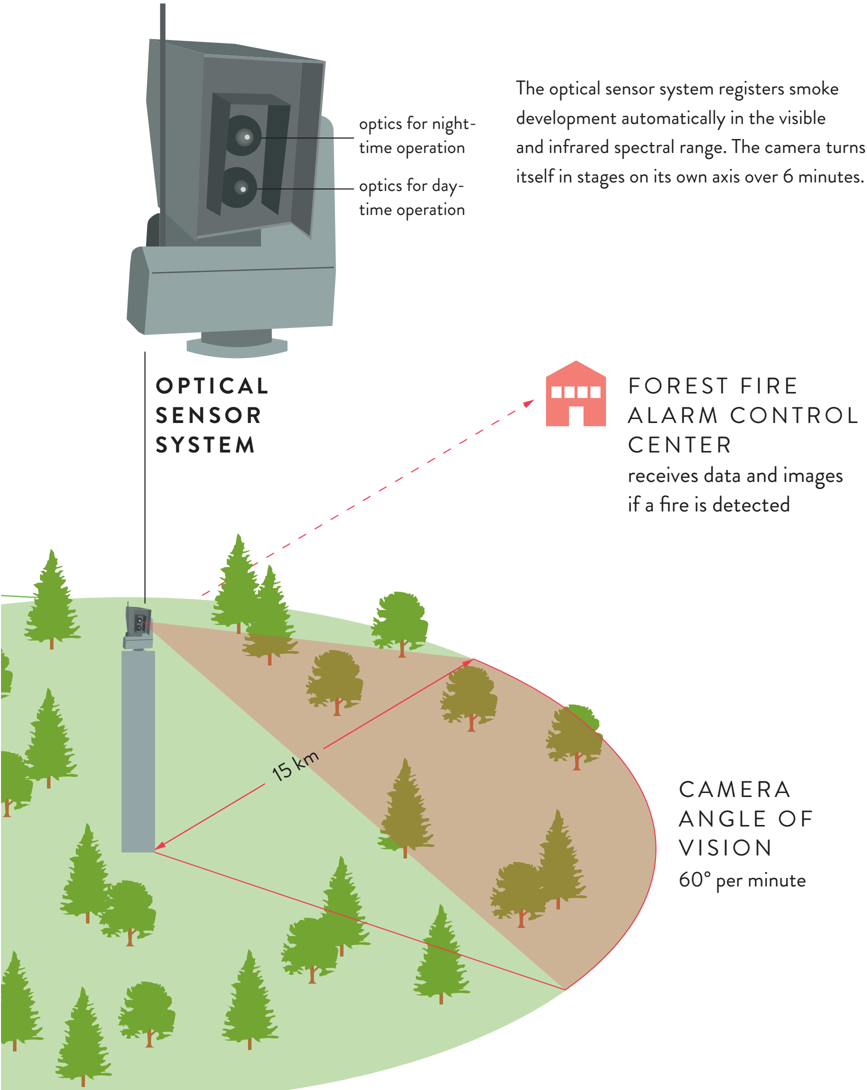
FOREST FIRE SURVEILLANCE

Automated optical sensor systems monitor large forest areas day and night for fires.

EXAMPLE
surveillance of the Teltow-Fläming county, near Berlin, Germany



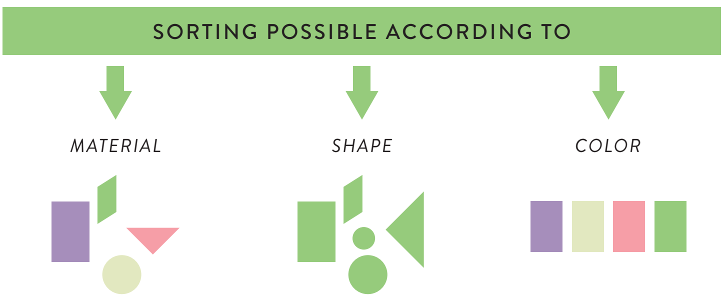
Coverage of an area of **310,000 ha** with **10 SYSTEMS** on fire watchtowers


The optical sensor system registers smoke development automatically in the visible and infrared spectral range. The camera turns itself in stages on its own axis over 6 minutes.
optics for night-time operation
optics for day-time operation
OPTICAL SENSOR SYSTEM
FOREST FIRE ALARM CONTROL CENTER
receives data and images if a fire is detected
15 km
CAMERA ANGLE OF VISION
60° per minute

