Topics in final

1. Interference & hologram: principle of hologram is based on interference. Interference of plane wave with spherical wave. Object, reference and conjugate beams in recording and playing back of hologram. Volume hologram.
2. Electro-optics: Δn in Pockel and Kerr effects. Principle and various configurations & their merits based on V_π and speed (circuit time and transit time) for phase modulator, intensity modulator and dynamic retarder. Know the process for obtaining V_π
3. Directional coupler and spatial switch: $L_o = \frac{\pi}{2\sqrt{C_{12}C_{21}}} = \frac{\pi}{2C}$ is the distance for a complete switch over from input port 1 to output port 2. Transmittance of a spatial switch $T = (\pi/2)^2 \mathrm{sinc}^2\left(\frac{1}{2}\sqrt{1+3(V/V_o)^2}\right)$ with $V_o = \frac{\sqrt{3}C\lambda_o d}{\pi n_3 r}$. Example of spatial light modulator, LCD and photorefractive materials

4. Anisotropic EO media: convention for r matrix and s matrix as well as the implication of matrix elements for design of modulators in terms of direction of microwave and optical fields. Equation for index ellipsoid. Procedure for finding the new principle axes and refractive index for EO media and find n for certain propagation direction. Applications and principles of Nematic LC, twisted LC and photorefractive materials.

5. Nonlinearity:
   2nd order $p^{NL}(t) = 2de^2(t) = \varepsilon_o \chi^{(2)} e^2(t)$.
   3rd order $p^{NL}(t) = 4\chi'^{(3)} e^3(t) = \varepsilon_o \chi^{(3)} e^3(t)$.
   Able to find P^{NL} phasor, e.g. $P_{NL}(0)$ for 2nd order nonlinearity with one beam with ω and $P_{NL}(\omega)$ for 3rd order nonlinearity with two beams with ω and DC.
   d matrix and its application for finding off-axis nonlinear polarization ($P(\omega_3) = 2d_{eff} E(\omega_1) E(\omega_2)$, sum-frequency generation; $P(2\omega) = d_{eff} E^2(\omega)$, second-harmonic generation).

6. 2nd order nonlinear processes: Conditions for efficient conversion -- a) $\omega_3 = \omega_1 + \omega_2$, b) $\vec{k}_3 = \vec{k}_1 + \vec{k}_2$ (phase matching), c) high beam

intensity, d) long interaction length and e) large nonlinear coef. Parametric interaction (up conversion, down conversion, parametric amplification and parametric oscillation), 2nd harmonic generation, rectification. Know the pump and variation of signal for each process. Meaning of nondepleted pump, phase mismatching factor $[\sin(\Delta k\, l/2)/(\Delta k\, l/2)]^2$

Types I and II phase matching. For 2nd harmonic (negative uniaxial) $\sin^2\theta = (n_o^{-2}(\omega) - n_o^{-2}(2\omega))/(n_e^{-2}(2\omega) - n_o^{-2}(2\omega))$

Condition for parametric oscillation -- gain coef = loss coef., parametric amplification providing gain for one direction (phase matching).

Manley-Rowe Relations

$$-\frac{dI_2}{dz}\frac{1}{\hbar\omega_2} = -\frac{dI_1}{dz}\frac{1}{\hbar\omega_1} = \frac{dI_3}{dz}\frac{1}{\hbar\omega_3}, \ (\hbar = h/(2\pi)).$$

7. 3rd order nonlinear processes: 3rd harmonic generation, DC Kerr effect, nonlinear refraction, DC field induced 2nd harmonic generation, SRS, FWM and sum and difference freq generation. Nonlinear refraction includes SPM (one beam), XPM (multiple beams), self-focusing, self-

defocusing, self-bending, soliton formation. Definition of nonlinear coef n_2 and its relation with Δn and $\chi^{(3)}$.

8. Conditions for 3rd nonlinear processes: Fundamental bright soliton $A = A_o \text{sech}(x/w_o)\exp(-jz/(4z_o))$
   (1+1)D spatial soliton threshold power $P_{cr} = 2nw/(n_2 k^2 w_o)$, self-focusing counters diffraction; threshold power for collapse of a (2+1)D beam due to self-focusing $P_{cr} \approx \pi n/(k^2 n_2)$
   FWM conditions -- $\omega_1 + \omega_2 = \omega_3 + \omega_4$, $\vec{k}_1 + \vec{k}_2 = \vec{k}_3 + \vec{k}_4$ (phase matching)
   Optical phase conjugation (degenerate FWM) forms dynamic hologram.
   Conditions for temporal bright soliton -- $n_2 \beta'' < 0$
   SPM canceling freq chirp from dispersion, $N^2 = 2z_o k_o n'_2 A_o^2$ (where N is integer, e.g. N=1 for fundamental soliton).
   Conditions for temporal dark soliton -- $n_2 \beta'' > 0$