MSc in Photonics & Europhotonics

Laser Systems and Applications 2016/2017

High power lasers and medical lasers

Prof. Cristina Masoller
Universitat Politècnica de Catalunya
cristina.masoller@upc.edu
www.fisica.edu.uy/~cris

UNIVERSITAT POLITÈCNICA DE CATALUNYA

UAB Universitat Autònoma de Barcelona

UNIVERSITAT DE BARCELONA

ICFO Institut de Ciències Fotòniques

Outline

Block 2: High power laser systems

- High power diode lasers
- Fiber lasers

Block 3: Lasers for biomedical applications

- Medical lasers
- Applications of lasers in the life sciences

UNIVERSITAT POLITÈCNICA
DE CATALUNYA
BARCELONATECH

Learning objectives

- Become familiar with different types of high-power lasers and their applications.
- Become familiar with the broad range of therapeutic and diagnostic applications of medical lasers.
- To describe a few examples.
- To provide further reading.

What is “high power”?

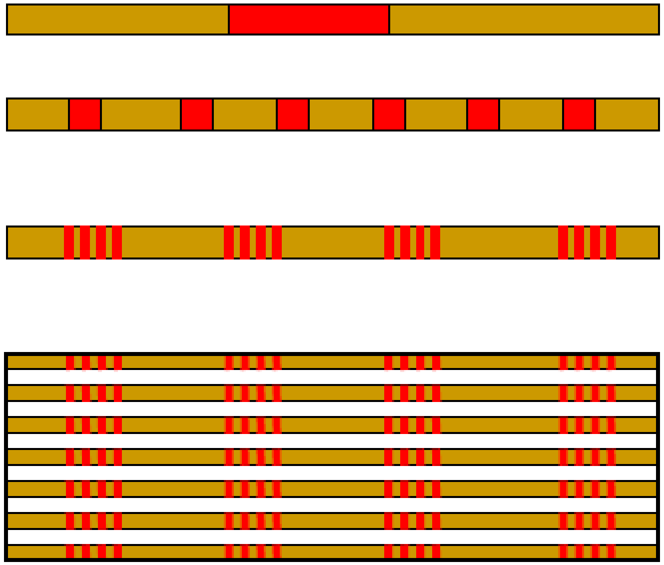
- It depends!
- “high power” melts, ablates, cuts, welds, etc. (Prof. Botey)
- First applications: soldering and plastic welding (requires few kWs and spot size ~ 400-600 μm)
- Cutting metals require higher power and < spot size (~ 100 μm)

- Defense
- Highest powers (fiber lasers)
  - Multimode CW ytterbium – 100 kW
  - Single-mode CW Yb– 10 kW

Diode lasers: how to increase the output power?

Two approaches:

- Make individual diode lasers bigger: **“wide-stripe” or “broad-area” lasers.**



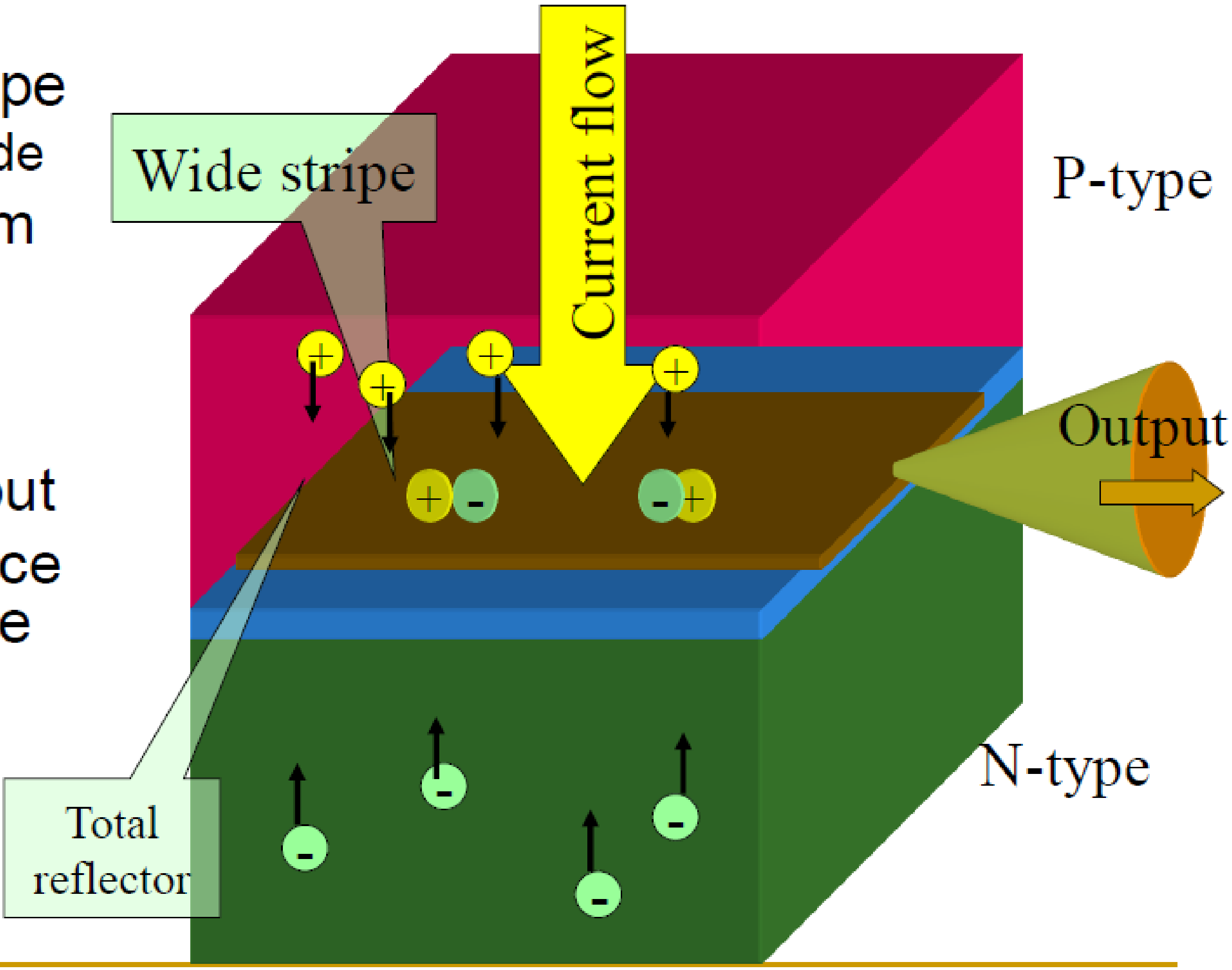
- Integrating many laser stripes into a single “**semiconductor bar”**
  - First demonstrated in 1978
  - Scalability
    - Multiple arrays in linear bar
    - Stacks of two-dimensional arrays

Allows to deliver **multi KWs power**

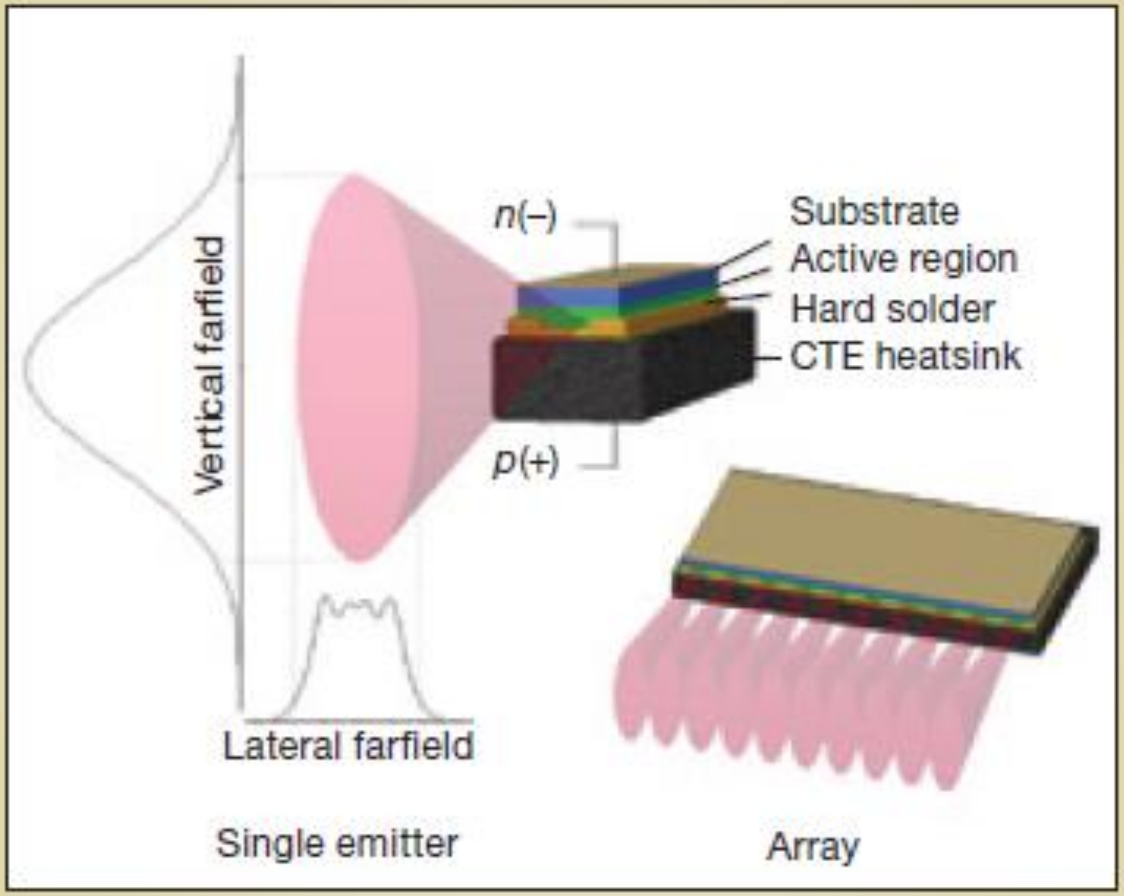
Source: Jeff Hecht, Laser Focus World

Wide-stripe edge-emitter

- Broad laser stripe
  - 100-200 µm wide
- High power from single aperture
- Emission from wide area
- Multimode output
- Beam divergence reduced by wide stripe
- Watts of output
- Good for fiber laser pumping



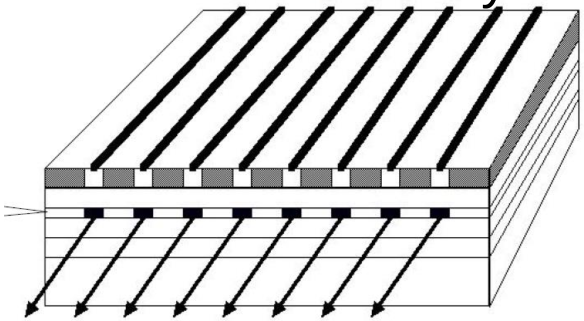
Source: Jeff Hecht, Laser Focus World



Edge-emitting single-emitter bonded junction side (*p*) down onto a CTE-matched heat sink that shows anisotropic beam divergence and extension to array geometry.

The laser is bonded onto a **heat sink** that has a coefficient of thermal expansion (CTE) matched to that of GaAs.

