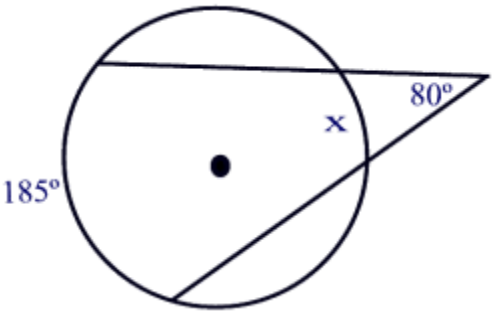
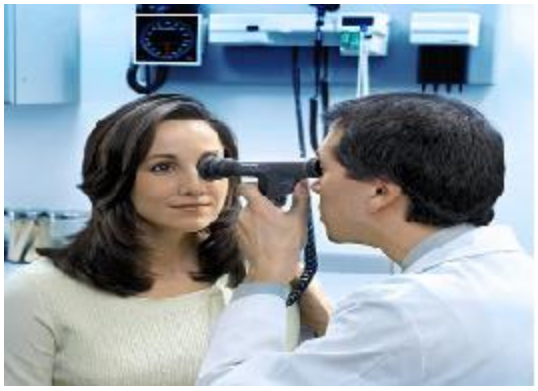


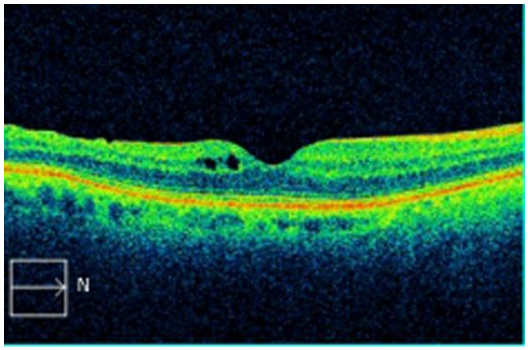


The **Scholars** Programme

Scanning the eye – a mission to save retinas and lives

September 2016

Tutor Name Dr. Stancu



Pupil Name _____

The Scholars Programme – 2016/2017 – Pupil Feedback Report

Grade	Marks	What this means
1st	70+	Performing to an excellent standard at first year undergraduate level
2:1	60-69	Performing to a good standard at first year undergraduate level
2:2	50-59	Performing to an excellent standard at GCSE level
3rd	40-49	Performing to a good standard at GCSE level
Workings towards a pass	0-39	Workings towards a pass
Did not submit	DNS	No assignment received by The Brilliant Club

Lateness	
Any lateness	10 marks deducted
Plagiarism	
Some plagiarism	10 marks deducted
Moderate plagiarism	20 marks deducted
Extreme plagiarism	Automatic fail

Name of PhD Tutor			
Title of Assignment			
Name of Pupil			
Name of School			
ORIGINAL MARK / 100		**FINAL MARK / 100**	
DEDUCTED MARKS		**FINAL GRADE**	

If marks have been deducted (e.g. late submission, plagiarism) the PhD tutor should give an explanation in this section:

Learning Feedback Comment 1 - *Enter Key Learning Priority Here*	
What you did in relation to this Key Learning Priority *Enter feedback here*	**How you could improve in the future** *Enter feedback here*
Learning Feedback Comment 2 – *Enter Key Learning Priority Here*	
What you did in relation to this Key Learning Priority *Enter feedback here*	**How you could improve in the future** *Enter feedback here*
Learning Feedback Comment 3 – *Enter Key Learning Priority Here*	
What you did in relation to this Key Learning Priority *Enter feedback here*	**How you could improve in the future** *Enter feedback here*
Resilience Comment	
How you showed learning resilience during the course *Enter feedback here*	**How you could build learning resilience in the future** *Enter feedback here*

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Course Rationale

Eye diseases that can cause impairment, even blindness, represent a more and more common problem in the modern society. Several affections are common, like poor vision or cataract. Other diseases of the eye are extremely dangerous, like glaucoma, which affects the nervous system in the eyes and ultimately lead to total blindness. But how do scientists and doctors go about diagnosing these issues? What tools do we have at hand? How can we improve those tools to make them more efficient, to help doctors in diagnosing and preventing early dangerous diseases like glaucoma?

This course is aimed at students who are interested in mathematics, physics and human biology and looks at how these subjects can be applied to generate efficient diagnosing tools that will improve prevention and enable a proper course of treatment that will overall improve human health in the future.

The initial tutorials will introduce the basic concepts of biology and physics of the interaction of light with living tissue and more specifically, with the tissues in the eye. Once the students are confident with these concepts, they will be applied within the concept of my doctoral research: through the presentation of my theory and data, pupils will discover the methods, optical sources and interferometric tools available in eye disease diagnosing, the disadvantages in different approaches, and possible new approaches.

Finally, the students will be asked to complete an essay based assignment on an eye disease of their choice where they explain how the disease arises, how features of the disease can be exploited by scientists designing eye imaging devices, and critically assess different diagnosing strategies.

Mark Scheme

Key Skill	1st	2.1	2.2
Knowledge and understanding	• Pupils demonstrate accurate, detailed and comprehensive knowledge of key concepts regarding eye anatomy, interaction of tissues with radiation and methods of imaging the eye. • Pupils produce answers which fully address the requirements of the questions and demonstrate good contextual awareness. • Pupils provide accurate evidence and independently researched examples to illustrate the points made.	• Pupils demonstrate accurate, less detailed and some comprehensive knowledge of key concepts regarding eye anatomy, interaction of tissues with radiation and methods of imaging the eye. • Pupils produce answers which are addressing the requirements of the questions and demonstrate good contextual awareness. • Pupils provide good evidence and some independently researched examples and concepts to illustrate the points made.	• Pupils offer some analysis that shows some awareness of the concepts regarding eye anatomy, interaction of tissues with radiation and methods of imaging the eye. • Pupils provide simple evaluation of key concepts and make some comparisons. • Pupils partially address the requirements of the course, and lack the evidence of independent research.
Analysis and evaluation	• Pupil answers provide analysis that synthesises key concepts like eye anatomy, interaction of tissues with radiation and methods of imaging the eye, evaluating the information clearly and fully. • Answers make effective comparisons, connections, similarities or differences.	• Pupil answers provide analysis which synthesises most of the key concepts like eye anatomy, interaction of tissues with radiation and methods of imaging the eye, evaluating the information clearly but incomplete in some places. • Answers make approximate comparisons, connections, similarities or differences.	• Pupil answers provide analysis that displays an approximate awareness of the key concepts, they show some comparisons and connections • They are not showing similarities of differences.
Communication	• Pupils construct and communicate coherent arguments and explanations, offer a coherent conclusion which flows from the discussion. • Pupils use a relevant and appropriate vocabulary.	• Pupils construct and communicate good arguments and explanations, offering simple conclusions, but which are not flowing from the discussion all the time. • Pupils use a relevant and good vocabulary	• Pupils construct and communicate some unclear, but structured arguments and explanations, using simple, but relevant vocabulary. • Pupils are offering good conclusions, but unsupported by clear explanations.
Application	• Clear links are made between optical physics and biology of tissues, mathematical equations are well applied, course content is successfully applied in new elaborated examples (diagnosing eye diseases using certain techniques).	• Good links are made between optical physics and biology of tissues, course content is almost successfully applied in new elaborated examples (diagnosing eye diseases using certain tools).	• A good attempt is made to describe the physical and biological mechanisms and the connections between them. Course content is successfully applied to familiar problems. Some mistakes done in applying mathematical formulas.

