What is light?

Light is a type of electromagnetic wave. It is composed of electric and magnetic fields that vibrate at a right angle to the direction of propagation. The wavelength of light is measured by the distance between two wave crests and is also characterized by its frequency. Light does not require a medium to spread out. When travelling through a vacuum, it moves at the speed of light – the highest possible speed (299 792 458 m/s). Light also has the properties of a particle. We call the individual packets of light photons. The energy of an individual photon depends on the light wave's frequency. The greater the frequency and the shorter the wavelength, the higher its energy.

The human eye is capable of seeing light at wavelengths between approximately 400 nm and 700 nm (nanometres – one nm is equal to one billionth of a metre). The range visible to the human eye is only a tiny section of the electromagnetic spectrum. It ranges from radio waves with a length of several kilometres, to gamma rays that are measured on the scale of picometres (1 pm is a one-thousandth of a billionth metre).

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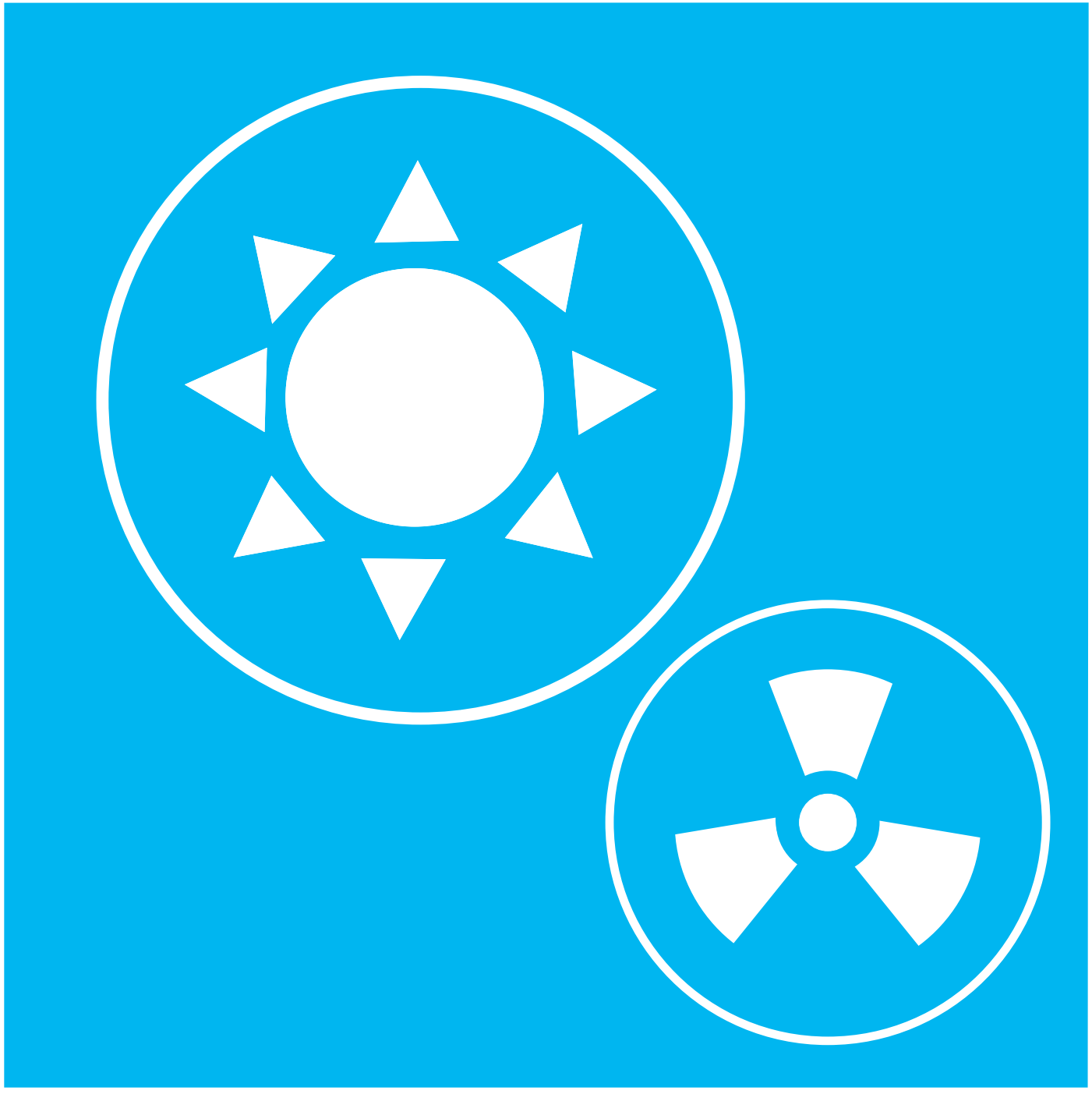
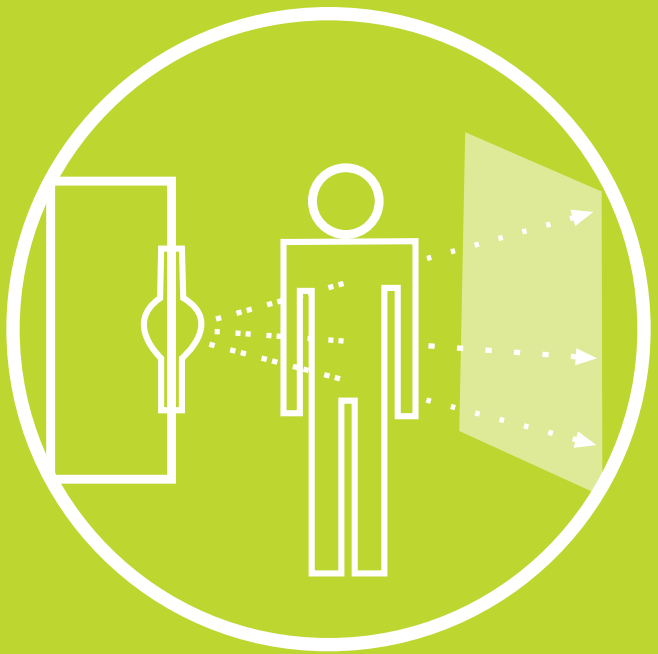
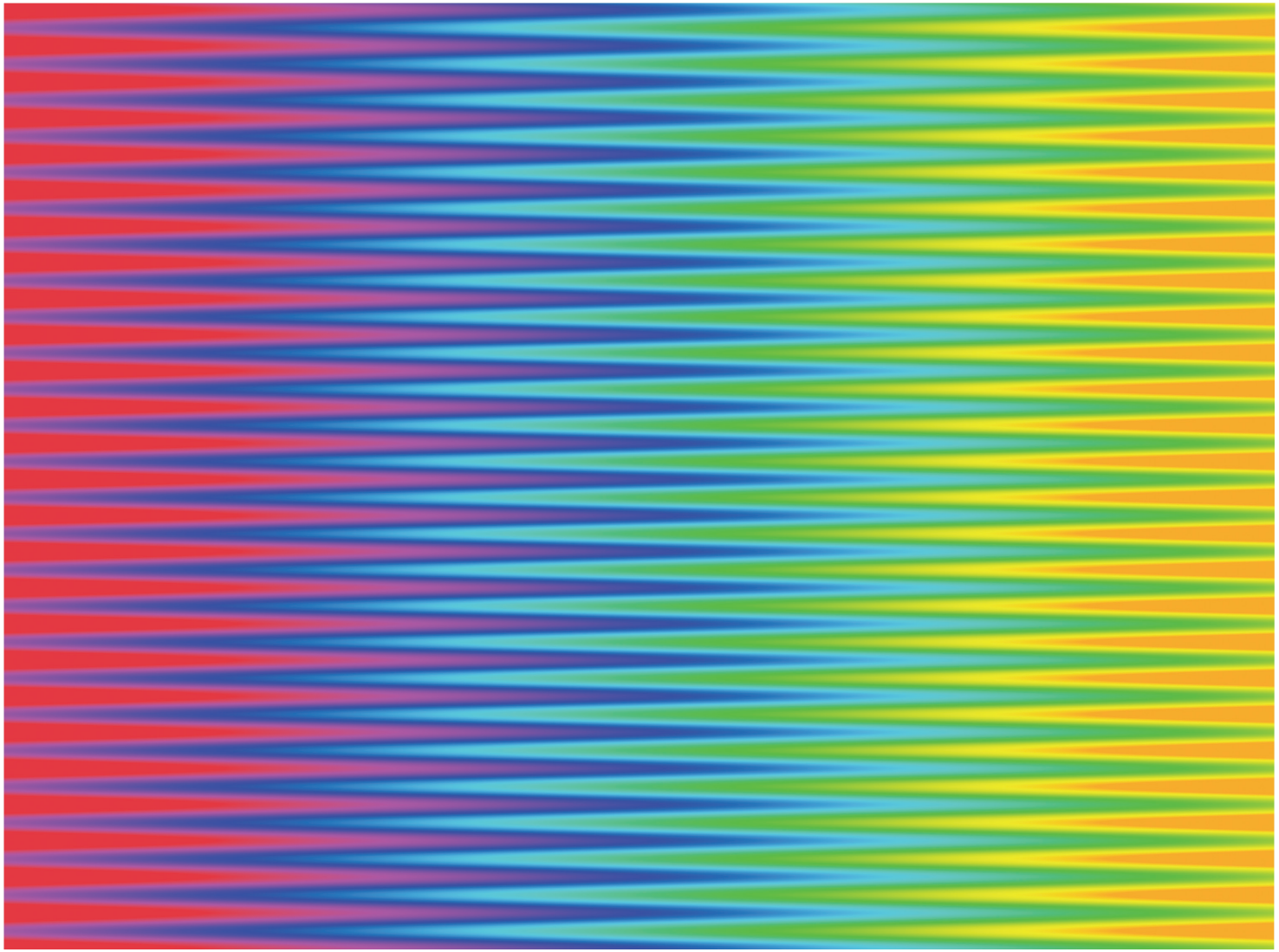




