Optical Instruments

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This colorful burst of “spaghetti” is really a bundle of optical fibers. These are hair-thin threads of glass that transmit laser light that has been encoded with messages. Optical fibers are a crucial component of modern communications. The use of light in devices such as these is possible because of optics.

Optics and Optical Instruments

Optics is the study of visible light and the ways it can be used to extend human vision and do other tasks. Knowledge of light was needed for the invention of optical instruments such as microscopes, telescopes, and cameras, in addition to optical fibers. These instruments use mirrors and lenses to reflect and refract light and form images.

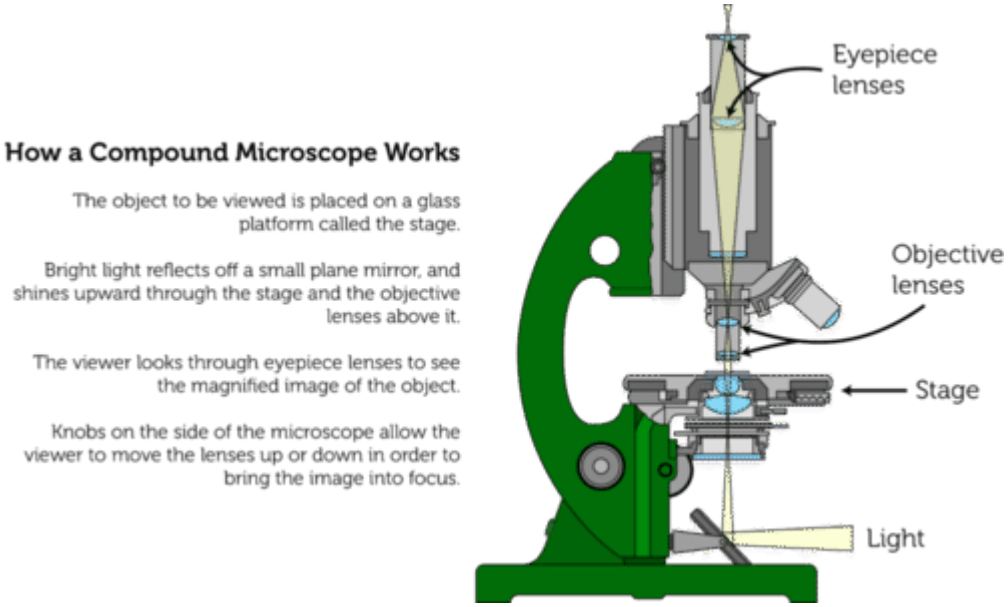
Q: What is an image?

A: An image is a copy of an object created by the reflection or refraction of visible light.

Light Microscope

A light microscope is an instrument that uses lenses to make enlarged images of objects that are too small for the unaided eye to see. A common type of light microscope is a compound microscope, like the one shown in the **Figure** below. A compound microscope

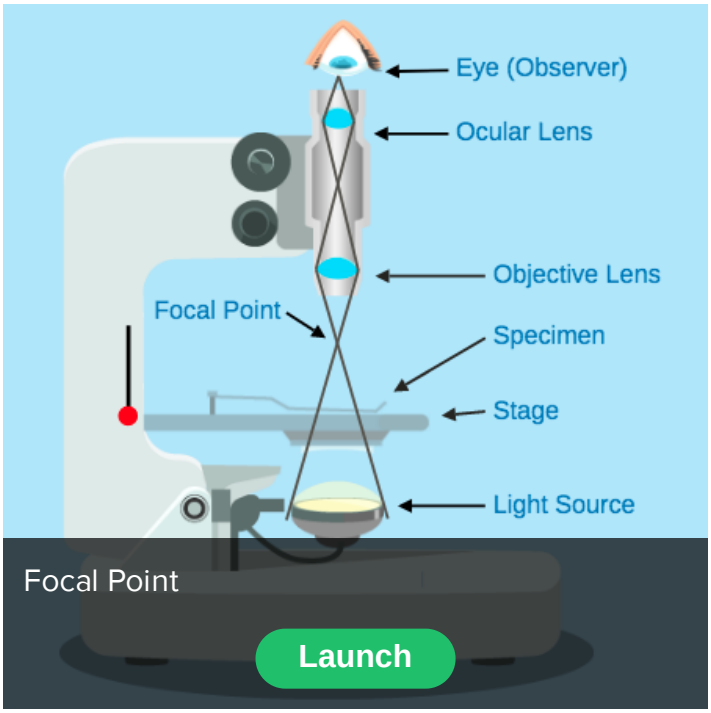
has at least two convex lenses: one or more objective lenses and one or more eyepiece lenses. The objective lenses are close to the object being viewed. They form an enlarged image of the object inside the microscope. The eyepiece lenses are close to the viewer's eyes. They form an enlarged image of the first image. The magnifications of all the lenses are multiplied together to yield the overall magnification of the microscope. Some light microscopes can magnify objects more than 1000 times!



