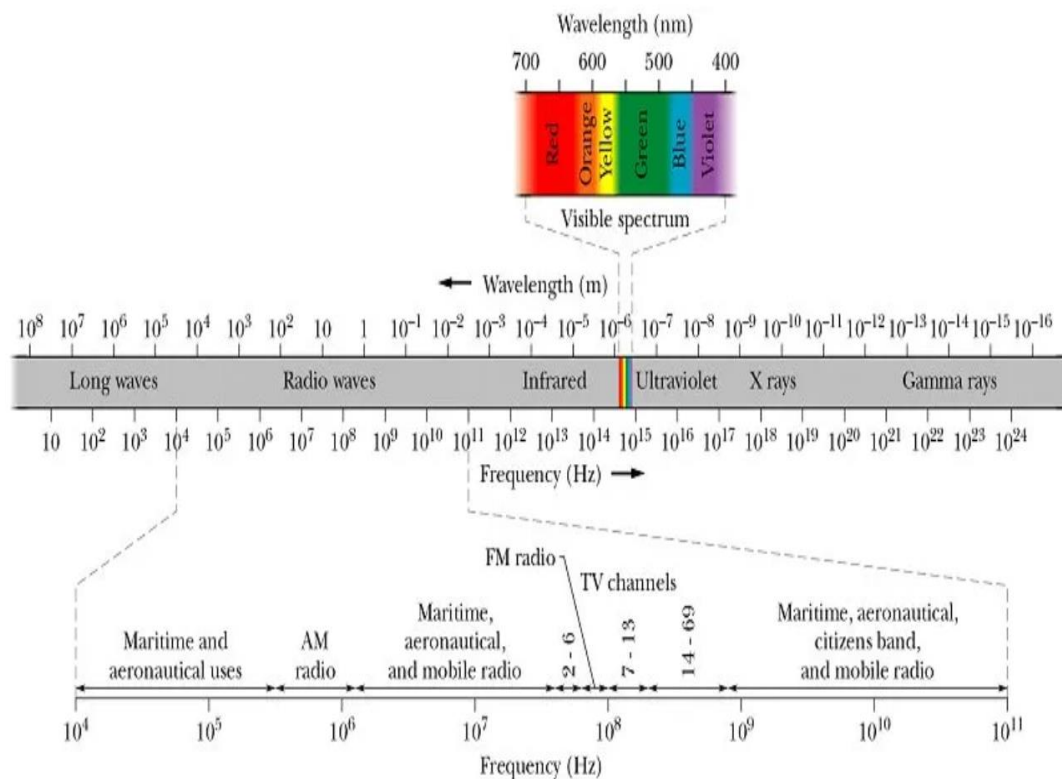
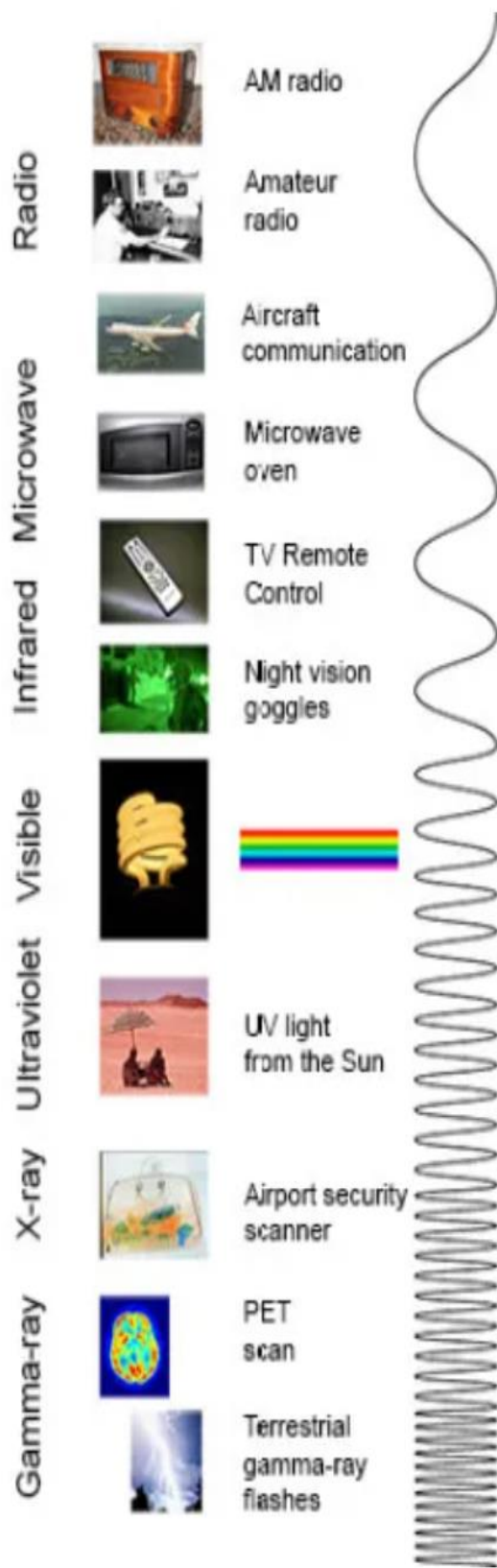