Berlin Adlershof



JUST THE PLACE FOR BRIGHT IDEAS
Our contribution to the International Year of Light
and Light-based Technologies

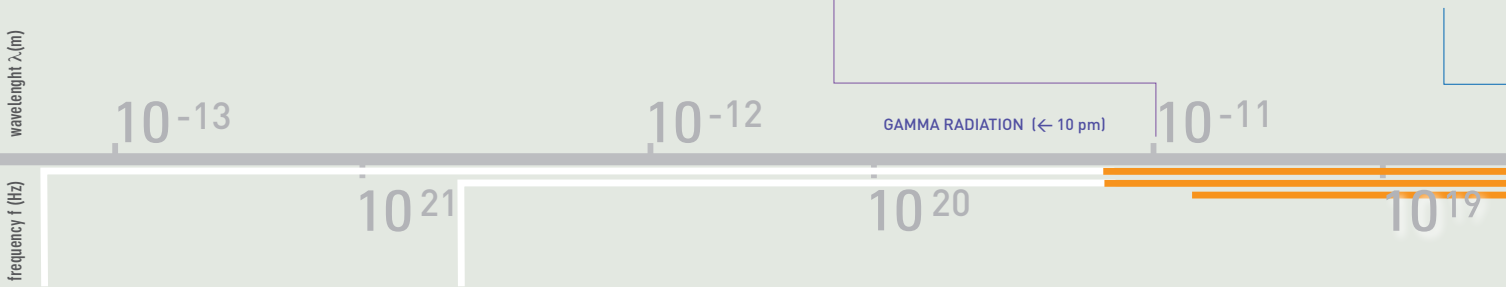
Adlershof. Science at Work.

Just the place for bright ideas!

The General Assembly of the United Nations has declared 2015 the "International Year of Light and Light-based Technologies". Electromagnetic waves are the basis of key technologies such as radio, radar, and wireless communication. Whether in medical diagnostics, mobile phones, or microwave ovens – light-based technology pervades our everyday life. Adlershof, Germany's largest science and technology park, ranks among the world's leading sites for research and development of light-based technologies. It is currently home to six research institutes and 70 companies that are active in photonics, optics, and photovoltaics. They cover almost the entire electromagnetic spectrum – from hard X-rays to radio waves.

GAMMA RADIATION (< 10 pm)
When heavy atomic nuclei (those found in uranium) disintegrate into smaller chunks, they release fragments of their surplus energy as gamma rays. This process can be observed in natural radioactivity, in nuclear reactors, during the burst of an atomic bomb, and also when matter and antimatter collide. Gamma rays can easily pass through materials composed of heavy elements. They are very dangerous to living organisms due to their ability to break chemical bonds and destroy vitally important cells. However, they have useful properties that are used in radiation therapy, in food conservation, and sterilisation of medical equipment.

