How a Laser Works

(0:08 - 0:26)

For years, lasers have been a hallmark of science fiction, yet much of our technology today depends on them. Range finding devices, optical communications, and of course, barcode scanners. The unique characteristics of laser light make all these things possible.

(0:26 - 0:39)

However, its use by eye surgeons to reattach retinas highlights them all. Injury can cause the eye's retina to peel away from the tissue supporting it. Without rapid treatment, the entire retina can become detached, causing blindness.

(0:40 - 1:05)

Surgeons use green laser light of nearly a single wavelength because that colour passes through the eye's lens and vitreous humour without being strongly absorbed, and thus without causing damage. The laser beam then strikes the retina where the tissue strongly absorbs that light, using the high-intensity light to weld the detached retina back into place. The beam's narrowness allows the surgeon to affect only the area of the retina that needs to be repaired, areas as small as 30 microns.

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How a laser creates light with these three characteristics is a intuitive force of engineering. Let me show you. Any glow-in-the-dark toy can illustrate the basic principles of creating laser light.

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This glows because the zinc-copper-based compound coated in the inside can absorb energy from a light source and then later radiate it as light. The light provides energy to electrons in the coating, promoting them to higher energy levels. Once the light is off, these electrons slowly lose their added energy and return to their lower energy ground states.

(1:36 - 1:46)

The energy lost is given off as light. A closely related phenomenon lies at the heart of a laser. Let me tell you about the engineering in the very first laser based on ruby.

(1:46 - 2:03)

Here I have a tiny piece of ruby and some red-coloured glass beads. When I shine the blue light on the glass beads, nothing much happens, but shine it on the ruby and it glows red. Unlike the glow-in-the-dark ball, the light appears immediately and when I shut off the blue light, it disappears.

(2:03 - 2:18)

In 1960, Ted Maiman demonstrated the first laser by taking a cylinder of ruby and surrounding it with a xenon arc flash lamp used in aerial photography. An intense burst of light from the lamp initiates lasing. To see how it works, let's look at what happens with a weaker lamp.

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A flash would promote a few electrons from the ground state to an excited state. They'd lose a bit of energy, fall to a lower energy state without emitting light, and then drop from there to the ground state giving off a burst of light. The light produced would be incoherent light, a spectrum of colours and intensities, just as my small laser made the ruby sphere glow.

(2:38 - 2:50)

To create a laser takes an extremely powerful lamp. In the ruby laser, repeated flashes, called pumping, make something amazing happen. They supply so much energy that a population inversion occurs.

(2:50 - 3:10)

Here, more electrons in the energy level just above the ground state than in the ground state. Electrons from a population inversion returning to the ground state release light that starts an avalanche called stimulated emission. The photon produced when an electron decays induces other excited electrons to simultaneously decay and release nearly identical photons.

(3:10 - 3:27)

That creates coherent light, meaning that the crests and troughs of every light wave in the beam match up. Now at this point we have coherent light, but not yet the other two properties of laser light. To get a narrow beam with all the light rays parallel and of a nearly single wavelength requires an addition to the ruby rod.

(3:28 - 3:41)

Maiman silvered the ends to reflect the light within the ruby cylinder. He made the two ends of the rod astonishingly parallel to each other. From top to bottom, the distance between these two mirrors differs by no more than 200 nanometres.

(3:42 - 3:55)

Inside this resonant cavity, two things happen. First, any light rays that don't line up with the axis eventually just exit out the side of the cylinder. And the light parallel to the axis becomes intensified and narrowed in wavelength.

(3:55 - 4:13)

The mirrored ends create a standing wave, which means only light of particular wavelengths can exist inside the cavity. By choosing the rod length correctly, we can get the nearly single wavelength of light characteristic of a laser. A small hole in one of the mirrors, or a partially silvered mirror, allows the light to escape, creating the familiar beam.

(4:14 - 4:29)

Since the first ruby laser was created, lasers have become easy and cheap to manufacture. For instance, this laser pointer uses a semiconductor diode to produce light. Although many innovations and improvements have occurred since 1960, the essential principles are the same.

(4:29 - 4:39)

I'm Bill Hammack, the EngineerGuy. This video is based on a chapter in the book Eight Amazing Engineering Stories. The chapter features more information about this subject.

(4:39 - 4:41)

Learn more about the book at the address below.