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# School Science

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## To Our Contributors

School Science is a journal published quarterly by the National Council of Educational Research and Training, New Delhi. It aims at bringing within easy reach of teachers and students the recent developments in science and mathematics and their teaching, and serves as a useful forum for the exchange of readers' views and experiences in science and mathematics education and science projects.

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I, Anup Kumar Rajput, hereby declare that the particulars given above are true to the best of my knowledge and belief.

**Publisher**

# EDITORIAL

We have decided to publish a special issue of School Science as the year 2015 is observed as the International year of light. We have included articles in this issue dedicated to the area of optics. The International Year of Light and Light-based Technologies (IYL 2015) is a global initiative adopted by the United Nations to raise awareness of how optical technologies promote sustainable development and provide solutions to worldwide challenges in almost all areas. The first article of this issue focuses on this theme.

We have included four more articles in this issue of *School Science* from different areas of optics that provide different information to our readers. In the article, *Arriving at the Convenient Rays for Locating Image formed by a Spherical Mirror using Ray Tracing Technique and Verification of Mirror Formula by Graphical Method*, the convenient rays for locating image formed by spherical mirrors using ray tracing technique are discussed. The article *Photonis: Concept, Devices and Application*, provides concepts of photonics. It explains about photonics and its applications.

In the article *Sources of light: What they can Reveal*, the author explains the development and evolution of light sources since ancient times to modern times.

In the article *Gamma-Ray Laser: Some Notes*, the author has given the basic information about Gamma Ray Lasers and their applications.

Further, like the other issues, this one also has Science News.

The last feature article on *42nd Jawaharlal Nehru National Science, Mathematics and Environmental Exhibition (JNNSMEE) for Children* highlights the special event held at Nirmala College Campus, Muvattupuzha, Ernakulam, Kerala from 16-22 December, 2015.

We sincerely hope that our readers would find the articles, features and news interesting and informative. Your valuable suggestions, observations and comments are always welcome to bring further improvement in the quality of journal.

# International Year of Light and Light-based Technologies

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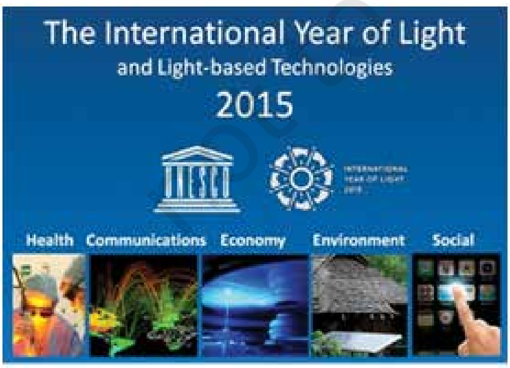
The International Year of Light and Light-based Technologies (IYL 2015) is a global initiative adopted by the United Nations to raise awareness of how optical technologies promote sustainable development and provide solutions to worldwide challenges in almost all areas. The proposal for celebrating 2015 as International Year of Light was first brought by United Nations Educational, Scientific and Cultural Organisation (UNESCO) delegates from Ghana and Mexico to the UNESCO Executive Board. Supported by 28 Board members, the resolution proposing IYL 2015 was placed before the 190th session of the UNESCO Executive Board held at Paris in October 2012. Recognising the importance of light and light-based technologies in the lives of the citizens of the world and for the future development of global society on many levels, the resolution was finally adopted by the UN in the 68th session of its General Assembly held in Paris in December 2013 (see Fig.1). Endorsed by a number of international scientific unions, IYL 2015 has partnership from more than 85 countries. Its global secretariat is located at the International Centre of Theoretical Physics (ICTP), TRIESTE, Italy, in collaboration with the UNESCO International Basic Sciences Program. In its resolution for adopting the IYL 2015, the General Assembly also considered that the light-based technologies and designs can play an important role in the achievement of greater energy efficiency, in particular by limiting energy waste, and in the reduction of light pollution, which is a key to preservation of dark skies.






United Nations Educational, Scientific and Cultural Organization

International Year of Light 2015

Fig. 1: The IYL 2015 (*http://www.epsnews.eu* and *http://www.Light2015.org*)

Light is essential for the most basic and the most advanced human activities. It is a source of life. Without sunlight, life on our planet earth, as we know it today, would not exist.

Why 2015? The year 2015 coincides with the anniversaries of a series of important milestones in the history of the science of light. Probably the most important one is the work on optics by Ibn Al-Haytham, also known as Alhazen (965 – 1040), in the year 1015. He wrote a seven-volume treatise, *Book of Optics* (Arabic: *Kitab al-Manazir*), the first book on optics (Fig. 2). Other major scientific anniversaries to be celebrated in 2015 include the notion of light as a wave proposed by Fresnel (Fresnel Theory of Diffraction) in 1815; Electromagnetic Theory of Light Propagation proposed by Maxwell in 1865, Einstein's Theory of the Photoelectric Effect in 1905 and Embedding of Light in Cosmology through General Relativity in 1915; the discovery of cosmic microwave background by Penzias and Wilson in 1965; and achievements


**Fig. 2: Cover page of the translated version of the first book on optics by Ibn Al-Haytham (taken from *https://en.wikipedia.org/wiki/Book_of_Optics*)**

of Charles Kao concerning the transmission of light in fibers for optical communication in 1965.

Celebration of anniversaries of these important discoveries and IYL 2015 is believed to provide an important opportunity to highlight the continuous nature of scientific discovery in different contexts, with particular emphasis on women's empowerment in the science sector and on promoting science education among young people, especially in developing countries. During this year many activities related to light and light-based technologies have taken place worldwide including an exhibition and a conference titled 'The Islamic Golden Age of Science for the Knowledge-based Society,'hosted by the UNESCO. India has also organised a national level competition on 'Golden Age of Science'. Amazingly, the two 2014 Nobel Prizes in Physics and Chemistry, awarded just before the IYL started, were in the area of optics and photonics. The 2014 Nobel Prize in Physics was awarded jointly to Isamu Akasaki, Hiroshi Amano and Shuji Nakamura for the invention of blue light emitting diodes. The 2014 Nobel Prize in Chemistry was awarded jointly to Eric Betzig, Stefan W. Hell and William E. Moerner for their work in fluorescence microscopy.

Sir Isaac Newton showed that white light is made of different colours – VIBGYOR. In early 20th century, Max Planck and Einstein proposed light behaves both as a particle and a wave. This duality in nature of light was experimentally verified later. The word Photonics was coined nearly 50 years ago, when the first laser was invented by T.H. Maiman in 1960.

The branch of science and technology that deals with the generation, control, and detection of particles of light— photons— is called Photonics. That is, Photonics is the science of light. We can only see a very small part of the electromagnetic spectrum— the visible region. However the invisible light waves are also indeed part of everyday life. Photonics is everywhere. It supports technologies that we use in our everyday life ranging from smartphones to laptops to the internet to the lightning technology to medical diagnosis and treatment procedures to education to manufacturing industries to entertainment to agriculture to defence and security to exploring universe to solve crimes to art and culture, etc. Photonics opens a world of unknown and far-reaching possibilities often limited by lack of imagination. It is believed that the 21st century will depend, if not more at least as much, on Photonics as the second half of the 20th century depended on electronics.

Solar energy can be converted into heat and electricity, and worldwide efforts are being made to develop affordable, productive and clean solar energy technologies. Another *round the corner* technology to use the powerful lasers to create fusion under controlled conditions, is awaiting, and can indeed make our energy future quite bright. Harnessing heat from the sun rays using technologies like solar photovoltaic panels, solar heating, solar thermal electricity, etc., can solve our problems coupled with architecture and urban planning; agriculture and horticulture; transportation; desalination and water recycling; climate change, etc. Business, in the field of light-based technologies— including the photonics, depends on solving key societal challenges, such as energy generation and energy efficiency (or productivity), healthy ageing of the population, climate change, and security.

Low-cost phone calls, video conferencing and e-commerce are some examples of how the internet allows people around us to feel so close than ever before. Miraculously, all this is possible due to light! The light data in the form of nanosecond pulses propagate in extremely thin, flexible, and transparent optical fibers. These hair-like optical fibers made of silica or plastic propagate signals from one end to another, often long distances as long as thousands of kilometres, practically without any loss, even unaffected by any electromagnetic interference. The use of ultrashort light (or infra-red) pulses of modulated signals propagating in these fibers have revolutionised the way we interact nowadays. These optical fibers have similar useful and exciting applications in other areas too, like in measuring strain, temperature, pressure, etc. For security systems, the installation of optical fibers along a fence helps in monitoring disturbances and also to trigger alarms in case of intrusions. Using a photovoltaic cell, fiber optics can be used to transmit power by converting light into electricity.

# Convenient Rays for Locating Image formed by a Spherical Mirror using Ray Tracing Technique and Verification of Mirror Formula by Graphical Method

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## Abstract

In this paper, the convenient rays for locating image formed by spherical mirrors using ray tracing technique are discussed. Only concave mirror is taken for the purpose of illustration and simplification. Ray tracing technique is used to locate images formed by concave mirrors using graphical method. The mirror formula is verified empirically using graphical method by measuring the values of image distance, object distance and focal length of the concave mirror. This technique of finding the image formed by a concave mirror using ray tracing technique by graphical method was used in teacher training programmes and it is being published for wider dissemination.

## Introduction

Normally an image formed by spherical mirrors (concave and convex mirror) is taught at the secondary stage in the country. Ray tracing technique is used to find images formed by spherical mirrors. The paper tries to arrive at some of the convenient rays for locating images formed by spherical mirror using ray tracing technique. Preliminary concept of mirror formula is also introduced at secondary stage without giving derivation of the formula. Students are expected to use the mirror formula while solving problems related to image formed by a concave or convex mirror. In Section I of this paper, the assumptions made in arriving at these convenient rays for locating images formed by a concave mirror are discussed. In Section II, ray diagrams are sketched in a graph paper using the convenient rays for locating image formed by a concave mirror. Mirror formula is empirically verified by measuring the values of image distance, object distance and focal length of the concave mirror from the graph paper.

### Section I

The reflection of light in case of images formed by a plane mirror occurs on plane surface. The *laws of reflection* are obeyed in plane mirror. In spherical mirror (here we will consider only concave mirror for simplification purpose) reflection of light occurs at curve surfaces. It must be remembered that the *laws of reflection* hold for curve surfaces also. At each point on the curved surfaces one can draw a surface tangent and draw the corresponding normal. Once we have a normal we can find the angle of incidence and the corresponding angle of reflection for a ray incident on it.

Let us look into how some of the convenient rays used for locating images formed by spherical mirrors are arrived at and what are the assumptions made to arrive at these rays. Draw a circle preferably with a dotted line, with point C as its centre as shown in Fig. 1. Consider a section MN marked on this circle as shown in the Fig. 1, so that this section represents a concave mirror. Let us mark the geometrical centre of the arc MN as pole P of the concave mirror. The line PC represents the principal axis of the concave mirror. Let us take a point $X_1$ on the surface of the concave mirror and draw a tangent at the point $X_1$ on the surface of the concave mirror. A line perpendicular to the tangent at the point $X_1$ will be normal to the curve surface at the point $X_1$ and will pass through the centre of the curvature C of the concave mirror. Since the point $X_1$ can be moved anywhere along the section of the concave mirror, by applying the geometrical properties of a sphere, a normal can be drawn at the corresponding point and we can always find the directions of the reflected ray by applying the *laws of reflection*.

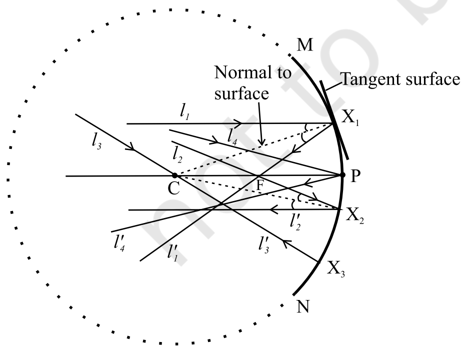


**Fig.1: Reflection at a spherical surface**

We can indentify more points say, $X_2$ and $X_3$ as shown in Fig. 1 and find the direction of the reflected ray. An incident ray $l_1$ parallel to the principal axis is incident at the point $X_1$, after reflecting from the concave mirror it is reflected as $l'_1$ and passes through the focus F. Let us apply the *laws of reflection* for the concave mirror at the point $X_1$, with the incident and reflected rays making the same angle $\theta_i$ and $\theta_r$ ($\theta_i = \theta_r$) with the normal to the surface at point $X_1$. Consider another incident ray $l_2$ passing through the focus F and incident at the point $X_2$, after reflection, the reflected ray $l'_2$ travels parallel to the principal axis. Similarly, we take incident rays $l_3$ and $l_4$, the reflected rays will travelled as $l'_3$ and $l'_4$ respectively as shown in the Fig. 1. Remember that all the rays considered above after reflection on the concave mirror obey *laws of reflection.*

Now coming to the image formation by a concave mirror, consider a point object A on the principal axis of the concave mirror as shown in Fig. 2. An infinite number of rays emanate from this point object. The rays then diverge from this point in all directions. The rays which get reflected from the concave mirror and converge at the image point I contribute to the image formation of the point object. As can be seen from Fig. 2, although all incident and reflected rays obey *laws of reflection*, only rays that strike the concave mirror near the axis AP, contribute to the image formation whereas rays that strike the mirror at points far from the principal axis on reflection pass near the image point and not on the image point.

Similarly, let us consider the rays incident on a concave mirror parallel to the principal axis as shown in the Fig. 3. All rays which are near the principal axis after reflecting from

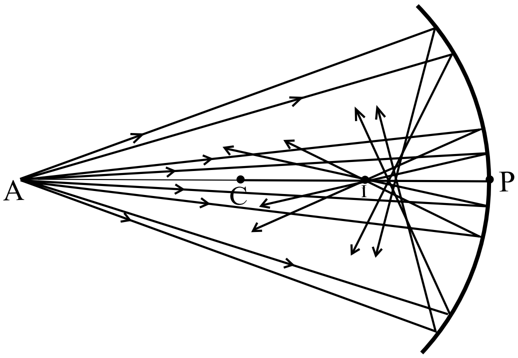


**Fig. 2. Incident rays from a point source reflected by a concave mirror**

the concave mirror pass through the focus F, whereas rays far off from the principal axis after reflecting from the concave mirror pass near the focus and not on the focus.