Optical Fiber: Three Windows



All electromagnetic signals propagate at different frequencies. The electromagnetic (EM) spectrum is the range of all types of EM radiation. Radiation is energy that travels and spreads out as it goes – the visible light that comes from a lamp in your house and the radio waves that come from a radio station are two types of electromagnetic radiation. The other types of EM radiation that make up the electromagnetic spectrum are microwaves, infrared light, ultraviolet light, X-rays and gamma-rays.

You know more about the electromagnetic spectrum than you may think.



The image to the left shows where you might encounter each portion of the EM spectrum in your day-to-day life.

Radio: Your radio captures radio waves emitted by radio stations, bringing your favorite tunes. Radio waves are also emitted by stars and gases in space.

Microwave: Microwave radiation will cook your popcorn in just a few minutes, but is also used by astronomers to learn about the structure of nearby galaxies.

Infrared: Night vision goggles pick up the infrared light emitted by our skin and objects with heat. In space, infrared light helps us map the dust between stars.

Visible: Our eyes detect visible light. Fireflies, light bulbs, and stars all emit visible light.

Ultraviolet: Ultraviolet radiation is emitted by the Sun and are the reason skin tans and burns. “Hot” objects in space emit UV radiation as well.

X-ray: A dentist uses X-rays to image your teeth, and airport security uses them to see through your bag. Hot gases in the Universe also emit X-rays.