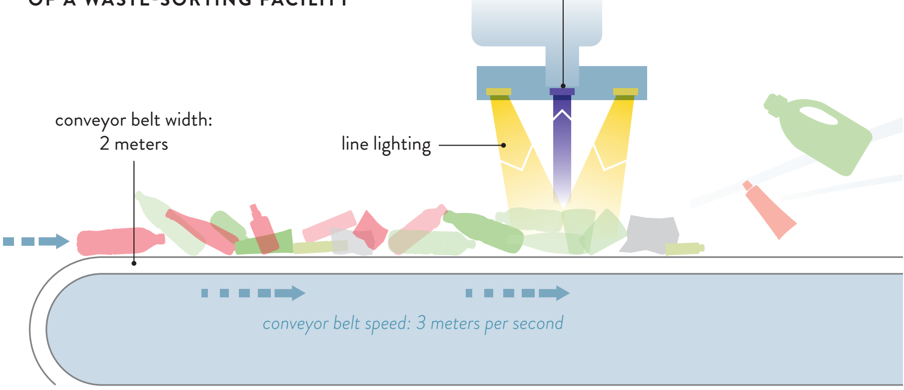
43

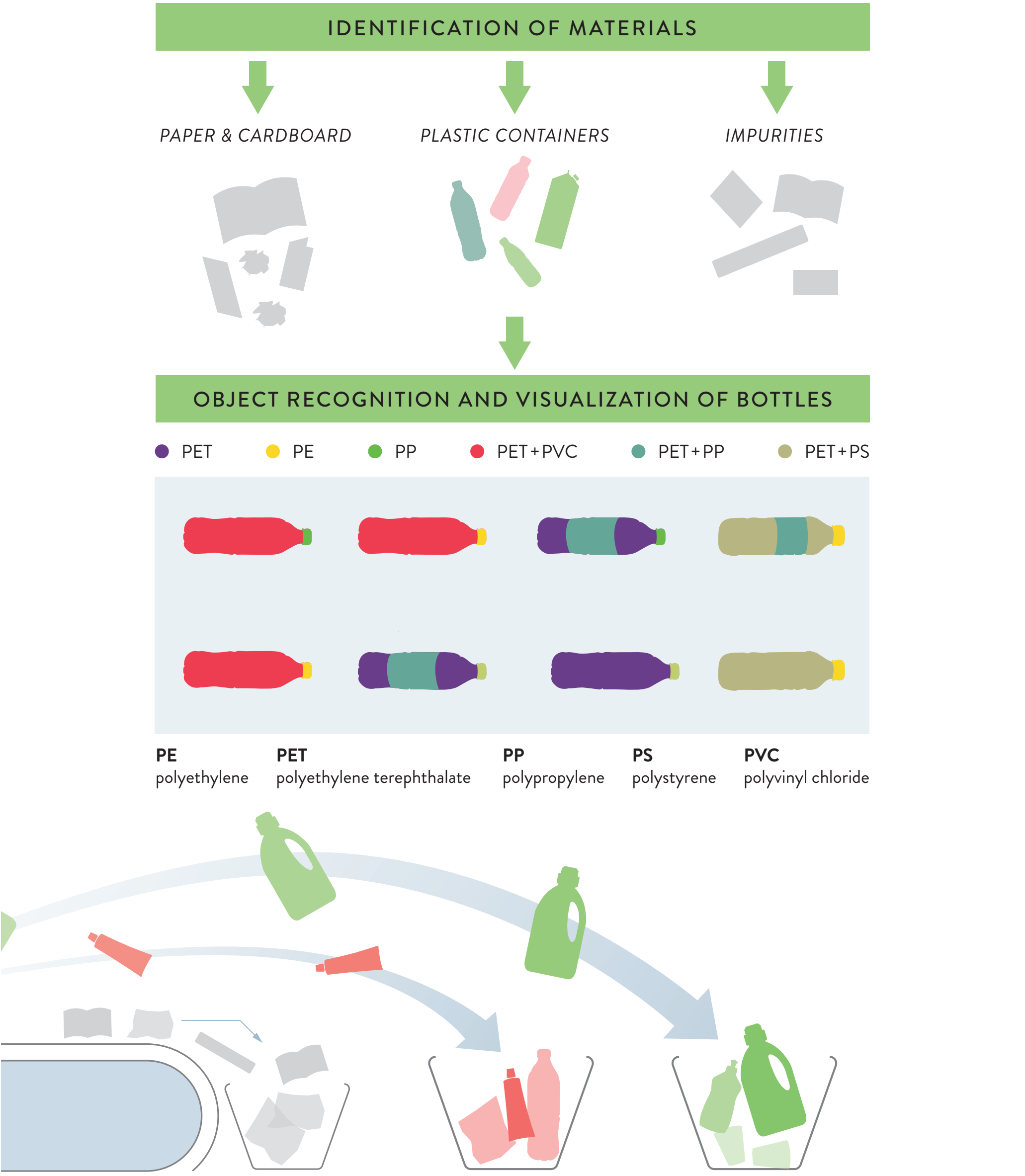
OPTICAL SORTING

Efficient sorting facilities are used to recover many materials in their raw form from heaps of domestic waste. Together with fast image processing software, multispectral cameras capture within a split second what should be placed in which raw material container.



