

Light and Light based Technologies used in Medicine

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Introduction

Light from the sun is the main energy source for the planet earth. Humans as a part of the earth get energy from plants and animals in terms of food which are nourished by the energy of light. When our body dysfunctions (i.e. when we contract a disease), the energy distribution in our cells and related chemical bonds become abnormal. Some of these abnormalities can be corrected by applying controlled dosages of energy in terms of light. Light can be used as a therapeutic tool and a diagnostic tool. Also light can be used in its normal form or after augmentation such as in

laser. This article describes specific applications of such uses of light in medicine.

Phototherapy is the term used for the application of light in its normal form for therapeutic purposes. This includes areas such as neonatal care, dermatology and for mental and sleep related disorders.

Neonatal jaundice

Applying blue light in the wavelength range of 420-480 nm is a well-established technique to treat neonatal jaundice where energy in the blue light is capable of converting excess toxic bilirubin in the blood to a form which can be removed from the body through urine and feces.



effective cosmetic skin treatment which enhances the appearance of skin. It uses a photosensitiser which is applied on to the sun-damaged or discoloured skin area and expose to light of specific wavelength (blue or red). This combination generates free radicals and highly reactive singlet oxygen which leads to a sunburn like effect that exfoliates the superficial damaged layers of skin. Apart from cosmetic

purposes, blue light photodynamic therapy is used to treat acne by reducing bacteria in the skin and to remove melanoma cells which contributes to

skin cancer.

Mental disorders

Light therapy is a promising treatment method for seasonal/ non-seasonal depression, insomnia and dementia where the patient is expected to sit or work near a light box emitting bright white light.

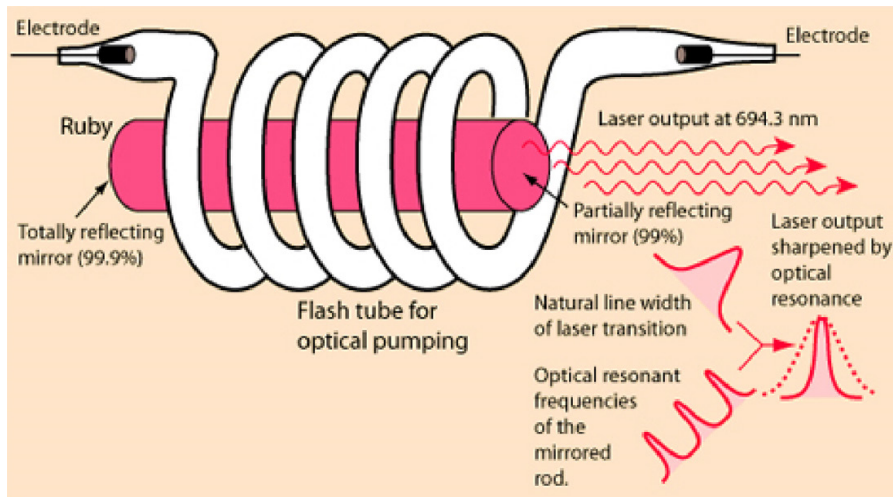
Laser

Compared to the therapeutic applications of light in normal form, augmented light has a wider scope. Among many light augmentation methods, laser (light amplification by stimulated

Dermatology

Light in dermatological treatments are used to slow down the cell growth and inflammation that causes skin abnormalities. Dermatologically, narrow band UVA (320-400 nm) and UVB (290-320 nm) light is used to treat psoriasis, vitiligo and other inflammatory skin disorders. Photodynamic therapy is a highly





emission of radiation) light help treating patient across most medical disciplines, including dermatology, dentistry, cardiology, neurosurgery and eye surgery. A laser device effectively makes atoms in a crystal pump out photons (light particles) all at once so that they line up to form a really concentrated light beam. The flash tube around the crystal flashes and supply photon energy to the atoms, which electrons of the crystal absorbs and move to a higher energy state. The instability at this level return these electrons back to a lower energy state radiating the photon energy in terms of light. When this photon hits an already excited atom, it will radiate two photons of light giving rise to an amplification of light by stimulation. A mirror at one end of the crystal keeps the photons bouncing within the crystal and a partial mirror at the other end let some escape outside which we see as a very concentrated beam of powerful laser light which bounces some photons back into the crystal.

Angioplasty

Laser angioplasty is a technique used to open coronary arteries blocked by plaque. In this procedure, a catheter is inserted

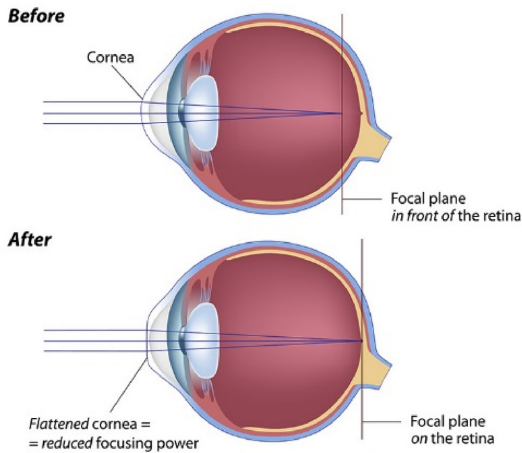
into an artery, then moved towards the blockage; once there, a laser at the tip of the tube sends pulsating beams of light to vaporize the plaque.

