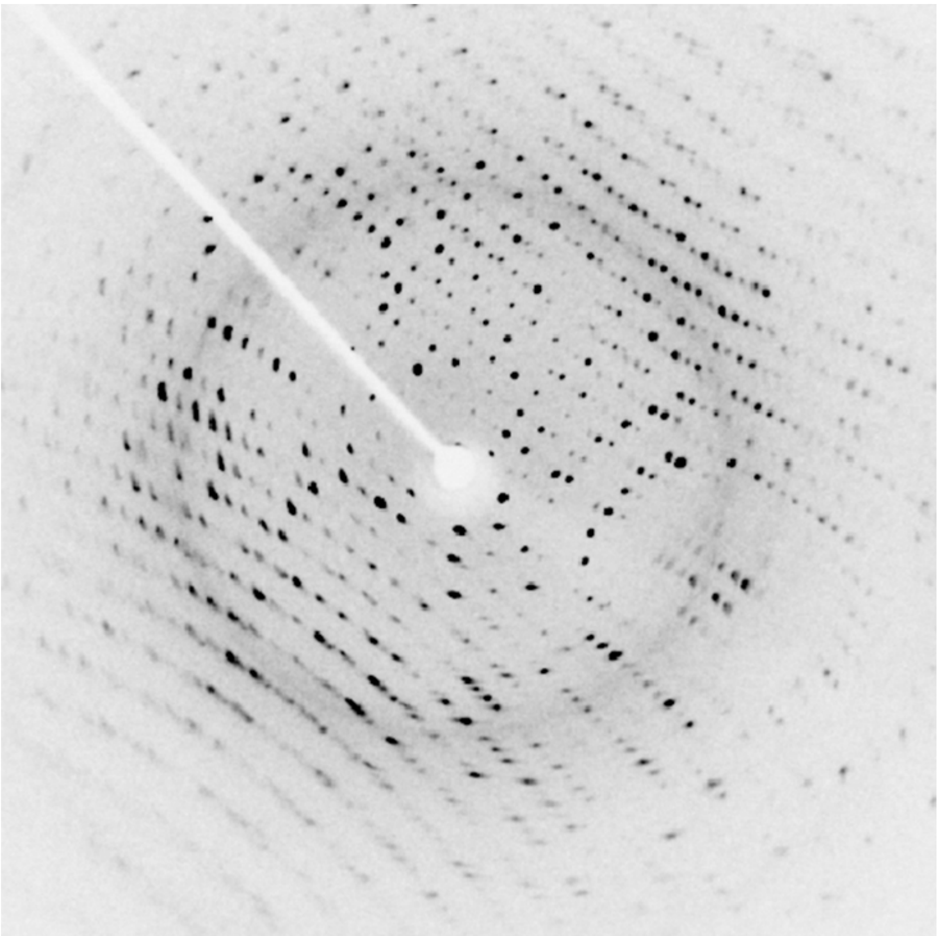

Figure 8.27 X-ray diffraction from the crystal of a protein (hen egg lysozyme) produced this interference pattern. Analysis of the pattern yields information about the structure of the protein. (credit: "Del45"/Wikimedia Commons)

8.6 | Lasers

Learning Objectives

By the end of this section, you will be able to:

- Describe the physical processes necessary to produce laser light
- Explain the difference between coherent and incoherent light
- Describe the application of lasers to a CD and Blu-Ray player

A **laser** is device that emits coherent and monochromatic light. The light is coherent if photons that compose the light are in-phase, and **monochromatic** if the photons have a single frequency (color). When a gas in the laser absorbs radiation, electrons are elevated to different energy levels. Most electrons return immediately to the ground state, but others linger in what is called a **metastable state**. It is possible to place a majority of these atoms in a metastable state, a condition called a **population inversion**.

When a photon of energy disturbs an electron in a metastable state (Figure 8.28), the electron drops to the lower-energy level and emits an addition photon, and the two photons proceed off together. This process is called **stimulated emission**. It occurs with relatively high probability when the energy of the incoming photon is equal to the energy difference between the excited and "de-excited" energy levels of the electron ($\Delta E = hf$). Hence, the incoming photon and the photon produced by de-excitation have the same energy, *hf*. These photons encounter more electrons in the metastable state, and the process repeats. The result is a cascade or chain reaction of similar de-excitations. Laser light is coherent because all light waves in laser light share the same frequency (color) and the same phase (any two points of along a line perpendicular to the direction of motion are on the “same part” of the wave”). A schematic diagram of coherent and incoherent light wave pattern is given in **Figure 8.29**.

