

Listed below are the primary topics from OPTI 511R that also have overlap with OPTI 570, OPTI 544, and OPTI 541A. These are the main topics that will be available for questioning on the PhD Qualifying Exam.

NOTE: For the 2022-2024 exams, the topics of optical resonators and laser physics (13 and 14 below) will not appear on the exam. **However, these topics will be tested again beginning with the 2025 exam, so all PhD students taking the exam that year must have taken either OPTI 511R or OPTI 541A prior to the August 2025.**

1. postulates of quantum mechanics
2. wavefunctions – interpretation, sketching, physically acceptable wave functions, normalization, orthonormality, probability density distributions, stationary states, position and momentum representations and Fourier transforms, uncertainty relations
3. calculating expectation values and probabilities
4. superpositions of energy eigenstates, and their time dependence
5. free-particle wave functions and wave packets
6. infinite square well – energy eigenfunctions and eigenvalues
7. harmonic oscillator (energy eigenfunctions and eigenvalues, raising and lowering operators)
8. hydrogen atom (spinless electron and proton model) – Coulomb potential, energy levels and energy eigenvalues, spherical harmonics and electron orbital angular momentum, quantum numbers, kets that indicate the quantum numbers of energy eigenstates
9. 2-level systems, spin-1/2 problem – spin-1/2 particle in a magnetic field, Stern-Gerlach
10. Rabi oscillations
11. basics of light-matter interaction – Electric dipole interaction, single-photon transitions especially between hydrogen atom energy eigenstates, dipole matrix elements, selection rules
12. photon number states, photon annihilation and creation operators
13. basics of laser physics – 3 and 4 level systems, population rate equations (in terms of atomic densities, but not density matrix elements), gain and absorption, round trip gain and loss for cw lasing (NOT mode-locked or Q-switched operation of lasers)
14. optical resonators – longitudinal and transverse modes, Hermite-Gaussian modes of curved-mirror optical resonators, stability of two-mirror optical resonators, Fabry-Perot resonators, free spectral range