Cancer treatment and surgery

Laser is used for treating cancer and cancer surgery in vocal cords, oesophagus, cervical, skin, lung, vaginal, vulvar, penile and in certain lung cancers. The precision and the minimal damage to the normal tissues make laser surgery preferable over conventional surgical tools. As a result, patients

usually have less pain, bleeding, swelling, and scarring. Treatment for superficial cancers which are on the surface of the body or the lining of internal organs are very easy with laser technology, whereas cancers at harder to reach places are accessed with the use of optical fibres. Carbon dioxide (CO₂) lasers, Neodymium:yttrium-aluminum-garnet (Nd:YAG) lasers, laser-induced interstitial thermotherapy (LITT) and Argon lasers are some of the different types of lasers used for cancer treatment. Photodynamic therapy can also be conducted using laser light instead of normal form of light such as for the treatment of certain cancer tumors because cancer cells can be selectively destroyed while sparing most healthy cells. The photosensitizing agent is usually injected into the blood so that they get collected more in cancer cells than in normal cells. When the laser is focused directly on the tumor, the cancer cells absorb the light triggers a chemical reaction which destroys the cancer cells.





Eye surgery

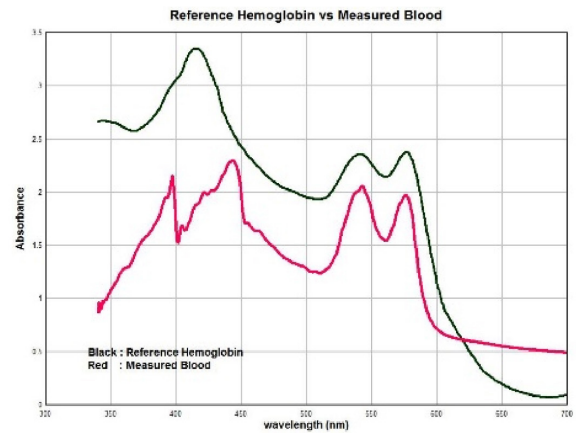
Performing eye surgery using laser as a tool is very common these days due to the high success rate and the precision the surgeon can achieve. ‘Laser vision correction’ is a common phrase used for refractive eye surgery. Here, the laser is used to reshape the cornea to correct short-sightedness, long-sightedness and uneven curvature of the cornea by adjusting the focal point back on to the retina. Usually the patient does not need to wear an eye glass once this surgery is performed. The common laser used for this type of surgery is called excimer laser which uses UV light to vaporize and

remove tissue from the eye’s surface during vision correction procedures. Non-refractive eye surgery includes repair of retinal tears, cataract surgery and glaucoma surgery. A cataract is a cloudiness of the eye’s crystalline lens due to aging or disease which prevents light from forming a clear image on the retina. During cataract surgery, a patient’s impaired natural

lens is removed using Nd-YAG laser and replaced with a synthetic lens to restore the lens’s transparency. Glaucoma is a group of diseases that damage the eye’s optic nerve which is frequently characterized by raised eye pressure resulting in vision loss and blindness. Argon or Nd-YAG laser is used to burn areas of the trabecular meshwork located near the base of the iris to increase fluid outflow thereby reducing the eye pressure.

Personalized medicine

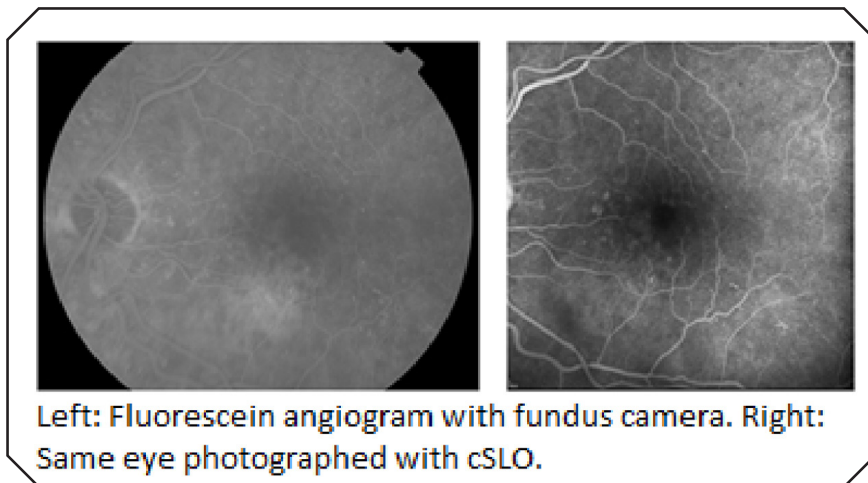
Personalized medicine refers to the concept that detection and treatment of disease can be tailored to match the characteristics of the individual patient and their particular pathology, moving away from the ‘one size fits all’ traditional approach. Light based technologies play a vital role in this futuristic treatment method by enabling the identification of nanoparticles using known biomarkers to limit