Remember that all the rays obey the law of reflection while reflecting from the concave mirror. Rays almost parallel with the principal axis and near to it are paraxial rays. Rays that strike the mirror at points far from

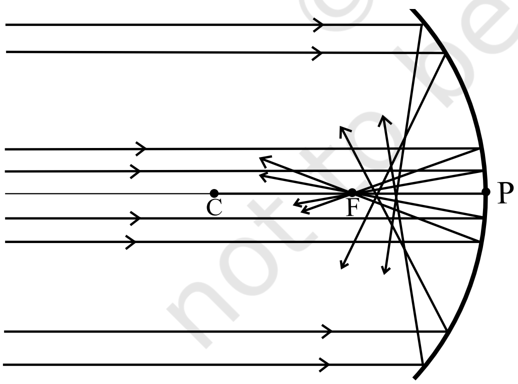


**Fig. 3. Incident parallel rays reflected by a concave mirror**

the principal axis upon reflection pass near the image point, but not through it. Such rays cause the image to blur and the effect is called spherical aberration. The image can be sharpened by blocking all non paraxial rays. To minimise spherical aberration a concave mirror having large focal length or large radius of curvature and small aperture is used. Thus the concave mirror which we will be referring is assumed that it has large focal length and small aperture. For such a concave mirror, $f = \frac{R}{2}$, where *f* is the focal length of the mirror and *R* is the radius of curvature of the mirror.

Thus the assumption we have made so far is that only paraxial rays contribute to the image formation and the mirror has a large focal length and small aperture. Although all paraxial rays reflected by the concave mirror contribute to image formation, some rays are more convenient to use due to the geometrical construct of spherical surfaces or symmetrical nature of the incident and reflected ray and not requiring us to measure every time the angle of incident and reflected rays. The convenient rays used for locating image formed by a concave mirror in most of the textbooks including Science Textbook, Class X, NCERT are listed below.

(i) A ray parallel to the principal axis, after reflection, will pass through the principal focus in case of a concave mirror [Fig.1].

(ii) A ray passing through the principal focus of a concave mirror after reflection will emerge parallel to the principal axis [Fig.1].

(iii) A ray passing through the centre of curvature of a concave mirror after reflection is reflected back along the same path [Fig.1].

(iv) A ray incident obliquely to the principal axis, towards a point P (pole of the mirror), on the concave mirror [Fig1.] is reflected obliquely. The incident and reflected rays follow the laws of *reflection* at the point of incidence (point P), making equal angles with the principal axis.

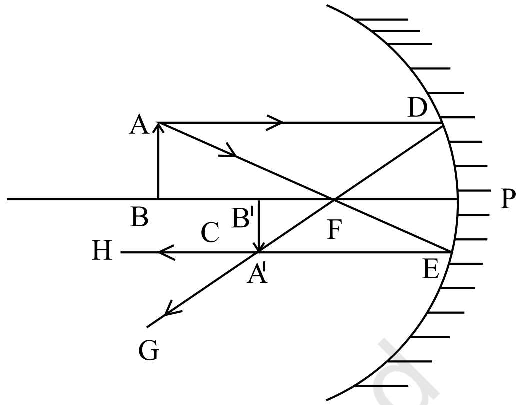


**Fig. 4. Image formed by a concave mirror**

## Section II

Let us take a graph paper and draw a concave mirror of focal length, say 25 cm (or in grid unit) as shown in the Fig. 4. This may be taken as a representative Fig. and it is ensured that the mirror has a large radius of curvature and we are considering rays closed to the principal axis only.

We place an object AB on the principal axis at a distance u from the pole of the spherical mirror. Now, measure the distance of the object from the pole of the mirror (say in the unit of centimetre or in grid unit). Using a ray tracing technique we traced a ray AD parallel to the principal axis and after reflecting through the surface of the concave mirror it will pass through the principal focus F (Remember the ray which we have traced obey the *laws of reflection*) and travelled as ray DG as shown in Fig. 4. Similarly draw a ray AE which pass through the principal focus F and the ray after reflection on the surface of the concave mirror will travel parallel to the principal axis as EH as shown in the figure 4.

The ray DG and EH will meet at the point A'. This is the image of the object point A. Draw a line perpendicular to the ray EH from the point A' to meet at a point B' on the principal axis. Joined the point A'B' to obtain the image of the object AB. Now, measure the distance of the image from the pole to the point B'. This distance will give us the image distance $v$. From the ray we have traced on the graph paper we can verify the mirror formula. Substitute the value of the image distance, object distance and focal length in the mirror formula.

From the ray traced on the graph we can find the value of u, v and f in number of grid units.

Here, $u$= -12, $v$= -8 and f= -5 {Using Cartesian sign convention}

Putting these values in the mirror formula,

$$\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$$

Let us put the value for left hand side,

$$\frac{1}{u}+\frac{1}{v}=-\left(\frac{1}{12}+\frac{1}{8}\right)=-\frac{5}{24}$$

Again let us put the value for right hand side,

$$\frac{1}{f}=-\frac{1}{5}$$

Thus left hand side value is very close to the right hand side value (Ideally this two values should be equal and if we take a more closely space grid line graph, we can more accurately verify the mirror formula).

Further, we can also find the magnification produced by the concave mirror.

$m=-\frac{v}{u}-\frac{8}{12}=-\frac{2}{3}$, the negative sign shows that the image formed is inverted.

We have discussed about the image formed by a concave mirror when an object is placed on the principal axis. Now let us consider an object placed slightly away from the principal axis as shown in the Fig. 5.

We place an object KL as shown in Fig. 5.

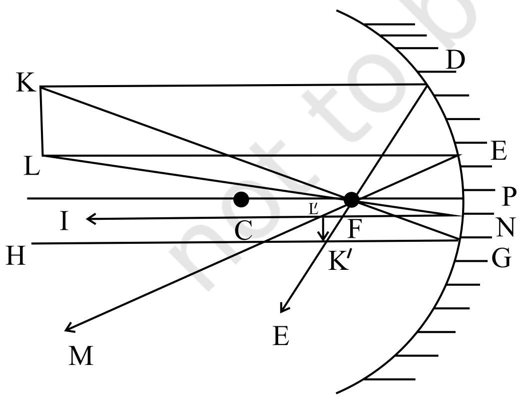


**Fig. 5. Image formed by a concave mirror when an object is lightly placed away from the principal axis**

Draw a ray KD parallel to the principal axis and after reflecting from the concave surface, it will pass through the principal focus F and travel as ray DE. We also traced a ray KG passing through the focus F and after reflection from the concave mirror, it will travel as ray GH parallel to the principal axis.

Similarly we can trace a ray LE parallel to the principal axis and after reflecting from the concave mirror, it will pass through the focus F as ray EM. Also we trace a ray LN passing through the focus and after reflecting from the concave mirror, it will travel as ray NI parallel to the principal axis. The ray DE and GH will meet at a point K' and the ray EM and NI will meet at the point L'. Now join the point K' and L'. The distance K'L' gives the size of the image.

### Conclusion

The convenient rays used for locating images formed by concave mirror in ray tracing technique follow laws of reflection. Only paraxial rays reflected by the concave mirror contribute to image formation. Further, images formed by a concave mirror can be located using a ray tracing technique on a graph paper. Hence image formation by spherical mirrors can be taught through ray tracing on a graph paper and we can also empirically verify the mirror formula.

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# Photonics: Concept, Devices and Applications

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## Introduction

Sense of vision is very important for all of us, as it is our window to the world. Light coming from objects after reflection or scattering facilitates our eyes to observe the objects and hence the entire world with the help of light. We cannot imagine about the world without light. As study of polity is politics and study of economy is economics; in the same way, study of photon (light) is the photonics.

The term 'Photonics' can be understood in close analogy with the familiar term of electronics. Electronics involves control of electric charge flow whereas photonics involves the control of photons in vacuum or in matter. Photonics reflects the growing tie between optics and electronics forged by the increasing role that semiconductor materials and devices play in optical systems.

Photonics deals with the generation, propagation, manipulation, and use of information and energy of light. To understand photonics, it is essential to know about behaviour and properties of light. The light waves are a part of electromagnetic spectrum ranging from short wavelength of gamma rays and X-rays to long wavelength of radio waves. All the components of electromagnetic spectra obey some common basic laws and in this sense, study of light is applicable in some way to other components of electromagnetic spectra also. Wavelength of light varies approximately from 400 to 780 nm. Different colours correspond to different wavelengths.

According to the view of classical physics light is a wave consisting of electric and magnetic field with a smooth distribution of energy. Observed phenomenon of light like reflection, refraction, diffraction, polarisation and interference give direct experimental evidence of the wave properties of light. However, in the earlier years of twentieth century, theoretical and experimental investigations established that light sometimes has particle properties. According to this view, light acts like a particle like energy packets. These energy packets are called quanta of light or photons. As photon is central theme of the photonics, it will be interesting to know the emergence of the concept of photon.

## Concept of Photon

It is worth mentioning here that every object (substance) emits thermal radiations above absolute zero temperature. We generally do not observe them because most of the radiations are in infrared region and our eyes are not sensitive to infrared region of the spectrum. Our eyes are sensitive only to the visible region of the electromagnetic spectrum. However, when objects are heated to higher temperatures, some of the thermal radiations get converted into light, i.e. objects emit light. Different objects have different emissive power (emissivity). There may be objects or bodies with high emissive power. An object with perfect emission power (at higher temperature) or perfect absorption power (at lower temperature) is termed as blackbody. The spectrum of a blackbody was a point of discussion for a long time. Rayleigh-Jeans law explained the higher wavelength side of blackbody spectrum, but it failed to explain the spectra at lower wavelengths. This failure is popularly known as "ultraviolet catastrophe". On the other hand, Wein's law was valid for lower wavelength region. There was no single theory which could explain the whole range of spectra. Planck, one of the pioneer of Quantum Mechanics, came up with very fascinating idea that atomic oscillators do not emit energy continuously rather they emit energy in packets and energy of one packet is Planck's constant multiplied by the frequency of the oscillator. Later on, in 1905 Einstein came up with the idea of quantum of light energy while explaining the photoelectric effect. This light quantum was termed as "Photon" first time by a chemist Gilbert N. Lewis in 1926. The name is derived from Greek (photo = light) and the "-on" at the end of the word indicates that the photon is an elementary particle belonging to the same class as the proton, the electron and the neutron.

## Dual Nature of Light

Different views have been given from time to time regarding nature of light starting from Newton's corpuscular model to Huygen's wave model and to Maxwell's electromagnetic wave model. Newton's model treats light in particle form, while other two models treat it as wave. Later on, de Broglie concluded that light has dual nature. Some observed phenomena of light like interference, diffraction, polarisation, etc. can be explained by its wave nature, while some other phenomena like Photoelectric effect, Compton effect, etc. need particle nature of light to be understood. It has dual character in the same way as subatomic particles like electron, proton, etc., exhibit both particle as well as wave nature. These two natures are complementary to each other.

Maxwell's electromagnetic theory reveals that the speed of electromagnetic waves including light in free space is given by $c=1/\sqrt{\mu_0 E_0}$ where $\mu_0$ is permeability of free space and $E_0$ is permittivity of free space. Speed of light is less than $3 \times 10^8$ m/s in other media. It gives a clue that there is interaction between light and matter.

## Interaction of Light with Matter

In interaction of light with matter, light behaves as if it is made up of particles called photons. Each photon has energy hv and momentum $h\nu/c$ where c is the speed of light. The rest mass of photon is zero. However, it is never at rest. It moves with speed c relative to all frames of reference. The moving mass of photon is $m=E/c^2=h\nu/c^2$. All photons of particular frequency v have the same energy ($E= h\nu$) and momentum ($p= h\nu/c$), whatever the intensity of radiation may be. Photons are electrically neutral and are not deflected by electric and magnetic fields. In a photon-particle collision the total energy and total momentum are conserved. However, the number of photons may not be conserved in a collision. The photon may be absorbed or a new photon may be created.

Photon interacts with matter in three ways depending on its energy. When it has a low energy in few electron volts and is made incident on a metal surface with low ionisation potential, it knocks out the loosely bound electrons on the surface and these electrons are known as photo electrons contribute in producing electric current. This effect of photons with matter is known as photo electric effect. Cells, made to be operated using this phenomenon are known as photo cells.

If energy of an interacting photon is more than 1.02 MeV then it is able to produce a pair of electron and a positron (particle-antiparticle) both having same rest masses of 0.51 MeV, with opposite charges. This phenomenon is termed as Pair Production. This is one of the best examples where energy (non matter in terms of photons) is converted into mass (in terms of massive particles – electron and positron). The annihilation of an electron with a positron again provides photons.

When the required energy of photon is not very low for photo electric effect and not so high for pair production, Compton scattering takes place where scattered photon has longer wavelength. This change in wavelength results in a Compton shift or Compton profile which is used in characterisation of materials.

The interaction between light and matter is at the heart of Photonics. Let us discuss about photoelectric effect in more detail.

## Photoelectric Effect

Emission of electrons from the surface of certain materials when exposed to light is known as the photoelectric effect. The effect was discovered by Hertz in 1887 during his investigations of electromagnetic wave propagation by means of spark discharge. Hertz observed the increase in high voltage sparks across the detector loop when the emitter plate was illuminated by ultraviolet light from an arc lamp. Later on, during 1886-1902, Wilhelm Hallwachs and Philipp Lenard investigated the phenomenon of photoelectric emission in detail. They studied how the photo current varied with collector plate potential, and with frequency and intensity of incident light and also observed that electrons were emitted only when they used ultraviolet light of frequency greater than a certain minimum value, called the *threshold frequency*. This minimum frequency depends on the nature of the material of the emitter plate.

The phenomenon of photoelectric emission could be understood qualitatively on the basis that when light is absorbed by the surface, it transfers energy to electrons near the surface and that some of the electrons acquire enough energy to overcome the potential energy barrier at the surface and escape from the material into space. All the photosensitive substances emit electrons when they are illuminated by light.

### Experimental features of photoelectric emission

The experimental features of the photoelectric emission encompasses that (i) for a given photosensitive material and frequency of incident radiation above some minimum frequency, photoelectric current is directly proportional to the intensity of light, (ii) saturation current is found to be proportional to the intensity of radiation whereas the stopping potential is independent of intensity, (iii) below a certain minimum cut off frequency, called threshold frequency, no emission of photoelectrons takes place.

Above the threshold frequency, the stopping potential or equivalently the maximum kinetic energy of the emitted photoelectrons increases linearly with the frequency of the incident radiation, but is independent of its intensity, and (iv) the photoelectric emission is an instantaneous process without any apparent time lag (~$10^{-9}$s) even when the incident radiation is made exceedingly dim.

### Photoelectric effect and quantum theory of radiation

The wave nature of light was well established by the end of the nineteenth century. The phenomena of interference, diffraction and polarisation were explained in a natural and satisfactory way by the wave picture of light. But the wave picture is unable to explain the most basic features of photoelectric emission. In 1905, Einstein proposed a radically new picture of electromagnetic radiation to explain photoelectric effect. In this picture, continuous absorption of energy from radiation is not the cause of photoelectric emission. Rather energy is built up of discrete units, i.e. quanta of energy of radiation named as photon. Each quantum has energy h*v* where h is Planck's constant and *V* the frequency of light. In photo electric effect, a quantum of radiation with energy h*v* is used by electron to overcome the surface barrier and have some kinetic energy after liberation. Einstein's photoelectric equation given by $h\upsilon = h\upsilon_0 + K_{max}$ (where $\phi_0 = h\upsilon_0$ is work function of the material, $K_{max}$ is maximum kinetic energy of photo electron, $\upsilon$ is frequency of incident light, $\upsilon_0$ is threshold frequency and h is Planck's constant) gives the explanation of all the experimental observations on photoelectric effect in a very simple and elegant manner.