Q: How has the microscope advanced scientific knowledge?

A: The microscope has revealed secrets of the natural world like no other single invention. The microscope let scientists see entire new worlds, leading to many discoveries—especially in biology and medicine—that could not have been made without it. Some examples include the discovery of cells and the identification of bacteria and other single-celled organisms. With the development of more powerful microscopes, viruses were discovered and even atoms finally became visible. These discoveries changed our ideas about the human body and the nature of life itself.

Launch the PLIX Interactive below to further explore the parts of a microscope:



https://flexbooks.ck12.org/assessment/tools/geometry-tool/fullscreen.html?qID=5457ee118e0e0867607a339d

Telescope

Like microscopes, telescopes use convex lenses to make enlarged images. However, telescopes make enlarged images of objects—such as distant stars—that only appear tiny because they are very far away. There are two basic types of telescopes: reflecting telescopes and refracting telescopes. The two types are compared in the **Figure** below. They differ in how they collect light, but both use convex lenses to form enlarged images.

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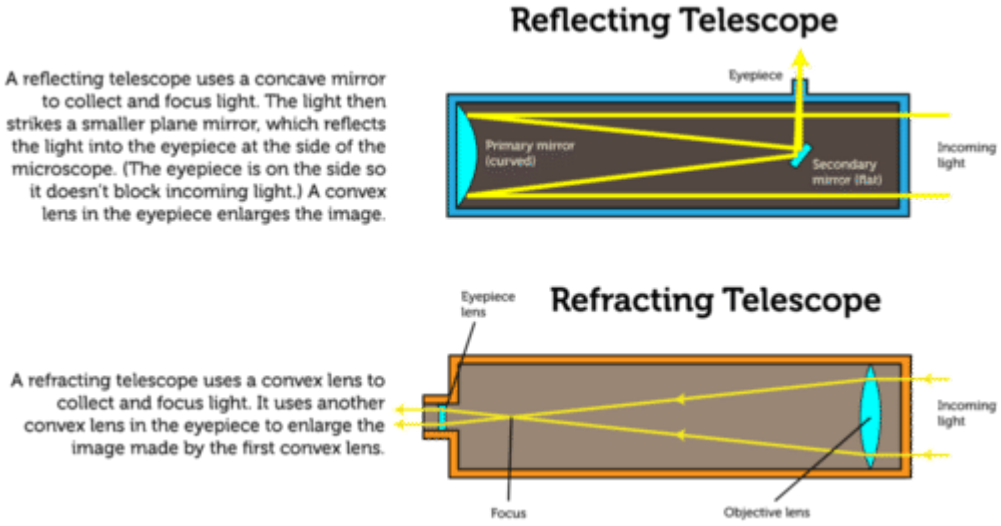


Play around with a Cassegrain Telescope in the simulation below and see if you can adjust the sliders to create a clear view of Jupiter in the eyepiece:

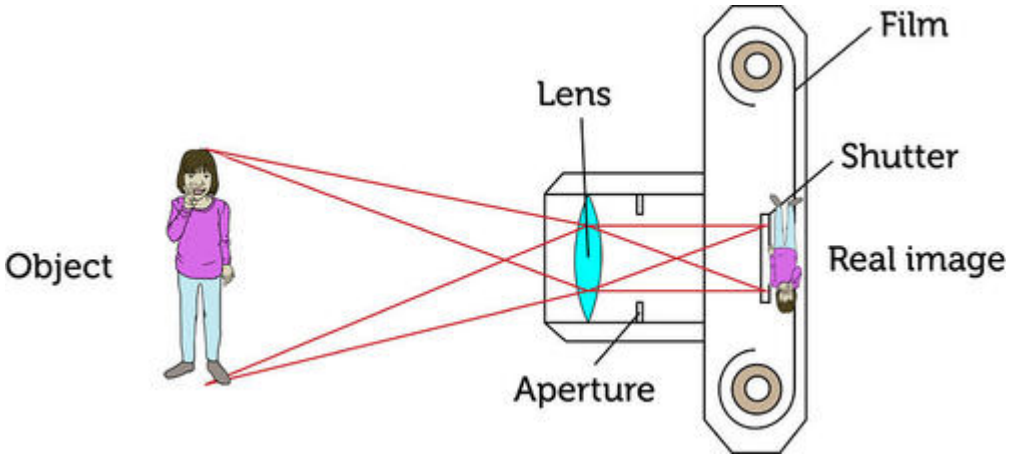
https://flexbooks.ck12.org/flx/show/interactive/user:c2hhdw5zagluetfik3rlc3r6nkbnbwfpbc5jb20./https://interactives.ck12.org/simulations/embed.html?embeded=true&interactive=cassegrain-telescope&subject=physics&lang=en&assignment=true&hash=7f98a4673d46667abadf1f1fdab29369

Camera

A camera is an optical instrument that forms and records an image of an object. The image may be recorded on film or it may be detected by an electronic sensor that stores the image digitally. Regardless of how the image is recorded, all cameras form images in the same basic way, as shown in the **Figure** below.

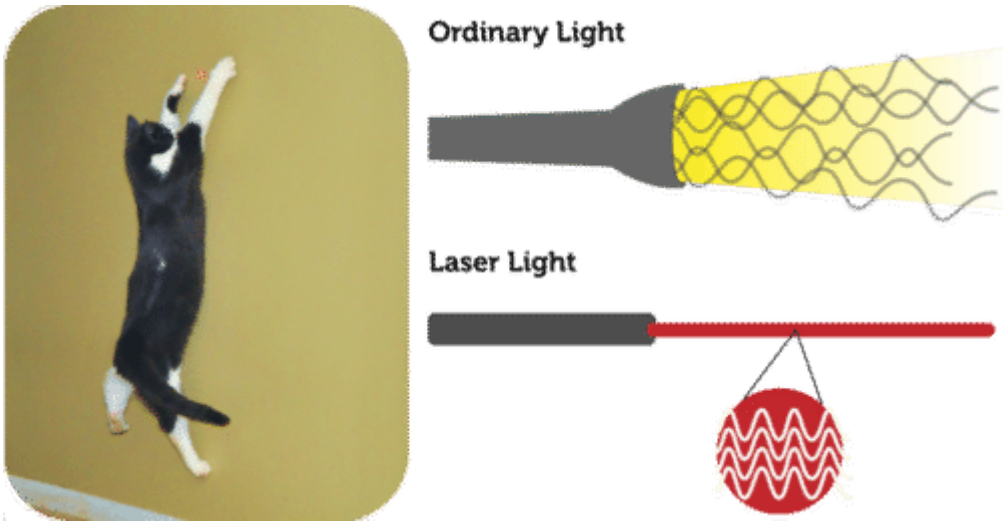
- Light passes through the lens at the front of the camera and enters the camera through an opening called the aperture.

- As light passes through the lens, it forms a reduced real image. The image focuses on film (or a sensor) at the back of the camera. The lens may be moved back and forth to bring the image into focus.
- The shutter controls the amount of light that actually strikes the film (or sensor). It stays open longer in dim light to let more light in.



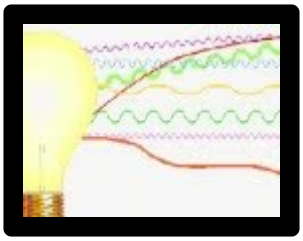
Lasers

Did you ever see a cat chase after a laser light, like the one in **Figure** below? A **laser** is a device that produces a very focused beam of visible light of just one wavelength and color. Waves of laser light are synchronized so the crests and troughs of the waves line up. The diagram in **Figure** below shows why a beam of laser light is so focused compared with ordinary light from a flashlight.



The following **Figure** below provides a closer look at the tube where laser light is created. Electrons in a material such as a ruby crystal are stimulated to radiate photons of light of one wavelength. At each end of the tube is a concave mirror. The photons of light reflect back

and forth in the tube off these mirrors. This focuses the light. The mirror at one end of the tube is partly transparent. A constant stream of photons passes through the transparent part, forming the laser beam.