Glossary of Keywords

Light

Laser

Radiation

Tissue

Reflection

Refraction

Transmission

Scattering

Absorption

Eye

Retina

Eye lens

Vision

Propagation

Impairment

Glaucoma

Diagnose

Interferometer

Interference

Photo-detection

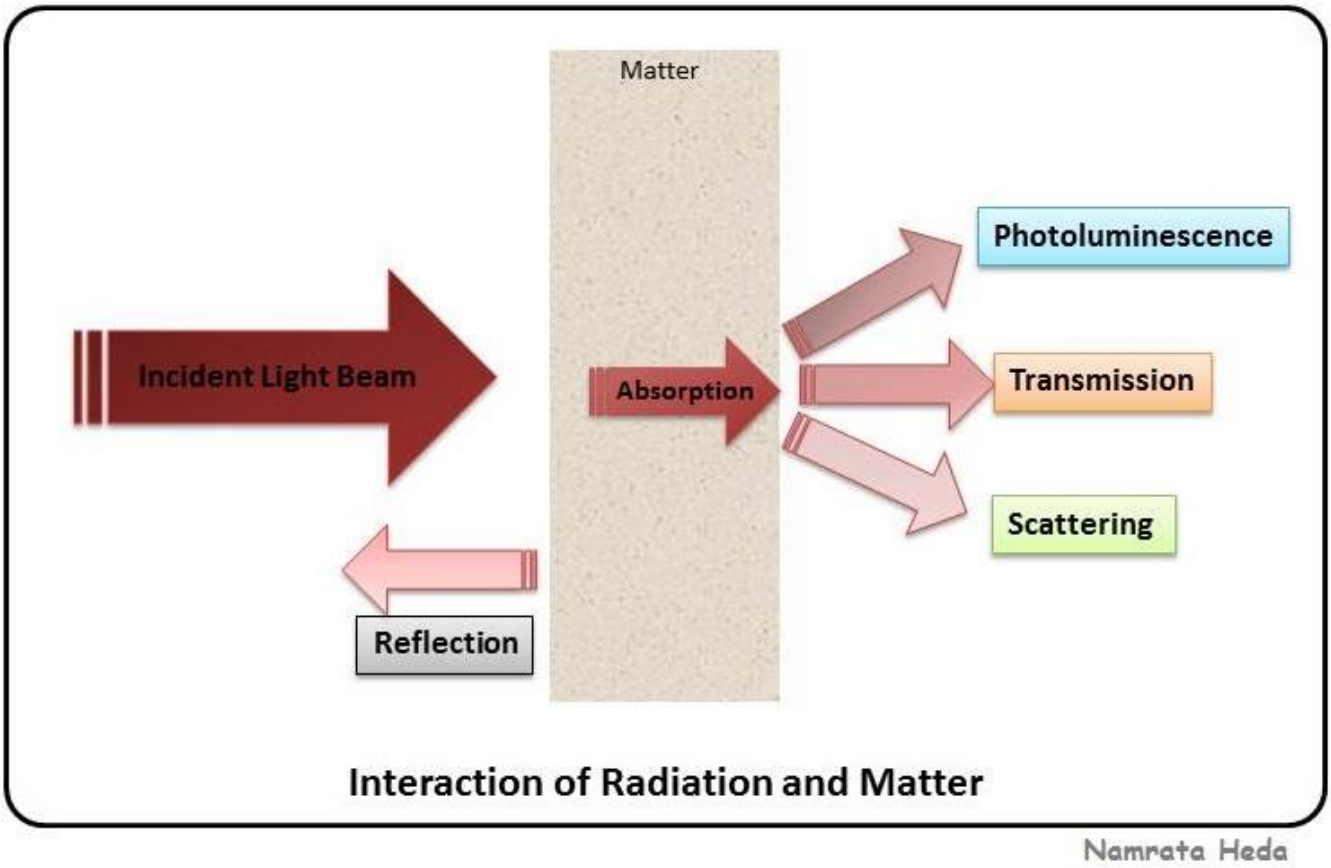
Microscope

Ophthalmoscope

Coherence

Tomography

Tutorial 1 – Interaction of light with radiation



What is the Purpose of Tutorial 1?

- Introducing myself to the class.
- Stating the general objectives of the course.
- Introduction to physical phenomena and equations which describe the interaction between light and matter.

The field of lasers developed for biomedical applications, either therapeutic or used in diagnosing, is a rapidly growing field. The light-tissue interaction in the diagnostic approach results in the study of the physiology or pathology of the tissue, with no damage being induced at cellular level. The three main optical properties that characterise this type of interaction are the absorption, scattering and refractive index.

The refractive index n of an optical medium is a number calculated by dividing the speed of light in vacuum to the light propagation speed in the medium: c_0/v. Refraction is an optical phenomenon that occurs when light is incident at the boundary between two media of different indices of refraction and it is defined by Snell's law:

$$v_1 \cdot \sin(\theta_1) = v_2 \cdot \sin(\theta_2),$$

where θ_1 is the angle of incidence, θ_2 is the angle of refraction, and v_1 and v_2 represent the speeds of light in the media. Biological tissue is a multi-structured media, each constituent being characterised by a different index of refraction.

Activity 1:

1. What is the speed of light in vacuum?

Answer:

2. A light beam travels through air (n = 1). At some point, it enters a water medium and some of the incident beam is being refracted. The beam is now propagated in water with a speed of 280.000.000 m/s. The angle of incidence was 30°. What is the angle at which the refracted beam travels? Draw after that an approximate depiction in order to describe the phenomena mentioned in this task.

Answer:

Another important parameter that characterises tissues is absorption. The transmitted light intensity *I(x)* across a homogeneous and non-scattering medium of thickness *x*, which is illuminated by a collimated beam of light is given by the following equation:

$$I(x) = I_0 e^{-\mu_{abs} x},$$

where I_0 represents the intensity of the incident light and μ_{abs} is the absorption coefficient characteristic for a given wavelength λ. In tissues, the compounds that absorb light in a certain spectral region of interest are known as chromophores.

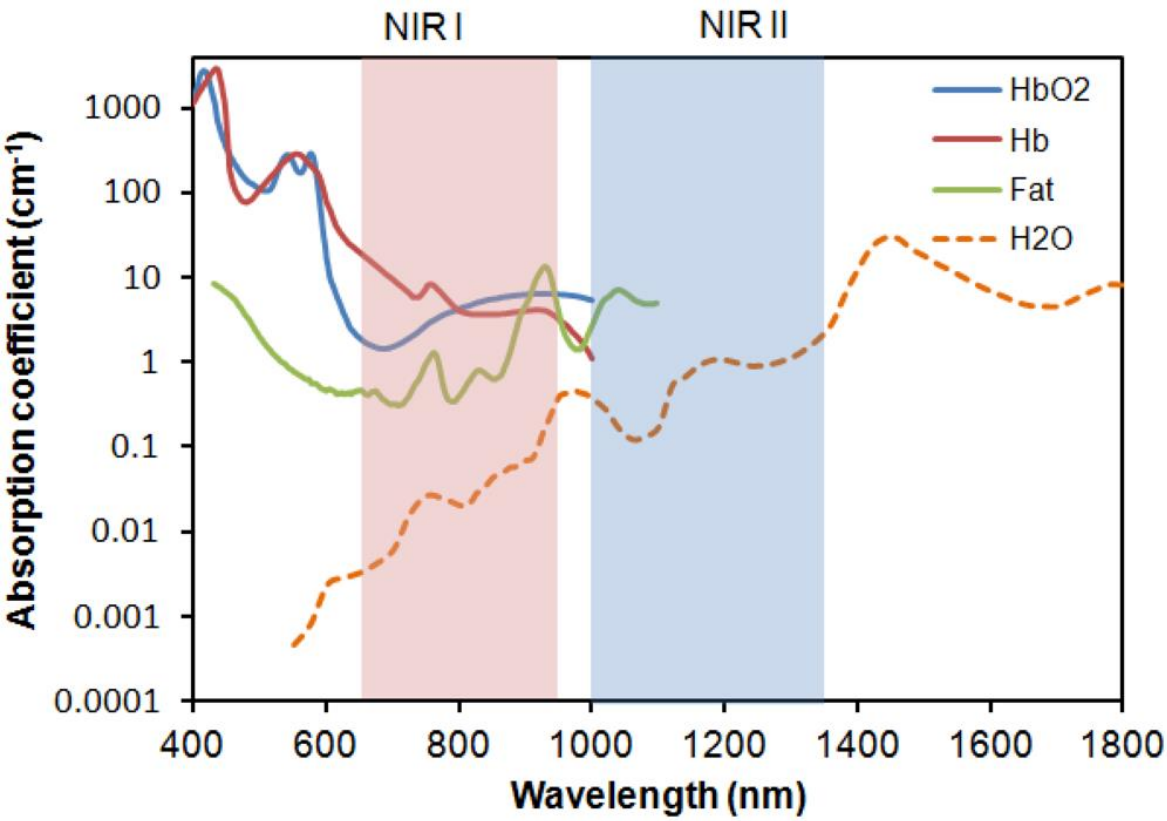


Fig. 1.1. The therapeutic window

The therapeutic window, depicted in Fig. 1.1, represents the chromophores absorption window in the near-infrared range (NIR). The major absorbents in the soft tissues are water (H_2O), oxyhaemoglobin (Hb) and deoxyhaemoglobin (HbO_2), while the minor ones are other chromophores like melanin and lipids (fat).

Activity 2: Look at the therapeutic window depicted in *Fig 1.1*. Identify: a) where are the peak values of absorption for water? b) at what wavelengths water is more absorbent?
Answer:

Scattering is defined very similarly as the absorption:

$$I(x) = I_0 e^{-\mu_{scatt} x},$$

where μ_{scatt} is the scattering coefficient of the medium, corresponding to a certain wavelength λ of the incident light. It is a physical process through which light transmitted in a tissue changes its direction when interacting with particles of variable size or when there is a change in the refractive index determined by various tissue components, like membranes.

Tutorial 1 – Baseline Test

The homework assignment for the first tutorial is a baseline test to see your initial level of attainment in this subject area. The assignment will test for some or all of the subject specific skills that are required later in the final assignment. However, it is shorter than the final assignment and is will be an introduction to the subject as well as a challenge!
Do not worry too much about doing 'well' or 'badly' on the baseline test, it takes into account the fact that you may not be familiar with the subject area. It is designed to help you and your PhD tutor identify where you are at the start of the programme and to help you measure your progress along the way.