## Emergence of Photonics

Emergence of photonics is an important area of research and technology because of the recent advances in the last few decades, i.e. the invention of laser, optical fibers and semiconductor optical devices. Let us discuss these briefly one by one.

### LASER

A laser is a device in which Intensity of particular electromagnetic wave (say light) is amplified by the process of stimulated emission. Laser light is highly directional, monochromatic and of high intensity. Lasers are of variable sizes ranging from approximately few micrometres to few metres. Power of a laser beam is enormous ranging from nanowatts to zettawatts ($10^{21}$ W) for very short bursts or pulses of very short duration (~$5\times10^{-15}$ s). Laser light is generally not used for lighting in our homes or streets. This is because they are costlier than their ordinary light counterpart of the same power and the same colour. Moreover, there are serious safety issues involved.

The word LASER is an acronym for Light Amplification by Stimulated Emission of Radiation. The process of stimulated emission of radiation was first identified by Einstein. The electrons in the atom are found in particular energy levels. They are moved to higher-lying (say excited) levels by getting energy from the external source. These excited electrons come back to lower-lying (say ground) levels within a period of time called the lifetime of the level. When light beam interacts with atoms that have electrons residing in various energy levels, three types of processes (spontaneous emission, absorption and stimulated emission) can happen (Fig. 1).

First, when an electron spontaneously jumps from excited state to the ground state, a photon of particular frequency is radiated out. This process is known as spontaneous emission as indicated in Fig. 1(a). The frequency of emitted photon depends on the energy difference ($E_{21}=h\nu_{21}=hc/\lambda_{21}$) of the two energy levels (2 and 1 in this case). Most of the excited energy levels undergo spontaneous emission. Lifetime of excited energy level is determined by the interactions of the electron with the other electrons and nuclei of that atom. It is of the order of 10–100 ns for visible portion of the spectrum. The ground state has infinite lifetime as it cannot decay further. The energy levels of different materials are arranged differently and thus we get different colours of light emitted by them which are specific to the material. Spontaneous emission is responsible for nearly all the light we see.

The second process is absorption, shown in Fig. 1(b), which occurs if the atom has its electron in level 1 and a photon of light of energy $E_{21}$ collides with the atom. In this process, the photon is absorbed by the atom and the electron is moved up to the higher energy level 2. This process is the way light interacts with practically all of matter. It enhances the energy of the atom and incident photon is disappeared (eliminated). Absorption often leads to heating of the absorbing material.

The third process, shown in Fig. 1(c), is referred to as stimulated emission. It results when an electron is already in a higher-lying level, such as level 2, and a photon of energy $E_{21}$ collides with the atom. This photon

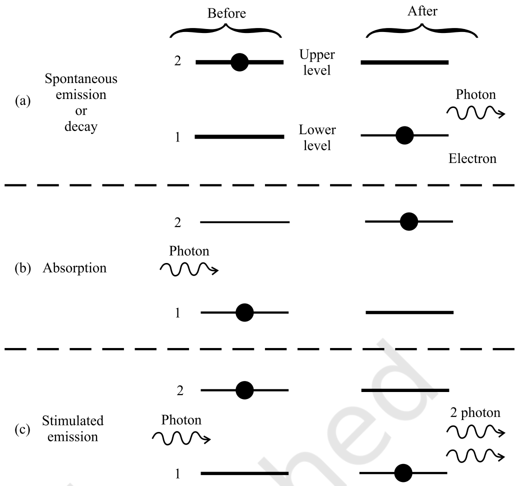


**Fig. 1 The three radiation processes that can occur when light interacts with matter (atoms)**

stimulates the atom to radiate a second photon having exactly the same energy $E_{21}$ as that of the incident photon and travelling in exactly the same direction in order to satisfy the laws of conservation of energy and momentum. Hence, one photon leads to two identical photons, leading to an amplification process. The amplification of light is at the expense of the loss of energy stored within the atom. This process is responsible for the operation of laser.

Generally the electrons in the higher-lying levels are less than that in the lower-lying levels at room temperature. When number of electrons is increased in the higher-lying levels by pumping them from external source, the population in lower-lying levels is decreased and this situation is known as population inversion. Population inversion resulting in stimulated emission is the basic requirement for getting a laser action. Moreover, for continuous amplification of light, the emitted photons of same energy should not be lost from the material except in the form of exit beam. Keeping these in view, the following are the requirements for a typical laser device (Fig. 2):

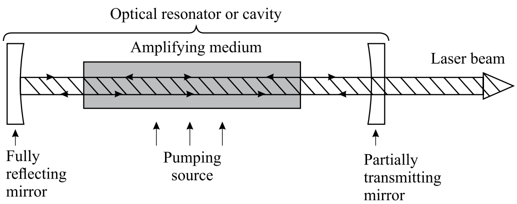


**Fig. 2 Basic laser components including gain medium, pumping source, and mirror cavity**

1. Amplify or gain medium
2. Pumping source to input energy into the device, and
3. An optical cavity or mirror arrangement that reflects the beam of light back and forth through the gain medium for further amplification.

### Laser gain medium

Laser gain medium refers to radiating species, where electrons in excited states jump to lower-lying levels as a result of stimulation by the pumping agency. These radiating species can include: atoms such as in the red helium-neon (He-Ne) laser, molecules such as in the infrared carbon dioxide ($CO_2$) laser, liquids such as those involving various organic dye molecules dilutely dissolved in various solvent solutions, dielectric solids such as those involving neodymium atoms doped in YAG or glass to make the crystalline Nd:YAG or Nd:glass lasers, semiconductor materials such as gallium arsenide or indium phosphide crystals. In each of the above species, there is a lowest energy level referred to as the ground state and various excited energy states.

### Laser pumping sources

The means, by which energy is transferred into the laser gain medium to produce the required population inversion, are known as laser pumping sources. Two types of pumping is generally used— electron pumping and optical pumping.

Electron pumping is used primarily in gaseous or semiconductor gain media. When few initial electrons are accelerated by an electric field in gaseous media and they collide to atoms, some of the atoms are ionized. Electrons are liberated in the ionization process. These liberated electrons are also accelerated and an avalanche of electrons is produced. In semiconductors, the electrons flow through the semiconducting material by applying a voltage across the *p-n* junction with the positive voltage on the side of the p-type material. This leads to recombination radiation when the electrons combine with the holes in the junction. Optical pumping of lasers generally applies to the pumping of liquid (dye) lasers and to dielectric solid-state lasers and is provided by either flash lamps or other lasers. A voltage is applied across the electrodes of the flash lamp and current flows through the gas, populating excited levels of the atoms within the gas that radiate and produce intense light emission. Xenon is the most common species used in flash lamps.

### Laser mirrors

The properties of laser beam such as direction and divergence of the beam, the beam profile, and the wavelength and frequency characteristics of the laser are determined largely by the laser mirrors. The factors determining those properties include mirror curvature, surface quality, and reflectivity as well as separation and location, assuming that the structure holding the mirrors is a secure, vibration-free structure. The unique electromagnetic wave properties produced by the mirrors are referred to as modes.

Examples of common lasers are He-Ne laser, Argon ion and Krypton ion laser, He-Cd laser, Copper vapour laser, $CO_2$ laser, Excimer laser, Organic dye laser, Ruby laser, Nd:YAG and Nd:glass laser, Ti:$Al_2O_3$ laser, Erbium fiber laser, Semiconductor lasers (solid state). Some of the laser properties which make them extremely useful for diverse applications are collimation, monochromaticity, coherence, intensity and focusability. Most of these properties are interrelated. Still, only one of the properties is typically sought for a specific application.

### Optical Fiber

Communication is an essential need of human being and it is becoming fast and more reliable in spite of the enormous increase in signal traffic. This became possible largely due to the availability of optical fibers. It is an established fact that the carrier frequencies associated with TV broadcast (~50–900 MHz) are much higher than those associated with AM radio broadcast (~600 kHz–20 MHz). More information can be sent by increasing the carrier frequency. The visible light has its frequency in the range of $10^{14}$ to $10^{15}$ Hz and one can expect tremendously large information-transmission capacity as compared to radio waves or microwaves.

It is worth to mention here that the idea of using light waves as a carrier wave was tried way back in 1880 by Alexander Graham Bell, who invented the photophone shortly after he invented the telephone in 1876. In this remarkable experiment, speech was transmitted by modulating a light beam, which travelled through air to the receiver. The flexible reflecting diaphragm (which could be activated by sound) was illuminated by sunlight. The reflected light was received by a parabolic reflector placed at a distance of about 200 m. The parabolic reflector concentrated the light on a photoconducting selenium cell, which formed a part of a circuit with a battery and a receiving earphone. Sound waves present in the vicinity of the diaphragm vibrated the diaphragm, which led to a consequent variation of the light reflected by the diaphragm. The variation of the light falling on the selenium cell changed the electrical conductivity of the cell, which in turn changed the current in the electrical circuit. This changing current reproduced the sound on the earphone.

After succeeding in transmitting a voice signal over 200 metres using a light signal, Bell wrote to his father: "I have heard a ray of light laugh and sing. We may talk by light to any visible distance without any conducting wire." To quote from Maclean: "In 1880 he (Graham Bell) produced his 'photophone' which to the end of his life, he insisted was '.... the greatest invention I have ever made, greater than the telephone...' Unlike the telephone, though, it had no commercial value."

The idea of using light waves as carrier waves for telecommunication didn't become a reality, because no suitable light source was available. The hopes were again high after the discovery of the laser in 1960. Still, there were no optical analogues of conventional communication systems because guiding the laser beam to long distances was a difficult task due to scattering and absorption by the atmosphere. This guiding of the light is done by the optical fiber, a hair-thin structure. The light is confined within the fiber because of total internal reflection. Transmission speed of about 2.5 Gbit/s (35,000 or more simultaneous telephone conversations) is possible through one glass fiber. Optical fibers are also characterised by extremely low losses (< 0.2 dB/km). It is worth to mention that it was historical paper of Kao and Hockham in 1966 that suggested that optical fibers based on silica glass could provide the necessary transmission medium. Indeed, this 1966 paper triggered the beginning of serious research in developing low-loss optical fibers. In 1970, Kapron, Keck, and Maurer (at Corning Glass in USA) were successful in producing silica fibers with a loss of about 17 dB/km at a wavelength of 633 nm. Since then, the progress in optical fibers technology has been phenomenal with routine production of optical fibers with extremely low losses (< 0.2 dB/km). Fig. 3 shows a typical optical fiber communication system. It consists of a transmitter, which could be either a laser diode or an LED, the light from which is coupled into an optical fiber. Along the path of the optical fiber are splices, which are permanent joints between sections of fibers, and repeaters that boost the signal and correct any distortion that may

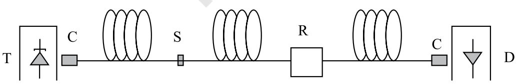


**Fig. 3: A typical fiber optic communication system: T, transmitter; C, connector; S, splice; R, repeater; D, detector**

have occurred along the path of the fiber. At the end of the link, the light is detected by a photodetector and electronically processed to retrieve the signal.

### Total Internal Reflection (TIR) in Optical Fibers

Whenever light travels from denser to rarer medium and its angle of incidence is greater than the critical angle, it reflects back in the denser medium without any refraction as shown in Fig. 4. (a-c). This phenomenon is known as total internal reflection (TIR).

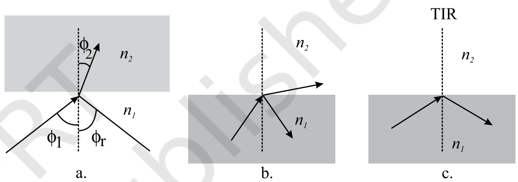


**Fig. 4 (a) mA ray of light incident on a denser medium ($n_2 > n_1$). (b) A ray incident on a rarer medium ($n_2 < n_1$). (c) For $n_2 < n_1$, if the angle of incidence is greater than critical angle, it will undergo total internal reflection.**

A typical optical fiber (Fig. 5a) consists of a (cylindrical) central dielectric core clad by a material of slightly lower refractive index (cladding). The refractive index of core ($n_1$) is greater than the refractive index of cladding ($n_2$). The cladding is usually pure silica while the core is usually silica doped with germanium. If a light ray enters through the end of a fiber core at the angle of incidence $\varphi$ (at the internal core-cladding interface) which is greater than the critical angle $\varphi_c$ [= $\sin^{-1}$ ($n_2$/$n_1$)], the ray will undergo TIR at that interface. Further, this ray will suffer TIR at the lower interface also leading to repeated total internal reflections within core (Fig. 5b). When fiber is bent, then also the light is confined in the fiber, if incident within acceptance cone. The material

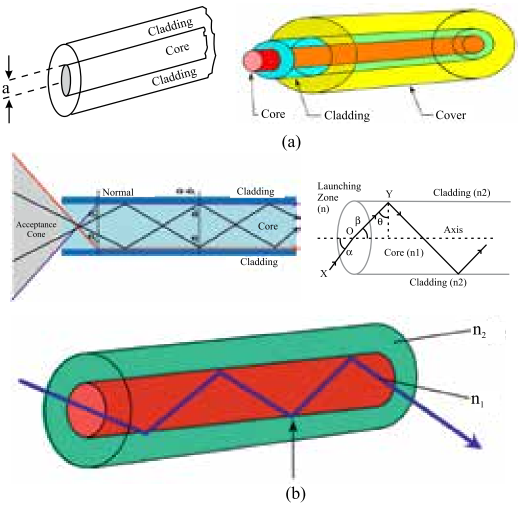


**Fig. 5: A glass fiber consists of a cylindrical central core clad by a material of slightly lower refractive index. (b) Light rays impinging on the core-cladding interface at an angle greater than the critical angle are trapped inside the core of the fiber.**

of the optical fiber should absorb very little amount of light, be temperature sensitive and should have considerable strength. All these requirements are fulfilled by the glass (silica). Typically, for commercially available silica fibers, if light signal is transmitted through 1 km of optical fiber, only 4% of the power is lost. This is remarkable achievement.

## Optoelectronic Devices

Optoelectronics is an important field of photonics, where a useful interaction between semiconducting materials and light is explored for the origin, control and detection of light. The list of these devices is very long. We would like to discuss three important optoelectronic devices here: photo diode, solar cell and LED. In these semiconducting junction devices, either light controls the charge carriers or the light is controlled by the charge carriers.

