1. (10 %)(Resonator Optics)
   The output beam from a He-Ne laser (633 nm) with a linear confocal resonator (cavity length: 50 cm) is focused by a lens of f=50 cm just away from the output mirror. Calculate the location of the focus and the beam waist in the focal plane.

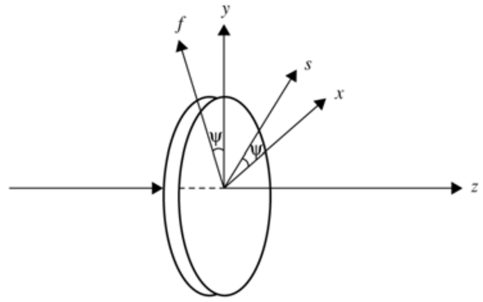
2. (10 %) (Pulsed Lasers)
   Please explain the working principles of "Q-Switching" and "Mode- Locking".

3. (10 %) (Semiconductor Laser) Consider a GaAs (n=3.6) laser diode placed in air (n=1) with un-coated cleaved facet and 0.25-mm crystal length. The intrinsic loss coefficient is 2 cm^{-1}. The facet reflectance is $|r|^2 = \left(\frac{n_1-n_2}{n_1+n_2}\right)^2$.
   (a) (5 %) Determine the effective loss coefficient (α_r) and the frequency spacing.
   (b) (5 %) Determine the spectral width of the individual resonator modes.

4. (10 %) (Interaction of Light and Sound)
   (a) (5 %) Please explain "Bragg Diffraction".
   (b) (5 %) Use the amplitude reflectance of AO devices
   $$r_{\pm} = \pm j r_0 \mathrm{sinc}\left[(2k\sin\theta \mp q)\frac{1}{2\pi}\right] e^{\pm j\Omega t}$$ to derive the Bragg angle.

5. (10 %) (Phase modulator)
   For Pockels effect, the refractive index change with electric field is $n(E) \approx n - \frac{1}{2}\mathrm{r}n^3E$. A beam of light traversing a Pockels cell of length L to which an electric field E is applied undergoes a phase shift $\varphi = \mathrm{n}(E)k_0L = \frac{2\pi\mathrm{n}(E)L}{\lambda_0}$, where λ_0 is the free-space wavelength. The electric field is obtained by applying a voltage V across two faces of the cell separated by distance d $(\mathrm{E} = \frac{V}{d})$. we can obtain $\varphi \approx \varphi_0 - \pi\frac{V}{V_\pi}$. Please derive φ_0 and V_π.

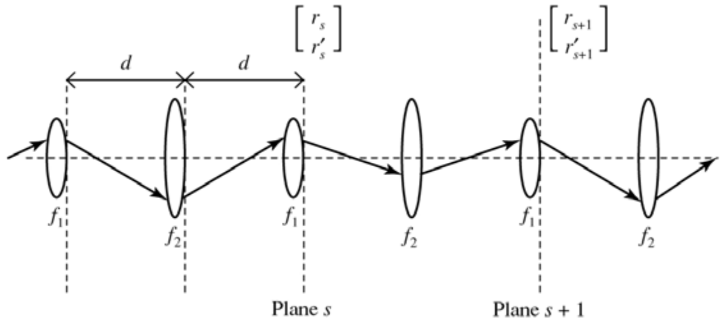
6. (15%) Polarization Optics
   Construct a Jones matrix for a wave plate (or retardation plate) with azimuth angle ψ. The *s* axis is in the direction of polarization of the slow mode, whereas the *f* axis is in the direction of polarization of the fast mode. The azimuth ψ is defined as the angle between the *s* axis and the *x* axis.



7. (15%) Electromagnetic Optics
   a) Use Maxwell's equations to derive the representation of Poynting vector and explain the physical meaning of this vector. (5 points)
   b) Derive the power per unit volume expended by the field on the electric dipoles, *i.e.* dipolar dissipation. You must explain the every term in the equation of the work done per unit volume by an electromagnetic field, $\vec{J} \cdot \vec{E}$. (10 points)

8. (10%)
   What is the Faraday rotation effect? Please prove that isotropic substances rotate the plane of polarization of linearly polarized light when placed in a strong magnetic field. (10 points)

9. (10%) Ray Optics
   Construct a *ABCD* matrix to describe the propagation of a ray through a periodic system, which consists of lenses of focal lengths f_1 and f_2 separated by a distance d. Discuss the condition for confined propagation.



10. (10 points) Compare the radiative efficiencies for GaAs (E_g = 1.42 eV) and $In_{.53}Ga_{.47}As$ (E_g = 0.74 eV), for the same electron density of $n = 5 \times 10^{18}$ cm^{-3}. Take Auger constants of 5×10^{-30} cm^6/s and 1×10^{-28} cm^6/s, and B_r values of 7.2×10^{-10} and 4×10^{-11} cm^3/s for GaAs and InGaAs, respectively.
11. (15 points) What is the whole name of VCSELs? Please draw a detailed scheme of GaInAlAs VCSELs and indicate what are the required fabrication conditions and electro-optical functions in each composed part?
12. (15 points) Assume that electron-hole pairs are injected into n-type GaAs (E_g = 1.42 eV, $m_c \fallingdotseq 0.07\ m_0$, $m_v \fallingdotseq 0.50\ m_0$) at a rate R=$10^{23}$/cm^3-s. The thermal equilibrium concentration of electrons is $n_0 = 10^{16}$/cm^3. If the recombination coefficient r=10^{-11} cm^3/s and T=300 K, determine:
    (a) The equilibrium concentration of holes p_0.
    (b) The recombination lifetime τ.

(c) The steady-state excess concentration Δn.

13. (10 points) Two typically used imaging detectors are CMOS and CCD devices, respectively. Please illustrate what are their individual operation concepts and compare their imaging capabilities?