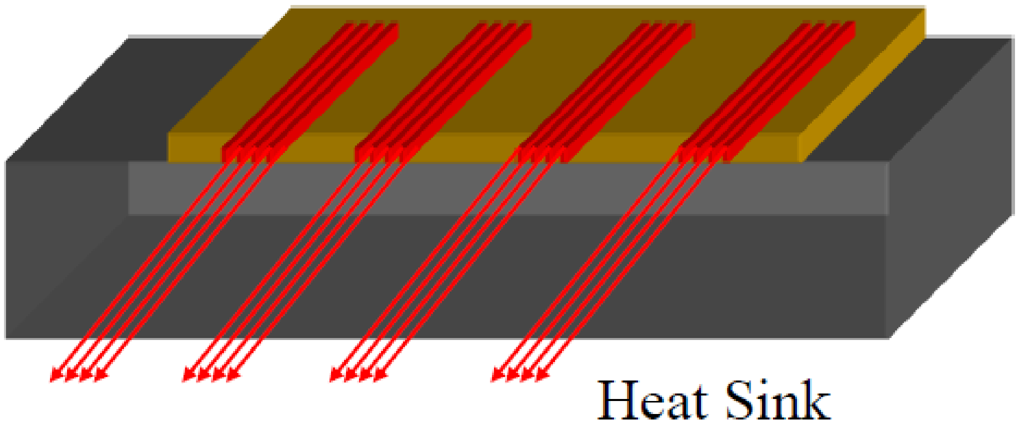
Diode array



Source: Optics and Photonics News, October 2010

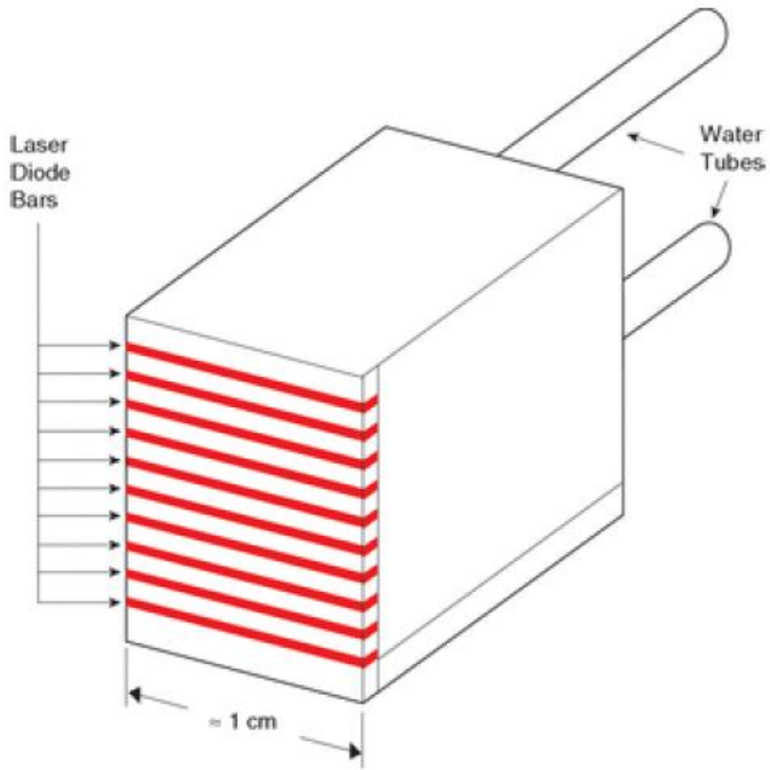
Scalability

Diode bar (10s of Ws up)

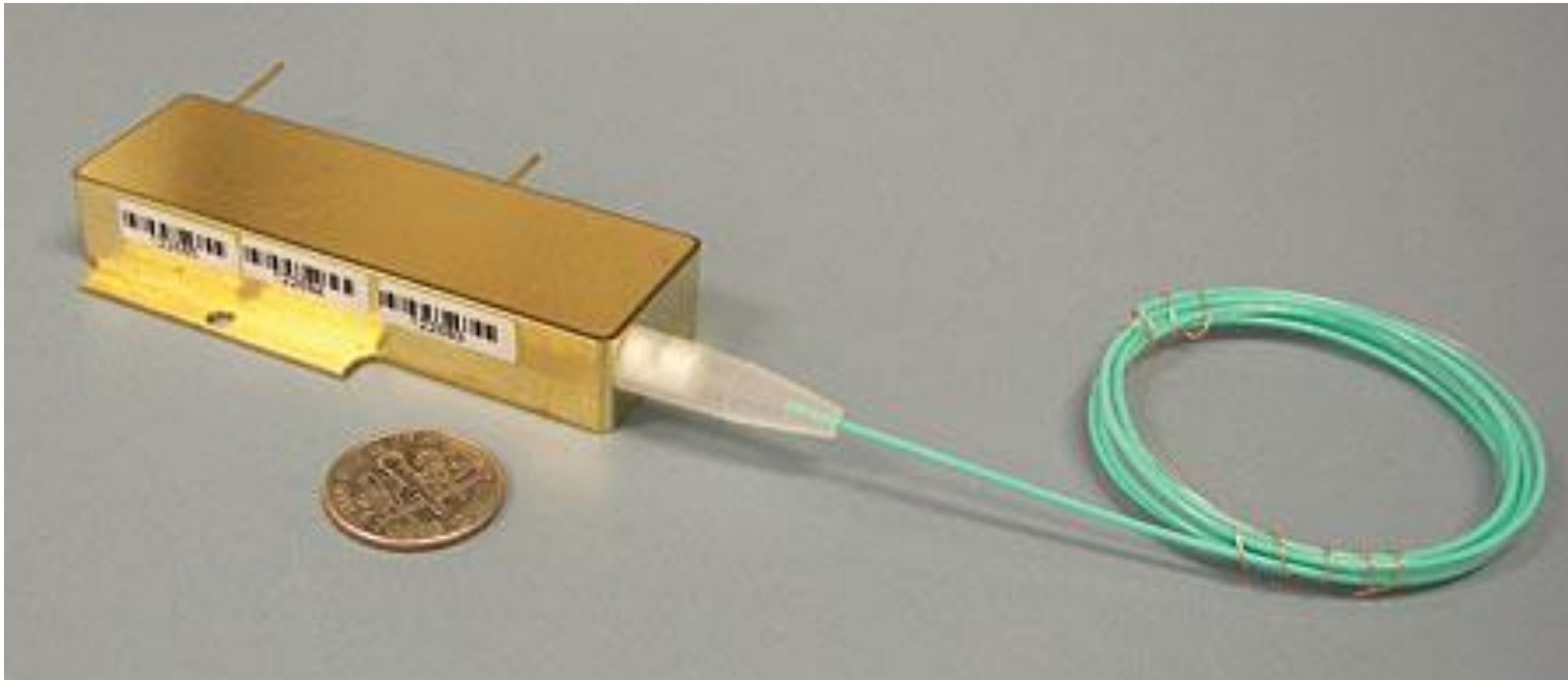


Outputs spread and merge

Stacked bar (kWs)



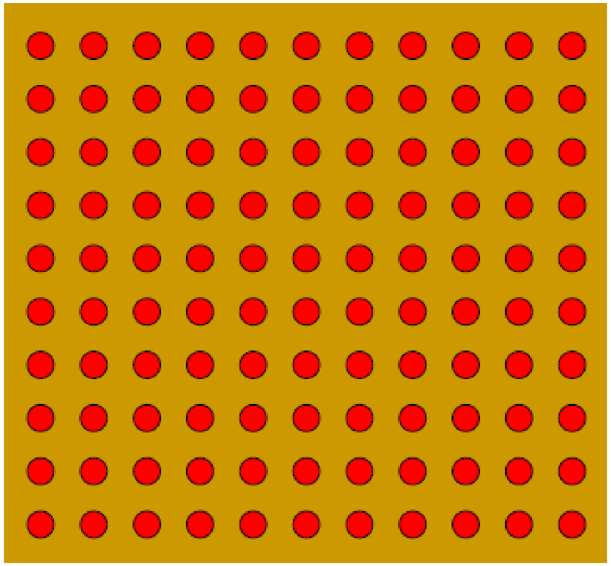
Source: Jeff Hecht, Laser Focus World



IPG Photonics has a diode laser for plastic and metal welding, brazing, cladding, and medical applications that comes in a small package. It offers a choice of wavelengths across the 9xx nm spectral range and delivers 100W power out of a 0.12 NA, 105-µm core fiber.

VCSELs

- Single VCSEL power in the mW range
- Two dimensional arrays of several hundred lasers: **tens of watts**
- Beam quality:
  - better than edge-emitters
  - array arrangement can tailor beam profile



Source: Jeff Hecht, Laser Focus World

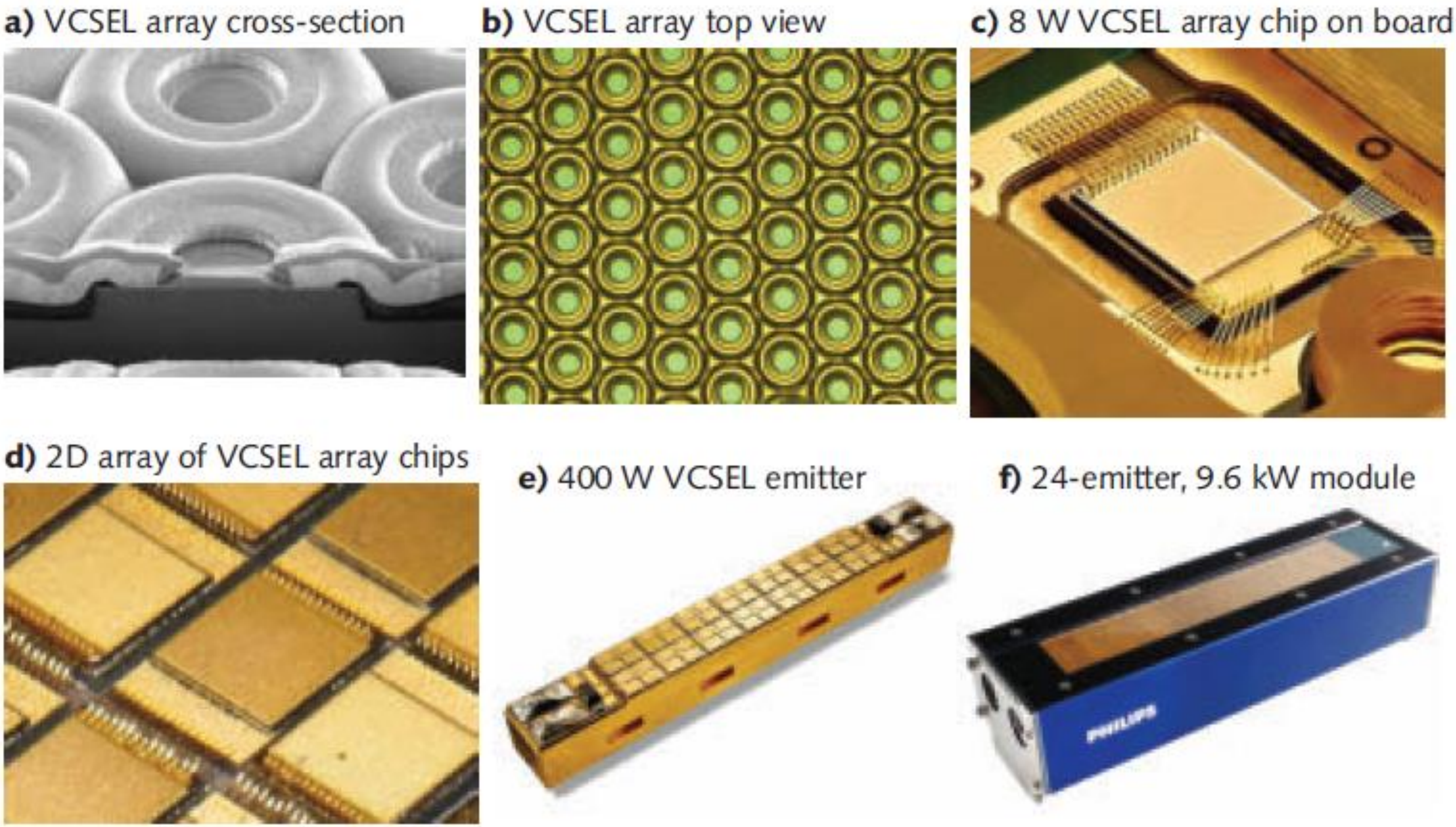
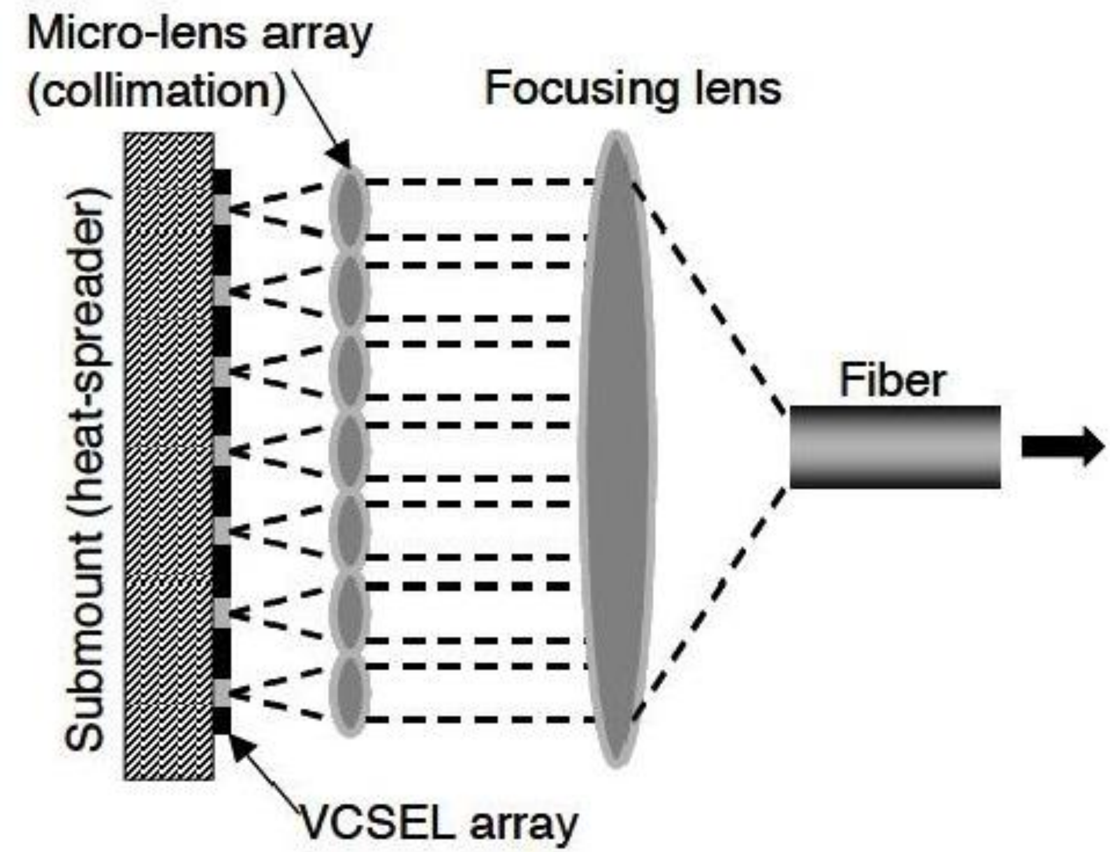