Baseline Test: Please answer the following questions:

1) A circle has the diameter D = 10 cm. Calculate the circumference and the area of the circle. [2 marks]

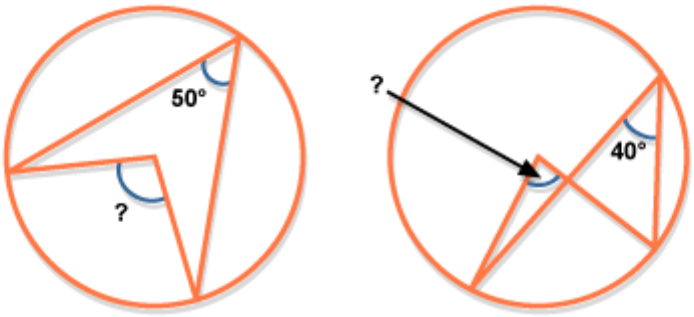
2) A light wave travels through a medium having the index of refraction 1.2 at an angle of 30° with respect to the vertical axis. The same wave enters suddenly a medium with the index of refraction 1.5. How is the propagation angle going to change? Justify your answer. [2 marks]

3) From a random point in space, a 2 m tangent is drawn to a circle having a radius of 1 m. What would be the length of the second tangent drawn to the same circle? [2 marks]

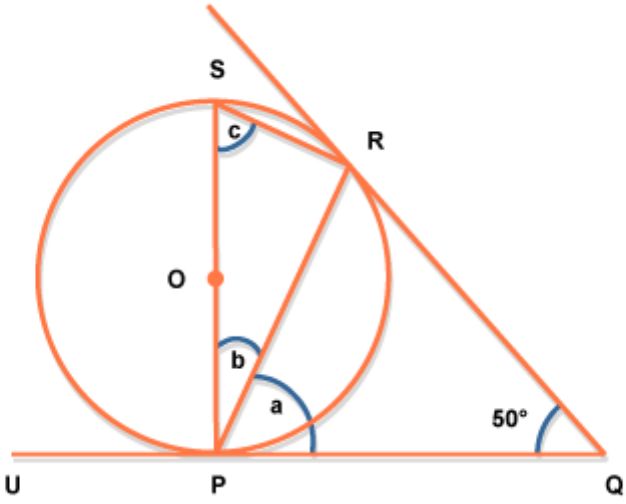
4) How do we describe the image in a plane mirror? [2 marks]

5) The power of a laser source is 10 W. The light emitted is transmitted through three consecutive media. Each media absorbs part of the light passing through as follows: 30%, 25% and, respectively, 50%. Work out what power is left after the beam exits the third medium? [3 marks]

6) Work out the size of the angle subtended by the arc at the centre of each circle. [3 marks]



7) Work out the angles a, b and c. [3 marks]



8) An object measures 35 cm in height. Looking at this object through a lens, the height of the image is 105 cm. How much is the magnification of the lens used? What would happen if we would use a lens with magnification less than 1? [3 marks]

Tutorial 2 – Anatomy of the human eye

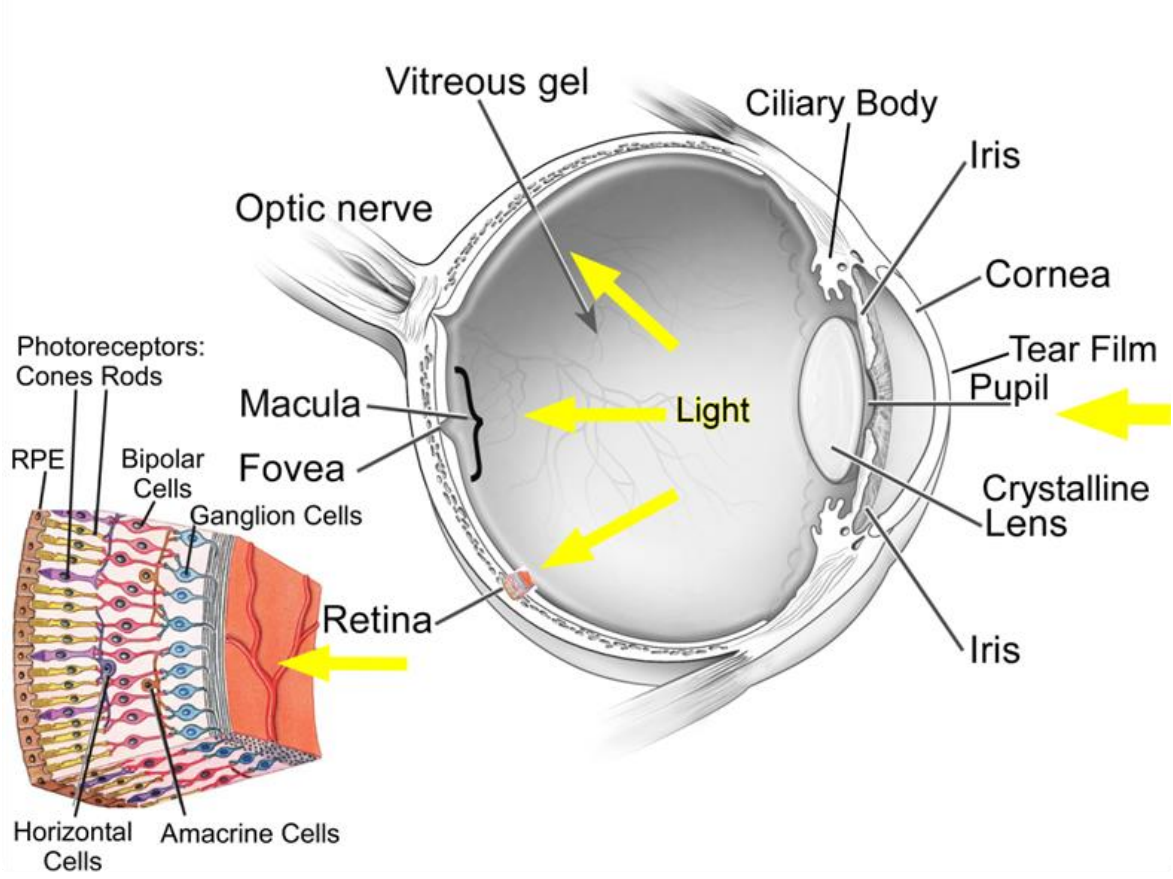


Fig. 2.1. Anatomy of the human eye

What is the Purpose of Tutorial 2?

- Introduction to general anatomy of the eye
- Explaining what vision means, how is created.
- Impairments and diseases that affect vision

The human eye, illustrated in Fig. 2.1, is a very complex organic optical system, comparable to a sophisticated camera, self-focusing, which adjusts automatically for light intensity, has a self-cleaning lens, and feeds information into a computer with parallel-processing capabilities so advanced that is not equalled yet by any artificial device. The light carrying information about the shapes and colours in the environment enters the eye through the first layer called cornea and it is adjusted in intensity by the pupil, which acts like a diaphragm or a pinhole. After passing a transparent region called the aqueous humour, the transmitted rays are focused by the eye lens on the retina.

The region that separates the lens and the retina is also transparent and it is called vitreous humour. The retina is a multi-layered photosensitive organ, as depicted in Fig. 2.1, comprising two main structures, the macular region and the optic nerve head. The retina is comprosing the following main components:

- **Blood vessels -** Blood vessels within the retina bring nutrients to the retina's nerve cells.

- **The macula –** This is the region in the retina where the highest visual acuity is achieved. The dead centre of it is called the fovea. Because it is situated at the focal point of the eye, it has more specialized light sensitive nerve endings, called photoreceptors, than any other part of the retina.
- **Photoreceptors -** There are two kinds of photoreceptors: rods and cones. These specialized nerve endings convert the light into electro-chemical signals sent to the brain.
    - **Rod cells** are one of the two types of light-sensitive cells in the retina of the eye. There are about 125 million rods, which are necessary for seeing in dim light.
    - **Cone cells** are the second type of light sensitive cells in the retina of the eye. The human retina contains between six and seven million cones; they function best in bright light and are essential for acute vision (receiving a sharp accurate image). It is thought that there are three types of cones, each sensitive to the wavelength of a different primary colour – red, green or blue. Other colours are seen as combinations of these primary colours.
- **Retinal pigment epithelium -** Beneath the photoreceptors is a layer of dark tissue known as the retinal pigment epithelium (RPE). These important cells absorb excess light so that the photoreceptors can give a clearer signal. They also move nutrients to (and waste from) the photoreceptors to the choroid.
- **The choroid -**This layer lies behind the retina and is made up of many fine blood vessels that supply nutrition to the retina and the retinal pigment epithelium.
- **Sclera -** It is the tough, fibrous, and white outside wall of the eye connected to the clear cornea in front, which has the role to protect the delicate structures inside the eye.