### Photodiode

*A photodiode is a specially designed* p-n junction diode, where light is allowed to fall on the junction region through a transparent window. It is operated under reverse bias. When the photodiode is illuminated with light (photons) with energy greater than the band gap of the semiconductor, then electrons are shifted from valence band to conduction band leaving vacancies behind as holes. Thus electron-hole (e-h) pairs are generated near the depletion region of the diode. The electrons and holes are separated before they recombine because of the in-built electric field of the depletion region. The direction of the electric field is such that electrons reach n-side and holes reach p-side. Electrons are collected on n-side and holes are collected on p-side giving rise to an emf. When an external load is connected, current flows in the circuit. On increasing intensity of light, more e-h pairs are generated and higher current flows in the circuit. It is easier to observe the change in the current with change in the light intensity, when a reverse bias is applied. Thus photodiode can be used as a photodetector to detect optical signals. The circuit diagram used for the measurement of *I-V* characteristics of a photodiode is shown in Fig. 6(a) and a typical *I-V* characteristic is shown in Fig. 6(b).

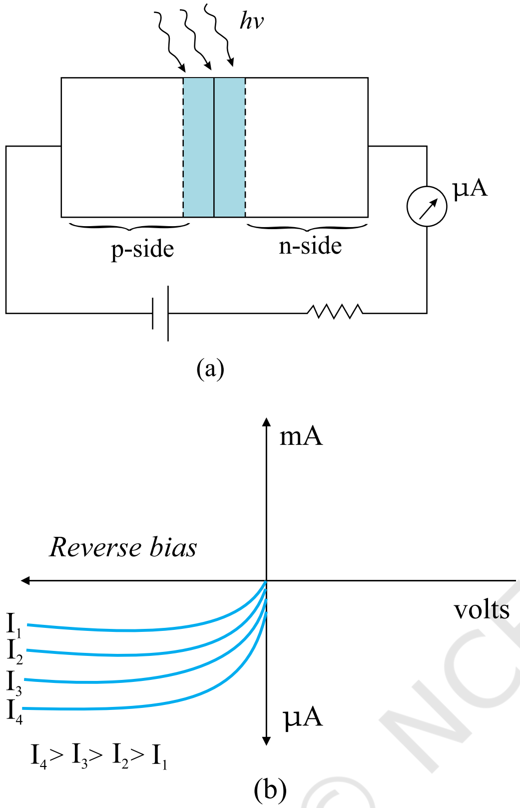


**Fig. 6 (a) An illuminated photodiode under reverse bias, (b) *I-V* characteristics of a photodiode for different illumination intensity $I_4 > I_3 > I_2 > I_1$.**

## Solar Cell

Solar cell (also known as photovoltaic cell) is a device, which converts sunlight into electricity. However, it should be noted that apart from sunlight, other types of light can also be used for a solar cell. Solar cell is basically a p-n junction diode working in the same way as photodiode, but solar cell has no external bias and it has more area to be exposed by sunlight. The material used for solar cell should have its band gap less than the energy of incident light. In order to reach the sufficient light to the junction area, the material should be of high optical absorption. Electrical conductivity, availability of the material and cost are another important factors behind the selection of materials for solar cell. Semiconductors with band gap $E_g$ close to 1.5 eV are ideal materials for solar cell fabrication. Solar cells are made with semiconductors like Si ($E_g$= 1.1 eV), GaAs ($E_g$ = 1.43 eV), CdTe ($E_g$= 1.45 eV), $CuInSe_2$ ($E_g$ = 1.04 eV), etc.

A typical solar cell is shown in Fig. 7. A p-Si wafer of about 300 μm is taken, over which a thin layer (~0.3 μm) of n-Si is grown on one-side by diffusion process. The other side of p-Si is coated with a metal (back contact). On the top of n-Si layer, metal finger electrode (or metallic grid) is deposited. This acts as a front contact. The metallic grid occupies only a very small fraction of the cell area (<15%) so that light can be incident on the cell from the top.

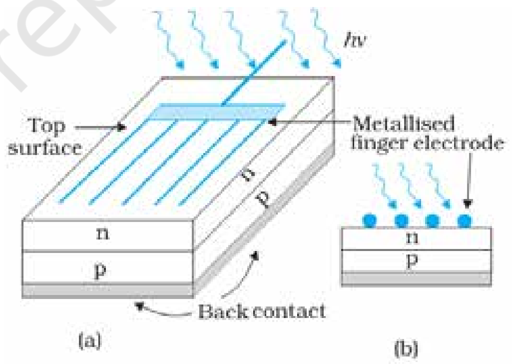


**Fig.7 (a) Typical p-n junction solar cell; (b) Cross-sectional view.**

The mechanism of solar cell involves three basic processes to produce the electricity, which are: (1) Formation of electron-hole pairs due to solar light close to the junction,

(2) Separation of electrons and holes due to electric field of the depletion region, and (3) Collection of the electrons reaching the n-side by the front contact and collection of holes reaching to p-side by the back contact. In this way, p-side of the cell becomes positive and n-side becomes negative giving rise to photo-voltage. When solar cell is connected through an external load, a photocurrent $I_L$ flows through it as shown in Fig. 8a. Photocurrent depends upon the intensity of light falling on the cell. A typical I-V characteristic of a solar cell is shown in the Fig. 8b drawn in the fourth quadrant of the coordinate axes. This is because a solar cell does not draw current but supplies the current to the load.

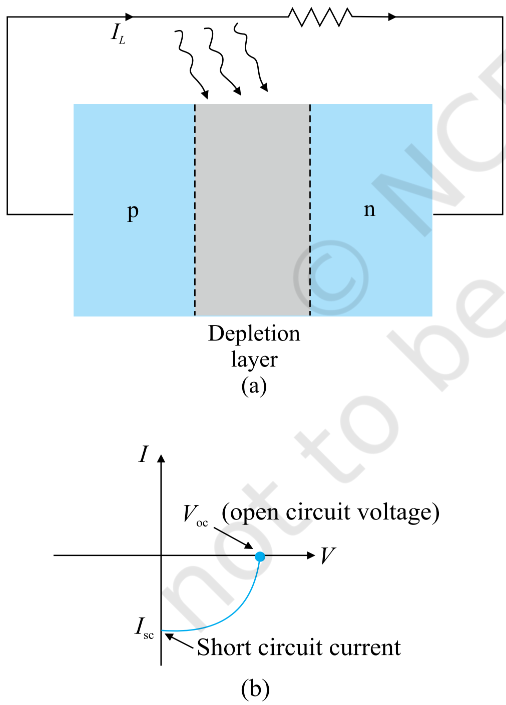


**Fig. 8 (a) A typical illuminated p-n junction solar cell; (b) I-V characteristics of a solar cell.**

Apart from its general use in daily life for the electricity, Solar cells are particularly used to power electronic devices in satellites and space vehicles and also as power supply to some calculators. The future challenge in the solar cell technology is to reduce the cost and increase the efficiency.

### Light emitting diode

You would be familiar with the bright and colourful light of LED. The word LED is an acronym for Light Emitting Diode, which converts electrical energy into light. LED is a heavily doped p-n junction which under forward bias emits spontaneous radiation. The diode is encapsulated with a transparent cover to allow the emitted light to come out. When a voltage is applied across the junction in forward bias, electrons are able to move from n-side to p-side where they are minority carriers. In the same way holes are also injected from p-side to n-side, but less in number. The current is primarily due to the flow of electrons into the p-side. The electrons injected into the p-side recombine with the holes and the holes injected into the n-side recombine with the electrons. The recombination of e-h pairs results in spontaneous emission of photons (light) as shown in Fig. 9. The wavelength or colour of the emitted light depends on the band gap of the material. The semiconductor used for fabrication of visible LEDs must at least have a band gap of 1.8 eV (spectral range of visible light is from about 0.4 μm to 0.7 μm, i.e., from about 3 eV to 1.8 eV). LEDs are available in different colours of red, yellow, orange, green and blue. The compound semiconductor Gallium Arsenide – Phosphide ($GaAs_{1-x}P_x$) is used for making LEDs of different colours. $GaAs_{0.6}P_{0.4}$ ($E_g$ ~ 1.9 eV) is used for red LED.

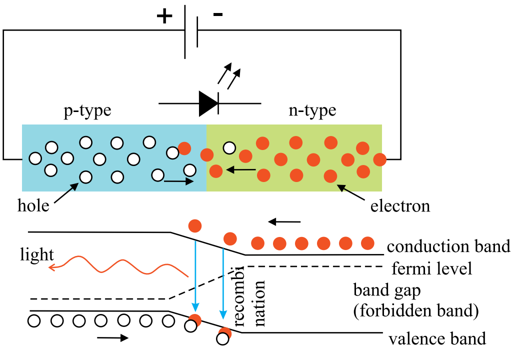


**Fig. 9: The inner workings of an LED, showing circuit (top) and band diagram (bottom) (adopted from Wikipedia)**

GaAs ($E_g$~ 1.4 eV) is used for making infrared LED.

The intensity of the light produced by LED is function of forward current of the diode. It first increases with the increase in forward current and then decreases after further increase in the forward current. LEDs are biased such that the light emitting efficiency is maximum. The I-V characteristic of an LED is similar to that of a Si junction diode. But the threshold voltages are much higher and slightly different for each colour. The reverse breakdown voltages of LEDs are very low, typically around 5 V. LEDs have the following advantages over conventional incandescent low power lamps:

(i) Low operational voltage and less power.

(ii) Fast action and no warm-up time required.

(iii) The bandwidth of emitted light is 100 Å to 500 Å or in other words it is nearly (but not exactly) monochromatic.

(iv) Long life, light weight, smaller size and ruggedness.

(v) Fast on-off switching capability.

(vi) Do not contain toxic material like mercury.

The LEDs are extensively used in remote controls, burglar alarm systems, optical communication, traffic signals, digital computers, camera flashes, aviation lighting, etc. Extensive research is being done for developing white LEDs which can replace incandescent lamps.

## Application of Photonics

Photonics finds its use almost in all spheres of the life. It has contributed remarkably in the advancement of various technologies. Information technology and telecommunications have benefitted a lot by photonics. Transport and processing of information became fast, optical storage has increased manifold and displays became better. Photonics offers new and unique solutions where today's conventional technologies are approaching their limits in terms of speed, capacity and accuracy. It is very difficult to imagine the world today without photonics. It has tremendous applications in various fields and many more are yet to come. Let us have a glimpse of these:

### Photonics in our daily life

Whatever comes to us in daily life is linked to photonics in direct or indirect way. Few examples are— Infrared remote controls, TV flat panel or large screen, compact disc players, Laser light shows, IR motion sensors for home security, video disk players, alarm clock radio with LED display, IR noncontact "ear" thermometers, and infrared remote headphones. In offices, the frequently used tools such as optical scanners, fax machines, optical data storage, laser printers, photocopiers, overhead slide projectors, video teleconferences, laser pointers, computer active matrix displays, computer displays, and infrared remote connections are all because of photonics. In cars, the comfort and control provided by the Infrared security systems, optical monitors for antilock brakes, optical fiber dashboard displays, LED traffic signals, laser traffic radar, and solar-powered emergency services are manifestation of photonics. In stores, supermarket bar-code scanners and credit card holograms include photonics.

### Photonics in Healthcare and Life Sciences

With the ability of light to detect and measure in a fast, sensitive and accurate way, photonics has an extensive role in health care and life sciences. It can detect diseases at an early stage with non-invasive imaging techniques or point-of-care applications. From diagnosis to therapy, photonics finds an indispensable role to play in the sector of healthcare. One can find the success stories of cataract treatment with CPA laser technology by LASIK (Fig. 10) very frequently in newspapers. Ultrafast lasers (femtosecond lasers) can be employed for the treatment of Glaucoma as well. Lasers are useful for cancer treatment also by killing the ill cells selectively. New avenues are being explored in cardiovascular medicine by the use of photonics technology in the form of intracoronary imaging and sensing, laser ablation and optical pacing. Lasers can be used for analysis of blood flow inside the tooth for painless laser tooth pulp vitality check.

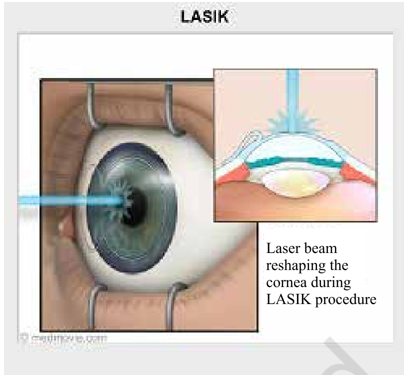


Fig. 10: LASIK procedure

Dermatological conditions can be monitored and cared by the use of phototherapy. In general surgery such as endovascular surgery and gastro intestinal surgery, lasers are used extensively. Fig. 11 shows a schematic diagram of non-invasive treatment for brain tumours with Cyberknife system which works by delivering beams of high dose radiation to tumours with extreme accuracy. A laser scalpel is extremely useful in surgery, cutting and ablating living biological tissue with tremendous light energy. Photonics is also used in the manufacturing of medical devices, for example stents and catheters. It is an important tool in genomic research, microbiology (viral and bacterial analysis) and drug discovery because analysis of


Fig. 11: Non-invasive treatment for brain tumours with Cyberknife system which works by delivering beams of high dose radiation to tumours with extreme accuracy.

processes at the molecular level gives a greater understanding of the origin of diseases, and hence allowing prevention and new treatments. Sterilization of medical tools is done using light sources. There are novel biomedical materials that change their properties after light treatment. Photonics is used in in-vivo imaging techniques, such as X-ray, MRI, CT, PET, photoacoustic imaging and OCT. In-vitro diagnostics, for cell-based studies to identify diseases such as cancer and neurodegenerative diseases is done using optical microscopy and spectroscopy. Photonic technologies also play a major role in addressing the needs of our ageing society: from pace-makers to synthetic bones and from endoscopes to the micro-cameras used in in-vivo processes.

### Photonics and Energy Saving

Today's world is energy driven world and in order to have a sustainable world, the need of renewable and clean energy is obvious. Solid state lighting (SSL) based on light emitting diode (LED) and organic LED (OLED) technologies are energy efficient, cost-effective and provide higher quality lighting. Apart from these, SSL lighting is robust, has more life time, has dimming and colour tenability and hence it is easy to shape and adjust the lighting environment to accommodate individual needs.

### Telecommunication

It is difficult to imagine life without information and communication technology (ICT) in modern time. The whole world has become a global village, any information is at your fingertip, and access to services is as easy as never before. This is an era of easily accessible and fast internet with immediate transfer of information whether in the form of e-mail or social networking sites or e-commerce activities. Users of internet have increased substantially to remote areas. All these became possible because of the new advances in optical fiber technology which provides very large bandwidth for transmission of signals. It is now possible to send data beyond a terabit per second (>1000 Gb/s) over distances in excess of 100 km. This is equivalent to transmitting more than 10 million simultaneous phone calls through a single hair-size glass fiber. At this speed, one can transmit 100,000 books coast to coast in 1 second!

