1.2.3 Alexandrite Laser (Cr$^{3+}$:BeAl$_2$O$_4$)

Alexandrite laser is a solid state laser in which Chromium ions (Cr$^{3+}$), at the amount of 0.01-0.4 %, are embedded in BeAl$_2$O$_4$ crystal. It has energy level structure similar to the energy level structure of Ruby laser. Alexandrite laser was operated for the first time as a three level laser in 1973 at a wavelength of 680 nm.

A few years later, it was found that at longer wavelengths the Alexandrite laser can be operated as a four level laser, which can be tune over a range of wavelengths: 720-800 nm. It was the first tunable solid state laser to reach the market. A model of energy level diagram which explain the tunability can be seen in figure 1.16.

![Energy Level Diagram of Alexandrite Laser](Image)

**Figure 1.16: Energy Level Diagram of Alexandrite Laser.**

**Vibronic Lasers**

Ions of Chromium replace atoms in the crystal BeAl$_2$O$_4$ such that an asymmetric distribution of the atoms in the crystal occurs. This asymmetry causes vibrations in the crystal, which can be seen in the energy diagram as vibrational energy levels. Thus Alexandrite lasers (and a similar family of Titanium Sapphire lasers) are called Vibronic Lasers.
Since the laser transitions are into these closed packed energy levels, the laser wavelengths are tunable over almost a continuum of wavelengths. The Alexandrite laser operates at a single wavelength that can be tuned.

Choosing the specific laser wavelength is done by another element within the optical cavity. This element needs to be a tunable filter with very narrow bandwidth. The filter cause losses at all other wavelengths, except the required wavelength.

**Tuning the Laser Wavelength**

An example of such tuning element can be seen in figure 1.17, which show a prism inside the optical cavity.

![Prism in Optical Cavity](image)

Figure 1.17: Choosing a single wavelength in a tunable laser with a prism.

The dispersion of the prism cause each wavelength to bend at different angle and only one wavelength will continue to move back and forth within the optical cavity. Moving the prism enable selecting the desired wavelength. The pump bands are:

- **nm spectrum range which is suitable for flash-lamps.**
- **nm which is suitable for diode laser pumping.**

**Summary of Alexandrite laser Properties:**

- Average output power of Alexandrite laser can reach 20 watts.
- Pulses of 100 μsec each with power of 1-3 J can be obtained.
- Overall electrical efficiency of flash-lamp pumped Alexandrite laser is about 1%.
- Slope efficiency (Increase in output power with increase in electrical input) can be 5%.