Activity 1

1) Locate and enumerate the transparent regions in the human eye.

Answer:

2) Is the eye lens convex or concave? Is it convergent or divergent?

Answer:

Activity 2

Let us look at the sketches of a film camera and, respectively, a modern digital photographic camera, both depicted in Fig. 2.2. Which components of the human eye do you think correspond to each part constituting each camera?

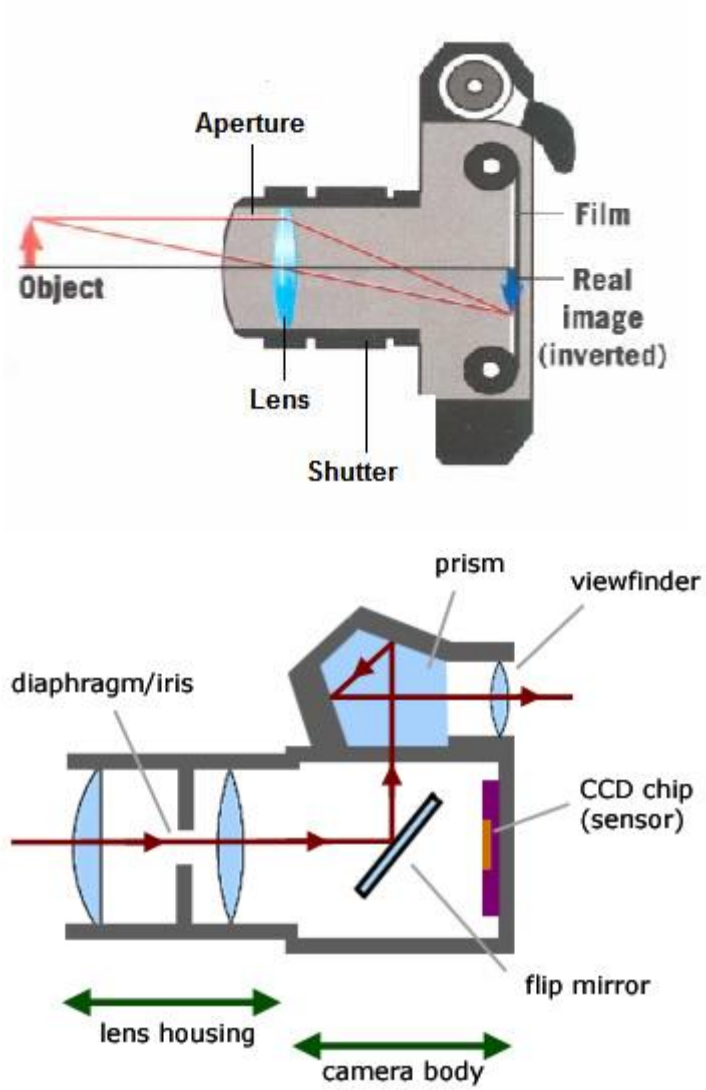


Fig. 2.2. Film camera (above), reprinted from www.odec.ca*; Digital camera (bellow}, reprinted from* www.a-levelphysicstutor.com

Answer:

The most common problems with vision are nearsightedness (myopia), farsightedness, (hyperopia), a defect in the eye caused by nonspherical curvature (astigmatism) and age-related farsightedness (presbyopia), according to the National Eye Institute.

Most people will develop presbyopia in their 40s or 50s, and start needing reading glasses. With age, the lens gets denser, making it harder for the ciliary muscles to bend the lens. The leading causes of blindness include cataracts (clouding of the lens), age-related macular degeneration (deterioration of the central retina),

glaucoma (damage to the optic nerve), and diabetic retinopathy (damage to retinal blood vessels). Other common disorders include amblyopia ("lazy eye") and strabismus (crossed eyes).

Activity 3

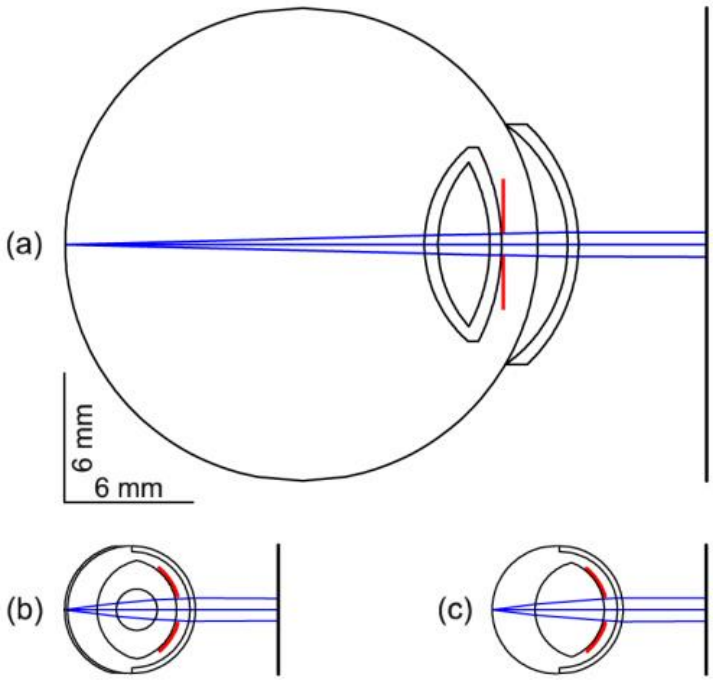
The Moorfields Eye Hospital in London made the following table regarding patients with glaucoma.

a) Draw a histogram and identify the median for this data.

Age (x) [years]	**Number of glaucoma patients (frequency)**	**Frequency density**
$0 < x \leq 10$	3	
$10 < x \leq 20$	24	
$20 < x \leq 30$	32	
$30 < x \leq 50$	58	
$50 < x \leq 70$	82	

b) How many patients are in total?
Assuming that this data was taken for a region with 300.000 inhabitants, work out the percentage of people affected by glaucoma.

Tutorial 3 – The geometrical model of the human eye



What is the Purpose of Tutorial 3?

- Understand the simple geometrical model of the human eye
- Understand the geometry of the light propagation through the eye
- Learn how to calculate main parameters light diameter, area and volume of the eye

I order to be able to design a suitable ophthalmic imaging and diagnosing equipment, scientists create first a theoretical model of the eye. Such models, as the one represented in Fig. 3.1, are meant to be introduced into numerical computer simulations that will offer a dimensional estimation, thus helping researchers to find innovative solutions.

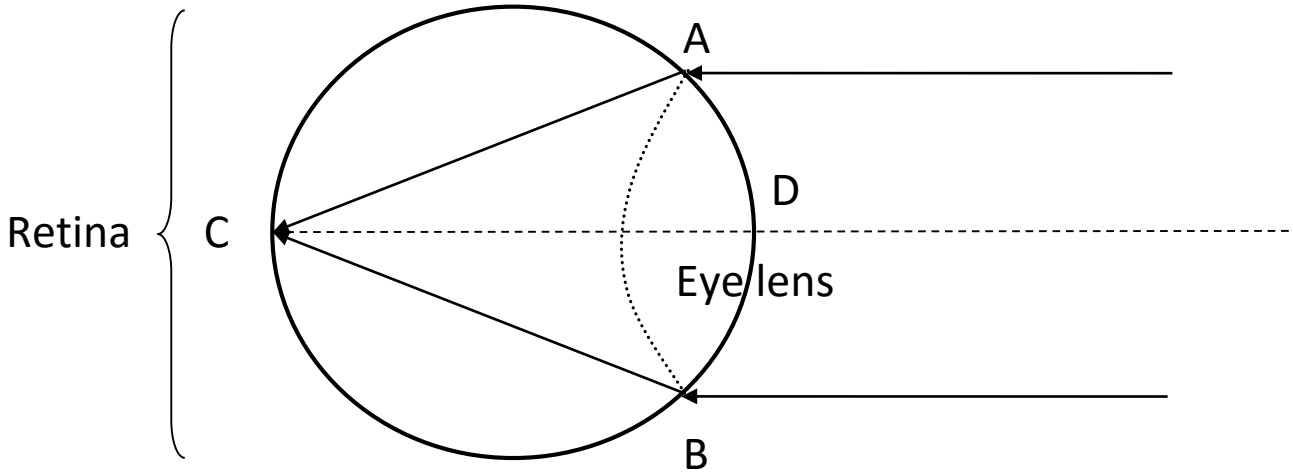


Fig. 3.1. Basic geometrical eye model

Activity 1:
Look again at the sketch representing the basic geometrical depiction of the human eye.
Calculate the radius R of the eye, if AC = AB = 2 mm and the angle ACB = 30º.
Answer:

Activity 2:
Calculate the area and volume of the average human eye (D = 16 mm).
Answer:

Lefohn et al. (http://graphics.cs.ucdavis.edu/~lefohn/work/eye/irisSynthesis.pdf) proposed another simple geometric model of an eye, as depicted in Fig. 3.2. Both sclera and the cornea are modelled using simple spheres whose centres are placed approximately 4.7 mm apart. The part of spheres C2 that sticks out of C1 serves as the cornea. The iris, which is not shown in Figure 1, basically takes the shape of a flat cone, whose apex has been cut off (also known as frustum), and sits below the cornea to fill in the circle that is described by the intersection of C1 and C2.