SCHEMATIC REPRESENTATION OF A WASTE-SORTING FACILITY




IDENTIFICATION OF MATERIALS
PAPER & CARDBOARD
PLASTIC CONTAINERS
IMPURITIES
OBJECT RECOGNITION AND VISUALIZATION OF BOTTLES
PET
PE
PP
PET+PVC
PET+PP
PET+PS
PE
polyethylene
PET
polyethylene terephthalate
PP
polypropylene
PS
polystyrene
PVC
polyvinyl chloride

RESEARCH & ECONOMY

44

PHOTONICS AS AN INDUSTRY SECTOR

Within a few decades, the term photonics has developed from a technical term, used in research, to an industry term that encompasses all technical applications of light.

Photonik GERMAN

Fotónica SPANISH

Фотоника RUSSIAN

Photonique FRENCH

フォトニクス JAPANESE

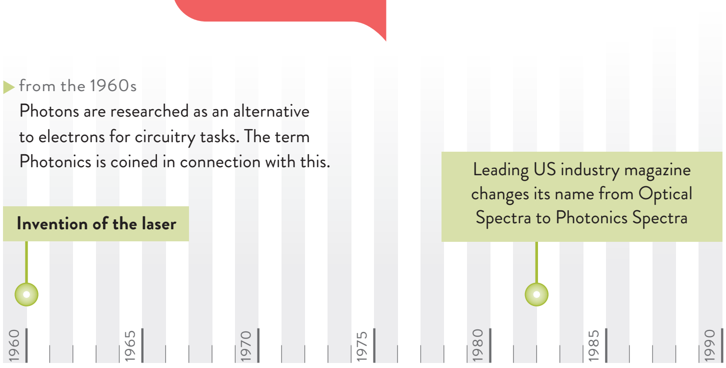
光子学 CHINESE

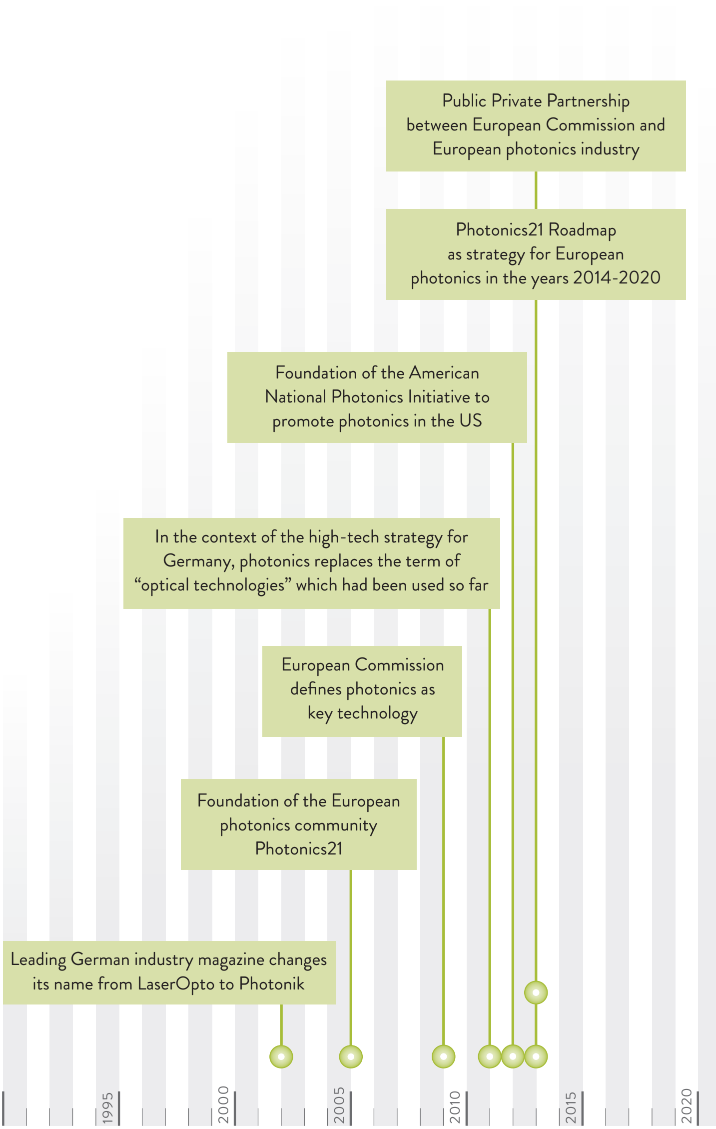
Fotonica ITALIAN

Fotônica PORTUGUESE

포토닉스 KOREAN

Photonics ENGLISH

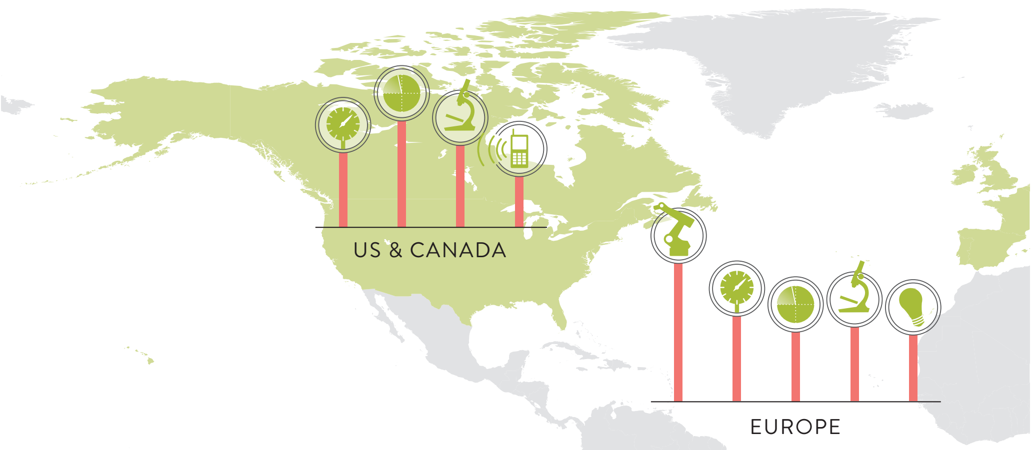



Public Private Partnership between European Commission and European photonics industry
Photonics21 Roadmap as strategy for European photonics in the years 2014-2020
Foundation of the American National Photonics Initiative to promote photonics in the US
In the context of the high-tech strategy for Germany, photonics replaces the term of “optical technologies” which had been used so far
European Commission defines photonics as key technology
Foundation of the European photonics community Photonics21
Leading German industry magazine changes its name from LaserOpto to Photonik
1995
2000
2005
2010
2015
2020

45

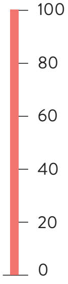
PHOTONICS AROUND THE GLOBE

Photonics is a global industry today. This graphic shows the strongest market segments in each region.



Global market share in the market segment
(information in %)

To emphasize regional strengths, only market shares of more than 10% are shown.