X-RADIATION (10 pm – 1 nm)
is also called Röntgen radiation – named after its discoverer Wilhelm Conrad Röntgen. X-rays are emitted when an electron is knocked out of the inner part of a metal atom, when fast electrons are abruptly stopped or accelerated, or when they fly at very high velocity in a circular path. X-rays not only provide us with images from the inside of our bodies, but also with pictures of the atomic structure of matter. Ultra-short hard X-ray pulses allow us to observe the movement of atoms in crystals or chemical reactions in real time. X-rays are also used in optical lithography to produce microchips and integrated circuits.



The **BAM Federal Institute for Materials Research and Testing (BAM)** in Adlershof focuses on materials research and materials testing with the aim of advancing security in engineering and chemistry. This also involves optical methods and procedures which are able to detect, for example, residue in foods, the flow behaviour of concrete, and the efficiency of light-emitting diodes.
www.bam.de

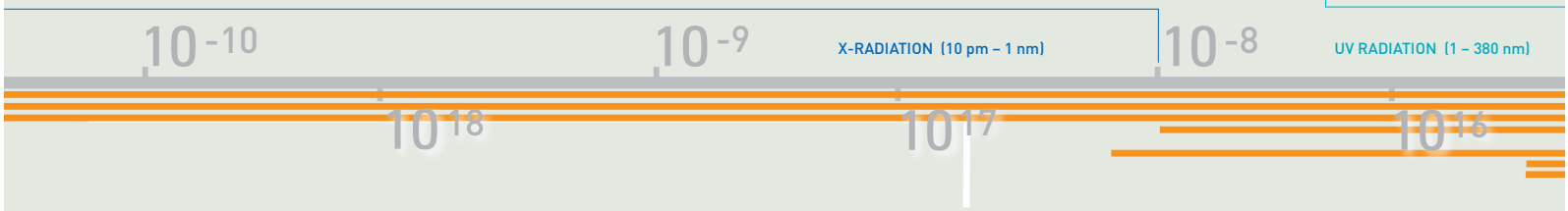
The **Helmholtz-Zentrum Berlin für Materialien und Energie (HZB)** explores complex material systems and contributes to, for instance, overcoming challenges such as the transition to renewable energy in Germany ("Energiewende"). Key areas of research are materials for thin-film photovoltaics and for the conversion of solar energy into chemical energy carriers (e.g. molecular hydrogen and complex materials for future energy storage technologies).

The **Electron Storage Ring BESSY II at HZB** in Adlershof accelerates electrons to near speed of light (300,000 km/s). Strong magnets force the electrons to travel in a circular path with a 240 metre perimeter. This results in the emission of intense "synchrotron"-light that is highly collimated due to the extreme high-speed of the electrons. The produced light covers a large spectral region spanning the terahertz (THz), the vacuum-ultraviolet (VUV), and the X-ray range.
www.helmholtz-berlin.de

The HZB, in cooperation with the Max-Planck-Society, is currently building the laboratory **EMIL (Energy Materials In-situ Laboratory Berlin)**. It serves to analyse materials for producing regenerative energy in order to develop better thin-film solar cells, energy storage and catalysts.
www.helmholtz-berlin.de

PRODUKTE UND LEISTUNGEN: **Astro- und Feinwerktechnik Adlershof GmbH**: Camera heads for use in aviation, black body radiators, radiation resistant optical technology for use in aerospace, calculation of light scattering, simulation of scattering surfaces, construction of light scattering lens hoods, environmental tests of aerospace components and systems (www.astrofein.com) // **Bruker Nano GmbH:** X-ray analysis systems and components for elemental and structural analysis on the micro and nano-scale (www.bruker-nano.de) // **IfG Institute for Scientific Instruments GmbH:** One of the world's leading manufacturers of X-ray capillary optics and devices for X-ray analytics (www.ifg-adlershof.de) // **LTB Lasertechnik Berlin GmbH:** Short-pulse lasers covering the entire optical spectral range, metal-ceramic laser tubes, high resolution echelle spectrometer and laser-based measurement technology; areas of application include lasers for mass spectrometry, materials analysis using LIBS, spectrometer for developing and manufacturing, spectrometer used for development and