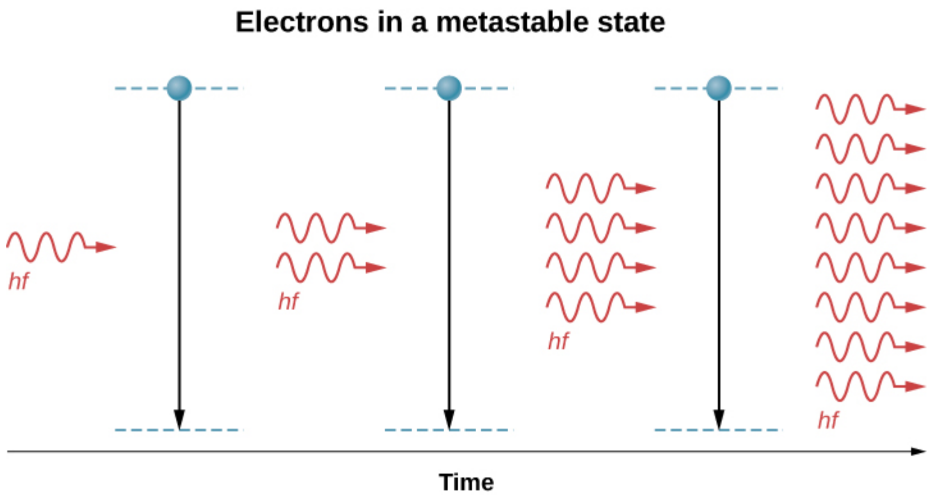

Figure 8.28 The physics of a laser. An incident photon of frequency *f* causes a cascade of photons of the same frequency.

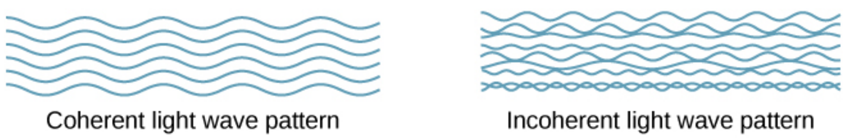

Figure 8.29 A coherent light wave pattern contains light waves of the same frequency and phase. An incoherent light wave pattern contains light waves of different frequencies and phases.

Lasers are used in a wide range of applications, such as in communication (optical fiber phone lines), entertainment (laser light shows), medicine (removing tumors and cauterizing vessels in the retina), and in retail sales (bar code readers). Lasers can also be produced by a large range of materials, including solids (for example, the ruby crystal), gases (helium-gas mixture), and liquids (organic dyes). Recently, a laser was even created using gelatin—an edible laser! Below we discuss two practical applications in detail: CD players and Blu-Ray Players.

CD Player

A CD player reads digital information stored on a compact disc (CD). A CD is 6-inch diameter disc made of plastic that contains small “bumps” and “pits” nears its surface to encode digital or binary data (**Figure 8.30**). The bumps and pits appear along a very thin track that spirals outwards from the center of the disc. The width of the track is smaller than 1/20th the width of a human hair, and the heights of the bumps are even smaller yet.

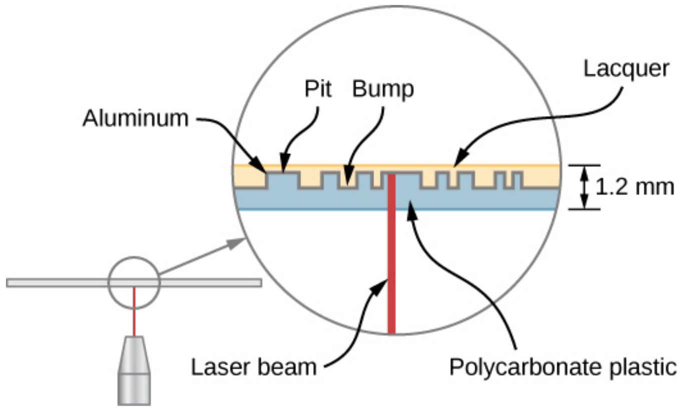

Figure 8.30 A compact disc is a plastic disc that uses bumps near its surface to encode digital information. The surface of the disc contains multiple layers, including a layer of aluminum and one of polycarbonate plastic.

A CD player uses a laser to read this digital information. Laser light is suited to this purpose, because coherent light can be focused onto an incredibly small spot and therefore distinguish between bumps and pits in the CD. After processing by player components (including a diffraction grating, polarizer, and collimator), laser light is focused by a lens onto the CD surface. Light that strikes a bump ("land") is merely reflected, but light that strikes a "pit" destructively interferes, so no light returns (the details of this process are not important to this discussion). Reflected light is interpreted as a "1" and unreflected light is interpreted as a "0." The resulting digital signal is converted into an analog signal, and the analog signal is fed into an amplifier that powers a device such as a pair of headphones. The laser system of a CD player is shown in **Figure 8.31**.