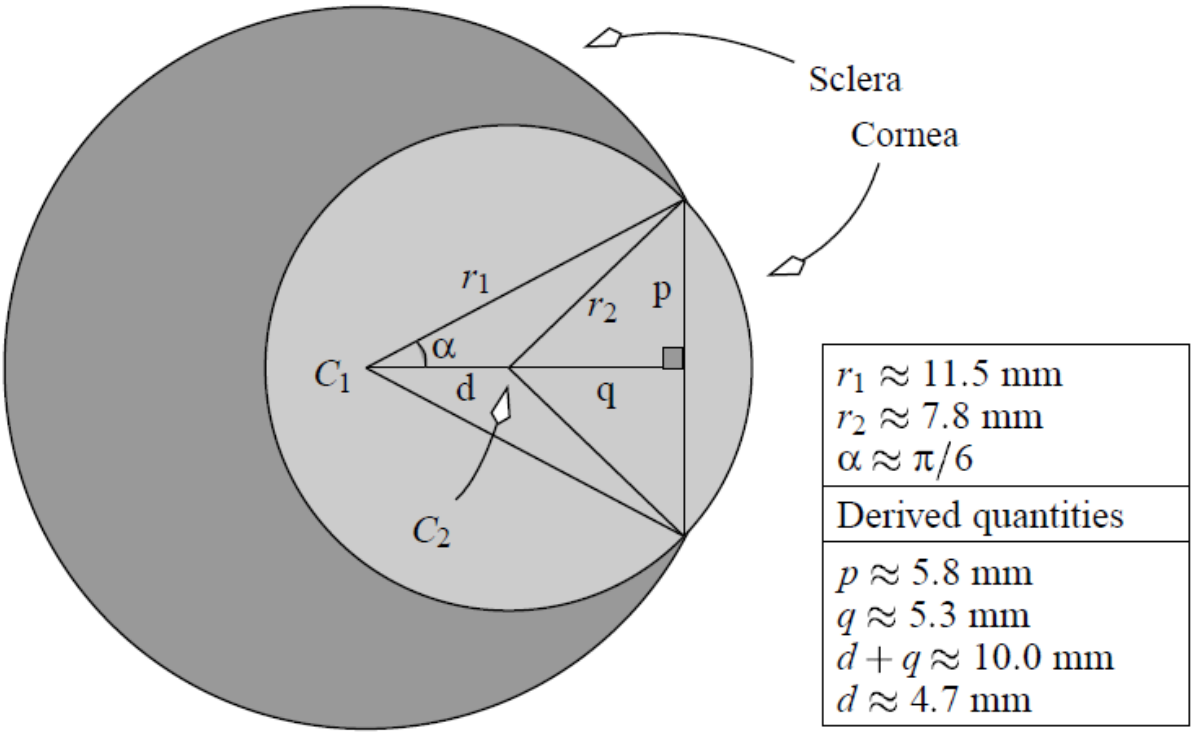


Fig. 3.2. Geometric model of an eye (Lefohn et al.)

The authors of this model wanted to illustrate the iris by stacking several layers of such cone frustums. Each layer of the cone frustum is texture mapped with an opacity map chosen from Figure 3.3.

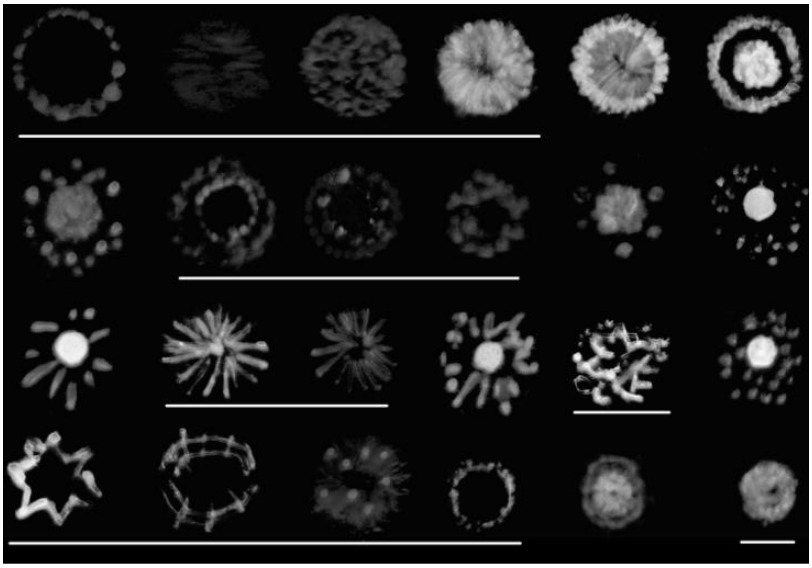


Fig. 3.3. Opacity maps used for iris layers

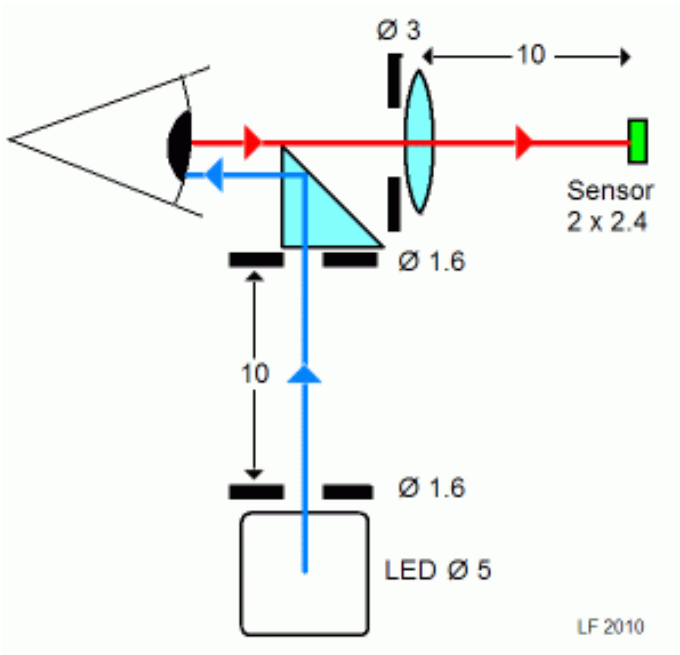
Activity 3

Using a geometrical model of a human eye, scientists from the Applied Optics Group at the University of Kent obtained the following table:

Eye diametre (x) [mm]	Number of subjects	Frequency density
$14 < x \leq 14.5$	12	
$14.5 < x \leq 15$	8	
$15 < x \leq 15.5$	22	
$15.5 < x \leq 16$	18	
$16 < x \leq 16.5$	34	
$16.5 < x \leq 17$	15	

Draw a histogram showing this data. Where is the median?

Tutorial 4 – Imaging the eye using microscopy



What is the Purpose of Tutorial 4?

- Understand the basic concept and operation of a microscope used in ophthalmology
- Connect the information gathered so far about the eye anatomy and the interaction of radiation with tissue in describing the functionality of a microscope

Helmholtz invented the first ophthalmoscope in 1851, which was later commercialised in 1920 by Zeiss, naming the technique applied with this back of the eye imaging device fundus photography. This technology was quite straight forward; a carbon-arc lamp illuminated the back of the eye using a partially reflective mirror. The light reflected from the retina was magnified to form an image, first of this kind being achieved in 1886, showing the optic disk and the larger blood vessels.

In 1957 the confocal microscopy (CM) was invented by Marvin Minsky. While with the fundus photography ophthalmoscope the whole retina was illumined in the same time on the whole surface, the confocal microscope uses point by point illumination and a pinhole in an optically conjugate plane in front of the detector to eliminate the reflected signal that is not in focus. This method creates a 2D image with about 300 µm depth resolution, but on the on the other hand it is not fast. The confocal scanning laser microscopy became the standard technique used worldwide by the end of the 1980s.

Confocal laser scanning microscopy (CLSM or LSCM) is a technique used to obtain high-resolution optical images with depth selectivity, by acquiring in-focus images from selected depths (optical sectioning). Images are acquired point-by-point and reconstructed with a computer, allowing 3D reconstructions of topologically complex objects. For interior imaging, the quality of the image is greatly enhanced over simple microscopy because image information from multiple depths in the specimen is not superimposed. A conventional microscope can scan as far into the specimen as the light can penetrate, while a confocal

microscope only registers images one depth level at a time. In effect, this technique achieves a controlled and highly limited depth of focus.