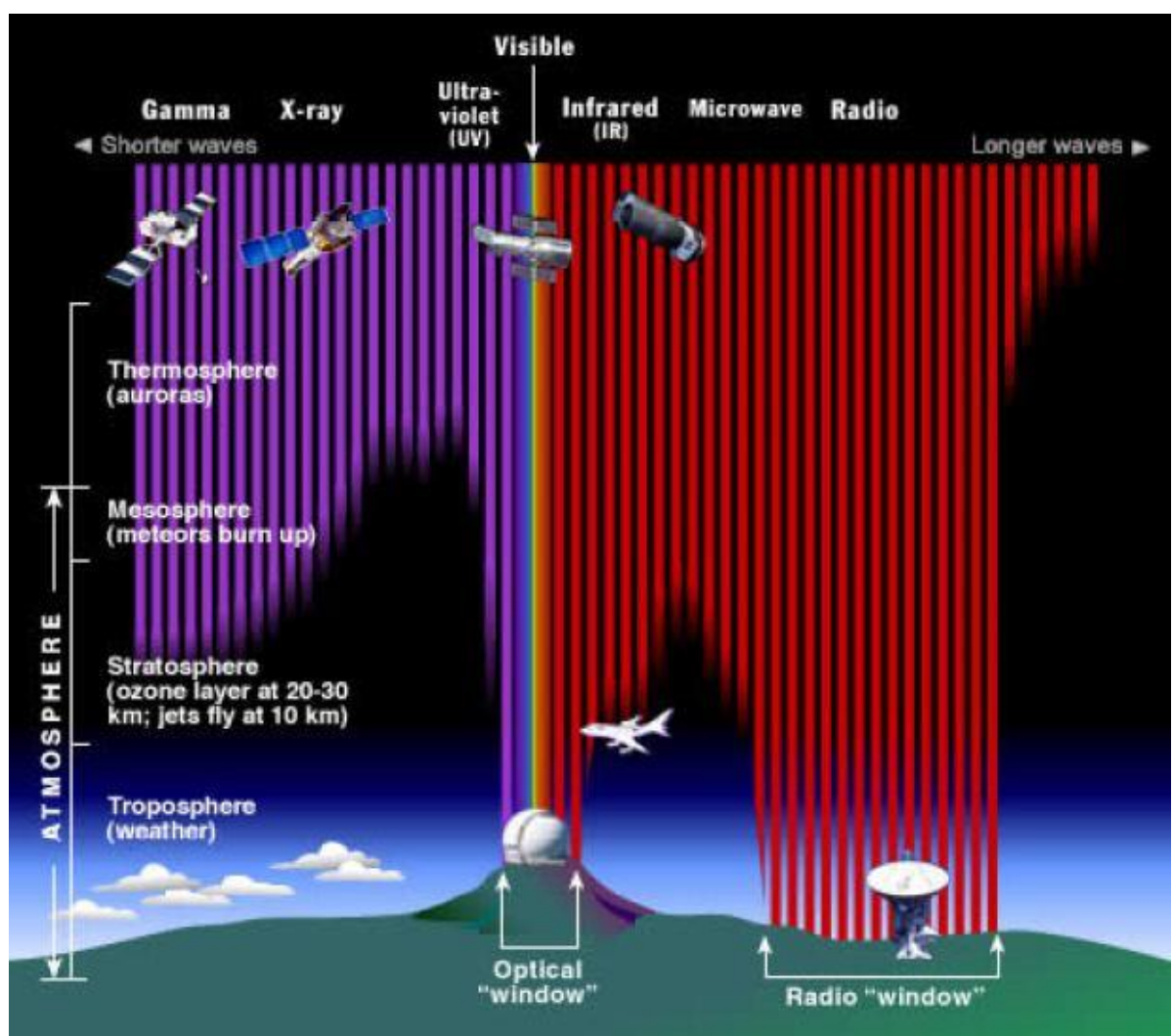
Gamma ray: Doctors use gamma-ray imaging to see inside your body. The biggest gamma-ray generator of all is the Universe.

Most people commonly know how we refer to frequency. For example, in Wi-Fi you hear about 2.4 GHz and 5.0 GHz. In other applications, we hear about 900 MHz. These are simple ways to describe the frequency of the signals. **Science** loves simplicity, so we often use terms that are the simplest to describe the signal. Electromagnetic radiation can be expressed in terms of energy, wavelength, or frequency. Frequency is measured in cycles per second, or Hertz. Wavelength is measured in meters. Energy is measured in electron volts. Each of these three quantities for describing EM radiation are related to each other in a precise mathematical way. But why have three ways of describing things, each with a different set of physical units? They are all describing the same thing, **the signal**.

The short answer is that scientists don't like to use numbers any bigger or smaller than they have to. It is much easier to say or write

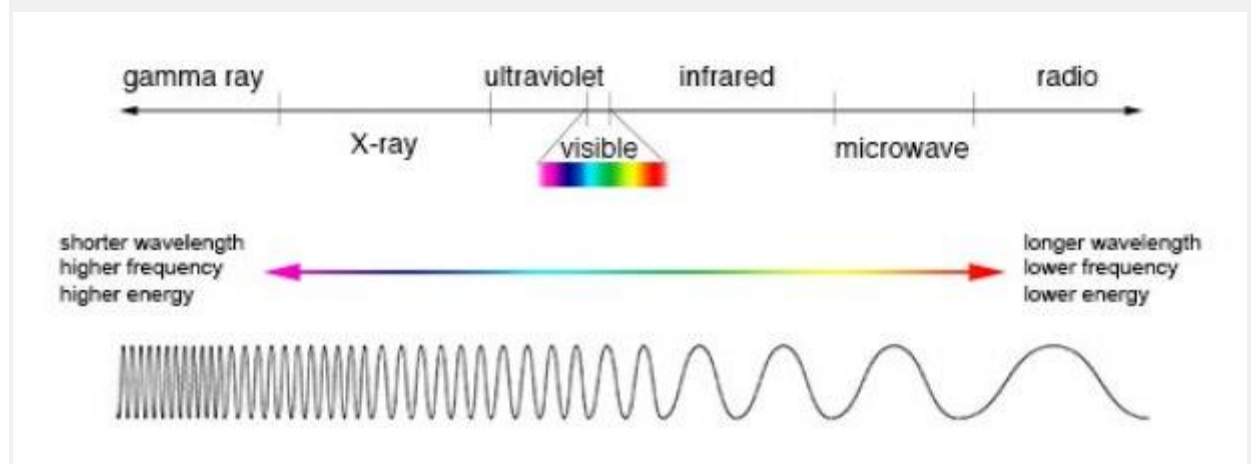
“two kilometers” than “two thousand meters.” Generally, scientists use whatever units are easiest for the type of EM radiation they work with.