FIGURE 2. A VCSEL-array chip assembled on a board forms an illumination module (a-c). Many chips can be assembled next to each other for higher powers (d). A 400 W emitter consists of 56 chips arranged in four rows of 14 chips (e). A 9.6 kW module has an emitting area of 40 × 200 mm^2 (f). *(Courtesy of Philips Photonics)*

Source: Laser Focus World, December 2014

VCSEL beam combination

Thousands of single-mode emitters (976nm) in array: 40 W output from 400-µm, 0.46 NA fiber



Source: Jeff Hecht, Laser Focus World

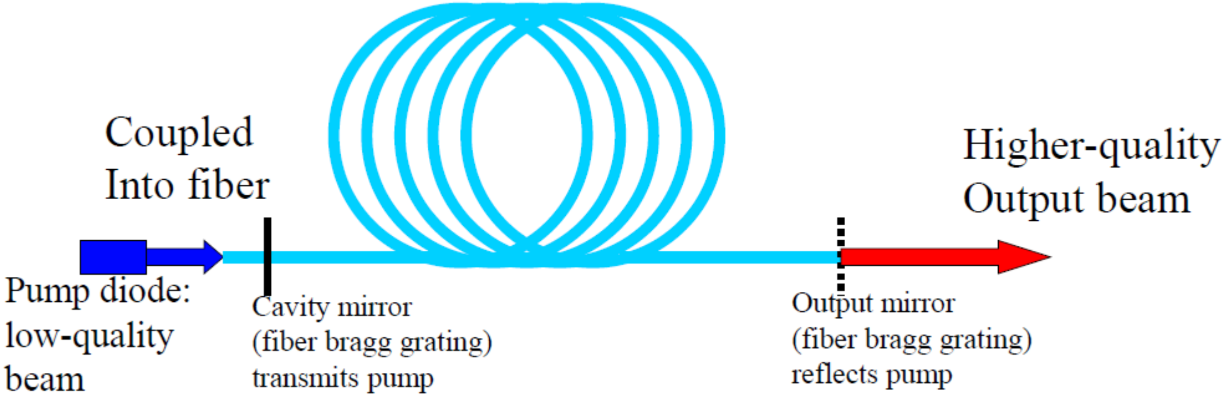
Fig. 18.10 VCSEL-based multi-function laser printer (*left*: DocuColor 1256 GA) and on-demand publishing system (*right*: DocuColor 8000 Digital Press)

Two-dimensional 8 × 4 VCSEL arrays at 780 nm wavelength enable **2,400 dots per inch resolution**, high printing speed, and reduced power consumption.

Source: R. Michalzik, VCSELs

Fiber lasers: operating principles

- Gain medium: a doped optical fiber
  - fiber: silica glass;
  - dopants: rare earth ions such as erbium (Er^{3+}), neodymium (Nd^{3+}), ytterbium (Yb^{3+}), thulium (Tm^{3+}), or praseodymium (Pr^{3+}),
- Optically pumped, usually with diode lasers



Source: Jeff Hecht, Laser Focus World

Advantages

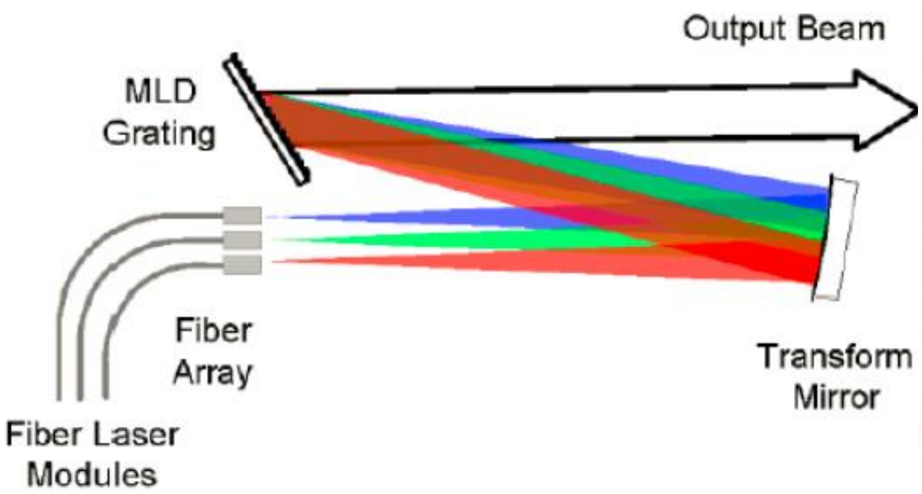
- High average power
- High beam quality
- High efficiency
- Low cost maintenance and operation
- Fiber beam delivery –attractive for biomedical applications
- New glass hosts and use of various rare-earth dopants allow expanding to new wavelength bands
- Energy efficient: diode pumping (~ 50% electrical to optical efficiency) and high optical to optical energy conversion give **wall-plug efficiency** (optical output power/electrical input power) of $\sim$ 30 - 40%

Fiber laser types: single-mode vs multi-mode

- Single-mode
  - Power: watts up to 10 kWs (limited by nonlinear effects and optical damage)
  - High quality beam
  - Nonlinear effects arise from high power density in small core
  - Nonlinearity ~ fiber length : long transmission length increases nonlinear effects
- Multimode
  - Large core diameters avoid nonlinearities and damage
  - Powers to 100 kW
  - Low beam quality

For higher power: beam combination

- Reached 30 kW
- Target reached over a mile away (Laser Focus World News March 2015)



MEDICAL LASERS

Main applications of lasers in life sciences

- Photomedicine: therapeutic and diagnostic use of light
  - Therapeutic
    - Neurophotonics (neurosurgery, optogenetics=drugs activated by light)
    - Surgery (hart, vision, cancer, etc.)
      - Vision correction (laser-based procedures to reshape the cornea, to re-attach retinas, to treat cataracts, etc.)
    - Light therapies (photodynamic therapy, photobiomodulation, photothermal treatments, etc.)
      - Dermatology (hair and tattoo removals, treatment of port wine stains)
  - Diagnostic
    - Imaging (microscopy, fluorescent, photoacoustic, etc.)
    - Sensors (flow cytometry, nanosensors)

- Safety (drugs, food) & environmental monitoring

Therapeutic applications of laser light

- Drugs activated by light
  - Optogenetics: controlling neurons with light
  - Photodynamic therapy (PDT): uses nontoxic light-sensitive compounds –photosensitizing agents – that, when exposed to light, they become toxic to target malignant cells.

- Light therapies: exposure to light leads to beneficial clinical effects (e.g. analgesia: diminish inflammation, relieve pain).

- Surgery, dermatology, ophthalmology & dental medicine

Which light source?

Depends of:

- optical properties of cells/tissue and
- light – cells/tissue interactions.

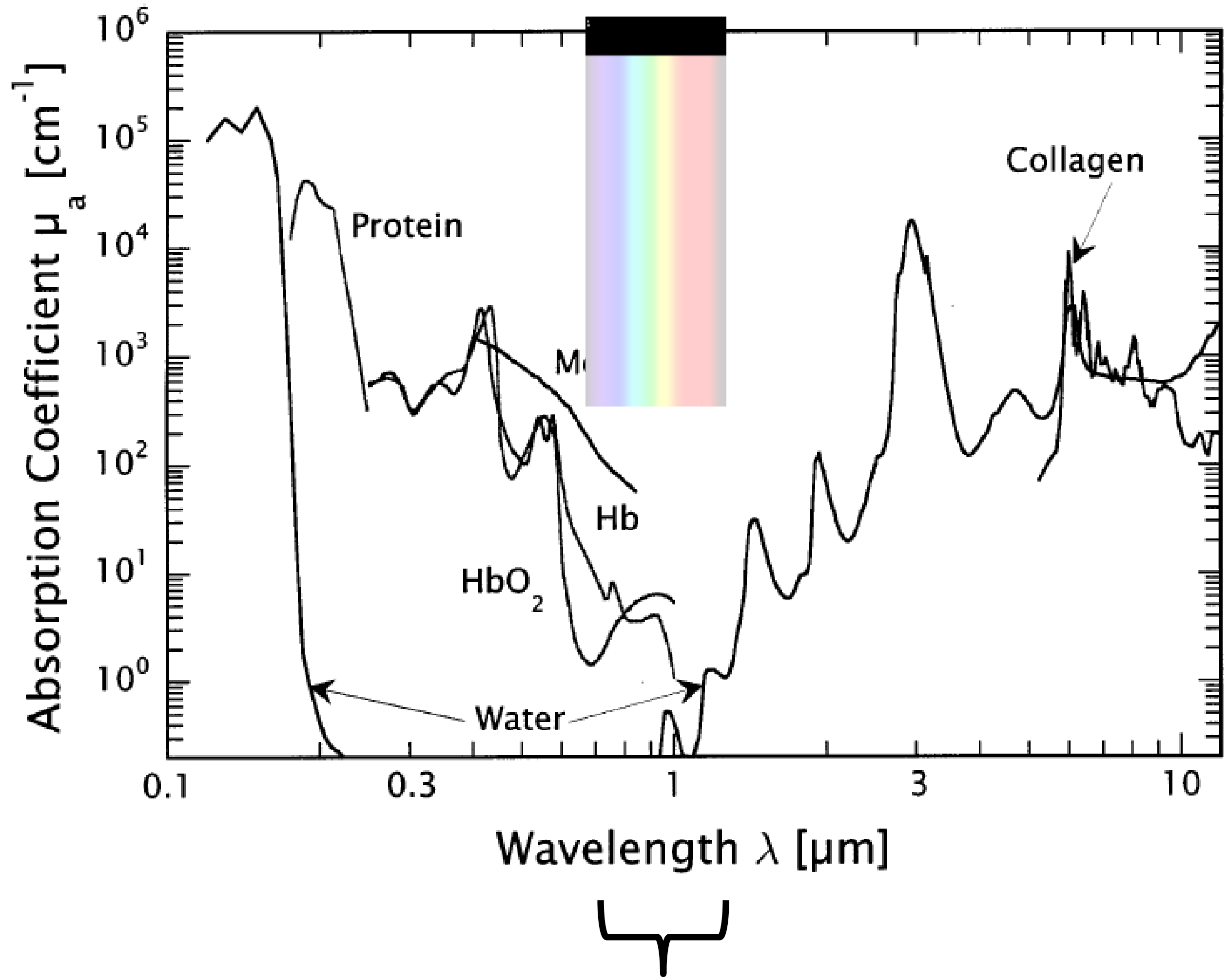
- **Chromophores** are responsible for the color of a molecule, absorb certain wavelengths and transmit or reflect the rest.

