10.3: Examples of Laser Systems

There are many types of laser commonly used in science today. The range of applications of lasers in science and technology is extremely broad, ranging from household applications (such as television remote controls) to manufacturing applications (such as laser cutting and welding, or laser lithography used in the manufacture of microelectronics), to medicine (including specific procedures such as laser eye surgery) to basic fundamental science. The specific needs of a particular job determine which laser is best for the job.

N_2 laser

A nitrogen laser is a **continuous wave** laser that provides ultraviolet output at 337 nm, but can be tuned to several wavelengths near its strongest output line. The laser gain transition is the 0-0 band in the B-X transition of N_2. The upper state is populated by subjecting the gas to an electrical discharge. Applications of theN_2 laser is pumping of dye lasers (described in section B.4.d), diagnostics of air samples and laser desorption techniques.

Excimer Lasers

An excimer laser is one in which the upper state of the transition is a **metastable state** of a molecule, and the lower state is dissociative. Because the lower state is not bound, molecules that land in that state after emitting a photon immediately dissociate, allowing for no buildup of population in the lower level of the laser transition. As such, any population in the upper state implies a population inversion.

The upper (metastable) state is populated by a pulsed electrical discharge through a gas containing the precursors of the excimer molecules. Since these precursors (usually involving HCl or HF gas) are particularly caustic (to say nothing of how reactive the soup of radicals and ions produced by the electrical discharge are!) these laser require a very high level of maintenance. However, because of the simplicity of the energy level scheme, these lasers are very easy to tune to provide strong laser output. These lasers are used in a number of applications including the pumping of dye lasers and laser eye surgery. The pulses that emanate from these laser have a time on the order of a few nanoseconds.

The output wavelength of an excimer laser is determined by the particular excimer formed in the discharge. The most commonly used excimer lasers are XeCl (308 nm) and ArF (193 nm.) The following table shows several common excimers and their output wavelengths.

Table: Common Excimers with Output Wavelengths

Excimer	Wavelength (nm)
ArF	193
KrCl	222
KrF	248
XeCl	308
XeF	351

Rare Gas Ion Lasers

Another important class of lasers is the **rare gas ion laser**. In this laser, the gain medium is provided by an ion of a noble as (such as Ar^+). The gas is ionized by means of an electrical discharge. These lasers typically have several wavelengths which can be selected for the output. These lasers are used widely as pump lasers for dye lasers and also in Laserium light shows.

Tunable Dye Lasers

Tunable dye lasers are a very flexible type of laser as they provide selectable output wavelengths. Many of them can be scanned through a set of wavelengths which can be very useful in a number of applications (such as laser spectroscopy.) The gain medium in a dye laser is provided by a strong fluorescent dye dissolved in a liquid solvent (such as methanol.) The range of output wavelengths is determined by the specific dye. Commercially available dyes are available that span the entire visible spectrum. Ring dye lasers are capable of very high resolution (narrow wavelength or frequency range.)

Pulse Amplification

Pulse amplification is a technique used to increase the output power of a laser. In this technique, a seed beam is passed through a dye cell and is crossed by a pulsed pump beam which excites the dye, providing another stage of gain for the seed beam. Most dye lasers have at least one stage of pulse amplification in them to achieve suitable power for the specific application.

Frequency Doubling

Another useful technique that extends the wavelength output range of laser is **frequency doubling**. In this technique, laser output is focused on a special crystal (such a beta-Barium Borate or BBO) which has nonlinear optical properties that allow it to fuse two photons of frequency ω into one photon with frequency 2ω. Frequency doubling is not a terrifically efficient process and usually comes at a significant price to output intensity. However, the benefit of frequency doubling a tunable dye laser output is that one can extend the tunable range of laser output into the ultraviolet.

Ultrafast Lasers

A fairly recent development in technology is the development of **ultrafast lasers**. This class of device delivers laser output in very short (on the order of femtoseconds) pulses of laser output. On this time scale, it is possible to take snapshots of chemical reaction intermediates since the laser pulse time is comparable to the lifetime of a chemical intermediate. These lasers, however, have very brad spectral output due to the **Heisenberg uncertainty principle** precluding simultaneously small uncertainties in time and wavelength.
