# 浙江大学 2020–2021 学年 秋冬 学期

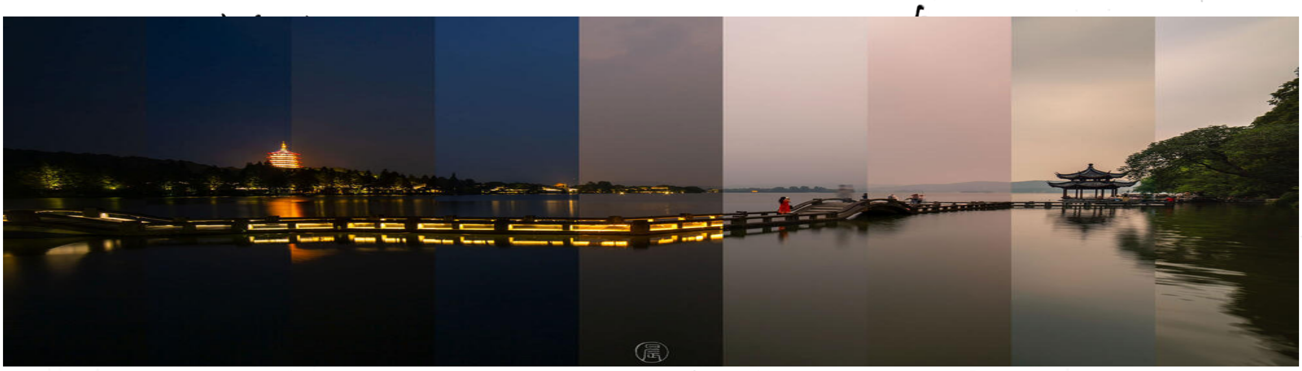
# 《光电子学》课程期中考试试卷

课程号：11120071，开课学院：光电科学与工程学院

考试形式：闭√、开卷（请在选定项上打√），允许带 计算器 入场

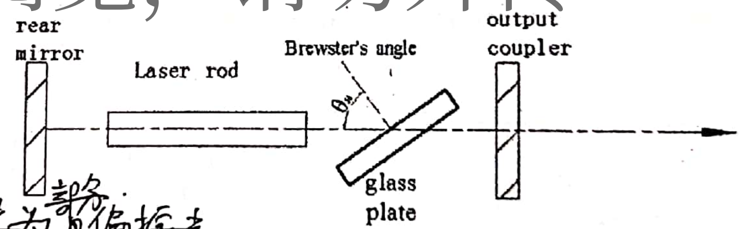
考试日期：2020 年 11 月 9 日，考试时间：120 分钟

**诚信考试，沉着应考，杜绝违纪。**





1. Nd:YAG 是一种各向同性的介质，以 Nd:YAG 作为增益介质的激光器通常情况下输出的激光是随机偏振的。如图所示的 Nd:YAG 激光谐振腔内，如果增加了一块以布儒斯特角放置的光学平板（假定平板对 p 光的透过率为 100%，对 s 光的透过率为 70%），试分析此时输出激光的偏振特性，并说明原因。(10 分)




解：~~此时输出的激光为部分p偏振光，~~

入射角为布儒斯特角，~~p光全部通过，s光少量通过~~.

~~激光中p分量占主导，~~

激光此时输出为p偏振光，因为p光在布儒斯特角下无反射损失，经过多次振荡后仍保留下来；s光经过多次振荡，多次通过平板后，一次它减30%，几乎全被反射出去，激光最终输出时无s分量。

因此加了布儒斯特窗后，输出p偏振光。

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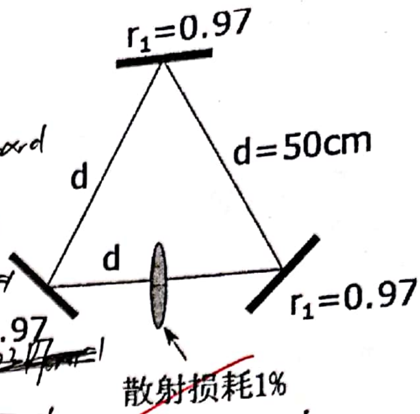
+2