- The absorption properties of tissue are determined by the absorption of properties of the four main chromophores of tissue (proteins, DNA, melanin, hemoglobin), and water.

- Tissue optics: the most important factor for penetration depth is wavelength.

Optical absorption properties of tissue

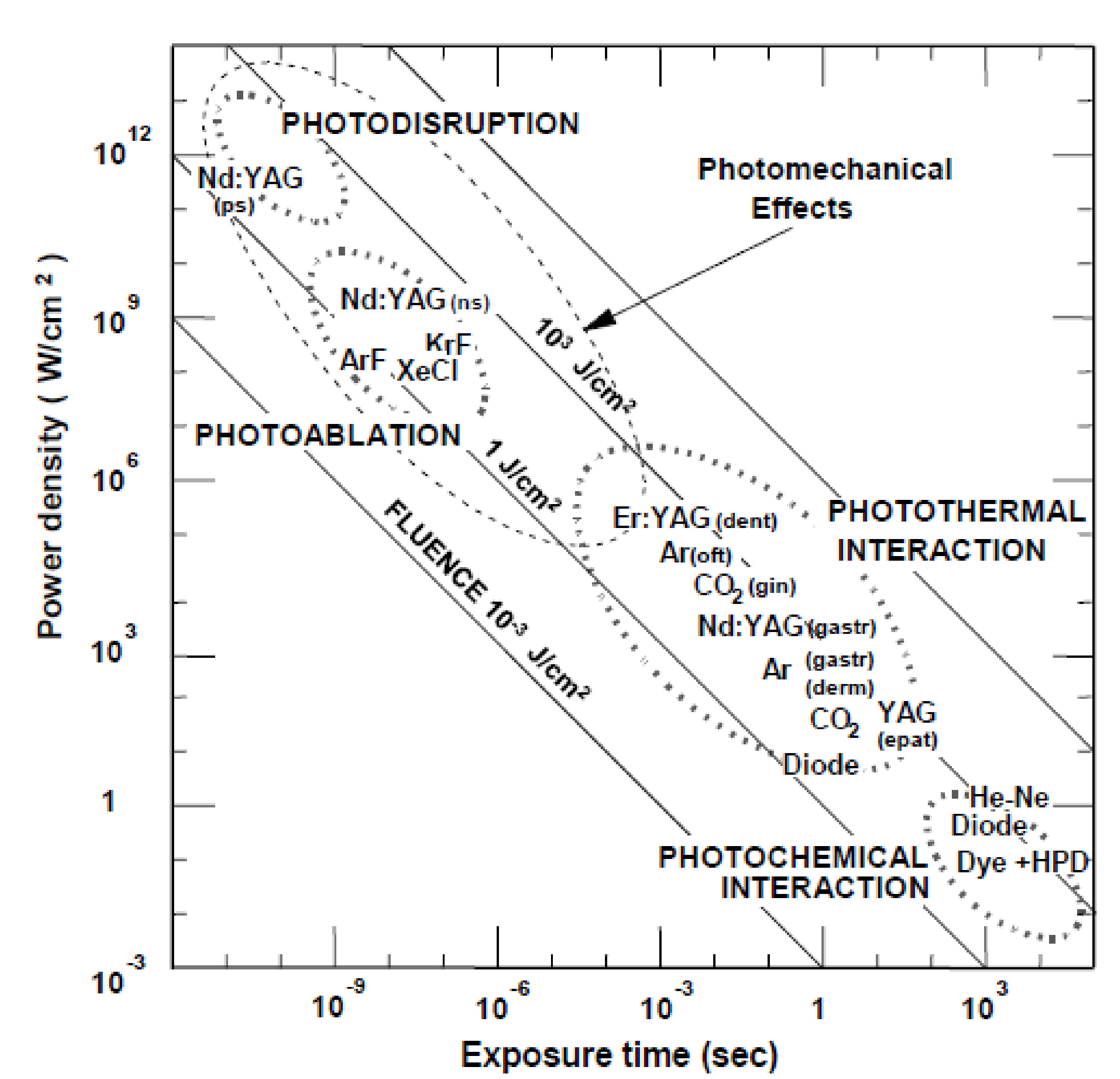
Tissue transparency is maximum in the near-infrared (600–1000 nm): light penetrates several cms because of low absorption by water.



Therapeutic window

Chemical Reviews, 2003, Vol. 103, No. 2

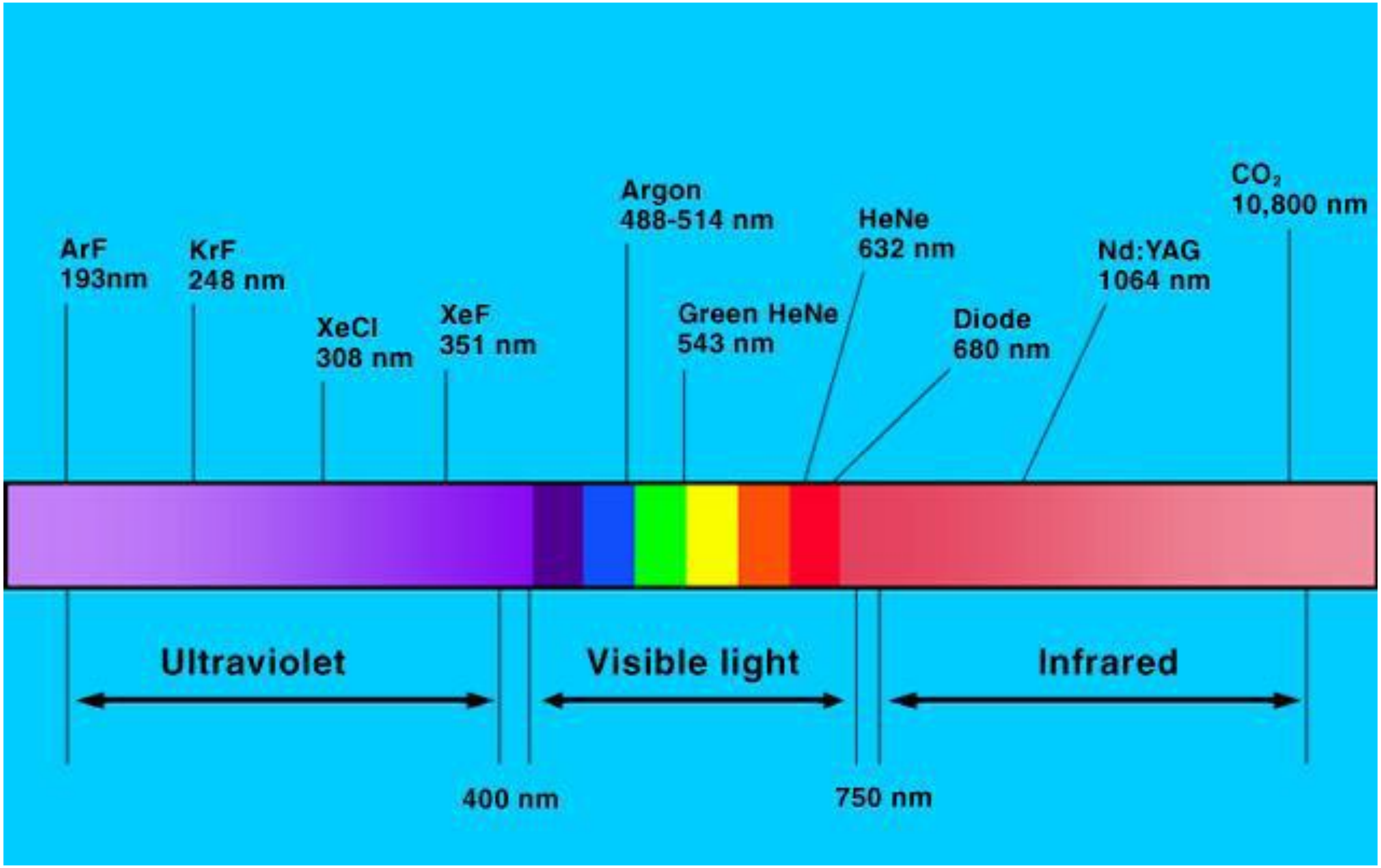
Map of laser-tissue interactions



The diagonals show constant energy fluences (J/cm²).

Source: R. Pini, Institute of Applied Physics-CNR, Florence

Wavelengths



Source: R. Pini (Institute of Applied Physics-CNR, Florence)

Light delivery systems

- **MICRO MANIPULATORS**


- **OPTICAL FIBERS**


- **ARTICULATED ARMS**

- **HAND PIECES**

Source: R. Pini (Institute of Applied Physics-CNR, Florence)

Diode lasers for biomedical applications

- Gallium arsenide (GaAs) yield **reds** (above 630 nm)
- Indium phosphide (InP) yields **blues** (375-488 nm)
- Indium gallium nitride (InGaN) yields **greens** (515- 536.6 nm)

- Power: up to 0.5 Watts

- Biomedical instruments often combine multiple lasers for multiple wavelengths.

Lasers – therapeutic applications

- **Welding of tissue**
  - Lasers: CO_2, Argon, Diode
  - For welding of blood vessels, cornea, skin

- **Photo-coagulation**
  - Lasers: Nd:YAG, Dye, Diode, Argon, frequency doubled Nd:YAG
  - For photocoagulation of the retina; treatment of pigmented and vascular lesions.

Firsts medical applications of lasers

Almost as soon as the laser was invented:

- **Dermatology**: in 1960 **Leon Goldman** ("father of laser medicine") tried to lighten tattoos by aiming a **ruby** laser at the pigmented skin until the pigment granules broke apart. He managed to remove the marks with the laser (and also performed pioneering research into the treatment of vascular lesions with **argon** lasers). His research led to discoveries such as lasers being able to simultaneously cut skin and seal blood vessels to restrict bleeding.
- **Ophthalmology**: in 1963 Charles Campbell used a **ruby** laser to treat a detached retina.

Nowadays lasers routinely used for **therapeutic** & **diagnostic**

Examples

Dermatology

- Treatment of port wine stains (skin birthmarks).
- Hair and tattoo removal.
- UV light to treat psoriasis, eczema and other skin diseases.

Houston Cosmetic Dermatology- Port Wine Stain Laser Treatments http://www.friedmanmd.net

Ophthalmology

- Laser-based procedures to reshape the cornea, re-attach retinas, etc.
- LASIK: laser-assisted in situ keratomileusis corrects several vision problems.

Examples

- **Tumor ablation**
  - 590–1064 nm: maximum photo-thermal effect in human tissue
  - laser diodes emitting in the 800-980 nm range have been used for kidney and brain tumors ablation

- **Cardiac surgery**
  - for patients with blocked or narrowed coronary arteries photo-thermal treatments are commonly used in angioplasty to remove blood-vessel plaque.

Photo-thermal treatments: laser light removes port-wine stains

The argon laser light is selectively absorbed by the red pigment in the abnormally enlarged blood vessels that cause the stain.
Dilated vessels are burned and sealed off while normal skin tissue is undamaged.

In dermatology, the type of laser and wavelength depend on the lesion being treated and what the main absorber is within it. The wavelength also depends on the patient’s skin type.

Laser use in dentistry

- **High power infrared** lasers are used to remove decay within a tooth and prepare the surrounding enamel for receipt of the filling. **Blue LEDs** "cure" and harden white composite fillings.

- **Low power near-infrared** diode lasers are used for **gum surgery**, gently slicing soft tissue with less bleeding than would occur with a scalpel (**laser cauterization of tissue**).

- **Teeth whitening**. A peroxide bleaching solution, applied to the tooth surface, is "activated" by laser energy, which speeds up of the whitening process.

- Lasers are also used to **remove bacteria** during root canal procedures.
- Optical Coherent Tomography (OCT) uses near-infrared light to view cracking and cavities in teeth more effectively than x-rays.

CANCER TREATMENT
-THERAPEUTIC
-DIAGNOSTIC

Lasers in cancer treatment

- Laser light can be used to remove cancer or precancerous growths or to relieve symptoms of cancer.

