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(a) Yes, medium can exhibit homogeneous and inhomogeneous broadening at the same time. Because homogeneous and inhomogeneous broadening have different mechanisms, they can occur in the same medium simultaneously.

(b) The precondition is an active medium with an excited state that is stronger populated than its lower level.

(c) The regenerative amplifier is a kind of amplifier which sends partial feedback of the amplifier output signal to the amplifer input. The reason is that the regenerative amplifier can increase the output power by passing through the active medium several times.

(d) Gain saturation occurs when the increasing intensity leads to the decrease of the gain.

(e) Spectral hole burning means selective decrease of gain near frequency of signal. It occurs because the incoming light only interacts with atoms with fitting frequency.

Problem 2

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(a)

$$\nu = \frac{c}{\lambda} = \frac{3\times10^{8}\,m/s}{999\,nm} = 3.003\times10^{14}\,Hz$$

$\because$ $g(\nu)$ is centered at a wavelength of $1\,\mu m$.

$$\therefore \lambda_{21} = \frac{c}{\nu_{21}} = 1\,\mu m \qquad \therefore \nu_{21} = 3\times10^{14}\,Hz$$

$$g(\nu) = 1000\,m^{-1}\,\frac{\left(\frac{\Delta\nu}{2}\right)^2}{(\nu-\nu_{21})^2+\left(\frac{\Delta\nu}{2}\right)^2} \qquad \because \frac{\Delta\nu}{\nu_{21}} = \frac{\Delta\lambda}{\lambda_{21}}$$

$$\therefore \Delta\nu = 1.2\times10^{12}\,Hz$$

$$= 1000\,m^{-1}\,\frac{(6\times10^{11}\,Hz)^2}{(3\times10^{11}\,Hz)^2+(6\times10^{1}\,Hz)^2}$$

$$= 1000\,m^{-1}\,\frac{36\times10^{22}}{9\times10^{22}+36\times10^{12}}$$

$$= 1000\,m^{-1}\times\frac{36}{9+36}$$

$$= 800\,m^{-1}$$

(b)

Problem 3

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(a)

$$P_0 = P_{in} \cdot (1-R_3)$$

$$P_{out} = G \cdot (1-R_3) \cdot (P_0 + P_1 + P_2 + P_3 + \cdots)$$

$$P_n = P_{n-1} \cdot G \cdot R_3$$

$$\therefore P_{out} = G(1-R_3) \cdot (P_0 + P_0 \cdot G \cdot R_3 + P_0 \cdot (G \cdot R_3)^2 + \cdots)$$

$$= G(1-R_3) \cdot P_0 (1 + G \cdot R_3 + (G \cdot R_3)^2 + \cdots)$$

$$= \frac{P_0 \cdot [1-(G \cdot R_3)^n]}{1 - G \cdot R_3} \cdot G \cdot (1-R_3)$$

$$= P_{in} \cdot (1-R_3) \cdot \frac{1-(G \cdot R_3)^n}{1 - G \cdot R_3} \cdot G \cdot (1-R_3)$$

$$\therefore G_s = \frac{P_{out}}{P_{in}} = G \cdot (1-R_3)^2 \cdot \frac{1-(G \cdot R_3)^n}{1 - G \cdot R_3}$$

if $G \cdot R_3 < 1$,

$$G_s = \frac{G \cdot (1-R_3)^2}{1 - G \cdot R_3}$$

(b)
$\because$ This configuration should work as a regenerative amplifier.

$\therefore G \cdot R_3 < 1$ $\therefore$ the maximum value of R_3 is 0.909.

(c) Because a pulsed signal has many frequency components. But only specific frequency component can exist in the ring resonator.

(d) $P_{out} = P_n \cdot V_s$

$P_n = P_{n-1} \cdot V_s \cdot G$

$P_1 = P_{in} \cdot V_s \cdot G$

$\therefore P_n = P_{in} (V_s \cdot G)^{N_R}$

$\therefore P_{out} = P_{in} (V_s \cdot G)^{N_R}$

$G_s = (V_s \cdot G)^{N_R}$

(e) $V_s \cdot G > 1$

Reason: In the CW case, each round has a contribution to the output power.

(f) Gain saturation occurs when the increasing intensity leads to the decrease of the gain. In the regenerative amplifier for pulse operation, only a certain frequency interacts with the absorbing particles which causes spectral hole burning.