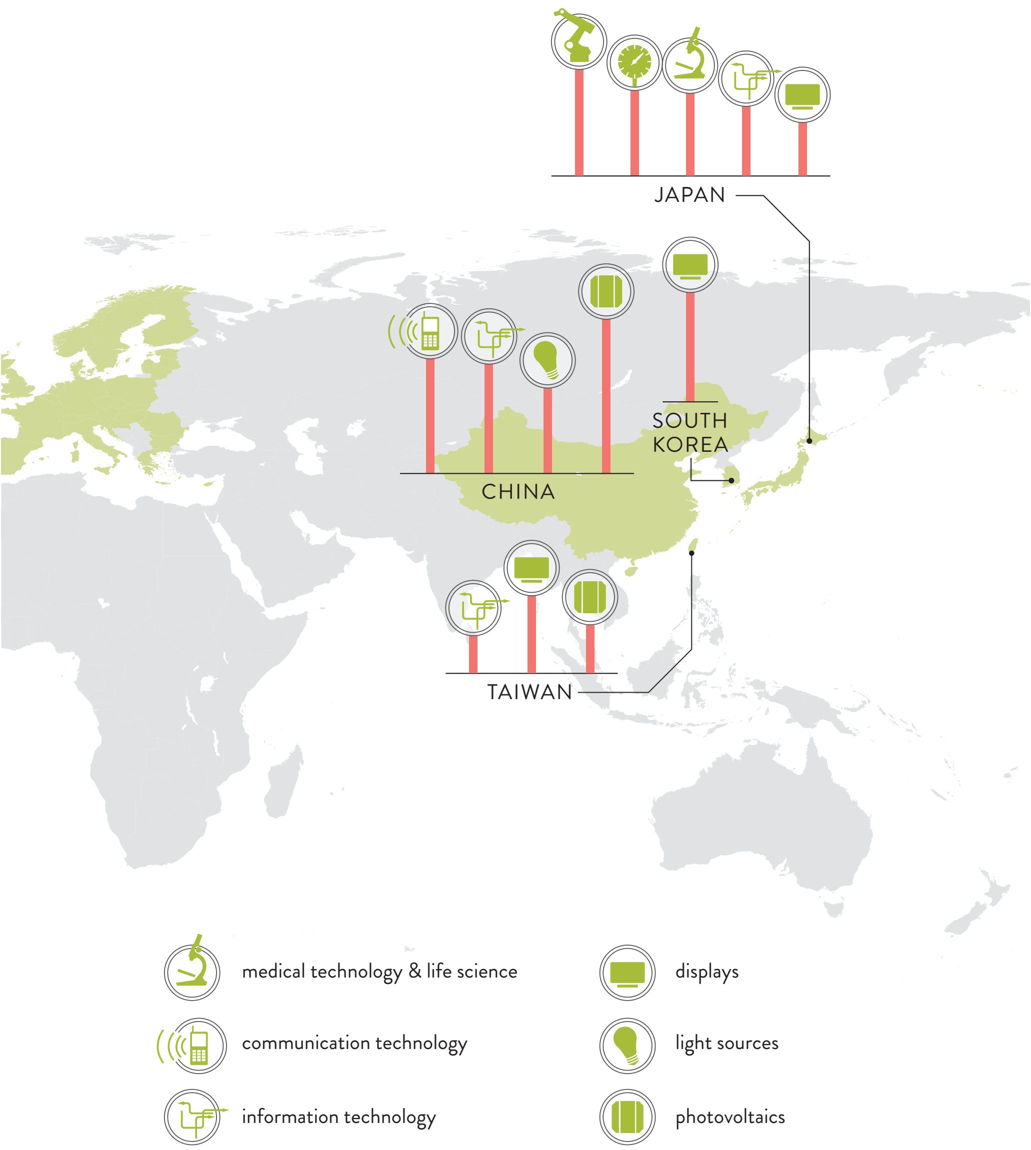


Market segments

production technology

image processing & metrology

security & defense technology

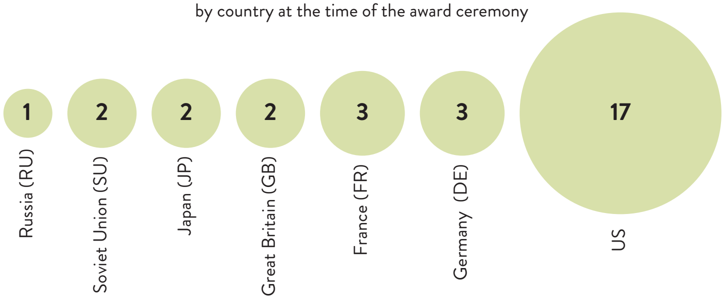

JAPAN
SOUTH KOREA
CHINA
TAIWAN
medical technology & life science
communication technology
information technology
displays
light sources
photovoltaics

46 NOBEL LAUREATES

Nobel laureates with a connection to photonics since the invention of the laser in 1960