- It is used to treat cancers on the surface of the body or the lining of internal organs (in this case, laser light is delivered through an **endoscope**).

- Laser therapy causes less bleeding and damage to normal tissue than standard surgical tools do, and **there is a lower risk of infection.**

- However, the effects of laser surgery may not be permanent, so the surgery may have to be repeated.

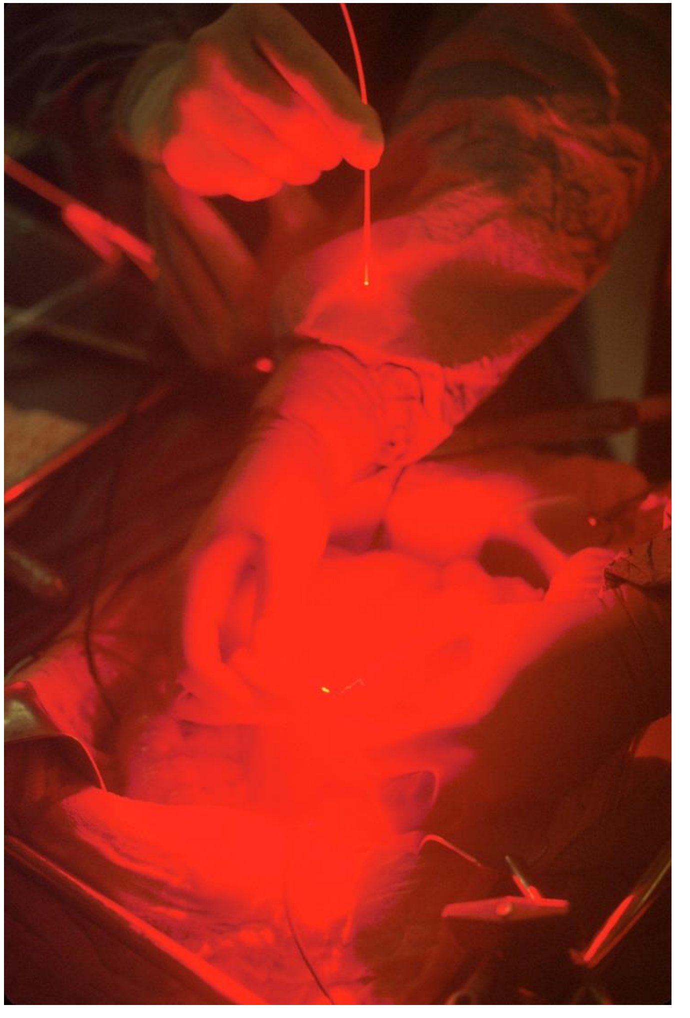
Cancer treatments

- **Thermotherapy** (LITT, also known as laser photocoagulation): uses heat to shrink tumors by damaging or killing cancer cells. Laser light at the tip of the fiber raises the temperature of the tumor cells and damages or destroys them.
- **Photodynamic therapy** (PDT): a drug (photosensitizing agent), is injected into a patient and absorbed by cells all over the patient's body. After a couple of days, the agent is found mostly in cancer cells. Laser light (of specific wavelength) is then used to activate the agent and destroy cancer cells.
- Which lasers?
  - CO2 and argon lasers can cut the skin's surface without going into deeper layers: used to remove superficial cancers (skin cancer).
  - Nd:YAG laser: applied through an endoscope to treat internal organs.
  - Argon lasers are often used to activate the drugs used in PDT.

Photosensitizing agents are activated by light to kill cancer cells

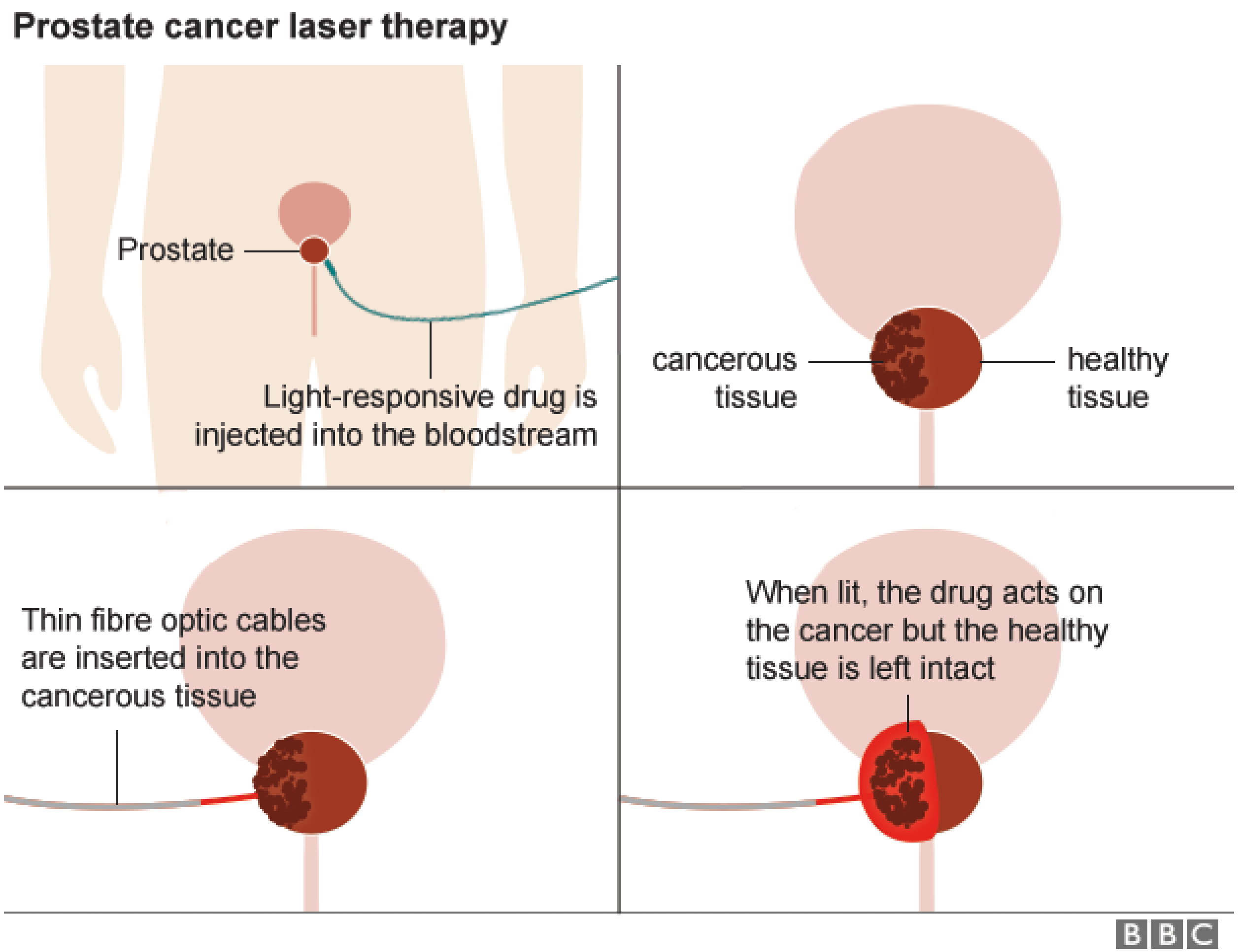
How does it work?

Close up of surgeons' hands in an operating room with a beam of light traveling along fiber optics for photodynamic therapy. A patient is given a photosensitive drug that is absorbed by cancer cells. During the surgery, the light beam is positioned at the tumor site, which then activates the drug that kills the cancer cells.



Source: wikipedia

Prostate cancer laser treatment 'truly transformative'



The approach, tested across Europe, uses lasers and a **drug made from deep sea bacteria to eliminate tumours**, but without causing severe side effects.

BBC News 20/12/2016

http://www.bbc.com/news/health-38304076

Light sources for PDT

- Careful control of and exposure to the light source is crucial for the success of the treatment.
- Because of the high precision required, lasers are often used due to their focused output.
- Visible diode lasers are predominantly used in PDT treatments (630-760 nm).
- However, other types of light sources (LED arrays, lamps) can also be used, delivered to the treatment site via an optical fiber.

Cancer diagnosis

- **Flow cytometry** is a laser-based technology employed in cell counting, cell sorting, biomarker detection and protein engineering.
- By suspending cells in a stream of fluid and passing them by an detection apparatus, it allows simultaneous multi-parametric analysis of the physical and chemical characteristics of up to thousands of particles per second.
- Flow cytometry is routinely used in the diagnosis of health disorders, especially blood cancers.
- Instruments include several lasers (for example, allowing to see two UV, six violet, seven blue and three red fluorescent parameters).

Flow cytometry: Fluorescence Activated Cell Sorter (FACS)

- Is routinely used to diagnose blood cancers and other diseases
- Employed in cell counting, cell sorting, biomarker detection and protein engineering, by suspending cells in a stream of fluid and passing them by an electronic detection apparatus.
- It allows simultaneous multiparametric analysis of the physical and chemical characteristics of up to thousands of particles per second.

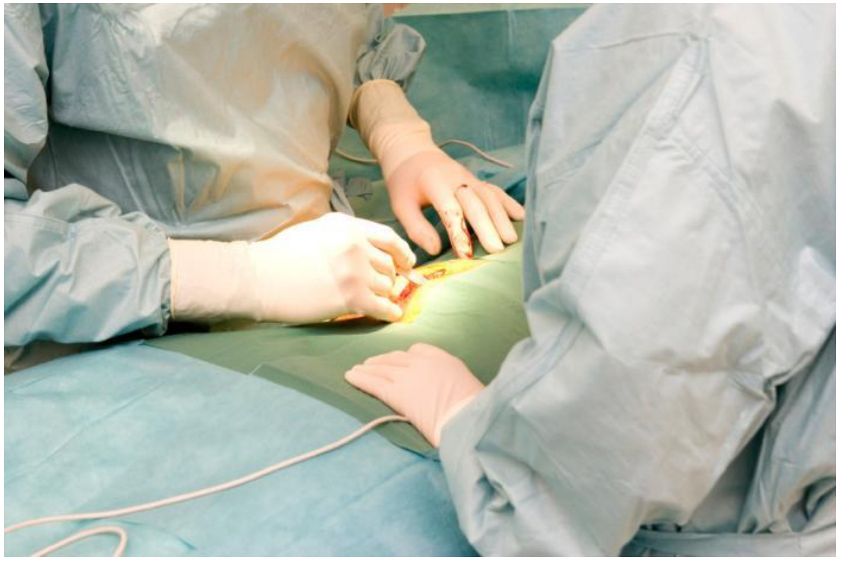
FACSCalibur. Source: Wikipedia

A flow cytometer has:

- A flow cell: liquid stream which carries and aligns the cells so that they pass single file through the light beam for sensing
- A measuring system : commonly used are measurement of impedance (or conductivity)
- Optical systems: lamps (mercury, xenon); high-power water-cooled lasers (argon, krypton, dye laser); low-power air-cooled lasers (argon (488 nm), red-HeNe (633 nm), green-HeNe, HeCd (UV)); diode lasers (blue, green, red, violet)
- A detector and Analogue-to-Digital Conversion (ADC) system - which generates forward-scattered light (FSC) and side-scattered light (SSC) as well as fluorescence signals from light into electrical signals that can be processed by a computer
- An amplification system and a computer for analysis of the signals.

A fluorescent agent could help surgeons remove all of tumor first time

- A fluorescent marker is injected into a tumor.
- The marker attaches only to cancer cells, which glow blue when illuminated by appropriated light.
- This method makes tumor more visible to surgeons <u>wearing special glasses</u>, improving their ability to fully remove the tumor.