UV RADIATION (1 – 380 nm)
is invisible to the human eye. The sun radiates ultraviolet rays which are largely absorbed by the earth's ozone layer. Longwave ultraviolet radiation (UV-A, 320 – 380 nm) significantly precipitates skin ageing. Ultraviolet radiation between 280 and 320 nm (UV-B) is the cause of sunburn, while also stimulating the production of vitamin D which plays an important role in osteogenesis. UV stimulation makes atoms and molecules emit fluorescent light. Fluorescence occurs when atoms and molecules transform invisible light into visible light. Fluorescent patterns can be found on paper money and stamps. Finally there are high-performance lasers in the ultraviolet range.

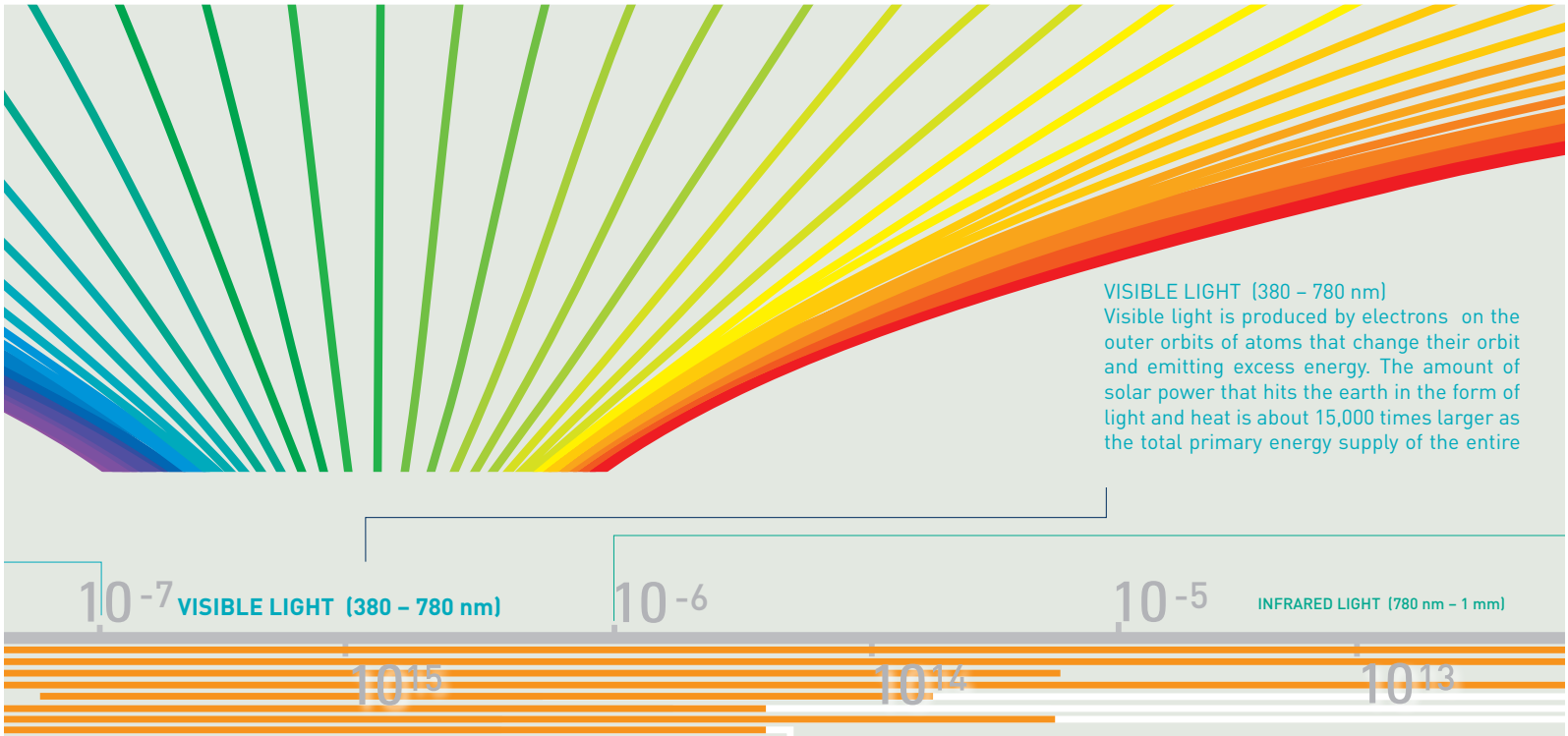


The **Competence Centre Thin-Film- and Nanotechnology for Photovoltaics Berlin (PVcomB)** develops thin-film photovoltaics technology and products in cooperation with partners in the industry. It operates production lines for silicon-based thin-film modules and for solar cells based on copper, indium, gallium, and selenide. www.helmholtz-berlin.de

The **Physikalisch-Technische Bundesanstalt (PTB)**, Germany's national metrology institute, uses its electron storage ring Metrology Light Source (MLS) as dedicated source for metrology in the spectral ranges from the Terahertz (THz) to the extreme ultraviolet (EUV) regime. The applications cover radiometric calibrations as well as characterisation of optical components for EUV lithography, space-based instrumentation and nanometrology. By use of synchrotron radiation from the MLS and BESSY II up to the X-ray spectral range, PTB offers a broad scope of services and contracted research for industry and science. www.ptb.de

The **Max-Born-Institut für Nonlinear Optics and Short Pulse Spectroscopy (MBI)** conducts basic research in the field of nonlinear optics and ultrafast dynamics of the interaction of light and matter, and explores resulting aspects of application. It develops and uses ultrafast and ultra-intense lasers and laser-driven short-pulse light sources in a broad spectral range ranging from hard X-rays, to visible light, to terahertz rays combined with methods of non-linear spectroscopy. www.mbi-berlin.de

manufacturing of laser diodes and laser-based lithography (www.ltb-berlin.de) // **art photonics GmbH**: A worldwide leader in Broad Spectra Fiber Solutions from 180 nm to 18 µm, manufacturing of spectroscopy probes, laser cables and bundles including unique Mid IR-fibers for 2 - 17 µm range and customized fiber systems for industrial, scientific and medical applications (www.artphotonics.com) // **eagleyard Photonics GmbH:** Singlemode Emitter, Multimode Laser, Gain Chips and Amplifiers, DFB and DBR lasers, leading market