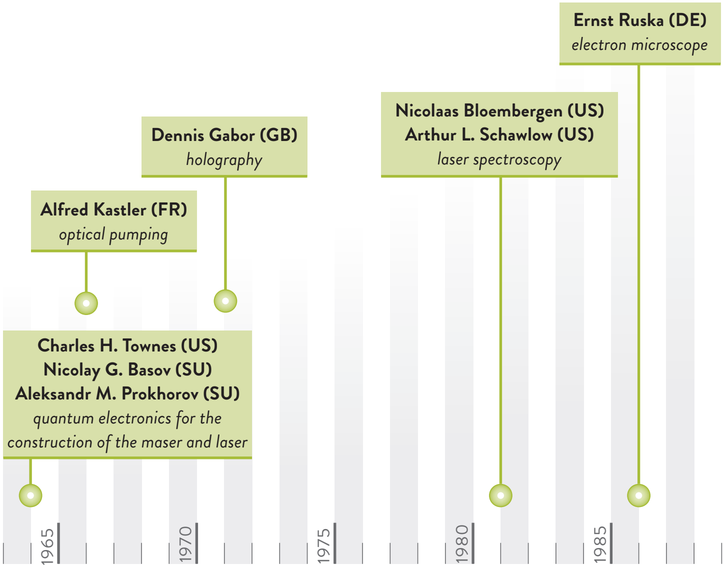
NUMBER OF LAUREATES

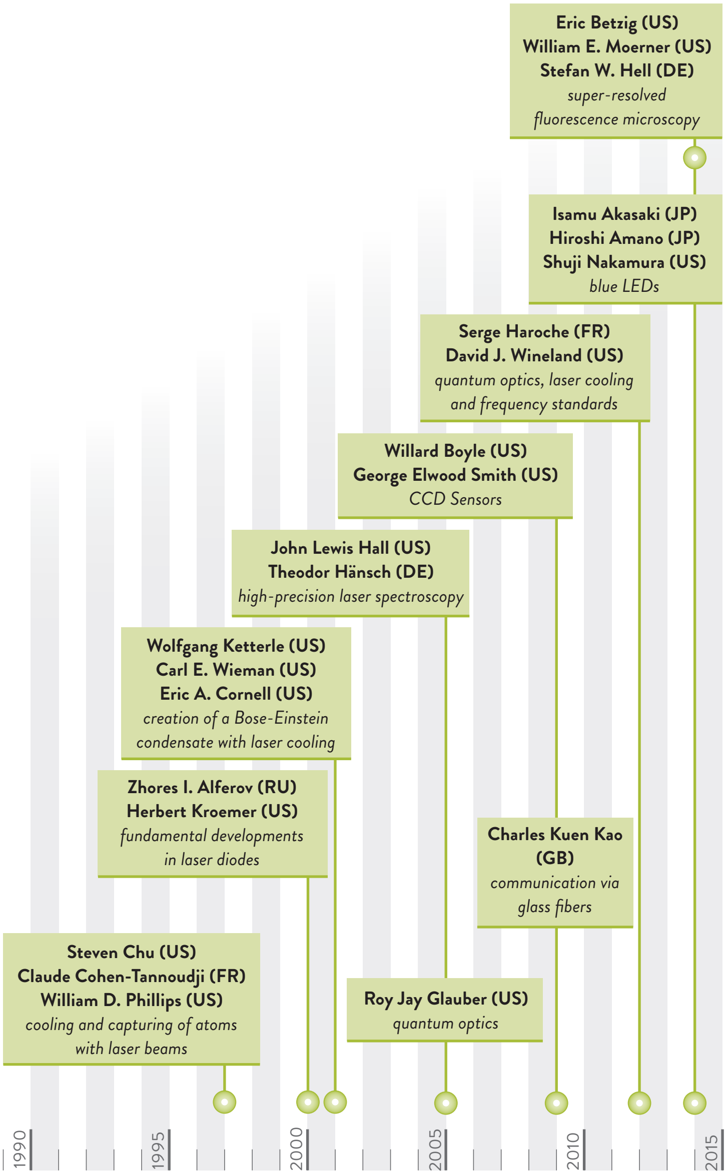
by country at the time of the award ceremony