### Safety and Security

Photonics can also be useful in safety and security of the people, property and environment. It can reliably detect potential hazards. Contactless sensors are possible to make with photonics. Detecting structural defects in the building sector, security applications like biometrics and border security systems, video surveillance systems and equipment to detect dangerous or illegal goods are only to name a few, where photonics has major role to play.

### High Quality Manufacturing

Laser processing has become essential for high-volume, cost-effective and precision manufacturing. They are used for treatment of plastics in the automotive industry, for the manufacture of solar cells, semiconductors and miniaturised components for use in medical technology, etc.

### Defense

The properties of high intensity, good spectral brightness and very less divergence of a laser beam make them very useful in warfare. Laser range finders (LRF), laser guided bombs, target trackers, and simulators of weapon training are some of the devices and equipment based on photonics technology. These devices use laser as source with optical components and electronic instrumentation for measurement and fire control. More recent in the series are beam weapons for destroying targets, thermal imaging for night viewing, surveillance (airborne and satellite platforms), and concepts of multisensory fusion and countermeasures.

The short wavelength of optical radiation compared to the microwave radar makes it possible to distinguish different specific targets at distances up to 10-20 km. These radars can range the target area at low grazing angles and the possibility of the direct interruption of the beam is considerably reduced. Laser range finders are developed for maximum range of 10-20 km with range accuracy of ±5 m. Different versions of LRFs are available for use in infantry, artillery, tanks, observation posts, and aircraft. LRFs are now available in the form of handheld binoculars. Guidance of weapons by laser assisted technology (smart bomb) is another important use of photonics in warfare. In modern low flying aircrafts used for ground attack, suitable laser instrumentation is provided for range finding and target designation capabilities for seeking the target, measuring its range, and sending the weapon onto it thereby reducing the human element to the minimum.

Tracking of spy satellites can be done by laser. The laser beam of high intensity and high directivity is sent to the satellite (or high flying airborne platforms including missile and aircraft) and return echo is used to keep the target in view. Laser-based weapon simulators have the advantage of saving ammunition during training exercise. Laser weapons are so destructive because a large quantity of energy is delivered on a small area in a short time. Heat deposited by a continuous beam, shock waves produced by a pulsed beam, or a combination of thermal and shock produced by a series of rapid pulses can penetrate the skin of the target. The intense laser beam disables the guidance system of warhead, or triggers an explosion of the fuel or warhead. Underwater TV surveillance systems based on optical fibers are already in use. In numerous applications, from infantry weapons to airborne ground attack systems, photonics provide the ability to see, detect, recognise and engage targets with speed, clarity and precision that no other systems can match.

## Acknowledgements

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# Sources of Light: What they can Reveal

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## Abstract

Human curiosity resulted in the invention of telescope and microscope enabling human beings to view far off objects, as well as very tiny objects, using visible light. With the discovery of electromagnetic spectrum, ways to produce and detect light beyond visible range were invented. The techniques were developed to explore using non-visible light, which resulted in rapidly expanding human knowledge about nature during last century.

## Introduction

From ancient times, humans, being curious, tried to fathom mysteries of the world around them. During the daytime, the sun, their only source of light, revealed the glory of nature in their immediate surroundings; and at night time, they gazed at the sky and watched the light emitted by the distant stars, to try to make some sense of the universe. The light was detected by the human eye which is sensitive only to the visible portion of light.

With time, human beings learned to manipulate light; bend and change the direction of light using mirrors and lenses. Few hundred years ago, two closely related inventions were made — telescope and microscope. Telescopes made far off objects visible and microscopes made very tiny objects visible. With the help of these, the wonders of nature which were hitherto unseen by the human eye, were revealed to the humans. This whetted their appetite for more.

## Exploring with Visible Light

From the first telescope invented reportedly by Galileo, there was a period of about three centuries which witnessed rapid improvements in telescopes. Larger and more powerful telescopes were developed which helped in the discovery and study of many faint stars and calculation of interstellar distances, leading to fundamental changes in our understanding of the universe. All the studies of universe were limited to the visible light emitted by the objects in the universe.

Microscopes appeared at the end of sixteenth century and their origin is often associated with Robert Hooke and Antonie van Leeuwenhock. More and more complex optical microscopes were developed over the time. Microscopic observations revealed the details of biological and other specimens which were not visible with naked eye. Various techniques of light microscopy were developed with the aim to improve resolution and sample contrast. Light microscopy started being used in medical diagnosis as well as in industry. The source of light for illumination in microscopy was sun, which is broad band, relatively bright and widely available. Artificial sources of light, such as oil lamps and with the advent of electricity, the incandescent bulbs were also used. However, microscopy was initially limited to visible light range.

## Non-visible Light

During the nineteenth century, it was realised that visible light was just a tiny slice of the vast range of light in the universe; and the light beyond visible light was discovered. In the year 1800, Sir William Herschel was experimenting with the different colours of visible light and discovered infrared light just beyond the red light of the spectrum. A year later, Johann Wilhelm Ritter discovered ultraviolet light just beyond the purple end of the spectrum of visible light. During the 1860s James Clerk Maxwell formulated a set of equations, known as Maxwell's equations, from which emerged the prediction for existence of electromagnetic waves. As per Maxwell's equations, the speed of electromagnetic waves turned out be very close to the speed of light, which led to the conclusion that light is an electromagnetic wave. Heinrich Hertz experimentally demonstrated the existence of electromagnetic waves by producing the radio waves in his laboratory in 1887. By the end of 1800s, X-rays and Gamma rays were also discovered. X-rays were first observed by Wilhelm Conrad Rontgen in 1895 and Gamma-rays were observed by Paul Villard in 1900. It was realized that radio waves, infrared waves, visible light waves, ultraviolet waves, X-rays and Gamma rays together form electromagnetic spectrum from large wavelength (low frequency) end to small wavelength (high frequency) end. The electromagnetic spectrum covers wavelengths from thousands of kilometres to a fraction of a size of atom.

## Exploring with Non-visible Light

In the twentieth century, scientists started attempting the studies of universe at wavelengths other than visible range of electromagnetic spectrum. Construction of telescopes began which could produce images using wavelengths other than visible light, from radio waves to gamma rays. With the development of space observatories, it became possible to access several wavelengths not possible to observe from ground, such as microwaves, ultraviolet, X-rays, gamma rays. It was found that entire sky is a source of microwaves in every direction which are remnant of Big Bang. Many cosmic X-ray sources were detected including binary X-ray pulsars. Einstein observatory was launched in 1978 which revealed that much of the X-ray background radiation was due to the individual sources. Compton Gamma Ray Observatory was deployed in 1991 and it has recorded nearly daily bursts of gamma radiation which may be due to merging of extremely distant neutron stars into black holes. The universe looks very quiet in visible range of electromagnetic spectrum but at other wavelengths, the most prominent features observed are violently energetic, for example the initial cosmic explosion.

Microscopy also started being performed at wavelengths beyond visible range. Resolution depends upon the wavelength of light and ultraviolet microscopes provide better image resolution due to shorter wavelength of ultraviolet light. Arc lamps, such as mercury lamps and xenon arc lamps, coupled with filters were developed around 1900 which provided radiation from near ultraviolet to infrared. These provided brighter illumination than sun in a narrow spectral band, giving rise to fluorescence microscopy. With the invention of ways to produce and detect light beyond visible range, newer techniques came up to explore the world around us which helped us to see things in much finer detail than what we can see with our eyes or optical microscopes.

In 1940s, scientists discovered synchrotron radiation, a light ten billion times brighter than the sun. With this, began the era of light sources which use particle accelerators to generate super bright beams of electromagnetic radiation. The light is so intense that it can reveal the atomic and molecular details of all kinds of matter in far more detail than is possible with microscope. It made possible for researchers to view life and world around them at previously impossible scales. Synchrotron light is now available in infrared, ultraviolet light and X-ray ranges. Each range of light is suited to a particular job. Short wavelength X-rays are useful for probing atomic structures; from simpler structures in metals and semiconductors to highly complex structures in biological molecules, such as proteins and DNA. Long wavelength X-rays and ultraviolet light are used for studying chemical reactions. Infrared is suited to studying atomic vibrations in molecules. Synchrotron light is being used for a broad range of research such as finding sustainable energy sources, inventing smart, new materials, and creating novel vaccines.

In 1960 the first laser was built. Lasers have special properties which make them better source of light as compared to sunlight or other sources of light. The light emitted is coherent and within a very narrow wavelength range. Due to these properties, lasers have many applications in imaging and diagnosis, particularly in medicine. A technique, called Optical Coherence Tomography, allows the mapping below the surface in opaque materials such as human tissue. It is safer than X-ray and yields a 3-D image in real time. It is useful in many areas of medicine, such as seeing the cross-section of cornea or imaging of arteries. Another technique, called Cavity Ring-Down Spectroscopy, is useful in many applications, such as rapidly detecting components in human breath that act as markers for a range of diseases. Scanning near-field optical microscopy is an emerging technique for imaging of individual cells in IR. Optical fibres further extend the potential use of lasers enabling imaging techniques within the body. Laser tweezers promise better and faster cancer screening. Two-photon laser scanning fluorescence microscopy is ideal for imaging living cells buried deep inside intact embryos or organs.

Next generation light sources are Free Electron Lasers (FELs) with brightness that can be much higher than that of synchrotron light. These are becoming a major source of photons for materials research in the wavelength regions previously unavailable.

## Some Recent Revelations!

In medicine, the knowledge of protein functions is necessary to understand the origin of diseases on the molecular level and thus to be able to develop tailored agents for their treatment. Synchrotron radiation is an important tool for studying protein structure.

Researchers in UK used Diamond Light Source to study a 'superdrug' bacteria in great detail, thereby paving way for a breakthrough in solving antibiotic resistance. X rays were used to decode two key proteins of the malaria parasite Plasmodium which may contribute to designing tailor-made anti malarial medication. Researchers in Germany have investigated for the first time the internal structures of living cancer cells in their natural environment using hard X-rays.

To understand the properties of a material, finely tuned X-ray beams are used to determine the structure of single-molecule crystals. Using X-ray laser, observations have been made of molecular structure of liquid water at temperature down to -51°F which may help improve our understanding of its unique properties which are relevant to global ocean currents, climate and biology.

Using world's most powerful X-ray laser SLAC's Linac Coherent Light Source (LCLS), researchers have taken femtosecond 'snapshots' of photosynthetic water oxidation. This may help understand the nature's ability to split the water molecule during photosynthesis. This understanding could help advance the development of artificial photosynthesis for clean renewable energy.

The non destructive techniques of synchrotrons are increasingly being used for analyses of ancient samples and historical artefacts such as the bone of the vocal tract of a neonathral man to find out if they could talk. Non invasive X-ray fluorescence was used to study the chemical composition of individual tree rings for historical data. The anomaly in one of the rings provides direct evidence to a volcanic eruption in mid-late 17$^{th}$ century BC, the timing of which is believed to be the reason for rise of ancient Greece, thereby improving credibility of historical data. X- ray microscopes are being used to view the interiors of fossil specimen without cracking them. This has helped decode the full body colour pattern of a 155 million year old dinosaur.

Innovation is continuing and likely to advance, making the future possibilities exciting. Advances in light microscopy techniques and developments in super resolution will continue. Most of the knowledge about the universe comes from light and newer technologies will allow extracting more and more information from this light.



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# Gamma-ray Laser: Some Notes

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During the last six decades, since their invention, lasers have become common-place in our society. These devices, producing highly directional light of a single wavelength, are important on their own and also as critical components of various systems. These energetic devices have applications in almost all fields of research and applications ranging from tailoring clothes to music to cookery to medicines and surgery to defence or even to cooling and trapping neutral atoms (Metcalf and Straten, 2007). Lasers made up of different materials can be as small as two microns and as large as a football field (the free electron laser - FEL). Their development has been characterised by a successive series of shorter-wavelength-lasers. The development of free-electron laser, first proposed by Madey in 1971, has significantly reduced laser wavelengths to sub-angstrom ranges. At the present state-of-the-art, lasers can emit radiations from infrared to hard X-ray regions. At the shortest wavelength, using an 8 GeV electron beam, scientists at SLAC (Stanford Linear Accelerator Centre) National Accelerator Laboratory at Stanford University have demonstrated the successful generation of laser light at 0.0634 nm, that is 63.4 pm (Emma, 2010) in a compact X-FEL device. The radiations produced are of wavelength four orders of magnitude smaller than the 694 nm produced by the first laser developed by Maiman in 1960.

X-FEL sources have also been used to pump the atomic X-ray lasers (also called raser) to achieve population inversion. In 2012, Rohringer N. *et al.* have demonstrated the generation of 1.46 nm soft X-ray laser radiations from an X-FEL pumped $K_{\alpha}$ transition in singly ionized neon plasma. These X-ray lasers (also called rasers), capable of generating powers as high as 10 GW (that is nearly ten orders of magnitude beyond conventional synchrotron sources) with a range of pulse durations from 500 to 10 fs; 1 fs or 1 femtosecond = $10^{-15}$ s. Such light sources are useful in high-resolution microscopy and are capable of imaging the structure and dynamics of particles at atomic size and time-scales. These light sources are now also known as fourth-generation light sources.

After developing excimer lasers in vacuum ultraviolet region, atomic rasers in soft X-ray region and FELs in hard X-ray region, one of the dreams of laser physicists has been the development of gamma-ray lasers (or grasers). These were first visualised more than five-decades ago (Vali and Vali, 1963; and Baldwin, 1981) and have been considered to be one of the two dozen most important and interesting problems in physics and astrophysics (Ginzburg, 1999).

Like electromagnetic radiations in microwaves to X-rays, gamma-rays differ from the photons in their wavelength, possessing wavelengths shorter than 0.05 nm (or 50 pm). According to the Einstein's formula, the probabilities of spontaneous (A) and stimulated (B) emissions at wavelength λ are connected through $\frac{A}{B} = \frac{8\pi h}{\lambda^3}$; *h* being the Planck's constant (Yariv 1967). It shows that for shorter wavelengths, spontaneous emission is a stronger competitor to stimulated emission.

It is a general feeling that, in principle, amplification by stimulated emission can be obtained up to all wavelengths, larger than 10 pm. Such radiations that lie in the 5 – 100 keV region would not emerge in atomic transitions rather would emerge through nuclear transitions (Baldwin, 1981; Gupta, 1991; and Rivlin, 2007). It is, therefore, grasers are also termed as nuclear gamma-ray lasers (NGL). The development of grasers in a laboratory, though attracting scientists for more than half a century, has been a fiction due to the absence of convincing data about their experimental reality. The flamboyant exciting proposals have been obscure in overcoming the real difficulties to be dealt with as the nuclear gamma radiations are quite different from the atomic and molecular transitions that are necessary for infrared to soft X-ray lasers.