2. 如图所示的环形腔，三个反射镜的反射率均为 0.97，透镜的散射损耗为 1%，忽略其它损耗，求：（15 分）

(1) 谐振腔的总的有效分布损耗系数 $\alpha_r$。

(2) 谐振腔对于波长为 1.06μm 激光的 Q 值。




(1) $\alpha_r = \alpha_s + \alpha_1 + \alpha_2 + \alpha_3$, $R_1R_2R_3 e^{-3\alpha_s d} = e^{-3\alpha_r d}$

$\alpha_i = \frac{1}{3d}\ln\frac{1}{R_i}$ $\quad R_i = 0.97 \ (i=1,2,3)$

$\Rightarrow \alpha_1 = \alpha_2 = \alpha_3 = 2.03\times10^{-2}\,m^{-1}$

而 $e^{-\alpha_s\cdot 3d} = 99\%$ $\Rightarrow \alpha_s = 6.7\times10^{-3}\,m^{-1}$

$\therefore \alpha_r = \alpha_s + 3\alpha_i = 6.76\times10^{-2}\,m^{-1}$

(2) $\nu_0 = \frac{c}{\lambda}$ $\Rightarrow Q = \frac{2\pi}{c\alpha_r/\nu_0} = \frac{2\pi}{\lambda\alpha_r} = 8.77\times10^{7}$

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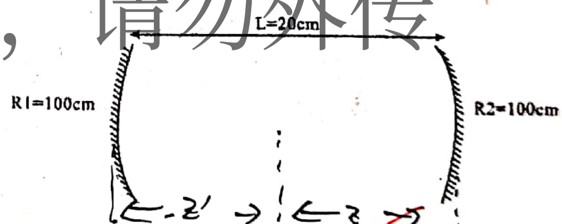
3. The diagram below describes a laser resonator cavity, now please determine: (20 分)

(1) Whether the resonator is a stable resonator?

(2) If it is, determine the beam waist position and the waist size ( $\lambda = 1064$ nm).




(1) 由稳态条件 $0 \le g_1g_2 \le 1$

$g_1g_2 = (1+\frac{d}{R_1})(1+\frac{d}{R_2}) = 0.64$ （$R_1$、$R_2$为凹面镜，取负值）

知该谐振腔稳定。

(2) 由条件知 波前曲率半径 $|R_1(z)| = |R_2(z)|$ 设束腰位置距左镜为$z'$，距右镜为$z$.

$\because R_1 = R_2$ 知 $|z'[1+(\frac{z_0}{z'})^2]| = |z[1+(\frac{z_0}{z})^2]|$ $\Rightarrow |z'| = |z|$ （其它增根已舍，因$z$与$z'$不超过20cm）

知 束腰位置在谐振腔的中心处，距前后腔镜分别为 10cm

且有 $z[1+(\frac{z_0}{z})^2] = |R_2|$ $\quad z = 10cm$ $\quad |R_2| = 100cm$.

$\Rightarrow z_0 = 30\,cm$ $\quad\therefore$ 束腰直径 $2W_0 = 2\sqrt{\frac{\lambda z_0}{\pi}} = 6.38\times10^{-4}\,m$

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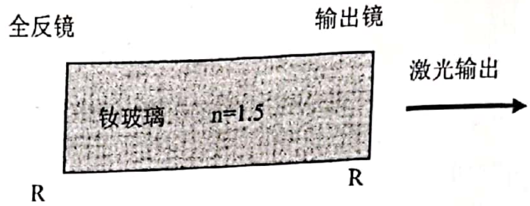
4. 一个钕玻璃激光器工作在锁模状态，输出波长为 1.06μm，输出脉冲的重复频率为 1 GHz，脉冲宽度为 330 fs。假定增益介质充满整个谐振腔，钕玻璃材料的折射率为 n=1.5，请计算：(15 分)

$T_F = 10^{-9}s$

$\tau_{pulse} = 3.3\times10^{-13}s$

(1) 谐振腔的长度 d；

(2) 估算输出激光的谱线宽度 Δν 及参与锁模的纵模个数 M




(1) 由条件知 $\nu_F = 1GHz$

$\nu_F = \frac{c_0}{2nd} \Rightarrow d = \frac{c_0}{2n\nu_F} = 10cm$

(2) $\Delta\nu = \frac{1}{\tau_{pulse}} = 3.03\times10^{12}Hz$.