NOBEL LAUREATES

with award-winning research projects



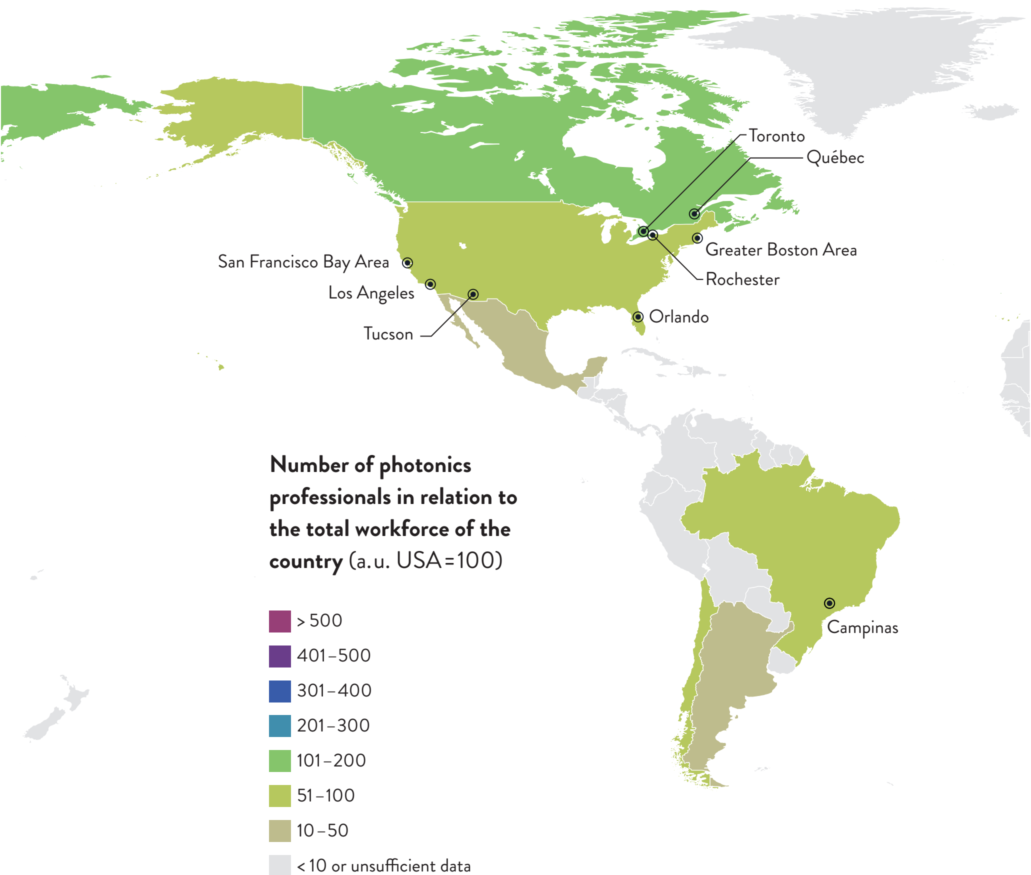


Eric Betzig (US)
William E. Moerner (US)
Stefan W. Hell (DE)
super-resolved fluorescence microscopy
Isamu Akasaki (JP)
Hiroshi Amano (JP)
Shuji Nakamura (US)
blue LEDs
Serge Haroche (FR)
David J. Wineland (US)
quantum optics, laser cooling and frequency standards
Willard Boyle (US)
George Elwood Smith (US)
CCD Sensors
John Lewis Hall (US)
Theodor Hänsch (DE)
high-precision laser spectroscopy
Wolfgang Ketterle (US)
Carl E. Wieman (US)
Eric A. Cornell (US)
creation of a Bose-Einstein condensate with laser cooling
Zhores I. Alferov (RU)
Herbert Kroemer (US)
fundamental developments in laser diodes
Charles Kuen Kao (GB)
communication via glass fibers
Steven Chu (US)
Claude Cohen-Tannoudji (FR)
William D. Phillips (US)
cooling and capturing of atoms with laser beams
Roy Jay Glauber (US)
quantum optics
1990
1995
2000
2005
2010
2015

47

PHOTONICS COUNTRIES

The highest density of photonics professionals are found in Europe and East Asia.



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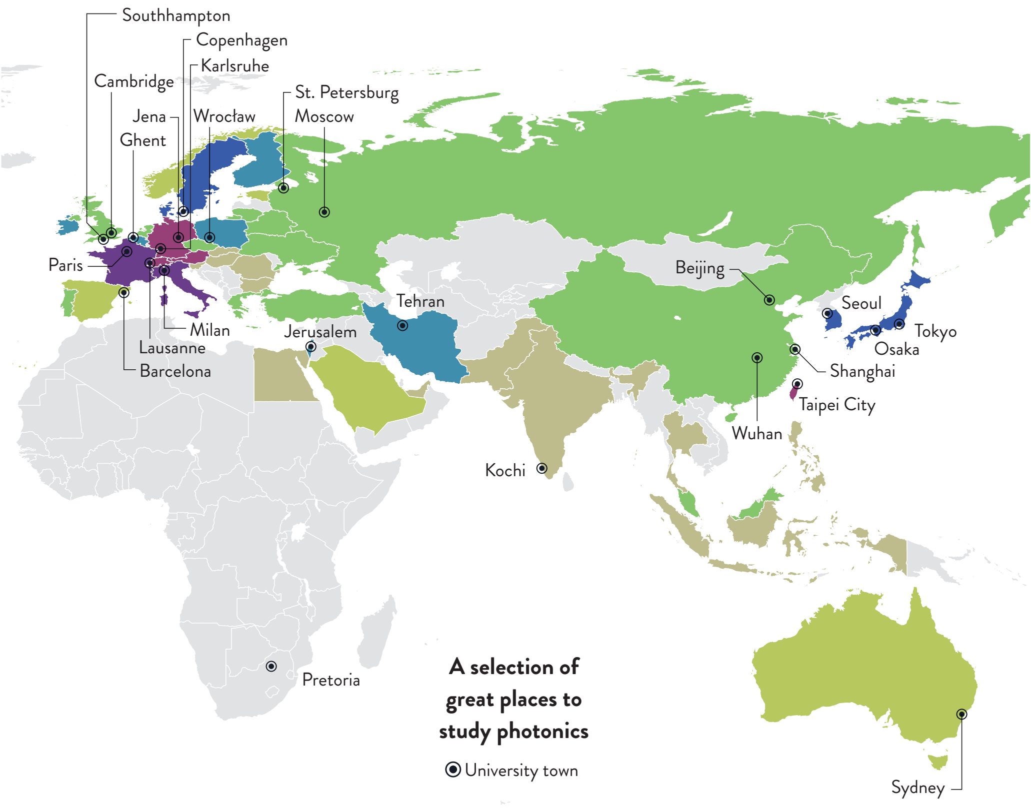
PHOTONICS SCHOOLS