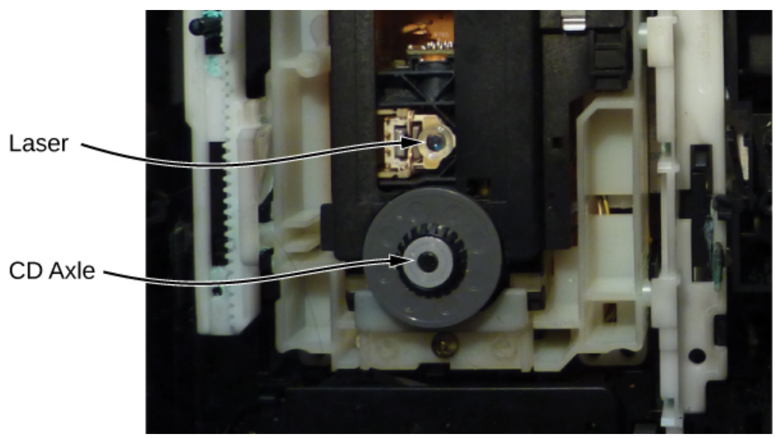

Figure 8.31 A CD player and its laser component.

Blu-Ray Player

Like a CD player, a Blu-Ray player reads digital information (video or audio) stored on a disc, and a laser is used to record this information. The pits on a Blu-Ray disc are much smaller and more closely packed together than for a CD, so much more information can be stored. As a result, the resolving power of the laser must be greater. This is achieved using short wavelength $(\lambda = 405 \text{ nm})$ blue laser light—hence, the name "Blu-" Ray. (CDs and DVDs use red laser light.) The different pit sizes and player-hardware configurations of a CD, DVD, and Blu-Ray player are shown in **Figure 8.32**. The pit sizes of a Blu-Ray disk are more than twice as small as the pits on a DVD or CD. Unlike a CD, a Blu-Ray disc store data on a polycarbonate layer, which places the data closer to the lens and avoids readability problems. A hard coating is used to protect the data since it is so close to the surface.

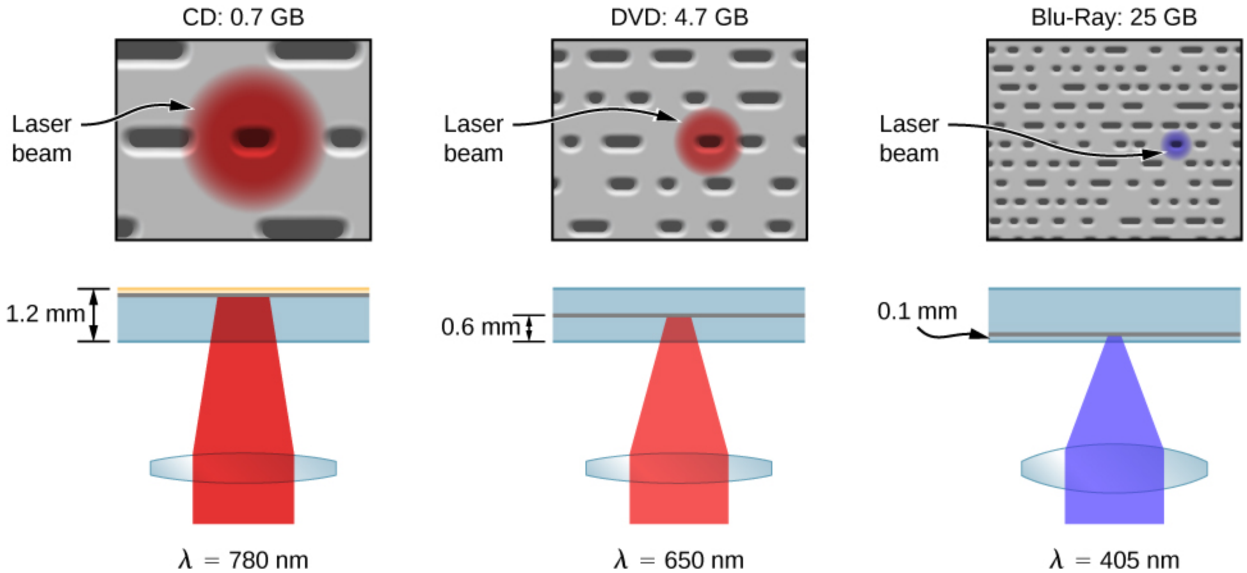

Figure 8.32 Comparison of laser resolution in a CD, DVD, and Blu-Ray Player.