Astronomers who study radio waves tend to use wavelengths or frequencies. Most of the radio part of the EM spectrum falls in the range from about 1 cm to 1 km, which is 30 gigahertz (GHz) to 300 kilohertz (kHz) in frequencies. The radio is a very broad part of the EM spectrum.



Infrared and optical astronomers generally use wavelength. Infrared astronomers use microns (millionths of a meter) for wavelengths, so their part of the EM spectrum falls in the range of 1 to 100 microns. Optical astronomers use both angstroms (0.00000001 cm, or 10^{-8} cm) and nanometers (0.0000001 cm, or 10^{-7} cm). Using nanometers, violet, blue, green, yellow, orange, and red light have wavelengths between 400 and 700 nanometers. (This range is just a tiny part of the entire EM spectrum, so the light our eyes can see is just a little fraction of all the EM radiation around us.)

The wavelengths of ultraviolet, X-ray, and gamma-ray regions of the EM spectrum are very small. Instead of using wavelengths, astronomers that study these portions of the EM spectrum usually refer to these photons by their energies, measured in electron volts (eV). Ultraviolet radiation falls in the range from a few electron volts to about 100 eV. X-ray photons have energies in the range 100 eV to 100,000 eV (or 100 keV). Gamma-rays then are all the photons with energies greater than 100 keV.



Now, with optical fiber links, we use nanometers to describe the wavelength. The wavelength is so short that others ways to describe it are clumsy and difficult to comprehend.

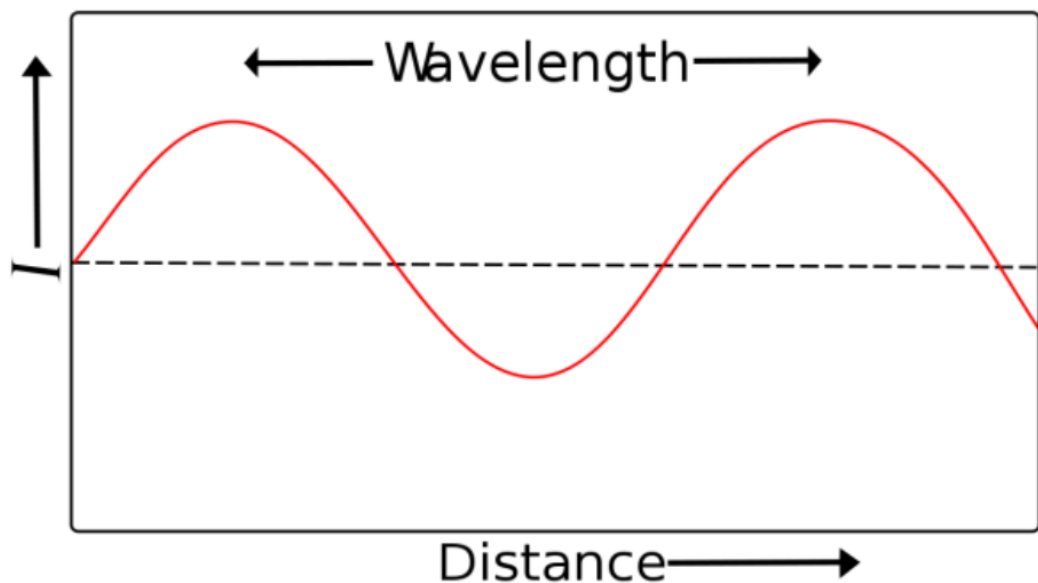
Since fiber optic signals must propagate through a medium, often glass, this media has an influence on the propagation characteristics. Not all frequencies propagate equally through all media. **In optical fiber, we have globally settled on three windows when the glass will permit the greatest throughput to flow.**

These windows are:

- 850nm – normally used for multimode links
- 1310nm – normally used for single mode links – coarse wave division multiplexing (CWDM)
- 1550nm – normally used for single mode links – dense wave division multiplexing (DWDM)

We use nanometers for these three windows since the energy is very low and the distance between the peaks of the oscillations is so tiny that it is hard to describe.

