Gain in Laser

Gain (or amplification) in laser physics is a process, where the medium transfers part of its energy to the emitted electromagnetic radiation, resulting in an increase in laser power. This is the basic principle of all lasers. Quantitatively, the ability of a laser medium to increase power of light is characterised with **Gain**.

The gain can be defined as the derivative of logarithm of power P as it passes through the medium:

$$G = \frac{\mathrm{d}}{\mathrm{d}z}\ln(P) = \frac{\mathrm{d}P/\mathrm{d}z}{P}$$

where z is the coordinate in the direction of propagation. This equation neglects the effects of the transversal profile of beam.

In the quasi-monochromatic paraxial approximation, the gain can be taken into account with the following equation

$$2ik\frac{\partial E}{\partial z} = \Delta_{\perp}E + 2\nu E + iGE,$$

Types of Laser Gain Media

- There are a variety of very different gain media; the most common of them are:
- Certain direct-bandgap semiconductors such as GaAs, AlGaAs, or InGaAs are typically pumped with electrical currents, often in the form of quantum wells (→ *semiconductor lasers*).

Certain laser crystals and glasses such as Nd:YAG (neodymium-doped yttrium aluminum garnet → *YAG lasers*), Yb:YAG (ytterbium-doped YAG), Yb:glass, Er:YAG (erbium-doped YAG), or Ti: sapphire are used in the form of solid pieces (→ *bulk lasers*) or optical glass fibers(→ *fiber lasers*, *fiber amplifiers*). These crystals or glasses are doped with some laser-active ions (in most cases trivalent rare earth ions, sometimes transition metal ions) and optically pumped. Lasers based on such media are sometimes called *doped insulator lasers*.

- There are ceramic gain media, which are also normally doped with rare earth ions.
- Laser dyes are used in dye lasers, typically in the form of liquid solutions.
- Gas lasers are based on certain gases or gas mixtures, typically pumped with electrical discharges (e.g. in CO_2 lasers and excimer lasers).