position for high-power laser diodes covering wavelengths from 630 nm - 1120 nm; cooperation in research projects on terahertz quantum-cascade laser and GaN laser (www.eagleyard.com) // **greateyes GmbH:** Scientific cameras for imaging and spectroscopy covering the range from X-ray to near-infrared for application in imaging and spectroscopy, electroluminescence and photoluminescence inspection systems (www.greateyes.de) // **Forth Dimension Displays Ltd:** High-resolution microdisplays / SLMs for near-to-eye (NTE) applications, 3D metrology and



The researchers at the **Physics Department of the Humboldt-Universität zu Berlin (HU)** focus on the fundamentals of light-matter interaction. Research questions include: How can quantum systems on the nanometre scale be controlled by light (in order to determine first components of future quantum technologies, for example, quantum cryptography and quantum computers)? Does light propagate in all directions at the same speed or are there deviations from Einstein's theory of relativity? Can laser pulses be used to make ultrafast processes in condensed matter or (bio-) molecules visible, and to get a better understanding of them? Can nanostructuring and new hybrid systems help us to produce materials with novel properties for application in optoelectronics? www.physik.hu-berlin.de/forschung

phase modulators (www.forthdd.com) // **HOLOEYE Photonics AG:** Diffractive optical elements (DOE); spatial light modulators (SLM); LCOS microdisplays and drive electronics (www.holoeye.com) // **JP-ProteQ:** Industrial process analytics, system integration of analysis devices from established manufacturers, development and distribution of NIR and MIR lasers (www.jp-proteq.com) // **SENTECH Instruments GmbH:** Spectroscopic ellipsometers, laser ellipsometers and reflectometers for measuring thickness and optical constants of ultrathin films and layer stacks. Plasma process technology for plasma deposition (PECVD), plasma enhanced atomic layer deposition (PEALD), and plasma etching (ICP-RIE) (www.sentech.com) // **Limmer Laser GmbH:** Experts on high-precision lasers with diverse applications in human, dental, and veterinary medicine (www.limmerlaser.de) // **ADVA Optical Networking SE:** Fiber optic networking (www.advaoptical.com) // **Lumics GmbH:** Fiber-coupled diode laser modules and high-performance laser diode covering the range from 750 nm to 1960 nm,

humankind (1,0 x 1014 kWh/year). Solar collectors use this radiation to produce heat (solar thermal energy). Solar cells convert this heat into electricity (photovoltaics). Colors can be created by mixing the three primary colours red, green, and blue. Colour TV screens and monitors are one example of how this works.