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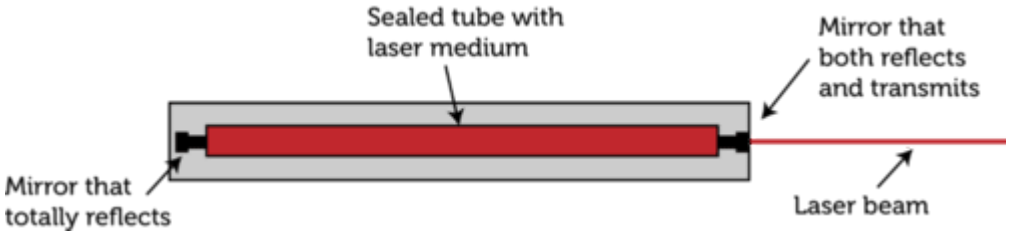
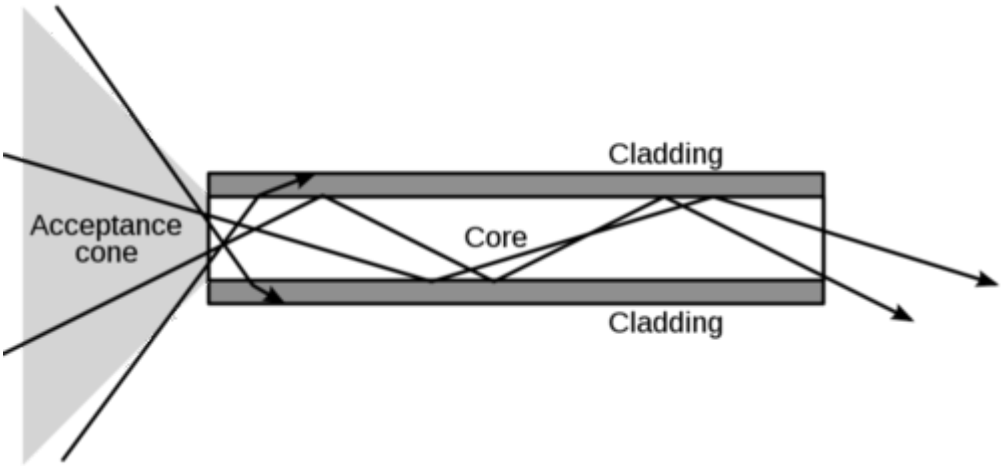


Optical Fibers

Besides entertaining a cat, laser light has many other uses. One use is carrying communication signals in optical fibers. Sounds or pictures are encoded in pulses of laser light, which are then sent through an optical fiber. All of the light reflects off the inside of the fiber, so none of it escapes. As a result, the signal remains strong even over long distances. More than one signal can travel through an optical fiber at the same time, as you can see in the **Figure** below. Optical fibers are used to carry telephone, cable TV, and Internet signals.



The optical fiber in the diagram is much larger than a real optical fiber, which is only about as wide as a human hair.

Q: When lasers were invented in 1960, they were called "a solution looking for a problem." Since then, they have been put to thousands of different uses. Can you name other ways

that lasers are used?

A: The first widespread use of lasers was the supermarket barcode scanner, introduced in 1974. The compact disc (CD) player was the first laser-equipped device commonly used by consumers, starting in 1982. The CD player was quickly followed by the laser printer. Some other uses of lasers include bloodless surgery, cutting and welding of metals, guiding missiles, thermometers, laser light shows, and acne treatments.

Summary

- Optics is the study of visible light and the ways it can be used to extend human vision and do other tasks. Optical instruments are based on optics. They use mirrors and lenses to reflect and refract light and form images.
- The light microscope and telescope use convex lenses and mirrors to make enlarged images of very tiny or distant objects. A camera uses a convex lens to make a reduced image of an object.
- A laser is a device that produces a very focused beam of visible light of just one wavelength and color. Pulses of laser light carry communication signals through optical fibers.

Review

1. Define optics.
2. Explain how a compound microscope uses convex lenses to make an enlarged image of a tiny object.
3. Compare and contrast reflecting and refracting telescopes.
4. Write a paragraph explaining how a camera works. Assume you are explaining it to a much younger student. Draw a sketch as a visual aid.
5. Explain how reflection is involved in the production of laser light.
6. How are optical fibers used?