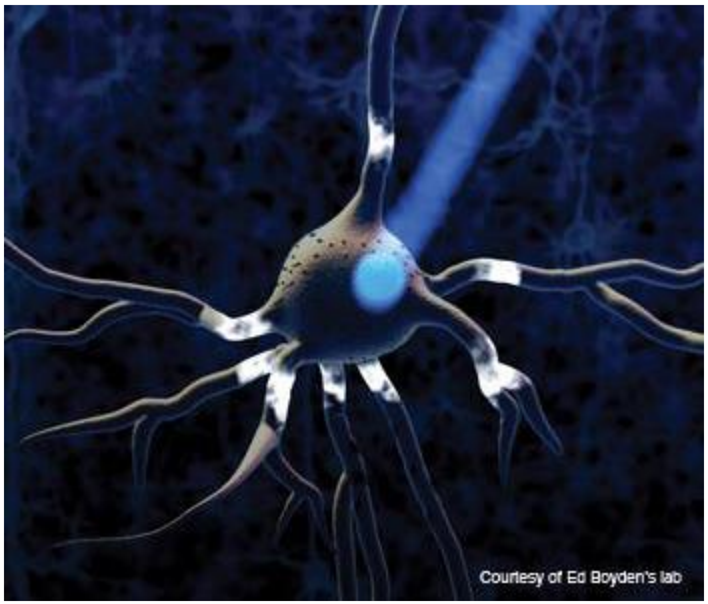
Current imaging methods (MRI, CT scans) do not always detect all the cancerous tissue at the margins of a tumor, so in the first operation some harmful cells can be left behind.

Read more: http://www.medicalnewstoday.com/articles/304776.php
January 2016

DRUGS ACTIVATED BY LIGHT - OPTOGENETICS

Optogenetics

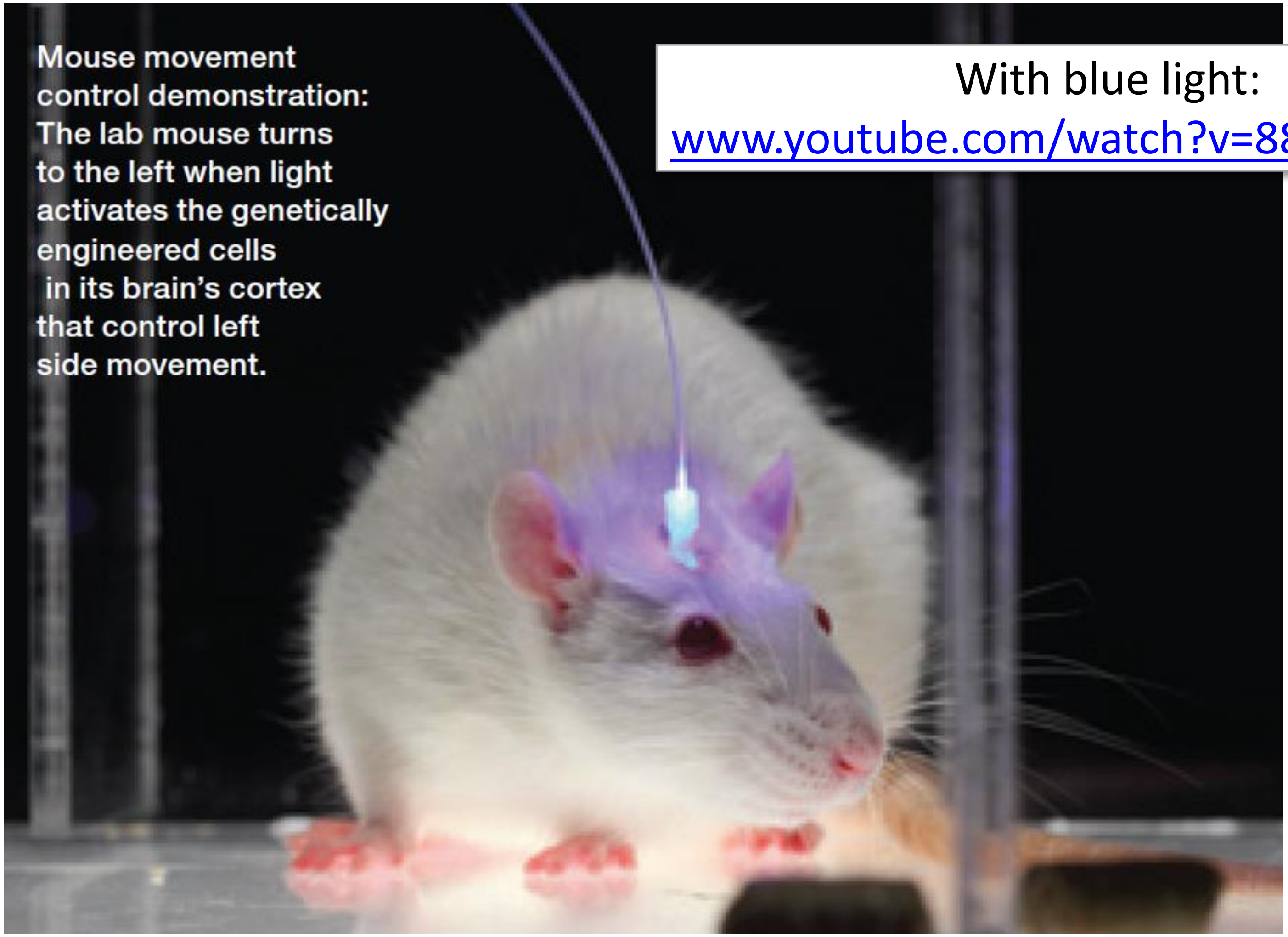
Controlling neurons with light



Opsin: light activated protein

[Making neurons react to light]

Neuroscientists insert opsin genes into brain cells with the help of engineered viruses. They can then trigger these cells on demand with pulses of light and observe the effects on experimental animals' behavior.



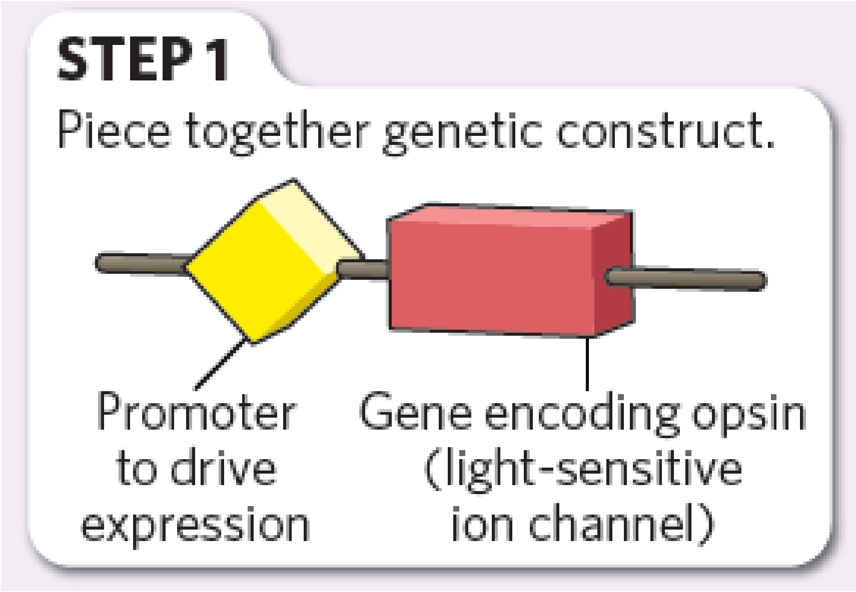
With blue light:
www.youtube.com/watch?v=88TVQZUfYGw

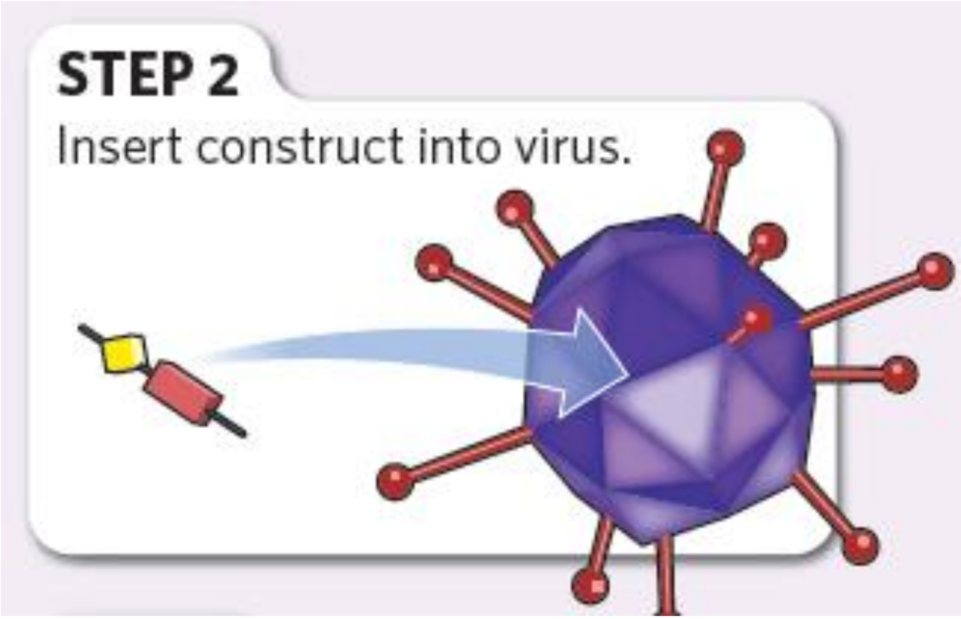
Nature May 2010; OPN August 2011

More info: TED TALK "A light switch for neurons"
https://www.ted.com/talks/ed_boyden?language=en

How does it work?

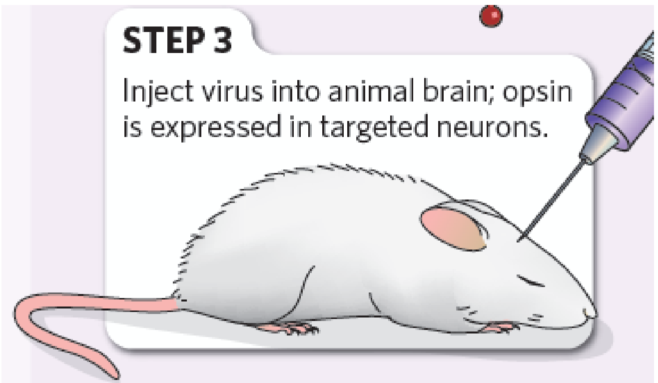
- Genes that code for light responsive proteins (known as opsins) are inserted into cells.
- Photo-excitation and/or photo-inhibition of these proteins causes them to alter cell function.