Any optimistic attempt to develop gamma-ray lasers must consider the very different nature of physics involved in nuclear (gamma-ray) transitions that is not present in the atomic or molecular transitions needed for generating longer wavelengths used for lasers in other regions. In a two-level laser system amplification takes place primarily by the emission of a photon that has the right properties to cause the inverse transition from upper level to lower level in another atom or molecule. With the knowledge of known metastable state(s) in atomic (or molecular) systems, it is relatively easy to pump the atoms by the photons in the upper level to achieve the required population inversion. This does not happen in normal nuclear transitions. The population inversion by the photon absorption in atoms can further be eased by devising a three-level or four-level systems.

For achieving a population inversion in nuclear energy levels, the photon absorption is not a preferred mechanism. Furthermore, unlike the decay of upper level to lower level in atomic transitions is photon emission, the decay of a nuclear energy level to another level is not photon emission. The probability of photon emission in nuclear transition is often less than 10%. For example, a 14 keV nuclear transition in 57Fe does not normally take place by photon emission. Moreover, the small number of emitted photons do not generally have the proper energy to excite another nucleus. This is mainly due to the recoil of radiators that becomes appreciable at such high photon energy levels. Thus to pump the nuclei population to the upper level is not simple by photon irradiation processes (the probability to produce a nuclear transition by a photon incident on a sample is very small.) Photons are dominantly absorbed by electronic mechanism and not nuclear. It means that the probability of a photon incident on a sample to produce a nuclear transition rather than being absorbed by electronic transitions is less than one in a million.

The differences between atomic and nuclear transition mechanisms (both for absorption as well as the emission) need to be taken into account for designing a graser. It is important to critically analyse approaches for solving the conflict of increasing the probability of photon emission; for finding the ways to get the emitted photons (or gamma-rays) to have the proper energy — Mossbauer schemes to reduce nuclear recoil in deeply cooled ensembles of free nuclei, maybe Bose-Einstein condensate; and to find efficient ways of achieving population inversion in an amplifying medium of long-lived isomers. This requires a considerable effort in this interdisciplinary problem. The search is therefore of interest due to a variety of physical disciplines and experimental approaches. At shorter wavelengths, the spontaneous emission becomes a strong competitor of stimulated emission. And therefore cooperative spontaneous emission (superradiance) provides a hope for the generation of coherent gamma-rays (Baldwin, 1981).

## Simple Scale Differences

There are inherent scale differences in sizes of the radiators, the wavelengths, etc. when we compare the atomic (or optical) transitions with the nuclear transitions. Let Ra and Rn denote the size of the two radiating systems, *viz.* an atom ($\sim 10^{-9}$ m) and a nucleus ($\sim 10^{-14}$ m), respectively. The symbol D represents the distance between two neighbouring radiators (the lattice constant in a crystal); typically of the order of the size of an atom. The wave number of radiations in optical laser transitions ($k_a$) and in nuclear laser transitions ($k_n$) is of the order of $10^7$ and $10^{11}$, respectively. Considering the radiating systems to be harmonic oscillator at zero-point (and thus requiring Bose-Einstein condensate!) and using Heisenberg uncertainty principle, the amplitude (x) of oscillations can be related for optical systems as $k_a x_a$ to be much lesser than unity while in nuclear transitions as $k_n x_n$ of the order of unity. Thus for optical laser transitions at around 100 nm

$x << R \sim D << (1/k)$.

or

$kx << kR \sim kD << 1$.

And for nuclear gamma-ray transitions at around 10 pm,

$R << x \sim (1/k) << D$

or

$kR << kx \sim 1/k << kD$.

Since $kR << 1$, for optical as well as nuclear transitions, the long-wavelength approximation necessary for lasing is valid (Yariv, 1967). But $kD$ is larger than one, and $kx$ of the order of unity for gamma-rays describes the motion of radiating nucleus in crystal lattice tends destroying the coherence (and superradiance) between the radiations emerging from different nuclei. This also tends to reduce the coherent intensity.

There are differences in the energy domains of atomic (or optical) and nuclear (or gamma-rays) domains as well. The optical radiation energies (each photon energy of few eV) are much lesser than the atomic ionization energies ($E_i$), while in the case of nuclear transitions the photon energies are much greater than the atomic ionization energies. That is

$$h\nu_{optical} << E_i << h\nu_{gamma}.$$

This indicates that in case of nuclear lasers, a part of the incident energy to pump the nuclei population to corresponding upper level (usually an isomeric one) would be lost by ionization processes. In optical transitions (atomic or molecular), the recoil kinetic energy of the radiating system is much lesser than the radiative linewidth of the levels involved in the lasing transitions. However, in case of gamma rays, the recoil energy is much larger than the natural (radiative and non-radiative both) linewidth and is of the same order as the thermal energy of the crystal (Lipkin, 1987).

## Consequences

1. Since the recoil kinetic energy of radiating systems is negligible for optical transitions and is crucial for nuclear transitions, the photon (electromagnetic radiation) emitted in a transition between two energy levels of an isolated nucleus is not capable to induce the inverse transition between the same two levels in other nuclei. However, in case of optical transitions, the photon emitted in a transition between two energy levels of an isolated radiator (atom or molecule) has the same frequency to induce the inverse transition between the same two levels in another radiator.

2. The ratio of natural line width of a nuclear energy level to the energy of a photon emerging in a nuclear transition is much smaller than for optical case. Thus the lineshifts which become crucial in the nuclear case tend to destroy the lasing action *(radiations are no longer monochromatic!)*.

3. Unlike in atomic transitions, the photon wavelength emitted in nuclear transitions (~10pm) is shorter than the distance between nearest neighbour atoms in normal matter (1 nm). It means that there will be an appreciable phase shift in the propagation of nuclear transitions between two neighbouring radiators (nuclei). This results adversely in phase coherence.

4. The phase coherence is also likely to be destroyed because the wavelengths of emitted gamma-rays are of the same order of magnitude as the amplitude of thermal or zero-point motion in normal matter ($kx$~1 for nuclear transitions.)

5. The emission of a photon is the most dominant mechanism for the decay of upper level to a lower level of isolated atoms or molecules. But in case of nuclear transitions, the most dominant mechanism for the decay of an upper nuclear level to a lower nuclear level in isolated nuclei is the internal conversion that is ejection of an atomic electron and not the photon emission.

6. In atomic or molecular transitions the most dominant mechanism for the absorption of photons emitted by electrons is absorption by bound electrons. These absorptions are instrumental in exciting the atoms from a lower level to a desired upper level for producing a state of population inversion in the matter. In case of nuclear transitions, the dominant absorption mechanism of the gamma-ray photons emitted by the nucleons is still the absorption by the electrons. Therefore the gamma-rays emitted in nuclear transitions cannot induce other nuclear transitions. *(The consequences given in points 5 and 6 are due to radiation-less transitions!)*

## Problems in Developing a Graser

The basic problems in achieving lasing in nuclear transitions are due to the recoil shift and internal conversion. The recoil shift changes the energy of emitted gamma-rays by the nucleons in the isolated radiator (nucleus) by a large amount to the extent that the emitted photon becomes useless for the purpose of exciting the other nucleus. And thus the emitted photon lost to stimulate another nucleus necessary for the stimulated emission and the amplification. On the other hand, the internal conversion takes most of the energy of emitted photon for further absorption. In addition to these two problems, the fact that the gamma-ray wavelengths are short compared to the interatomic spacing (lattice constant of a crystal) which destroys the phenomenon of super radiance necessary for coherence in the nuclear case.

Any radiator that emits a photon must recoil with a momentum equal and opposite to the photon momentum. This recoil brings a change in the energy of the photon which is known as recoil shift. This recoil shift is negligible in case of optical transitions but for nuclear transitions, the recoil shift is often larger than the natural width of the nuclear energy levels, as noted earlier. This loss in the energy of emitted photons may be minimized by using the Mossbauer effect, in which the atom making the transition (nuclear) is bound in a crystal and the recoil momentum is distributed in all radiators present in the whole crystal with negligible energy loss. This, however, depends on the energy of gamma-ray, temperature and crystal properties. These conditions heavily restrict the choice of medium in which graser transitions can be obtained.

As noted earlier that the energy of a nuclear transition is much greater than the ionization energy of the atom, it is, therefore, possible for the transition between two nuclear levels to take place with the energy emitted by ejecting an atomic electron (internal conversion) rather than in the form of a photon. In fact, in 57Fe nuclei, the probability of ejection of the atomic electron rather than a photon is only about 10%. The energy loss due to the internal conversion may only be eliminated by using the Bormann effect (or superradiance). It explains an anomalous increase in the intensity of X-rays (and possibly the radiations for the interest of grasers) through a perfect crystal when the electric field of the radiations approaches to zero amplitude at the crystal planes to minimize the absorption by the atoms (or to minimize the energy loss due to internal conversion).

In view of the exploitation of both the Mossbauer and Bormann effects in a crystal for graser medium, almost all nuclei have been searched for potential candidates for developing a graser but this needs further technological advancements in nuclear spectroscopy.

There is another problem with the pumping transitions. The radiations that are to be used to pump the nuclear population to an upper level must have higher energy than the lasing transition. The pumping then may populate the levels, *pumping levels*, higher to the upper level. Then there must be a radiation cascade from such pumping levels to the upper level. Thus creating a population inversion in the upper nuclear level in a sample is similar to *funnelling*. This upper level will then lase into the lower level. Yet the probability of absorbing photons by the desired nuclear transition (nuclear cross-sections) are much smaller than the probabilities for the photoelectric and Compton effects. In typical cases, it is as small as $10^{-8}$. This indicates that there could be an enormous waste of energy in the pumping process. This would necessarily require an efficient mechanism for disposing of this waste without excessively heating the sample. The funnelling of upper level from the higher pumping energy levels may also heat the sample. The Mossbauer and Bormann effects are very sensitive to the temperature and any excessive heat can destroy these effects. In this situation, one may envisage an isomeric storage level — that may have lifetimes as large as few days or more. Such storage levels need to be very close to the upper level that can lead to giving the desired graser output by decaying to a suitable lower level so that only a little amount of energy would be needed to create a population inversion without bringing any crystal defects that can destroy the Mossbauer and Bormann effects. However, no isomers having such properties are known.

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# SCIENCE NEWS


## Dogs give Friends Food

Compared to the rest of the animal kingdom, the human capacity for cooperation is something quite special. Cooperating with one another requires a certain amount of prosocial behavior. This means helping others without any direct personal benefit. Now a new study has found prosocial behaviour in dogs toward humans.

Prosociality has already been demonstrated in animals that are very closely related with humans, i.e. primates. In other animals, the phenomenon has so far only been studied experimentally in rats and jackdaws. One study found prosocial behaviour in dogs toward humans. According to Friederike Range of the Messerli Research Institute, however, it remains questionable whether the dogs were merely reacting to the communication from the humans and were being 'obedient' or if they were truly exhibiting prosocial behaviour.

"Dogs and their nearest relatives, the wolves, exhibit social and cooperative behaviour, so there are grounds to assume that these animals also behave prosocially toward conspecifics. Additionally, over thousands of years of domestication, dogs were selected for special social skills," explains study director Range. For this reason, Range and her colleagues Mylene Quervel-Chaumette, Rachel Dale and Sarah Marshall-Pescini studied 16 dogs to test their readiness to benefit familiar versus unfamiliar partners.

The researchers studied the prosocial behaviour of the animals using a bar-pulling task in which the dogs had to pull trays and decide whether a second dog would receive a treat or not. In the test, the donor dogs used their mouths to pull a string to bring a tray toward a second dog. They could choose either an empty tray or a tray containing a treat on the partner's side.

### Dogs donate to familiar partners more often than to unfamiliar ones

Whether the donor dogs knew the recipient made a difference. Donor dogs pulled the giving tray more often for familiar dogs than for unfamiliar ones. "Dogs truly behave prosocially toward other dogs. That had never been experimentally demonstrated before. What we also found was that the degree of familiarity among the dogs further influenced this behaviour. Prosocial behaviour was exhibited less frequently toward unfamiliar dogs than toward familiar ones.

### Prosocial behaviour put to the test

In the bar-pulling task, the donor dogs decided whether another dog would receive a treat or not. The donor dog itself did not get the treat. The only purpose of the task was to benefit the other dog. By conducting several control tests, the researchers excluded the possibility that the dogs were simply pulling the trays for the fun of it. Donor dogs were reserved in pulling the tray when an unfamiliar dog was in the next enclosure.

At the end of each test run, the researchers conducted another test to show that the donor dogs knew what pulling the tray meant. They allowed the donor dogs to pull on a tray to give themselves a treat, and all dogs did just that. "This control excludes the possibility that the dogs did not pull on the tray out of fear of the unfamiliar dogs. Given the same situation, the dogs gladly gave themselves a treat," says Range.

"We were also able to disprove the argument that the dogs pulled the string less frequently because they were distracted by the unfamiliar partner during the test. Only rarely did a donor dog interact with the unfamiliar dog," Range explains.

## Ten Cool Things the Kitchen of the Future Will Do

When the next generation of home cooks go to their kitchens, they'll be entering a world of interconnected smart appliances, 3-D printers, and touchscreen controls that will simplify food preparation, create customized meal solutions, and produce far less waste.

In the December issue of *Food Technology* magazine published by the Institute of Food Technologists (IFT), associate editor Melanie Zanoza Bartelme writes about some cool features that the kitchen of the future will offer.

1. Appliances will be wired to actively monitor their contents and reorder when it senses supplies are running low. Products that are near their expiration dates would be moved closer to the front.
2. Each family member can print the dinner they want when they want using a countertop 3-D printer that takes account likes and dislikes, food allergies and nutritional needs.
3. Induction cooktops using magnetic energy and compatible pans will heat up only the pan placed on it; the rest of the surface can be safely used for other tasks.
4. At the touch of a button, counters, sinks and cooking surfaces can move up or down appealing to the height of people sharing a kitchen as well those with disabilities. Stoves can be moved up so children don't hurt themselves, while the sink can be lowered so they can easily wash their hands.
5. Integration facial recognition technology will make it so that the kitchen can automatically set itself to a combination of desired settings — from counter height to ambient lighting to

background music — as soon as the user is home.

6. Virtual chefs will be projected directly into consumers' kitchens to guide their cooking.
7. Integrated systems will read data from fitness-monitoring devices and suggest meals appropriate to certain situations, such as muscle recovery after a strenuous workout.
8. Sinks would come equipped with a finger sensor that could read users' hydration levels, dispensing water when it is needed.
9. Video monitoring will help consumers see exactly what they have and systems that are linked to ovens and stoves will create recipes that use the meal preparation ingredients that are expiring.
10. A fridge will use ultraviolet light to sterilize food within it, keeping it safe from spoilage. A blast chiller instantly takes leftovers out of the danger zone where bacteria thrive.

## New Test for Ancient DNA Authenticity Throws Doubt on Stone Age Wheat Trade

Wheat DNA thought to provide evidence of trade between English hunter gatherers and more advanced Neolithic European farmers 8,000 years ago is younger than a few hundreds of years old.

A new method reliably tests whether DNA shows ancient or modern patterns of biochemical change. This has recently cast doubt on the authenticity of what was thought to be evidence of a Stone Age wheat trade.