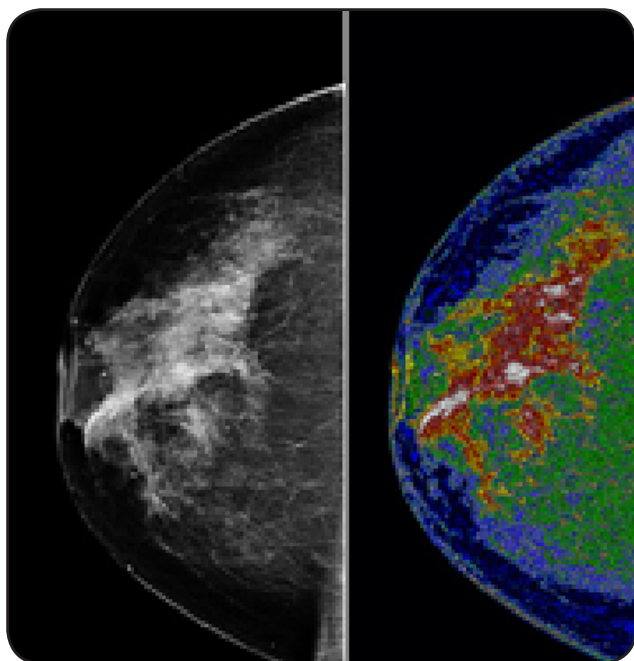
the therapeutic dose exclusively to that targeted tissue volume.

Target drug delivery

Light can also be used as a tool to target drug delivery. Current research on the drug delivery systems is focused on developing systems capable of delivering the adequate dose of drug at the target site, avoiding collateral effects and enhancing the therapeutic efficiency. In the case of cancer, light sensitive systems are particularly useful for direct treatment of malignant cells and minimizing damage to healthy cells. This process enables an easy and precise control of the medication. Switching the light



Left: Fluorescein angiogram with fundus camera. Right: Same eye photographed with cSLO.



on and off also triggers or stops the release of medication. Near infrared (NIR) light ($0.75\text{--}1.4\ \mu\text{m}$) is particularly useful as an agent capable of triggering the drug release since NIR does not cause significant heating in the area of its application.

Laser imaging

Scientists are also gaining an insight into how diseases develop and how cells react to disease, using a technique called laser imaging.

Confocal scanning laser ophthalmoscopy

Confocal scanning laser ophthalmoscopy (cSLO) is an ophthalmic imaging technology that uses laser light instead of a bright flash of white light to illuminate the retina. Confocal imaging is the process of scanning an object point by point by a focused laser beam and then capturing the reflected light through a small confocal pinhole. The result is a sharp, high contrast image of the object layer

located at the focal plane. The advantages of using cSLO include improved image quality, small depth of focus, suppression of scattered light, patient comfort through less bright light, 3D imaging capability and effective imaging of patients who do not dilate well.

Diffuse optical tomography (DOT) DOT is a non-invasive technique that utilize light in the near infrared spectral region to measure the optical properties of physiological tissue. It works best on soft tissues such as breast and brain tissue. By monitoring spatial-temporal variations in the light absorption and scattering properties of tissue, regional variations in oxy- and deoxy-haemoglobin concentration as well as cellular scattering can be imaged. Based on these measurements, spatial maps of tissue properties such as total haemoglobin concentration, blood oxygen saturation and scattering can be obtained using model-based reconstruction algorithms. DOT have applications including breast cancer imaging, brain functional imaging, stroke detection, muscle functional studies, photodynamic therapy and radiation therapy monitoring.

Spectrophotometry

Spectrophotometry data is often represented by a spectrum, i.e. a

plot of the response of interest as a function of wavelength. Spectrophotometry allows scientists to identify the makeup of organic and inorganic compounds with the use of UV, visible and IR of the light. Different molecules or inorganic compounds absorb energy at different wavelengths. Spectrophotometers use a light source to shine an array of wavelengths through a monochromators. The spectrophotometer then compares the light intensity passing through the sample to that passing through a reference compound. Spectrophotometers are used in laboratories to measure the concentrations of DNA or RNA samples, to measure the growth of bacteria cultures, to analyse blood, urine and saliva in pathology laboratories and to analyse melanoma in tissues.

Conclusion

Medical use of light and light based technologies are not limited to above mentioned application. Also, there is a high potential in exploring how light can be used to improve the field of healthcare in the years to come because light is a basic form of energy and the human body and its functionality is a complicated structure of energy based systems.



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