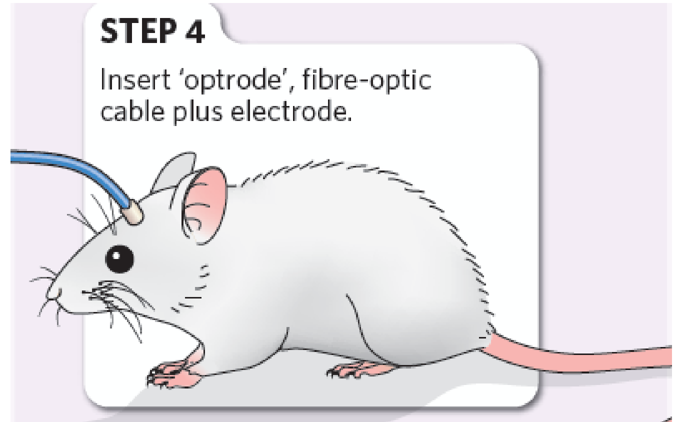


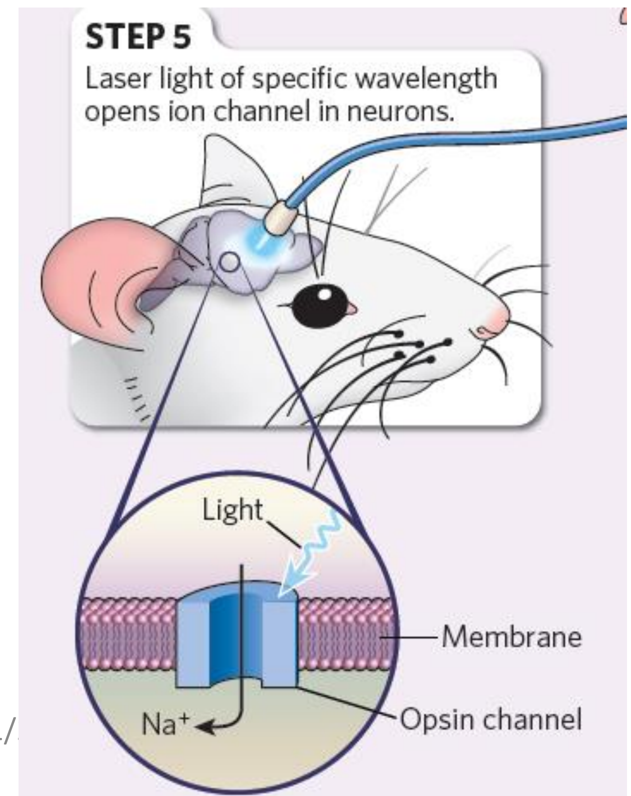


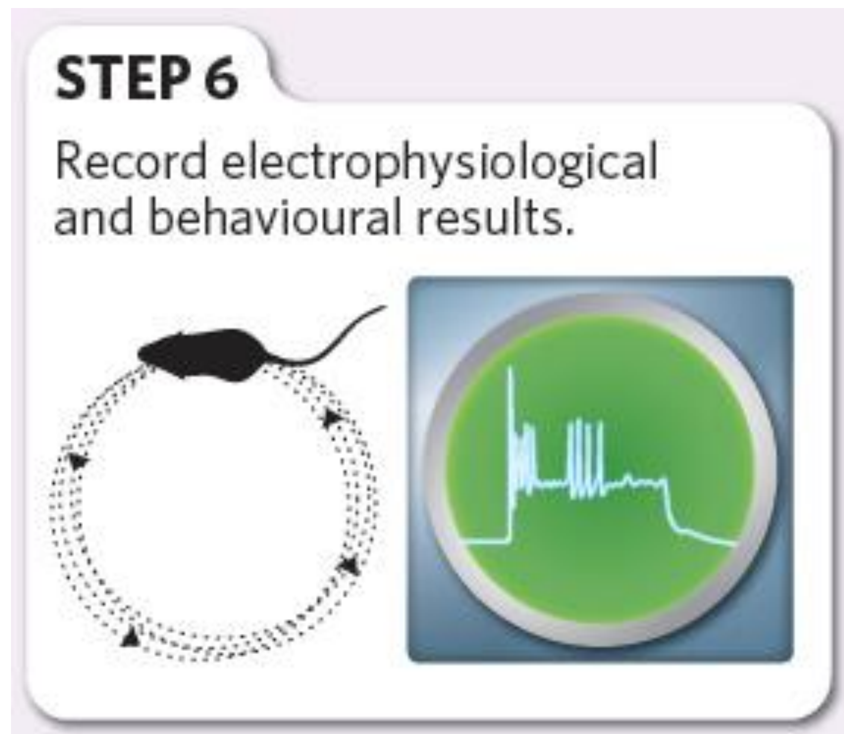
Nature Vol. 465, 6 May 2010

Six steps to optogenetics









Which light source?

- Choice of light source depends on the light sensitive protein (opsin) used.
- Good spectral, temporal, and spatial control is important.
- Diode lasers at 405 nm and 488 nm and diode-pumped solid state lasers at 473 nm, 532 nm, 561 nm and 593.5 nm are commonly used.
- For illuminating a small number of neurons in the brain, the laser beam needs to be focused to a very small spot.
- Usually two laser wavelengths are required: one to excite cells and one to inhibit them.
- Optogenetics requires good temporal control: the light source must be turned off and on in a very precise manner.
- In experiments involving multiple opsins, narrow emission spectrum is important to selectivity activate each opsin.
- Drawback of diode lasers: mode-switching noise, sensitivity to back reflections and speckle noise (random spatial intensity variation at the illuminated site)

LED advantages for optogenetics

- The emission spectrum of most LEDs is from 10 to 30 nm, a spectral width that allows the selective activation of multiple opsins.
- They are cheaper than laser diodes.
- Because LEDs don’t have resonant cavities, don’t exhibit noise related to mode switching or instability from back reflection. They also don’t have the problem of speckle noise.
- Drawback: spectrally less efficient.

LIGHT THERAPY

Light therapy (also known as phototherapy)

- Therapeutic radiation used to treat skin conditions (psoriasis)
- Also used to treat circadian rhythm (sleep) disorders, depression.

Treatment for neonatal jaundice (yellowish pigmentation of the skin): photo-induced degradation of bilirubin molecules.
Source: H. Failache, UDELAR, Uruguay

How does it work?

- Laser irradiation over *chromophores* (the part of a molecule that is responsible for its color, that absorbs certain wavelengths and transmits or reflects the rest).
- Results in: photon-induced chemical reactions and/or photon-induced alterations (stimulating or inhibiting cellular functions).
- Goal: to chose a wavelength to reach chromophores in target cells without the photons being absorbed by other substances.

Light sources

- A light box which emits up to 10,000 lux of light at a specified distance, much brighter than a normal lamp.
- Specific visible wavelengths, from the blue (460 nm) to the green (525 nm).

A light box in use for depression, seasonal affective disorder, or a circadian rhythm sleep disorder. Source: wikipedia

High intensity blue light (425 nm) used for the treatment of acne.

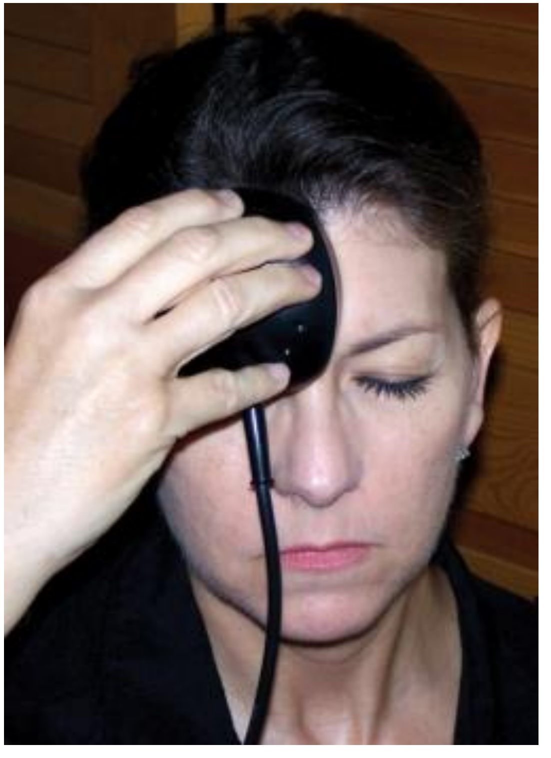
Transcranial Light/Laser Therapy (TLT)

- <u>Noninvasive</u> delivery of light into the brain for the treatment of
  - Brain injuries
  - Chronic neurological diseases
  - Mental illness
- Red and NIR light is used because it penetrates the scalp, skull and brain.
- cw or pulsed,
- To the entire head or to target specific areas of the brain.

Source: Bioptics World

TLT boosts cognitive function following brain injury

- Two patients with **chronic traumatic brain injury** were treated with transcranial LEDs.
- The patients showed significant improvement in concentration and memory.
- Light source: a LED console device, containing 52 near-infrared (870 nm) and nine red (633 nm) diodes for a total output power of 500 mW continuous wave.
- But the patients' improvements vanished if they stopped the treatment.



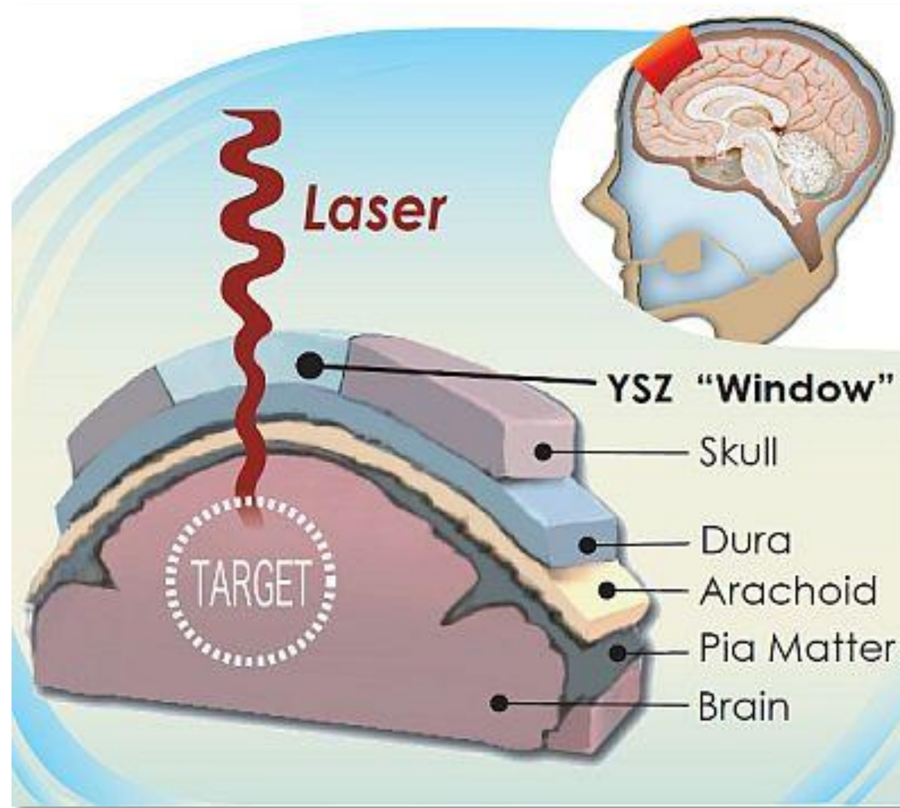
Photomedicine & Laser Surgery (doi:10.1089/pho.2010.2814)

How does it work?

- Exact mechanism unknown
- In rabbits, NIR laser light (808 nm) applied transcranially resulted in significantly higher levels of the energy-containing molecule ATP.
- Light energy is converted into chemical energy (stored in ATP).
- This energy is then available to power processes such as growth and repair.
- Thus, simultaneous repair and growth by neural cells fueled by ATP in response to light treatment.
- Also, increased blood circulation in response to light therapy.

A transparent permanent window to the brain

- Yttria-stabilized-zirconia (YSZ) is a ceramic material, which is well tolerated and used in hip implants and dental crowns.
- It was modified to make it transparent.
- The modified YSZ prosthesis can provide a permanent window through which doctors can aim light-based treatments for the brain without having to perform repeated craniectomies.



Y. Damestani et al, Nanomedicine: Nanotechnology, Biology and Medicine Volume 9, Issue 8 , Pages 1135-1138, November 2013

Nature video CLARITY

- Scientists have come up with a way to make whole brains transparent, so they can be labelled with molecular markers and imaged using a light microscope. The technique, called CLARITY, enabled its creators to produce the detailed 3D visualisations you see in this video. It works in mouse brains and human brains; here the team use it to look into the brain of a 7-year-old boy who had autism.
- https://www.youtube.com/watch?v=c-NMfp13Uug

MANY OTHER APPLICATIONS

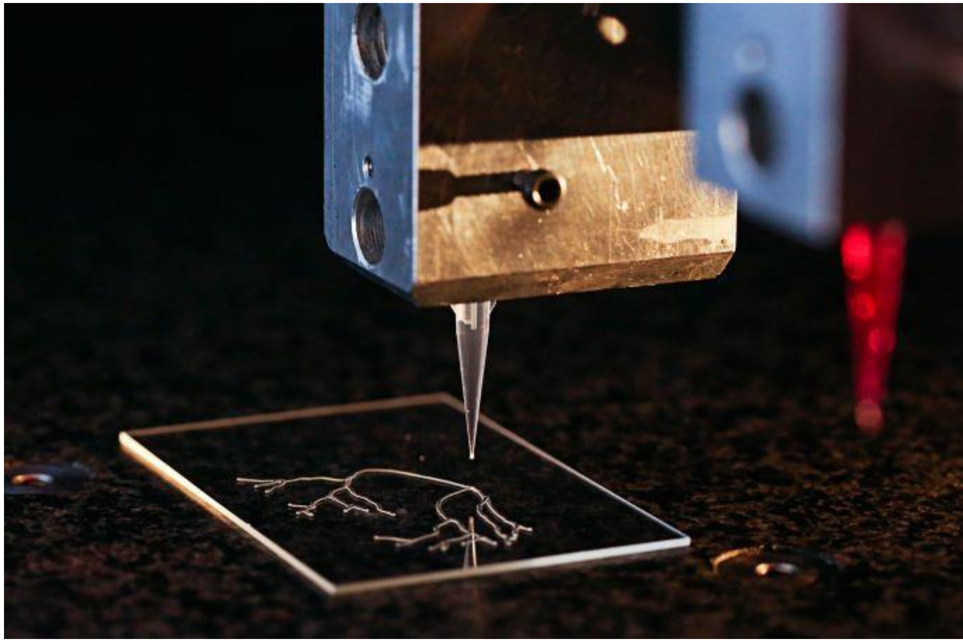
In vitro fertilization

- Lasers can be used to burn a tiny hole on a cell surface, allowing exogenous substances to enter the cell.
  - Example: perforate egg walls to assist in vitro fertilization.
  - A laser is focused to a diffraction limited spot (~1 μm diameter). The membrane of a cell is then exposed to this highly focused light for a small amount of time (typically tens of milliseconds to seconds), generating a transient pore on the cell membrane
  - This transient pore allows exogenous objects (DNA, RNA, QDs) to enter the cell.
  - In this technique, one cell is treated at a time.
  - Demonstrated using a variety of lasers, including 800 nm femtosecond pulsed Ti:Sapphire and 1064 nanosecond pulsed Nd:YAG.