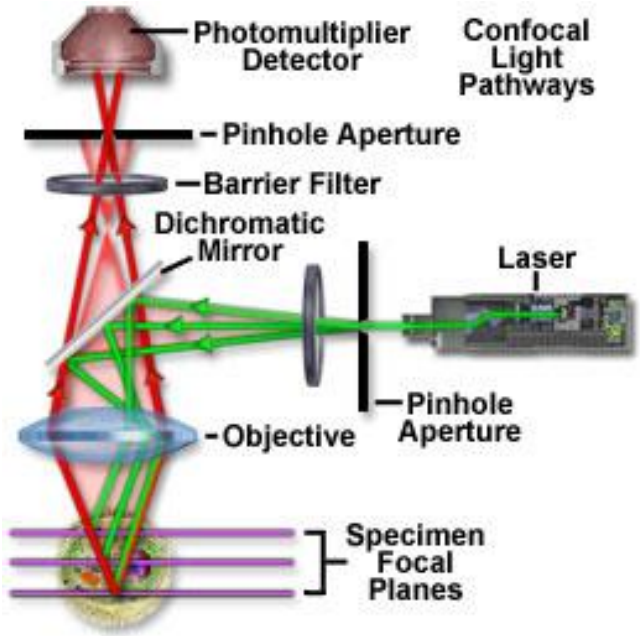


Fig. 4.1. Confocal laser microscope diagram, reprinted from www.olympusconfocal.com

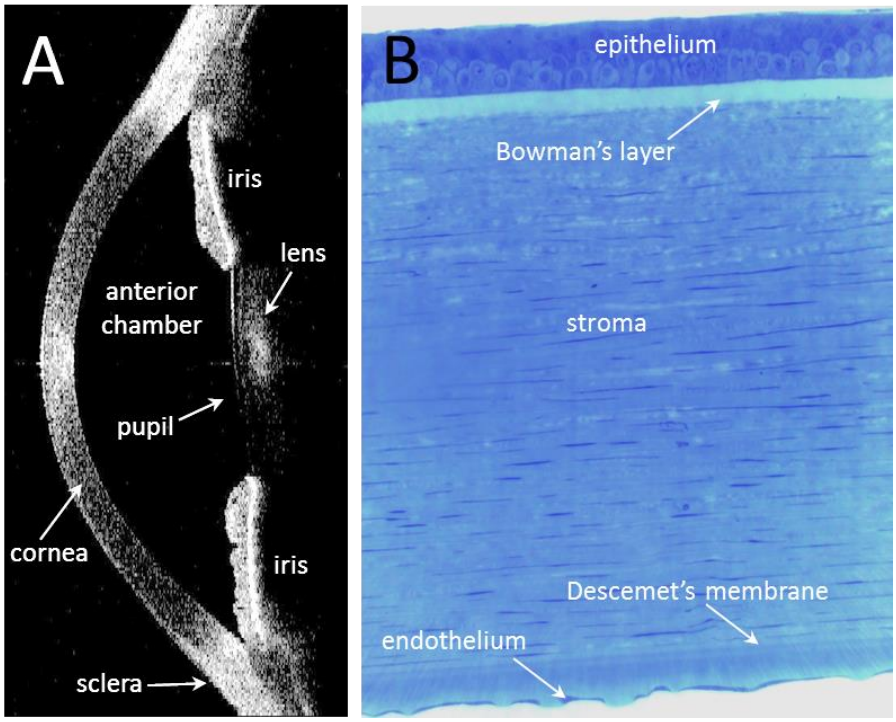


Fig. 4.2. The human corneal anatomy captured by confocal microscopy, reprinted from http://www.intechopen.com/books/confocal-laser-microscopy-principles-and-applications-in-medicine-biology-and-the-food-sciences/laser-scanning-in-vivo-confocal-microscopy-of-the-cornea-imaging-and-analysis-methods-for-preclinica

Clinically, confocal microscopy is used in diagnosing various eye diseases, and is particularly useful for imaging, qualitative analysis, and quantification of endothelial cells of the cornea, as represented in Fig. 4.2.

It is also used for localizing and identifying the presence of filamentary fungal elements in the corneal stroma, in cases of keratomycosis, enabling rapid diagnosis and thereby early institution of definitive therapy.

The main drawbacks of this technique are the slow acquisition (approx. 1 second to acquire one image), due to the point-by-point scan excitation, low light efficiency (due to the type of detector used). A solution proposed to compensate for these drawbacks would be to integrate in the system multiple pinholes and a faster camera. There is ongoing research around the world in this respect.

Activity 1

Look at Fig. 4.1, depicting a confocal laser microscope. A laser source emitts a 10 mW beam. 30% of the light is lost at the dichromatic mirror at every pass, while 50% is lost thorough all the other optical elements. 75% is lost in the specimen, while the loss at the detector is aproximately 10%. How much of the initial power is processed at the detector? Approximate the result to two significant figures. Work out what percentage it represents from the initial 5 mW of power?

Answer:

Activity 2

A confocal microscopy image of a liquid sample can be acquired with a red light emitting laser if the sample is mixed with a special dye in a proportion of 3:1. Knowing that the sample has a total volume of 2 mm^3, work out how much dye needs to be added in order to be able to acquire an image.

Answer:

Activity 3

A researcher is acquiring confocal microscopy images of the human cornea. He reports the power that the sample receives is 0.2 mW. In order to enhance his image, he decides to add 5 consecutive pinholes in his confocal microscopy setup. Knowing that each pinhole will induce a loss of 10%, how much does the researcher need to increase the input laser power to in order to achieve at the sample the same 0.2 mW.

Answer:

Tutorial 4 – Homework: Draft Assignment

When you are a researcher and you are looking for new methods to improve existing technologies or even to innovate and replace obsolete concepts, you need first of all to look for an idea. In order to see if this idea is new or it has been discovered before, a thorough literature review must be performed before starting the actual research activity and lab work.
Imagine you are a researcher and you want to develop a novel technique of eye imaging. Check online or in specialty books dedicated to eye disease imaging and diagnosis and see if there are other techniques than microscopy that are used in eye imaging. Write an 800-1000 words essay to describe what you have found.

Use the following structure for the essay:

1) Introduction – describe briefly what confocal microscopy is and what are the main benefits and limitations of this technique.
2) Motivation – what other eye imaging techniques are developed in the world, what do they bring new? Are they commercially available?
3) Brief comparative analysis between confocal microscopy and the alternative method found.
4) Conclusion.

Tutorial 5 – Optical coherence tomography – a revolutionary approach in eye imaging

What is the Purpose of Tutorial 5?

- Understand the basic concept and operation of an interferometer
- Understand the principle of operation of an ophthalmoscope based of optical coherence tomography
- Learn how to determine the main parameters in eye imaging and how are those in comparison with microscopy

Optical Coherence Tomography (OCT) is a non-invasive eye diagnostic technique. OCT utilizes a concept known as interferometry to create a cross-sectional map of the retina that is accurate to within at least 10-15 microns.

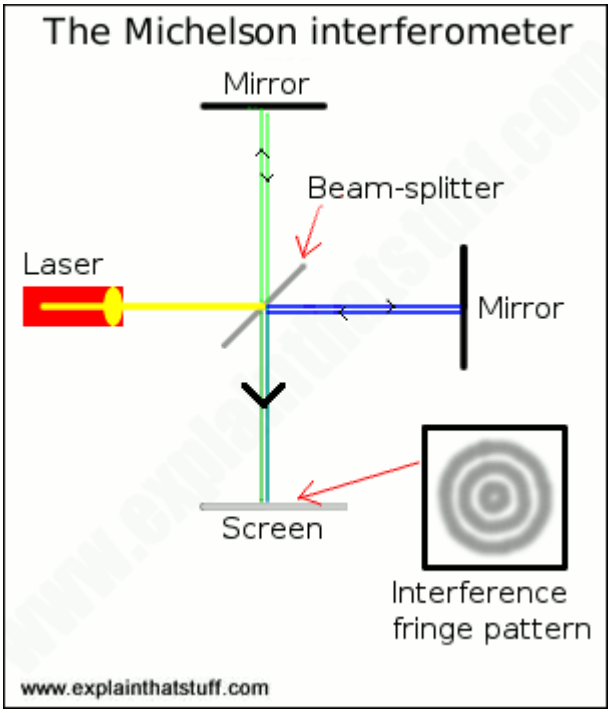


Fig. 5.1. Interferometer sketch

A Michelson interferometer, as the one depicted in Fig. 5.1, comprises a laser source, which directs the emitted light to a beam-splitter. The light is divided by this optical device in two beams, one called reference, the other called object. Each beam is incident on a totally reflective mirror. The two light beams returning from each mirror are meeting again on the beam-splitter, where they rejoin into one light wave which is after that projected on a screen. This rejoining is scientifically called interference, and the interference fringe pattern is visible on the screen.