INFRARED LIGHT (780 nm – 1 mm)
Vibrating or rotating atoms as well as molecules produce infrared light. Optoelectronics and optical communication make use of the recombination of electrons in diode lasers to produce infrared light. Light emitting diodes (LEDs) are used in consumer electronics, for example, wireless remote controls (950 nm). The maximum radiation emitted by light bulbs is not actually in the range of visible light, but in the infrared range. Fibre optic cables transport light across long distances at minimal loss while maintaining a very high data transmission rate. Infrared cameras work much like conventional cameras, but instead of detecting visible radiation they do so with infrared (2,5 - 50 µm).

TERAHERTZ RADIATION (30 µm – 3 mm)
It penetrates materials like paper or plastics as well as organic tissue. It is non-ionising and, unlike X-ray or gamma radiation, safe for biomedical application. Terahertz radiation is used in spectroscopy for identifying certain substances. Its application was disputed for a long time ("terahertz gap"). The main issue is the construction of efficient transmitters and receivers. Meanwhile, there have been breakthroughs in terahertz technology, opening up broad areas of application in medical technology (contrasting tissue), materials testing, radars, and security technology (identity checks, identification of drugs).

10^{-4} TERAHERTZ RADIATION (30 µm – 3 mm) 10^{-3} MICROWAVES (1 mm – 1 m) 10^{-2}

10^{12} 10^{11} 10^{10}

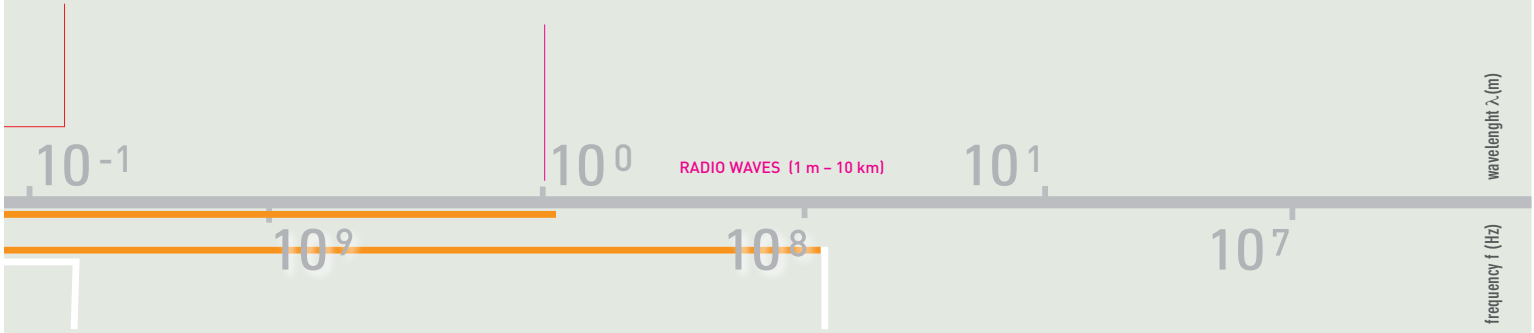
ISAS (Leibniz-Institut für Analytische Wissenschaften – ISAS – e.V.) is dedicated to advancing analytical technologies as a driver of scientific, social and economic progress by making measurable what cannot be measured today. Research at ISAS Berlin focuses on optical spectroscopy methods that can be used to characterize ultra-thin layered structures and interfaces without damaging or destroying them. ISAS Berlin also develops sensitive spectrometers to separate wavelengths that are only a 100,000th nanometer apart. www.isas.de