Wave



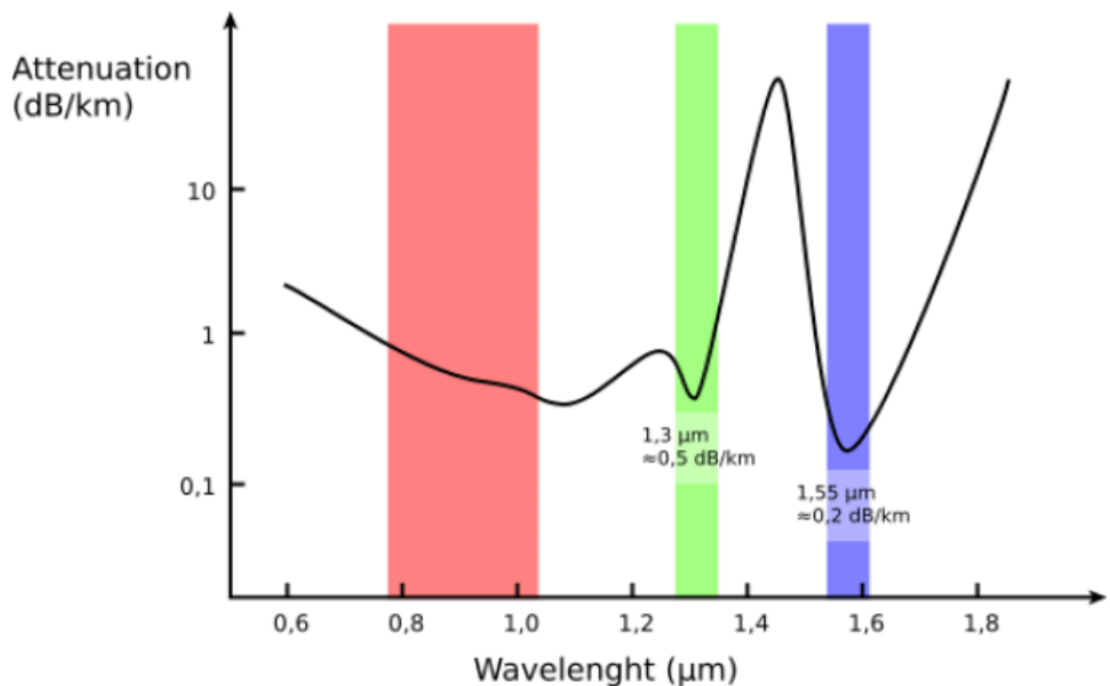
For example:

- 850nm equals 0.000033464567 inches
- 1310nm equals 0.000051574803 inches
- 1550nm equals 0.000061023622 inches

So, you can see why using the term nanometers is far easier to describe the signal.

In the early days of optical fiber communication, the LED was employed as a light source. The LED's mostly operated at the 780 nm or the 850 nm wavelength. This region is referred to as **the first transmission window**.

The LED's could not be employed for high bandwidth transmissions over a long distance due to their inherent disadvantages and were replaced by lasers. **Lasers operated in two wavelength regions namely 1310 nm and 1550 nm that are commonly referred to as the second and the third optical transmission windows.**



The wavy line in the graphic above shows the propagation characteristics of glass and as can be seen, it rises and falls at different wavelengths. The three coloured bars are the three most popular windows to permit signal to flow freely.

The effects of dispersion are zero at the 1310 nm window, whereas the losses are the least at 1550 nm window. The modern optical fiber networks operate around 1310 nm and 1550 nm, also 1490 nm is gaining steam because of GPON systems.

1550 nm wavelength band is also particularly important to the WDM networks that are increasingly being deployed in networks worldwide. These networks use amplifiers to counter the effects of attenuation. The commonly deployed amplifiers are the Erbium-doped Fiber Amplifiers (EDFA) that provides signal amplification across a range of wavelengths around 1550 nm and 1625 nm. This window is commonly referred to as the **EDFA window**.