We define the distance travelled by a light wave between two or more points as optical path length (OPL). The optical path difference (OPD) is defined as the difference between the optical path length in the reference arm and the one in the object arm: $OPD = OPL_{reference} - OPL_{object}$.

Assuming that one of the mirrors is fixed and the other is mobile, the OPD can be varied. If OPD = 0, the interference pattern on the screen would be a very small circle (sometimes is confounded with a very bright dot). As the OPD increases, the number on circles projected on the screen increases as well.

Activity 1

Remember the sketch of a microscope from the previous tutorial? What main differences can you spot between a microscope and an interferometer?

Answer:

Activity 2

The total optical path length in a Michelson interferometer is 20 m. The distance that the light travels between the laser and the beam splitter is 2 m, while the distance between the beam splitter and the screen is 3 m. Assuming that OPD = 1 m, work out the optical path length in the reference arm, respectively object arm. You must show the working out.

Answer:

OCT was first introduced in 1991 and has found many uses both in and outside of ophthalmology, where it has been used to image certain non-transparent tissues. Due to the transparency of the eye (i.e. the retina can be viewed through the pupil), OCT has gained wide popularity as an ophthalmic diagnostic tool.

From its inception, OCT images were acquired in a time domain fashion. Time domain systems acquire approximately 400 A-scans per second using 6 radial slices oriented 30 degrees apart. Because the slices are 30 degrees apart, care must be taken to avoid missing pathology between the slices.

Spectral domain technology, on the other hand, scans approximately 20,000-40,000 scans per second. This increased scan rate and number diminishes the likelihood of motion artifact, enhances the resolution and decreases the chance of missing lesions. Whereas most time domain OCTs are accurate to 10-15 microns,

newer spectral domain machines may approach 3 micron resolution. Whereas most time domain OCTs image 6 radial slices, spectral domain systems continuously image a 6mm area. This diminishes the chance of inadvertently missing pathology.

The main parameters that characterise an optical source used in OCT applications are the central wavelength, bandwidth, output power and stability. In order to be able to integrate them in portable equipment used in clinical *in vivo* imaging, a laser developer must also take in consideration facts like size, ease of use, maintenance and compatibility with the environment where it is used. Also, the costs of manufacturing and retail must be reduced as much as possible in order to make it attractive commercially.

One of the most important scientific aspects of an optical source used in OCT is the axial resolution ΔL in imaging. ΔL is given by the following equation:

$$\Delta L = \frac{2ln2}{\pi}\left(\frac{{\lambda_0}^2}{\Delta\lambda}\right) = 0.44\left(\frac{{\lambda_0}^2}{\Delta\lambda}\right), \qquad (5.1-1)$$

This equation shows that there is a proportional relationship between the resolution and bandwidth. A simple calculation shows that in order to achieve a 10 μm resolution at λ_0 = 850 nm, a bandwidth Δλ = 31.45 nm is necessary. On the other hand, if we repeat this calculation for λ_0 = 1550 nm, the bandwidth required increases significantly, to 94.6 nm.

Activity 3

Calculate the axial resolution in an OCT imaging system using a broadband light source emitting at a central wavelength of 1310 nm and a bandwidth of 60 nm. Show all the working out and give your answer to two decimal places.

Answer:

Activity 4

Look at the figure bellow, depicting an OCT system. A low coherence light source emitts a 5 mW beam. 20% of the light is lost at the beam-splitter at every pass, 30% of the light wave power is lost at each pass through either of the arms of the inteferometre, 80% is lost in the eye, while the loss at the receiver is aproximately 10%. How much of the initial power is processed at the receiver? Approximate the result to two significant figures. Work out what percentage it represents from the initial 5 mW of power?

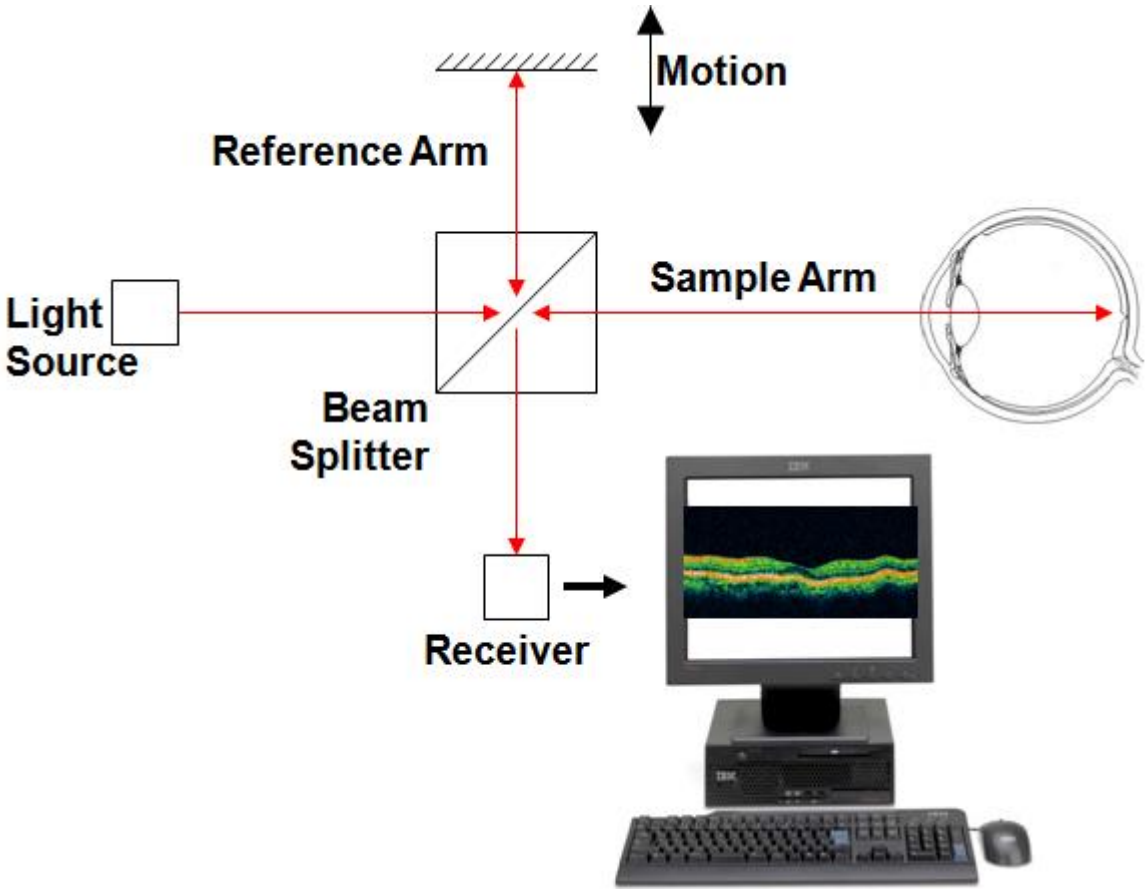


Fig. 5.2. General sketch of an OCT system

Answer:

Because OCT utilizes light waves media opacities in the eye can interfere with optimal imaging. As a result, the OCT will be limited if the patient is presenting one of the following afections: vitreous hemorrhage, dense cataract or corneal opacities.

As with most diagnostic techniques, patient cooperation is a necessity, because patient movement can diminish the quality of the image. In modern OCT machines, faster scanning light sources and acquisition softwares

were implemented to compensate for the reflex movement of the human eye, leading to a shoter acquisition time is shorter and fewer motion related artifacts in the images.

The quality of the image is also dependant on the operator of the machine. Early models of OCT tomographs relied on the accuracy of the operator to place the image over the diagnosed pathology. When serial images were acquired over time, later images could be taken that were off axis compared to earlier images. Newer technologies, such as spectral domain acquisition or eye tracking equipment, limit the likelihood of acquisition error.