The **Integrative Research Institute for the Sciences IRIS Adlershof** of the Humboldt-Universität zu Berlin conduct interdisciplinary research on novel hybrid materials and functional systems with previously inaccessible optical, electronic, mechanical and chemical properties. This research is connected to fundamental studies of structure and dynamics of matter on extreme length and time scales and in complex systems. www.iris-adlershof.de

for laser medicine and joining processes in industrial manufacturing (www.lumics.de) // **ColVisTec AG:** Inline technology for continuous process monitoring using probes in the UV-VIS spectrum (color measurement), e. g. directly in the extrusion of polymers, as PAT in pharmaceuticals (hot melt extrusion), powder and liquid coatings, inks, chemicals, food industry etc. (www.colvistec.de) // **FISBA Photonics GmbH:** Develops and manufactures high-power optical fiber cables for industrial and medical application, as well as fiber bundles, probes for spectroscopy, and optical fiber couplers (www.fisba-photonics.de) // **AdlOptica GmbH:** Refractive beam shapers for various industrial, scientific and medical applications, for example, holography, micromachining or welding (www.AdlOptica.com) // **DirectPhotonics Industries GmbH:** Ultra-high brightness direct diode lasers and laser systems for industrial materials processing including cutting and welding of metals and plastics (www.directphotonics.com) // **FCC Fibre Cable Connect GmbH:** Develops and manufactures high-power

MICROWAVES (1 mm – 1 m)
They are used detecting and locating objects (Radar). A microwave oven uses electromagnetic waves to set molecules in motion. This produces friction that creates heat. Microwaves are also used in wireless communication. For instance, mobile phones use a frequency range between 900 and 1800 MHz; wireless networks (WiFi) work at 2,4 GHz and 12,5 cm wavelength and TV receivers at 12 GHz and 2,5 cm wavelength.

RADIO WAVES (1 m – 10 km)
Thanks to the earth's ionosphere, radio stations can be listened to even in the most remote areas of the earth. The ionosphere is a layer of our atmosphere that starts at a height of about 80 kilometres and extends for approximately 300 kilometres. Cosmic radiation pulls electrons out of atoms which produces plasma that acts like a mirror for radio waves. A programme on the radio can thus be hurled from the earth to the ionosphere and back and, eventually, be received with portable radio in a far-off place.



The **German Aerospace Center (DLR)** in Adlershof focuses on the key research areas aerospace and traffic. The DLR develops sensor systems in the infrared and terahertz range that are used for earth observation and the exploration of the depths of outer space. The fascinating, three-dimensional photographs from Mars were recorded with a stereo camera developed in Adlershof. The camera ROLIS and the in-situ heat flow probes MUPUS, both developed in Adlershof, were used on board the Rosetta spacecraft's landing unit "Philae" that landed on the comet „Tschurjumov-Gerasimenko" in November 2014. MUPUS' task was to examine the surface temperature and thermal conductivity of the comet.
www.dlr.de

The **Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik,** conducts research on key technologies for application in RF electronics and photonics. This includes high-frequency components and circuits from the gigahertz to the terahertz range utilized in communication, power electronics, and sensor technology. Further products include high-performance high-brilliance diode lasers for materials processing, medical technology, and precision metrology. Moreover, the FBH develops innovative light-emitters on the basis of gallium and aluminium nitride: laser diodes in the blue-violet spectrum that are used in atomic spectroscopy and bioanalytics, and light-emitting diodes (LEDs) in the near and far ultraviolet (UV) spectral range. These UV-LEDs target applications in the fields of disinfection of water, medical technology, and gas sensors.
ww.fbh-berlin.de

optical fiber cables for industrial and medical application, as well as fiber bundles, probes for spectroscopy, and optical fiber couplers (www.fibrecableconnect.de) // **AEMtec GmbH:** Engineering expertise in development, production, and manufacturing process development; high accuracy placement of optoelectronic components including installing lenses, filters, and prisms in ISO-5 cleanrooms. Technologies: Flip Chip, CoB, 3D integration, opto-packaging. High service standards (quality, logistics, commercial) (www.aemtec.com) // **TRIOPTICS Berlin GmbH:** Compact and flexible interferometers for testing optical systems and high precision surfaces in measurement laboratories, research, and quality assurance; software and services for optical metrology (www.trioptics.berlin)
www.adlershof.de/en/technologies/photonics-optics/info/; http://www.adlershof.de/en/technologies/renewable-energy-photovoltaics/info/

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