A DNA sample thought to show prehistoric trade in cereals is most likely from modern wheat, according to new research led by the Max Planck Institute for Developmental Biology.

The scientists developed a new test to verify the authenticity of ancient DNA. They applied the test to a sample from submerged sediment off the Isle of Wight, thought to provide evidence of trade between English hunter gatherers and more advanced Neolithic European farmers 8000 years ago. The new test, described in the journal *eLife*, shows the sample to be younger than a few hundreds of years old.

"Modern DNA can easily contaminate precious samples so it is crucial to build in assurances that historic DNA is authentic," says first author Clemens Weiß.

"Only then can these molecular treasures tell tales unravelling history," he says.

The researchers developed a method focused on biochemical changes that accumulate with age and that are specific to ancient DNA. These changes cause one specific building block, cytosine (C), to be misread as thymine (T).

The new method reliably tests whether DNA shows ancient or modern patterns of such C-to-T changes. Testing the British wheat sequences with this approach showed that their DNA damage pattern does not fit with what would be expected for ancient DNA.

"As more and more scientists enter the field of environmental and metagenomics ancient DNA research, it becomes increasingly important to set certain standards for evaluation and interpretation of the data," says lead author Hernán Burbano.

Handling and interpreting ancient DNA data is challenging. DNA, the storage place for genetic information, can survive the death of the organism from which it originates for centuries or even millennia. However, it still ages and decomposes. Old or ancient DNA is often fragmented and present in only tiny quantities. These remaining traces of DNA are easily lost when the sample is contaminated with modern DNA from the surroundings or from researchers handling samples.

Both the high risk of contamination and the low amounts of available data make it even more important to present positive evidence that the retrieved DNA is of ancient origin. The new computational method could be used to authenticate ancient DNA even when only minute amounts of DNA can be extracted. Scientists will still be able to check whether the damage pattern matches that expected for ancient DNA.

"Ancient DNA can allow us a glimpse into the evolution and ecology of both plant and animal species, sometimes also revealing details of human history," says Burbano.

"We hope our new method is one step towards sound and successful extraction and interpretation of these windows into the past."

## Ancient Trade Routes between Bronze Age Iran and Mesopotamia Uncovered

Archaeologists have found evidence of raw materials trade between Bronze Age Iran and Mesopotamia.

Tübingen researchers and Iranian archaeologists have discovered evidence of raw materials trade between Bronze Age Iran and Mesopotamia.

Many of us have seen the impressive statues of ancient Mesopotamian rulers in the Louvre and the British Museum. They bear witness to the wealth of Bronze Age Akkadian and Sumerian city-states more than four thousand years ago. But they are made of black diorite and gabbro stone not found in the region of today's Iraq and northeastern Syria. Where did it come from? The blocks of stone must have been transported along ancient roads from distant trading partners to the Bronze Age cities of Mesopotamia.

A team of researchers from the University of Tübingen's ResourceCultures collaborative research centre has investigated the origins of the stone and the methods used to move such heavy loads over great distances. The team from Tübingen collaborates with the Iranian Center of Archaeological Research (ICAR) to find the answers and is jointly headed by Professor Peter Pfälzner and Nader Soleimani.

The archaeologists found diorite and gabbro in the Iranian province of Kerman, not far from the Persian Gulf, which matches that used in the Mesopotamian statues. In the same area, the archaeologists also found deposits of chlorite, which was used to make stone vessels traded as far away as Mesopotamia and the Levant. Close to these deposits, the researchers found petroglyphs and Early Bronze Age settlements, indicating that the stone was quarried during the Jiroft Culture of southeastern Iran (approx. 3000-2000 B.C.), and that it was traded across the Near East.

One of the recently-discovered settlements may have been a production and distribution centre for the valuable stone. "This shows that the civilizations of Mesopotamia and southeastern Iran were in direct contact in the Early Bronze Age," says Pfälzner of the Institute for Ancient Near Eastern Studies. "The Persian Gulf most likely served as a trade route." Pfälzner said this illustrated the great significance of this waterway in the international ties between important regions — from the Bronze Age to the present day.

Pfälzner and his Iranian colleague Nader Soleimani are jointly heading research into an area of 110 by 120 kilometres in Iran's Kerman Province — both on the ground and from the air using unmanned aircraft. Until now, there has been little archaeological research conducted in the hot, dry region south of the city of Jiroft. Using aerial photography, the team creates 3D models of ancient settlements (tells) from the Jiroft Culture era and other historical periods up to the coming of Islam. Along the potential trade routes running between high mountain chains to the coast of the Persian Gulf, the team is looking out for Early Bronze Age way-stations and any other trade activity. The German-Iranian team has so far mapped and investigated 42 settlements.

Now that the initial investigations have yielded results, work is set to resume in Iran in February 2016. The researchers are hoping to find out more about where the Bronze Age trade routes ran between the Jiroft Culture and the city-states of Mesopotamia, as well as what sort of effects this early long-distance trade had on Iranian civilizations more than four thousand years ago.

## New Anti-inflammatory Molecule Could Halt MS Progression

A new drug-like molecule that can halt inflammation has shown promise in preventing the progression of multiple sclerosis. Researchers developed a molecule that inhibits a key signal that triggers inflammation.

Walter and Eliza Hall Institute scientists have developed a new drug-like molecule that can halt inflammation and has shown promise in preventing the progression of multiple sclerosis (MS).

Dr Ueli Nachbur, Associate Professor John Silke, Associate Professor Guillaume Lessene, Professor Andrew Lew and colleagues developed the molecule that inhibits a key signal that triggers inflammation.

Multiple sclerosis is an inflammatory disease that damages the central nervous system including the brain, spinal cord and optic nerves. There is no cure and there is a desperate need for new and better treatments.

Inflammatory diseases such as MS were triggered by an over-active immune system, Dr Nachbur said. "Inflammation results when our immune cells release hormones called cytokines, which is a normal response to disease," he said. "However when too many cytokines are produced, inflammation can get out-of-control and damage our own body, all of which are hallmarks of immune or inflammatory diseases."

To apply the brakes on this runaway immune response, institute researchers developed a small drug-like molecule called WEHI-345 that binds to and inhibits a key immune signalling protein called RIPK2. This prevents the release of inflammatory cytokines.

Professor Lew said they examined WEHI-345's potential to treat immune diseases in experimental models of MS.

"We treated preclinical models with WEHI-345 after symptoms of MS first appeared, and found it could prevent further progression of the disease in 50 per cent of cases," he said. "These results are extremely important, as there are currently no good preventive treatments for MS."

Associate Professor Lessene, who developed the molecule with colleagues in the institute's ACRF Chemical Biology division, said WEHI-345 had potential as an anti-inflammatory agent. "This molecule will be a great starting point for a drug-discovery program that may one day lead to new treatments for MS and other inflammatory diseases," Associate Professor Lessene said.

Dr Nachbur said institute scientists would use WEHI-345 to further investigate the signalling pathway that produced inflammatory cytokines and to develop a better, stronger inhibitor of RIPK2 for treating inflammatory disease. "This signalling pathway must be finely balanced, because WEHI-345 only delayed signalling rather than blocked it. Nevertheless, this delay is enough to completely shut off cytokine production," he said.

"Not only is this a potential new treatment, it is a great tool we can use to unravel this signalling pathway and identify other important proteins that control inflammation that could be a drug target."

## 2015 Antarctic Maximum Sea Ice Extent Breaks Streak of Record Highs

The sea ice cover of the Southern Ocean reached its yearly maximum extent on 6 October, At 7.27 million square miles (18.83 million square kilometres), the new maximum extent falls roughly in the middle of the record of Antarctic maximum extents compiled during the 37 years of satellite measurements — this year's maximum extent is both the 22nd lowest and the 16th highest.

More remarkably, this year's maximum is quite a bit smaller than the previous three years, which correspond to the three highest maximum extents in the satellite era, and is also the lowest since 2008.

The growth of Antarctic sea ice was erratic this year: sea ice was at much higher than normal levels throughout much of the first half of 2015 until, in mid-July, it flattened out and even went below normal levels in mid-August. The sea ice cover recovered partially in September, but still this year's maximum extent is 513,000 square miles (1.33 million square kilometres) below the record maximum extent, which was set in 2014. Scientists believe this year's strong El Niño event, a natural phenomenon that warms the surface waters of the eastern equatorial Pacific Ocean, had an impact on the behaviour of the sea ice cover around Antarctica. El Niño causes higher sea level pressure, warmer air temperature and warmer sea surface temperature in the Amundsen, Bellingshausen and Weddell seas in west Antarctica that affect the sea ice distribution.

"After three record high extent years, this year marks a return toward normalcy for Antarctic sea ice," said Walt Meier, a sea ice scientist at NASA's Goddard Space Flight Center in Greenbelt, Maryland. "There may be more high years in the future because of the large year-to-year variation in Antarctic extent, but such extremes are not near as substantial as in the Arctic, where the declining trend towards a new normal is continuing."

This year's maximum extent occurred fairly late: the mean date of the Antarctic maximum is 23 September for 1981-2010.

## Global Sea Ice Diminishing, Despite Antarctic Gains

Sea ice increases in Antarctica do not make up for the accelerated Arctic sea ice loss of the last decades, a new study finds. As a whole, the planet has been shedding sea ice at an average annual rate of 13,500 square miles (35,000 square kilometres) since 1979, the equivalent of losing an area of sea ice larger than the state of Maryland every year.

"Even though Antarctic sea ice reached a new record maximum this past September, global sea ice is still decreasing," said Claire Parkinson, author of the study and climate scientist at NASA's Goddard Space Flight Center in Greenbelt, Md. "That's because the decreases in Arctic sea ice far exceed the increases in Antarctic sea ice."

Parkinson used microwave data collected by NASA and Department of Defense Satellites for her study, which was published last December in the *Journal of Climate*. She added Arctic and Antarctic sea ice extents month by month from November 1978 to December 2013 to determine the global ice extent for each month. Her analysis shows that over the 35-year period, the trend in ice extents was downward in all months of the year, even those corresponding to the Arctic and Antarctic sea ice maximum extents.

Furthermore, the global ice decrease has accelerated: in the first half of the record (1979-96), the sea ice loss was about 8,300 square miles (21,500 square kilometres) per year. This rate more than doubled for the second half of the period (1996 to 2013), when there was an average loss of 19,500 square miles (50,500 square kilometres) per year — an average yearly loss larger than the states of Vermont and New Hampshire combined.

"This doesn't mean the sea ice loss will continue to accelerate," Parkinson said. "After all, there are limits. For instance, once all the Arctic ice is gone in the summer, the Arctic summertime ice loss can't accelerate any further."

Sea ice has diminished in almost all regions of the Arctic, whereas the sea ice increases in the Antarctic are less widespread geographically. Although the sea ice cover expanded in most of the Southern Ocean between 1979 and 2013, it decreased substantially in the Bellingshausen and Amundsen seas. These two seas are close to the Antarctic Peninsula, a region that has warmed significantly over the last decades.

In her study, Parkinson also shows that the annual cycle of global ice extents is more similar to the annual cycle of the Antarctic ice than the Arctic ice. The global minimum ice extent occurs in February of each year, as does the Antarctic minimum extent, and the global maximum sea ice extent occurs in either October or November, one or two months after the Antarctic maximum. This contrasts with the Arctic minimum occurring in September and the Arctic maximum occurring in March. Averaged over the 35 years of the satellite record, the planet's monthly ice extents range from a minimum of 7.03 million square miles (18.2 million square kilometres) in February to a maximum of 10.27 million square miles (26.6 million square kilometres) in November.

"One of the reasons people care about sea ice decreases is that sea ice is highly reflective whereas the liquid ocean is very absorptive," Parkinson said. "So when the area of sea ice coverage is reduced, there is a smaller sea ice area reflecting the sun's radiation back to space. This means more retention of the sun's radiation within the Earth system and further heating."

Parkinson doesn't find it likely that the Antarctic sea ice expansion will accelerate and overturn the global sea ice negative trend in the future.

"I think that the expectation is that, if anything, in the long-term the Antarctic sea ice growth is more likely to slow down or even reverse," she said.

Parkinson calculated and published the global results after witnessing the public's confusion about whether Antarctic sea ice gain might be cancelling out Arctic sea ice loss.

"When I give public lectures or talk with random people interested in the topic, often somebody will say something in the order of 'well, the ice is decreasing in the Arctic but it's increasing in the Antarctic, so don't they cancel out?'" Parkinson said. "The answer is no, they don't cancel out."

## How Fatty Acids can Fight Prostate Cancer

Washington State University researchers have found a mechanism by which omega-3 fatty acids inhibit the growth and spread of prostate cancer cells. The findings, which are at odds with a 2013 study asserting that omega-3s increase the risk of prostate cancer, point the way to more effective anti-cancer drugs.

Scientists have long known that omega 3s reduce inflammation and have anti-diabetic effects, and some recently discovered how this happens.

"But we're the first to show that they work this way in cancer," said Kathryn Meier, a professor of pharmacy at WSU Spokane. "The attention has mostly been on inflammation and diabetes but there has always been an interest in cancer, and we were the first to show this mechanism in any cancer cell at all. And we're using prostate cancer, which is the most controversial subject in omega 3s."

A 2013 study in the journal of the National Cancer Institute found that men with higher levels of omega-3 fatty acids in their blood had a greater risk of developing prostate cancer. It was not clear if the fatty acids came from food—certain fish, seeds and nuts are high in omega 3s—or supplements like fish oil.

Working with prostate cell cultures, Meier and two students, Ze Liu and Mandi Hopkins, found the fatty acids bind to a receptor called FFA4 (free fatty acid receptor 4). Rather than stimulating cancer cells, the receptor acts as a signal to inhibit growth factors, suppressing proliferation of the cancer cells.

"This kind of knowledge could lead us to better treat or prevent cancer because now we know how it works," Meier said. The study also found that a drug mimicking the action of omega 3s can work as well or better than fatty acids in suppressing the cancer cells.

Meier said it is still unclear if the effect can be obtained by taking dietary supplements like fish oil. Some people don't tolerate fish oil very well, she said. Moreover, the effect of fish oil could fade as it is digested, while data from this study suggest that an omega-3 drug needs to be in a cancer cell all the time to have an effect.

"It's very difficult in dietary studies to tell how much to take or what form to take," Meier said. "Should you be eating fish? Should you be taking pills? But now we have a potential drug. Once you have a drug you can test very precisely whether it works or not in a certain disease and you would know exactly how much to give people."

*The study appears in the Journal of Pharmacology and Experimental Therapeutics.*

## Estimating the Cost of Flooding for Communities around Estuaries

Scientists have developed a new visualization tool to predict the maximum cost of coastal flooding to communities around estuaries.

The National Oceanography Centre (NOC) and the University of Liverpool have developed a new visualisation tool to predict the maximum cost of coastal flooding to communities around estuaries.