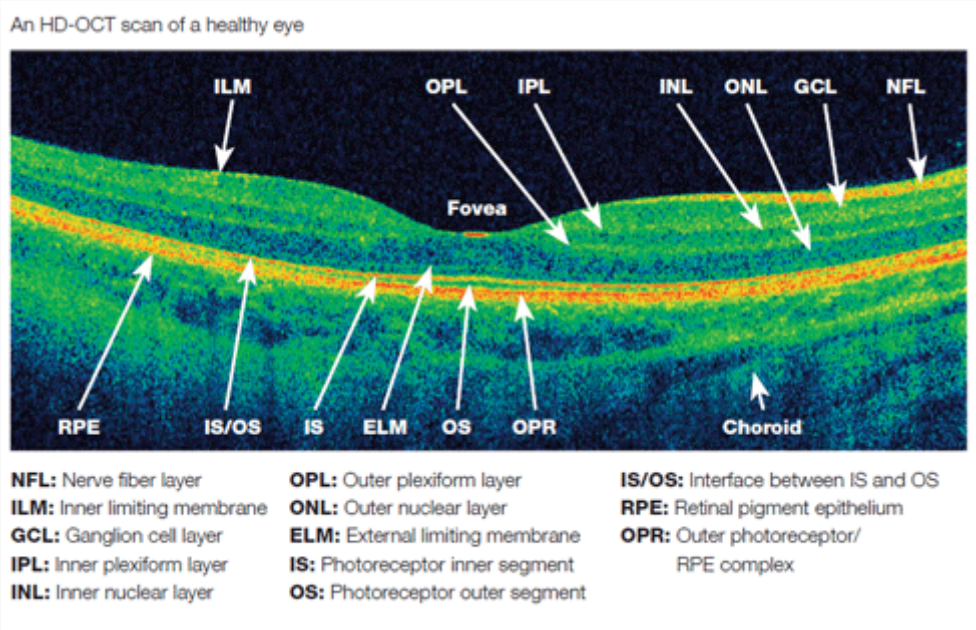


Fig. 5.3. OCT eye image (reprinted from www.optical.healthpartners.com.au)

Tutorial 5 – Homework: Final Assignment

Divide in teams of 4-5. You must revise the first 5 tutorials. After that you must think you are a project management team leading a private research company of scientists and doctors and you are supposed to devise an eye imaging device meant to diagnose a disease of their choice affecting any tissue or layer in the eye (retina, lens, optical nerves, photoreceptors etc.). You are required to motivate your choice, do some internet/library research, do some comparisons with other existing techniques, draw a clear sketch of their setup, naming and describing each component, and to explain how their technique is applied and why would be a very helpful tool for doctors to accurately diagnose and possibly save a patient's vision.

Have in mind the following structure for your project:

1) Find a catchy title for your project! Make sure you have on the cover page the title of the project and all the listed authors. On the second page, you might consider putting a quote of a famous person which is clearly related to the subject chosen.
2) A clearly structured table of contents, showing all the chapters/ subchapters in the document, with page numbers).
3) A brief introduction, presenting the achievements in the field done so far.
4) A brief description of your proposal, including a clear motivation (what disease are you targeting? How many people are affected yearly by this disease? What improvements would you like to achieve in the field?)
5) Show a sketch of your machine (you should include an interferometer, acquisition systems, software used etc.; also refer to the geometrical model of the eye)
6) Do a rough estimation of costs (Is the device expensive, but due to the advanced technology used in it, it will have little competition on the market? Or is it an affordable device that would be easy to upgrade whenever necessary in the future?)
7) Conclusions (a list of main achievements expected, possibly future/ parallel work to come as an addition to this project?)
8) At the end, make sure you have listed clearly the bibliography used to conceive this project; all bibliography must be clearly referenced in text.

Tutorial 6 – Feedback

What is the Purpose of Tutorial 6?

- Reflect on skills learned on the programme with a view to encouraging resilience
- Receive feedback on final assignment

What are the key questions?

- What strengths have I demonstrated in my work and what areas of development are there left for me to address?
- What steps do I need to take to improve my academic output?

Activity 2 – Marking your own

Using the mark scheme, identify three things you did well and three things you could improve.

What went well?

1.

2.

3.

What could be improved?

1.

2.

3.

Activity 3 – Responding to feedback

Read through your feedback sheet and highlight on your assignment where you received positive feedback (one colour) and areas for improvement (different colour). You might find it helpful to annotate this with a brief comment or two.

(Acknowledgement: The structure and the activities in this feedback tutorial were first designed by Hannah Manktelow in January 2015. We have repeated them here as they demonstrate thoughtful and excellent planning, and can be used by all tutors to ensure a successful and productive feedback tutorial.)

University Applications Guidance

For course choices and careers information: www.brightknowledge.org.uk

For information and statistics on universities and course: www.unistats.direct.gov.uk

For comprehensive information on universities, including rankings: www.thecompleteuniversityguide.co.uk

PLEASE NOTE – The Scholars Programme is designed to support the university applications process at your school. The work you complete for the programme should add to your schoolwork rather than detract from it. Please be aware of deadlines and try to manage your workload appropriately. If you are worried about the Scholars Programme interfering with your schoolwork then please speak to your teacher.

Subject Specific Top Tips for strengthening your application

What could you read around the subject?

http://www.bbc.co.uk/schools/gcsebitesize/science/ocr_gateway_pre_2011/ourselves/3_keeping_in_touch2.shtml
http://www.glaucoma.org/glaucoma/glaucoma-facts-and-stats.php
http://www.allaboutvision.com/conditions/
http://www.ophthalmologyweb.com/Retina/5458-Optical-Coherence-Tomography-OCT/

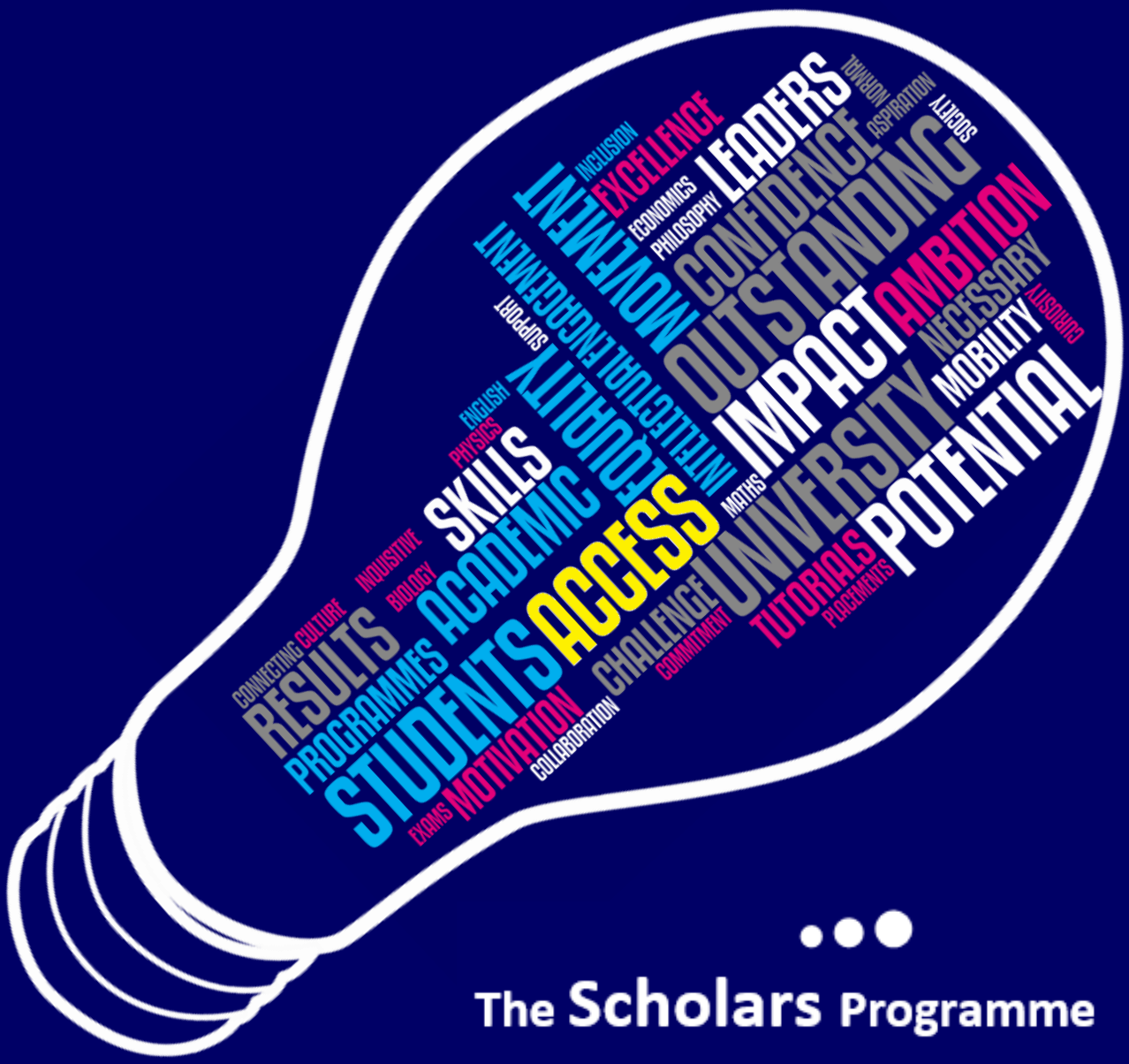
Suggestions of podcasts/videos that can be found online? Are there any age-appropriate, good films on this topic?

Optical Coherence Tomography Basic Explanation
https://www.youtube.com/watch?v=HJnNJIUPm4s

Kurt Thorn (UCSF): Confocal Microscopy
https://www.youtube.com/watch?v=YRQsjPAx9UU

What cheap or free events and talks would it be good to attend?

University of Kent Open Days, visit the Photonics Centre.
Visit the Science Museum in London.
http://www.light2015.org/Home.html



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