$M = \frac{T_F}{\tau_{pulse}} \approx 3030$

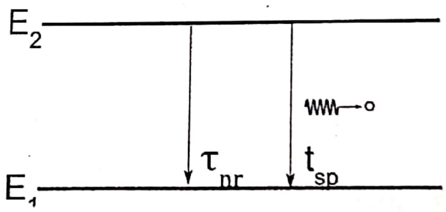
15.

5. Let's consider a laser medium with 2 energy levels. The spontaneous lifetime of the medium is $t_{sp}$, the nonradiative contribution is $\tau_{nr}$. If the atom density on the level $E_2$ is $n_{20}$ at time t=0, and the volume of the medium is V, the frequency of the spontaneous radiation is ν, please get the answers (do not consider absorption and stimulated emission process). (20 分)

(1) How the power of the spontaneous radiation changes with time t.

(2) The total number of the photons emitted from the medium during the decay process.






(1) 不考虑受激辐射与吸收

考虑 2 能级的速率方程. 有 $\frac{dn_2}{dt} = -\frac{n_2}{t_{sp}} - \frac{n_2}{\tau_{nr}}$

$\Rightarrow n_2 = n_{20}e^{-(\frac{1}{t_{sp}}+\frac{1}{\tau_{nr}})t}$

而能量为 $E(t) = Vh\nu(n_{20}-n_2) \rightarrow$

~~能级衰减~~ $= Vh\nu n_{20}[1-e^{-(\frac{1}{t_{sp}}+\frac{1}{\tau_{nr}})t}]$

能级 2 总共损失

总衰减功率 $P_总(t) = \frac{dE(t)}{dt} = Vh\nu n_{20}(\frac{1}{t_{sp}}+\frac{1}{\tau_{nr}})e^{-(\frac{1}{t_{sp}}+\frac{1}{\tau_{nr}})t}$

其中 V 为介质体积. ν 为辐射频率.

自发辐射的比例与其相关. 即 $P_{sp}(t) = \frac{\frac{1}{t_{sp}}}{\frac{1}{t_{sp}}+\frac{1}{\tau_{nr}}} P_总(t) = \frac{Vh\nu n_{20}}{t_{sp}} e^{-(\frac{1}{t_{sp}}+\frac{1}{\tau_{nr}})t}$

功率 衰减速率

(2) 衰减粒子总数为 $N = Vn_{20}$ (当 $t\to\infty$ 时)

一个原子参与自发辐射发出一个光子. 则 $N_{photon} = \frac{\frac{1}{t_{sp}}}{\frac{1}{t_{sp}}+\frac{1}{\tau_{nr}}} N = \frac{\tau_{nr}Vn_{20}}{t_{sp}+\tau_{nr}}$

V 为介质体积.

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6. A single-mode He-Ne laser with the wavelength λ=632.8nm, the length of cavity is 10cm, the reflectivity of these two mirrors are 100% and 98%, and the other loss is neglected. The steady output power is 0.5 mW and the beam diameter is 0.5 mm (assume that the beam transverse distribution is uniform). (20 分)

(1) Try to calculate the photon numbers in the cavity.

(2) Determine the gain coefficient of the medium in steady state.

($\phi = n c$, $P_0 = \frac{T}{2}\phi$)

(1) 由条件知 $P_{steady} = \frac{T}{2} A h\nu \phi$，A为腔的截面积，$\phi$为腔内光子数密度流

T为腔全部透射率.

$T = 1 - 98\% = 2\%$ $\nu = \frac{c}{\lambda}$. 腔的有用体积.

而腔内总光子数 $N = n \vec{V} = nAd$，$\phi = nc$ (n为腔内光子数密度).

结合以上各式，得 $n = \frac{2P\lambda}{TAhc^2}$ 即 $N = \frac{2P\lambda d}{Thc^2} = 5.31\times10^7$

故腔内总光子数约为 $5.31\times10^7$个

(2) 稳态时. $\gamma(\nu) = \alpha_r$

$\alpha_r = \alpha_{m1} + \alpha_{m2} + \alpha_s$ $\alpha_s = 0$

$\alpha_{m1} = \frac{1}{2d}\ln\frac{1}{R_1}$ $\alpha_{m2} = \frac{1}{2d}\ln\frac{1}{R_2}$ $R_1 = 1$ $R_2 = 0.98$

$\Rightarrow \gamma(\nu) = \alpha_r = \frac{1}{2d}\ln\frac{1}{R_2} = 1.01\times10^{-3}\ cm^{-1}$

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