Laser-based 3D printers

- Allow doctors and dentists to customize medical implants; researchers are experimenting with fabricating artificial organs.

- Surgeons have used 3D printed heart models to prepare for major surgery.



A 3D printer used by researchers at Harvard University's Wyss Institute creates a model vascular network.

Pillcam: vitamin-sized capsule

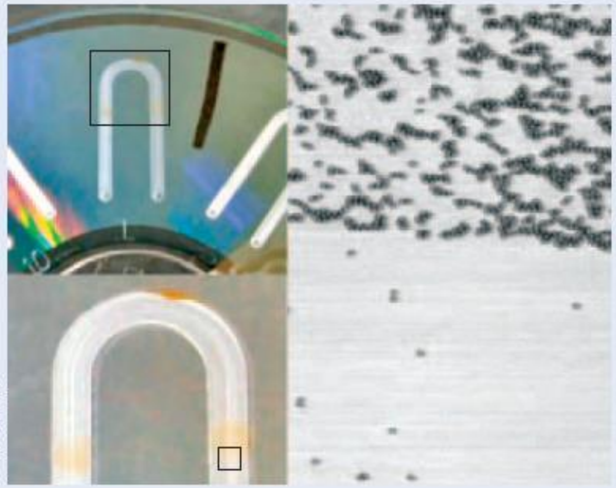
Capsule endoscopy with the PillCam SB video capsule enables your doctor to examine your entire small intestine. Your doctor will have you ingest a video capsule that has its own camera and light source. You can move freely during the exam, which lasts about eight hours. While the video capsule travels through your body, it sends images to a data recorder you will wear close to your waist. Afterwards, your doctor will view the images on a video monitor.

Source: wikipedia

BIOIMAGING

Lab on a DVD

Scientists based in Europe have succeeded in converting a commercial DVD drive into a laser scanning microscope that can analyse blood and perform cellular imaging with one-micrometre resolution (*Lab Chip*, doi: 10.1039/C3LC41360H; 2013). Harisha Ramachandraiah and the team from KTH Royal Institute of Technology in Sweden and the companies, Plarion in the UK and Lingvitae in Norway, say that their 'lab-on-a-DVD' system offers affordable and convenient cellular diagnostic testing for diseases such as HIV.



© RSC 2013

The approach makes two important modifications to the DVD drive and standard DVD media. First, an extra photodiode is added to the drive to detect transmitted and forward-scattered light through the disk. Second, the DVD media is replaced with a disposable, multilayer, semi-transparent polymer disk that contains fluidic microchannels in addition to the usual 0.74-μm-wide spiral track.

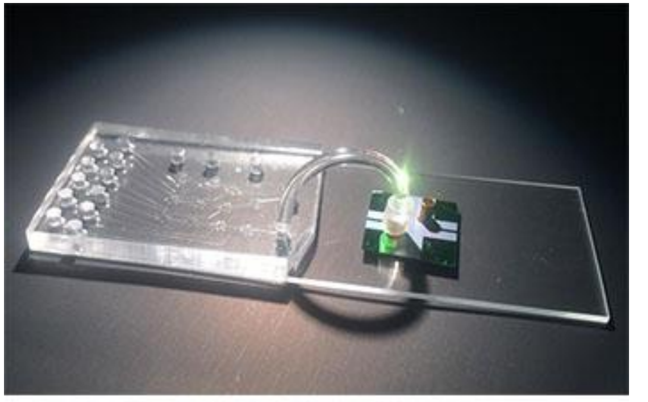
Before performing experiments, the inner surfaces of the fluidic channels are functionalized to allow surface attachment of the desired cells or particles. Samples of blood or another liquid of interest are then pumped into the channels and the DVD drive is switched on. The added photodiode records the amount of light from the drive's 658-nm semiconductor laser that is transmitted through the disk as it spins. The result is a two-dimensional image, which is saved to a computer hard drive for analysis. Cells or particles that have been successfully bound to the treated channels show up in the resulting images. To date, the team has tested their system by using it to image polymer beads of various sizes (1, 2.8 and 5 μm) suspended in a solution as well as $CD4^+$ cells in blood, which are an important marker for the HIV virus.

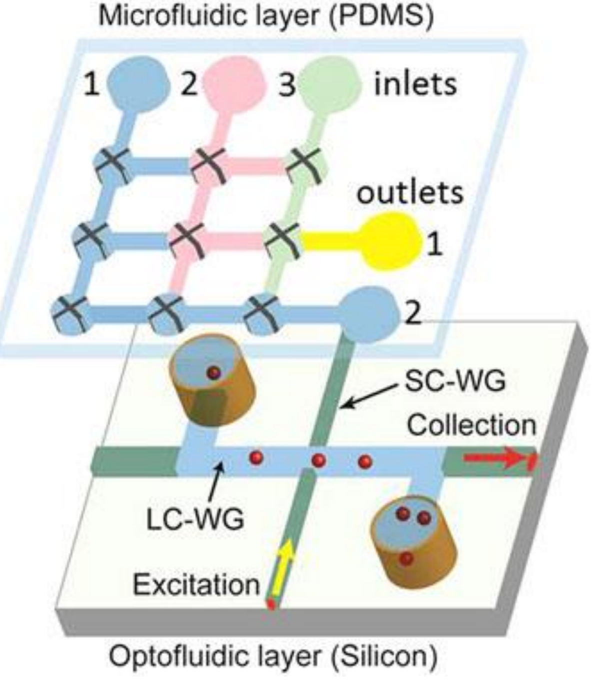
The researchers are now working on extending the system to handle larger sample volumes so that low-concentration species such as circulating tumour cells can be analysed in a fully integrated approach that automates the tasks of channel surface modification, washing and sample preparation.

OLIVER GRAYDON

A Chip-Based System for Detecting Ebola

- The device, which combines microfluidics and optics in a modular setup, reportedly can achieve sensitivities and dynamic range comparable to those of commonly used, far more complex and time-consuming lab techniques.





More info: http://www.osa-opn.org/home/newsroom/2015/september/a_chip-based_system_for_detecting_ebola/

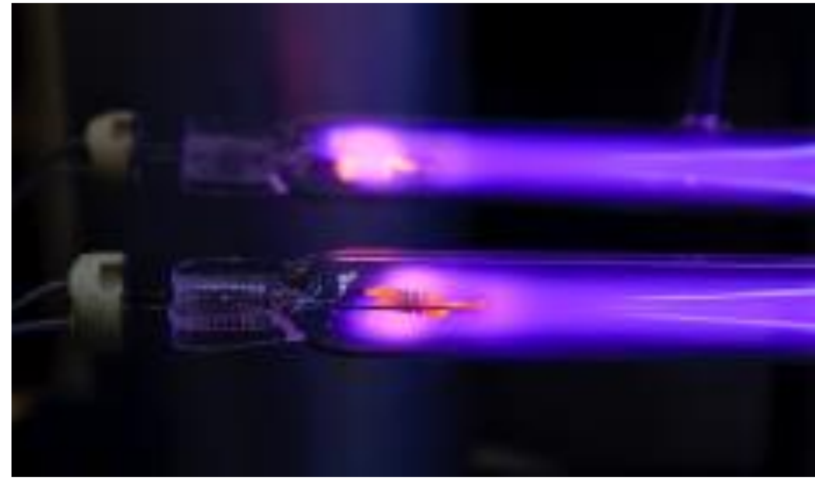
Drug verification & food safety

- Instruments employing lasers emitting a several frequencies use spectroscopy methods (eg, Fourier Transform Infrared Spectroscopy, FTIS) to identify different materials and verify the composition of different drugs.

- Hand-held spectrometers allow detecting chemical compounds during drug development and testing.
- Optical sensors also routinely used to ensure food quality and safety
  - to measure the oxygen levels inside sealed packaged food to ensure that the food inside the package will not spoil
  - Spectrometers allow to identify chemical signatures in food, to detect contaminants

UV light used for sterilizing water

- UV light's ability to alter virus DNA to halt its replication has made UV germicidal irradiant (UVGI) devices possible for water purification and medical equipment sterilization.
- UVGI devices could also disinfect hospital and healthcare rooms from deadly diseases such as Ebola, Tuberculosis and Lassa



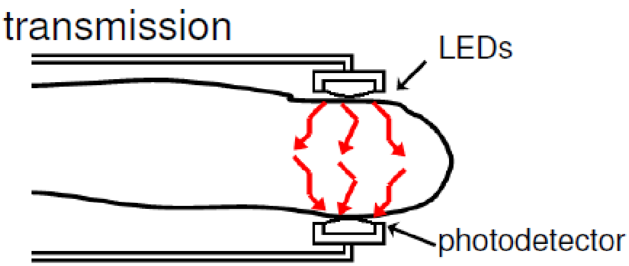
Source: ISTOCK

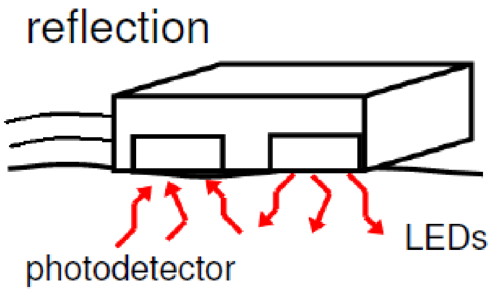
Current light sources: lamps that produce UV radiation by ionizing low pressure mercury vapor. These lamps are similar to typical fluorescent household lighting fixtures but do not have the phosphorescent coating which imparts the soft white light. Ionized mercury emits at 254nm -- s an ideal wavelength for disrupting the DNA of microorganisms. Blue LEDs can eventually replace UV lamps

Pulse Oximetry

Non-invasive method that gives information of blood oxygenation.

- A clip on the fingertip (or earlobe) is used, with a red (660nm) and IR (910 nm) LEDs facing a photodetector.
- Can be operated in reflection or transmission mode.





Source: M. Leahy (University of Limerick)

- Absorption at these wavelengths varies significantly for oxy and de-oxy haemoglobin.
- From the ratio of the absorption of the red and infrared light the oxy/deoxyhaemoglobin ratio can be calculated.
- Many conditions can be studied (depth of anesthesia, blood loss).

Take home message

- Early medical applications of lasers: dermatology, ophthalmology, dentistry.

- A huge range of advanced applications developed in the last decade:
  - Photosensitive drugs can be activated by light to detect and/or kill tumors.
  - The emerging fields of neurophotonics and optogenetics are drastically advancing our understanding of brain functioning.
  - Light therapies: delivery of light for therapeutic applications
  - Many others

TF

- High-power broad-area semiconductor lasers emit a single-mode output.
- Large two-dimensional VCSEL arrays can be combined to emit an output power of several Watts.
- Fiber lasers are optically pumped with diode lasers.
- In fiber lasers, nonlinear effects increase with the length of the optical fiber.
- Both, fiber lasers and high-power diode lasers emit high-quality outputs

TF

- In optogenetics, light activates natural chromophores, and their excitation induces alterations in cell function.
- Photodynamic therapy (PDT) requires the use of a photosensitizer.
- Light therapy uses light of appropriate wavelength, which is absorbed by chromophores, inducing chemical reactions or cellular alterations.
- Photo-bio-modulation requires high-intensity light sources to induce heating in tissue.

<cristina.masoller@upc.edu>

Universitat Politecnica de Catalunya

http://www.fisica.edu.uy/~cris/

UNIVERSITAT POLITÈCNICA
DE CATALUNYA
BARCELONATECH