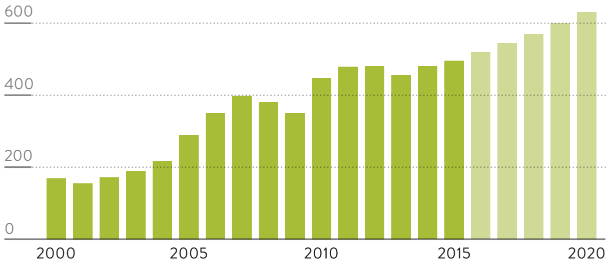
Business-oriented social media reveal where photonics-savvy professionals got their education.



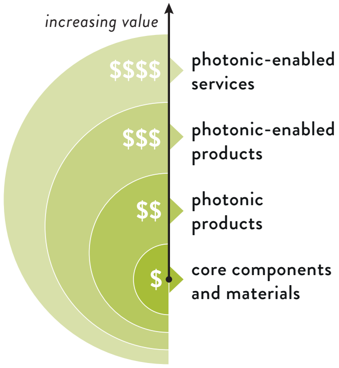
ECONOMIC IMPACT OF PHOTONICS

Data suggests that there were approximately 2.32 million jobs in photonics in 2015.

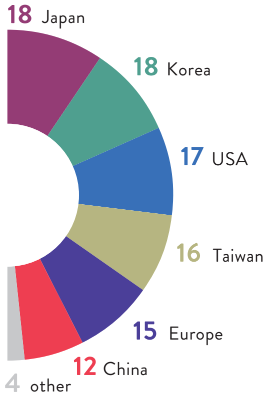
Worldwide photonics products market
in US-$ bn.



Photonics marketplace
from components to enabled services



Market by country
share of market in %

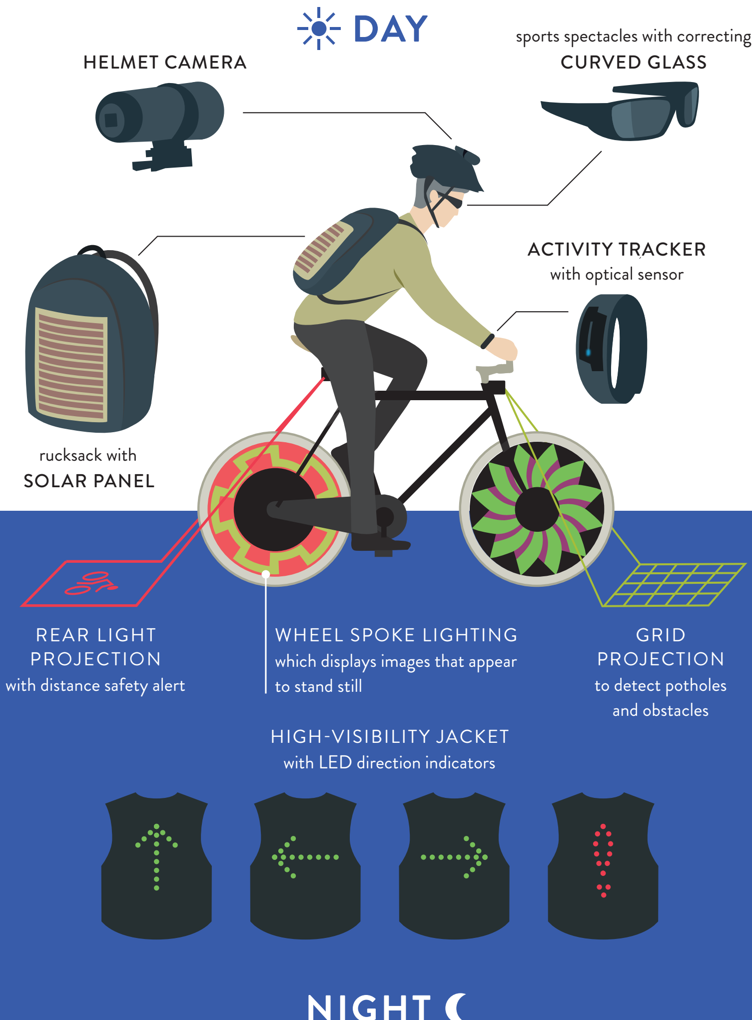


+1

50

PHOTONICS ENTHUSIAST

An enthusiasm for photonics can also
be implemented in the leisure sector.



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