Gain medium physics definition

Optical gain source in a laser The active laser medium (also called gain medium or lasing medium) is the source of optical gain within a laser. The gain is the result of the stimulated emission of electronic or molecular transitions to a lower energy state from a higher energy state previously populated by a pump source. Examples of active laser media include: Certain crystals, typically doused with rare earth ions (e.g. neodymium, ytterbium, or erbium) or transitional metal ions (titanium or chromium); most often yttrium aluminum yttrium (Y3Al5O12), yttrium orthovanadate (YVO4), or sapphire (Al2O3); [1] and not often caesium cadmium bromide (CsCdBr3) Glasses, e.g. silicate glasses or phosphate, doped with active laser ions; [2] Gases, e.g. helium and neon mixtures (HeNe), nitrogen, argon, carbon monoxide, carbon dioxide or metal vapours; [3] Semiconductors, e.g. gallium arsenide (GaAs), arsenide indium gallium (InGaAs), or gallium nitride (GaN). [4] Liquids, in the form of dye solutions as used in dye lasers. [6] In order to dismiss a laser, active gain support must be in a non-thermal energy distribution known as a population in investment. The preparation of this state requires an external energy source and is known as laser pumping. Pumping can be achieved with electrical currents (e.g. semiconductors, or gases through high voltage discharges) or with light, generated by discharge lamps or other lasers (semiconductor lasers). The most exotic means of gain can be pumped by chemical reactions, nuclear fission,[citation needed] or with high-energy electron beams. [7] An example of an average fig.1 profit model. Simplified outline of levels a means of gain A universal model valid for all laser types does not exist. [8] The simplest model includes two sublevel systems: top and bottom. Within each sublevel system, rapid transitions ensure that thermal equilibrium is achieved quickly, leading to Maxwell-Boltzmann excitation statistics among the sublevels of each system (fig.1). The top level is supposed to be metastable. In addition, gains and the refractive index are assumed independently of a particular form of arousal. For a good performance of the earning medium, the separation between sublevels must be greater than the working temperature; then at the frequency of the pump ω p {\displaystyle ~\omega _{\rm {p}}} , the absorption dominates. In the case of optical signal amplification, the lasing frequency is called signal frequency. However, the same term is used even in laser oscillators, when amplified radiation is used to transfer energy instead of information. The next model seems to work well for most solid-state lasers Optically. Cross-sections Simple media can be characterized by effective cross sections of absorption and emission at frequencies ω ω p {\displaystyle ~\omega _{\rm {p}} and ω s {\displaystyle ~\omega _{\rm {s}}} . Have N {\displaystyle ~N~} be concentration of active centers in solid-state lasers. To have N 1 {\displaystyle ~ N_{1} ~} be concentration of active centers in the ground state. Having N 2 {\displaystyle ~ N_{2} ~} be concentration of excited centers. Have N 1 + N 2 = N {\displaystyle ~ N_{1} + N_{2} = N} . Relative concentrations can be set to n 1 = N 1 / N {\displaystyle ~n_{1}=N_{1}/N~} and n 2 = N 2 / N {\displaystyle ~n_{2}=N_{2}/N} . The speed of transitions from an active ground state center to excited state can be expressed with W u = I p σ a p ħ ω p + I s σ a s ħ ω s {\displaystyle ~W_{\rm {u}}={\frac {I_{\\rm {p}}}\sigma _{\rm {ap}}}{\hbar \omega _{\rm {p}}}+{\frac {I_{\rm {s}}\sigma _{\rm {as}}}{\hbar \omega _{\rm {s}} and transi rate back to ground status can be expressed with W d = I p σ e p ħ ω p + I s σ e s ħ ω s + 1 τ {\displaystyle ~W_{\rm {d}}={\frac {I_{\rm {p}}\\sigma _{\rm {ep}}}{\hbar \omega _{\rm {p}}+{\frac {I_{\rm {s}}\sigma _{\rm {es}{\hbar \omega _{\rm {s}}+{\frac {1}{\tau }}}} , where σ a s {\displaystyle ~\sigma _{\rm {as}}~} and σ to p {\displaystyle ~\sigma _{\rm {ap}}~} are effective cross-sections of absorption at signal and pump frequencies. σ e s {\displaystyle ~\sigma _{\rm {es}}~} and σ e {\displaystyle ~\sigma _{\rm {ep}}~} are the same for stimulated broadcast; 1 τ {\displaystyle ~{\frac {1}{\tau }}~} is a rate of spontaneous decline at the top level. Then the kinetic equation for relative populations can be written as follows: d n 2 d t = W u n 1 − W d n 2 {\displaystyle ~{\frac {{\rm {d}}n_{2}}{{\rm {d}}t}}=W_{\rm {u}}n_{1}-W_{\rm d}}n_{2}} , d n 1 d t = − W u n 1 + W d n n 2 {\displaystyle ~{\frac {{\rm {d}}n_{1}}{{\rm {d}}t}}=-W_{\rm {u}}n_{1}+W_{\rm {d}}n_{2}~} However, these equations keep n 1 + n 2 = 1 {\displaystyle ~ n_{1} + n_{2} = 1 ~ } . Absorption A {\displaystyle ~A~} at pump frequency and G gain {\displaystyle ~G~} at signal frequency can be written as follows: A =N 1 σ p a − N 2 σ e {\displaystyle ~A=N_{1}\sigma_{\r we {pa }}-N_{2}\sigma _{\rm {pe}}~} , G = N 2 σ s e − N 1 σ is a {\displaystyle ~G=N_{2}\sigma _{\rm {se}}-N_{1}\sigma _{\rm {sa}}~} . Stable state solution In many cases, the means of gain works in a continuous or almost continuous wave regime, making those derived from the time of the populations insignificant. Stable status solution can be written: n 2 = W u W u + W d {\displaystyle ~n_{2}={\frac {W_{\rm {u}{W_{\rm {u}}+W_{\rm {d}} , n 1 = W d W u + W d . {\displaystyle ~n_{1}={\frac {W_{\rm {d}}}{W_{\rm {u}}+W_{\rm {d}}}}.} Dynamic saturation intensities can be set: I p o = ħ ω p (σ a p + σ e p) τ {\displaystyle ~I_{\rm {po}}={\frac {\hbar \omega _{\rm {p}}}{(\sigma {ap}} +\sigma _{\rm {ep}}})\tau }}}} , I s o = ħ ω s (σ a s + σ e s) τ {\displaystyle ~I_{\r let's {so}={\frac {\hbar \omega _{\rm {s}}}{(\sigma _{\rm {as}}+\sigma _{\rm {es}}})\tau }}~} . Strong signal absorption: A 0 = N D σ a s + σ e s {\displaystyle ~A_{0}={\frac {ND}{\sigma _{\rm {as}}+\sigma _{\rm {es}} Gain at the strong pump: G 0 = N D σ a p + σ e e p {\displaystyle ~G_{0}={\frac {ND}{\sigma _{\rm {ap}}+\sigma _{\rm {ep}} , where D = σ p a σ s e − σ e σ s a {\displaystyle ~D=\sigma _{\rm {pa}}\sigma _{\rm {se}}-\sigma _{\rm {pe}}\sigma _{\rm {sa}}~} is cross-section determinant. Gain never exceeds value G 0 {\displaystyle ~G_{0}~} , and absorption never exceeds the value A 0 U {\displaystyle ~A_{0}U ~} . At the given intensities p {\displaystyle ~I_{\rm {p}}~} , I s {\displaystyle ~I_{\rm {s}}~} pump and signal, gain and absorption can be expressed as follows: A = A 0 U + s 1 + p + s {\displaystyle ~ A = A_{0} {\frac {U +s}{1+p+s}}~} , G = G 0 p − V 1 + p + s {\displaystyle ~ G = G_{0} {\ fra c {p -V}{1+p+s}}~} , where p = I p / I p or {\displaystyle ~p=I_{\rm {p}}/I_{\rm {po}}~} , s = I s / I s or {\displaystyle ~s=I_{\rm {s}}/I_{\rm {so}}~} , U = (σ to s + σ e s) σ to p D {\displaystyle ~U={\frac {(\sigma _{\rm {as}}+\sigma__{\rm {es}})\sigma _{\rm {ap}}}}}{D}~} , V = (σ to p + σ e p) σ to s D {\displaystyle ~V={\frac {(\sigma _{\rm {ap}}+\sigma _{\rm {ep}}})\sigma _{\rm {as}}{D}}~} . Identities The following identities[9] take place: U − V = 1 {\displaystyle U-V=1~} , A/ A 0 + G / G 0 = 1 . {\displaystyle ~A/A_{0}+G/G_{0}=1~.\ } The average gain status can be characterized by a single parameter, such as upper level population, gain or absorption. Win Support Efficiency The efficiency of a gain media can be set to E = I'm G I p A {\displaystyle ~E={\frac {I_{\rm {s}}G}{I_{\rm {p}}}}}} . Within the same model, efficiency can be expressed as follows: E = ω s ω p 1 − V / p 1 + U / s {\displaystyle ~E={\frac {\omega _{\rm {s}}}{\omega _{\rm {p}}{\frac {1-V/p}{1+U/s}} . For efficient operation both intensities, pump and signal must exceed their saturation intensities; p V ≫ 1 {\displaystyle ~{\frac {p}{V}}\gg 1~} and u ≫ 1 {\displaystyle ~{\frac {s}{U}}\gg 1~} . The above estimates are valid for a uniform medium filled with pump and signal light. Burning space holes can slightly reduce efficiency because some regions are well pumped, but the bomb is not effectively removed by the signal in the nodes of counter-propagation wave interference. See also Population Investment Building Laser Science Laser List of Laser Articles Laser Type List References and Notes ^ Hecht, Jeff. The laser guide: Second edition. McGraw-Hill, Amstol (Chapter 22) ^ Hecht, Chapter 22 ^ Hecht, Chapters 7-15 ^ Hecht, Chapters 18-21 ^ F. J. Duarte and L. W. Hillman (Eds.), Dye Laser Principles (Academic, New York, 1990). ^ F. P. Schäfer (Ed.), Dye Lasers, 2nd edition (Springer-Verlag, Berlin, 1990). ^ Encyclopedia of laser physics and technology ^ A.E.Siegman (1986). Lasers. Books of university sciences. ^ a ↑ 3.0 3.2 3.2 3.4 3.4 3.4 3.4 3.4 3.6 3.6 3.6 ↑ D.Kouznetsov. J.F.Bisson; K.Takaichi; K.Ueda (2005). ^ Single-mode solid-state laser with unstable cavity and short wide. JOSA B. 22 (8): 1605–1619. 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