This method, published in *PLOS One*, works by combining high impact flooding scenarios with land use maps. Researchers used this method to find that the economic damage of coastal flooding increased much more than expected with the size of the flood.

Combining a model for flood inundation with one that simulates the effect of waves means that it is possible to estimate how likely it is that sea defences will be 'over-topped' in a changing climate. This threshold is based on a plausible amount of sea-level rise by 2100. The highest recorded river level was also added to this model to give an overall 'worst-case scenario' of flooding for communities around estuaries.

A new tool then relates the model output in terms of how many brick layers the flood water will reach, this can then be easily related to possible mitigation options for the different water levels.

The lead author of this study, Thomas Prime, from the University of Liverpool, said "By showing how high the flood water could rise in terms of brick courses, and providing a corresponding estimate of economic damage, these new maps can help residents see the impact of low probability flooding scenarios."

An estimate of the economic damage of the flood is obtained by relating the water depth predicted by this method with the land use maps. This information is then fed into 'depth-damage curves', which are used to give a value for the economic damage of flooding for a given water depth and land use type. For example, arable land under five metres of water or residential property under three metres.

Dr Jenny Brown, co-author of this study from the NOC, said "This research is an example of the NOC's commitment to developing transferable science that benefits coastal communities through the provision of evidence in support of flood risk management. This new visual representation of flood hazard identifies areas at risk, allowing improved adaptive management — increasing community resilience to climate change and rising sea levels. This work leverages the expertise in marine hazards from across NOC, and our external collaborators, to assess flood risk to a coastal community from extreme waves, water levels and projected rises in sea level."

## Experts Test New Ebola Vaccine on Frontline Medical Personnel and at Risk Groups after Promising Results

The World Health Organisation declared the Ebola virus outbreak a public health emergency in August 2014; since then the development of vaccines against Ebola virus has been fast tracked.

A live vaccine based on the "Vesicular Stomatitis Virus" (VSV) has yielded highly promising results for the rapid development of an effective vaccine against the Ebola virus. This vaccine would only need to be injected once for long-lasting immunoprotection.

Experts at St. George's, University of London, are working in collaboration with other international researchers on one of these vaccines; rVSV-ZEBOV-GP. Researchers are now vaccinating a larger population to examine the efficacy of this vaccine.

The initial study, which tested the safety, tolerability and immunogenicity of the vaccine, has been successfully completed; with the first volunteer vaccinated in November 2014. Volunteers in Kenya, Gabon, Switzerland and Germany participated in this harmonised Phase I clinical trial.

The rVSV-ZEBOV-GP vaccine, which is named after its components, carries only one protein (GP) from the Zaire strain of the Ebola virus (ZEBOV) on the surface of a different virus (VSV) that infects cows, horses, pigs and insects. The Ebola virus protein by itself is not able to cause any disease, and VSV only causes minimal illness in humans.

Currently, it is the only vaccine against Ebola virus disease in clinical trials that is made from a replicating virus. The advantage of this type of vaccine is that the immune system may develop an effective protective response to Ebola virus, and it allows the use of a lower dose of vaccine. Furthermore, only one shot of vaccine may be required, minimising the number of visits to healthcare workers needed to develop protection.

Experts at St. George's, University of London, are part of an international consortium (VEBCON) that provided results essential to begin a clinical trial to test the vaccine in Guinea. They say early results are good and responses to the vaccine are promising.

Professor Sanjeev Krishna, of the university's Institute for Infection and Immunity, said: "We have not had such urgency to deliver a viable vaccine or treatment since the coming together of medical experts in the early 1980s tackling HIV. The progress of these clinical trials is very promising and this vaccine adds significantly to the options available for testing against Ebola virus."

"Although cases of Ebola virus disease are now decreasing, the outbreak has left an appalling legacy. If a vaccine had been available, the health workers tackling this scourge could have been protected. We still urgently need a safe and effective vaccine to protect people in the future. This research works towards meeting that need."

The consortium examining the Ebola virus vaccine is led by our colleagues in Lambaréné at CERMEL, Gabon, coordinated by Dr Selidji Agnandji, and by Professor Peter Kremsner in their partner institute at University of Tübingen in Germany.

Professor Krishna acts as a scientific advisor to the consortium, and was among a consortium of experts convened by the WHO, in September 2014 in Geneva, to discuss solutions and strategies for combatting the current Ebola virus crisis. The candidate vaccine is called rVSV-ZEBOV-GP and was developed by the Canadian Public Health Agency and produced by the US firm NewLink Genetics. A new paper on the Phase I trial has been published in the *New England Journal of Medicine*.

*Source*: Science Daily Online

# 42nd Jawaharlal Nehru National Science, Mathematics and Environment Exhibition (JNNSMEE) for Children

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Organised by the Department of Education in Science and Mathematics. National Council of Educational Research and Training, Sri Aurobindo Marg, New Delhi 110016; in collaboration with the Government of Kerala. Venue: Nirmala College Campus, Muvattupuzha, Ernakulam, Kerala from 16 – 22 December 2015.

The 42nd Jawaharlal Nehru National Science, Mathematics and Environment Exhibition (JNNSMEE) for Children – 2015 was inaugurated on 16 December, 2015 by Padma Bhushan Dr. K. Radhakrishnan, a renowned Indian space scientist and former Chairman of the Indian Space Research Organization (ISRO), and presently the Chairman of the Indian Institute of Engineering Science and Technology at the Nirmala College Campus, Muvattupuzha, Ernakulam, Kerala. The inaugural function was also graced by Sri Joseph Vazhakkan, MLA; Professor Hrushikesh Senapaty, Director, NCERT; Smt. Usha Sasidharan, Municipal Chairperson, Muvattupuzha, Mar George Madathikandathil, the Bishop of Kothamangalam Diocese; and other dignitaries of Kerala Government, NCERT and Nirmala College Campus.

Main theme of the 42nd Jawaharlal Nehru National Science, Mathematics and Environment Exhibition for Children – 2015 was 'Science and Mathematics for a Sustainable World.' The organisation of this main theme has been supported by six sub-themes, viz., Community Health and Environment; Landmarks in Science and Mathematics; Information and Communication Technology; Energy-Resources and Conservation; Transport; and Waste Management. A total of 211 exhibits were selected at the NCERT level and invited to participate in this national exhibition. These were drawn from twenty-seven States, seven Union Territories, and ten other organisations (Kendriya Vidyalaya Sangathan, Navodaya Vidyalaya Samiti, CBSE affiliated independent Public Schools, Department of Atomic Energy Central Schools, Demonstration Multipurpose Schools of NCERT, etc.) These 211 exhibits belonged to 195 schools out of which 101 were rural and remaining 94 came from urban background. These were contributed by 354 children (232 boys and 122 girls) and by 310 teachers (182 male and 128 females). Out of these 211 exhibits, 160 participated in this event.

The venue of the exhibition, the Nirmala College Campus, a place of scenic beauty, was a sprawling green garden with a variety of plants. It was provided with a large exhibition area where the stalls for displaying the exhibits and other activities of NCERT. Many of the exhibits by the children were set in their allotted stalls by 15th December evening in a big well-equipped closed pandal. The medical and fire-brigade facilities were also made available at the venue. The different departments of NCERT also showcased their work during the exhibition. The Publication department displayed various print materials developed by NCERT while the CIET displayed various non-print materials of NCERT. The Department of Educational Kits displayed different types of educational kits developed by the department. Similarly, the Department of Elementary Education displayed models and kits in mathematics. A separate pavilion of the Department of Education in Science and Mathematics was also installed to provide necessary information and publicity material to all the participants and visitors. The Environment Education Group of the department also conducted activities to bring about environmental awareness amongst the students, teachers and visitors to the exhibition. A painting competition was arranged on the topic "Climate Change as I Know" wherein children depicted their understanding on the topic, their creativity and aesthetic sense. For teachers, a poster making competition was also arranged on sustainable Development. These posters and paintings were displayed in the exhibition pandal. All the participants and visitors were also given an opportunity to scribble their thoughts on the need to protect the environment by completing the sentence "We must protect our environment because ....... "

Besides the children exhibiting their scientific and technological units, activities during the JNNSMEE 2015 also introduced 'Idea Exchange Sessions – Among Young Minds' for the first time everyday evening. These sessions were arranged in a separate audio-video multimedia auditorium of the Nirmala College and open to all participants and visitors. During these sessions, four or five select exhibits were presented daily by the students and their mentors explaining the key idea behind, structure, working and application. Each presentation was followed by active peer discussion amongst the audience. In total there were 18 presentations. The idea of including this activity in JNNSMEE was appreciated and suggested to continue in future exhibitions by all.

Everyday activities during the JNNSMEE 2015 also included lectures by prominent activists and scientists arranged in the NESTT Auditorium for about one and half hours everyday evening. These included lectures on environment and human health, from Aryabhata to Mangalyan, excitement in mathematics, physics around us, etc. To commemorate International Year of Light 2015, stage shows and demonstrations with light and particles were also conducted. Another highlighting activity in this exhibition has been the cultural programmes arranged every day in the NESTT Auditorium that has the seating capacity of 600 persons. During these cultural programmes, the cultural heritage of Kerala state was shown. Participants from different parts of the country also took part in this activity for showcasing the different cultures of their respective places. One day excursion trip for the participating children and teachers to the areas in or around Ernakulam was also organised on the last day of the exhibition, 22 December, 2015.

A large number of school students and their teachers from local schools, colleges and all districts of Kerala state, parents and members of general public visited the exhibition on all days during the exhibition. Everyday nearly six thousand visitors visited the exhibition. The publicity material was also distributed among the visitors. The exhibition was also visited by several dignitaries from the Kerala state including the ministers of General Education, Tourism, etc. Many foreigners visiting Kerala also visited the exhibition.

The valedictory function was held on 21 December 2015. This function was presided over by the local MLA Sri Joseph Vazhakkan. He expressed his happiness on the successful organisation of the event. On behalf of the people of Muvattupuzha, he thanked NCERT and Government of Kerala for giving them opportunity to witness this national event. Honorable Member of Parliament Adv. Joice George also graced the occasion and delivered the keynote address. The valedictory function was also attended by the officers of Kerala Government and NCERT. Sri Shinmon M.K., Deputy Director of Education, Ernakulam delivered the vote of thanks. Certificates of Participation were also given to all the participants during the valedictory function.

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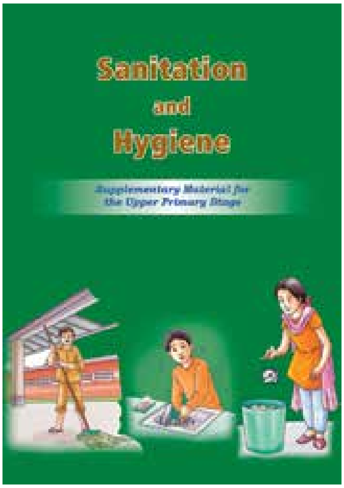


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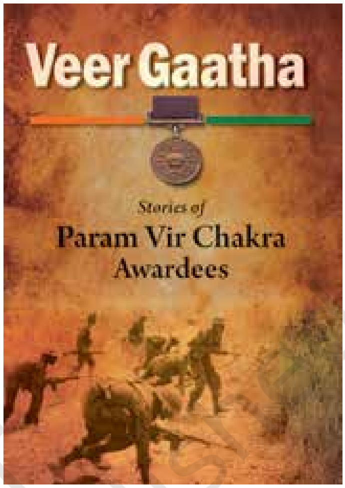


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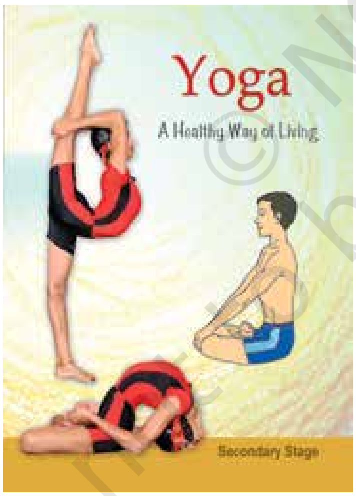


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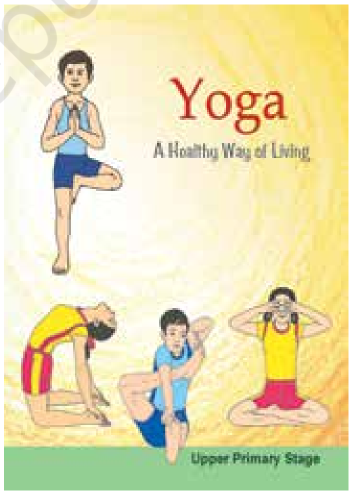


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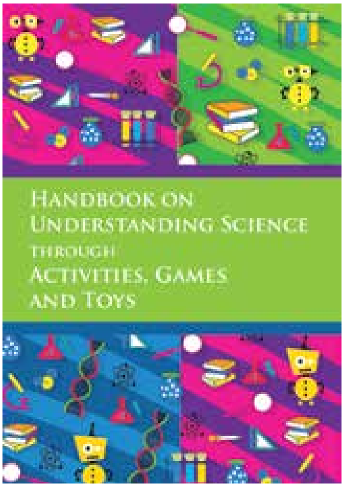


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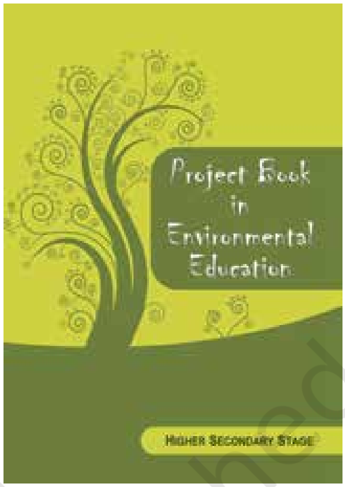


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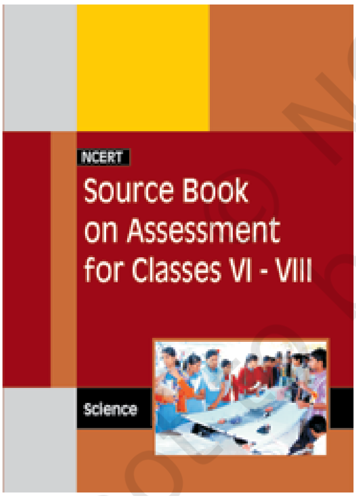


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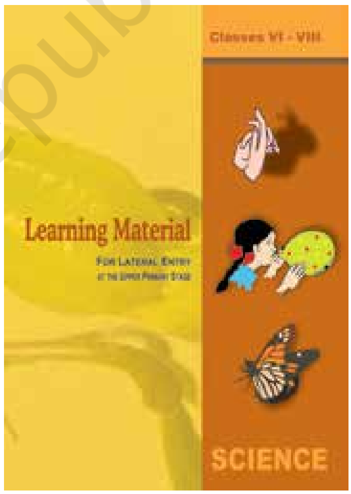


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