3C43 LASERS & MODERN OPTICS

Revision Checklist (Final version)

1. Matrix optics

- Know thin lens formula and be familiar with thick lens formula
- Know the approximations implicit in the use of the ray transfer matrix formalism (paraxial approximation, meridional rays only)
- Derive the ray transfer matrices for
  - -translation
  - -refraction at a spherical surface
  - -reflection at a spherical surface
- The ray transfer matrix of a complex optical system in terms of the transfer matrices of its components
- Know how to derive the ray transfer matrices for thin and thick lenses and systems of lenses
- Remember det(M) = n/n'
- Be able to derive the consequences for the system properties of A, B, C, D=0

2. Principles and applications of lasers

- Spontaneous and stimulated emission - definitions
- Derive the Einstein relations connecting the A and B coefficients
- Definition of population inversion
- Derivation of the small-signal absorption/gain coefficient
- The atomic lineshape function
- Know the difference between homogeneous and inhomogeneous broadening and examples of mechanisms causing each
- Be familiar with the various means of achieving population inversion:
  - selective pumping
  - spatial separation
  - selective collisional pumping

  and an example of a laser system employing each.
- Be familiar with the general scheme of laser operation
- Characteristics of three and four-level laser systems (an example of each)
- Be able to derive an expression for the threshold gain coefficient and the threshold population inversion
- Saturated absorption in homogeneous and inhomogeneously-broadened Systems, effect on the mode spectrum of an oscillating laser.
- Be able to write down and solve suitable rate-equations for three and four-level systems
- Be able to describe the dependence of output power and population-inversion on pumping rate
- Laser cavity modes: longitudinal (axial) and transverse
- Single-mode operation of lasers (longitudinal and transverse)
- Be familiar with the characteristics of important laser systems:

  ruby, Nd:YAG, dye, He-Ne, CO_2, NH_3, Ar+, semi-conductor

- Q-switching of lasers: advantages of and methods of achieving it.
- Mode-locking of lasers: derive form of the time-varying output power
- Be able to describe qualitatively the characteristic properties of laser light:
  directionality, narrow spectral linewidth, focusability,
  brightness, coherence

3. Gaussian beams

- The Gaussian beam as a paraxial solution of the wave equation
- Know the significance of the complex radius of curvature q and the Rayleigh range z_R
- Be able to derive expressions for w(z) and R(z)
- Be able to state and use the ABCD law of Gaussian beams,
- Focusing properties of Gaussian beams: know how to find the size and location of the beam waist,
- Be able to derive the stability condition for a laser cavity and the characteristics of a Gaussian beam cavity mode.

4. Electro-optics

- Know how to decompose linearly or circularly polarized light into two orthogonal linear components
- Uniaxial birefingent media (positive and negative): definition of the optic axis, principal axis and preferred axis.
- Definition of the ordinary and extraordinary rays
- Know how to find the refractive indices of the o and e-rays using the index Ellipsoid (in 2D: propagation in a plane through the optical axis)
- Half and quarter-wave plates (multiple and zero order)
- The Pockels electro-optic effect:
  Definition of and derivation of the half-wave voltage
  Be able to derive the dependence of intensity on voltage for the Pockels cell electro-optic modulator
- Be able to describe qualitatively the Faraday effect
- The acousto-optic modulator, including calculation of the frequency-shift and the deflection angle.

5. Non-linear optics

- Know what is meant by the non-linear susceptibility
- second-order non-linearity: second-harmonic generation (SHG)
- be able to derive the form of the spatial variation of the second-harmonic intensity and the coherence length
- know the conserved quantities in the photon model of SHG
- Know what is meant by phase-matching and be familiar with the example of type I phase-matching including calculation of the phase-matching angle
- third-order non-linearity: third-harmonic generation and the means of achieving phase-matching therein.