1.2: Electromagnetic Theory of Optics and Quantum Optics

Maxwell's equations provide a very complete description of light, which includes diffraction, interference and polarisation. Yet it is strictly speaking not fully accurate, because it allows monochromatic electromagnetic waves to carry any amount of energy, whereas according to quantum optics the energy is quantised. According to quantum optics, light is a flow of massless particles, the photons, which each carry an extremely small quantum of energy:~ ω, where ~ = $6.63 \times 10^{-34}/(2\pi)$ Js and ν is the frequency, which for visible light is of the order 5×10^{14} Hz. Hence ~ ω ≈ 3.3×10^{-19} J.

Quantum optics is only important in experiments involving a small number of photons, i.e. at very low light intensities and for specially prepared photons states (e.g. entangled states) for which there is no classical description. In almost all applications of optics the light sources emit so many photons that quantum effects are irrelevant see Figure 1.2.1

Light Source	Number of photons/s.m2
Laserbeam (10m W, He-Ne, focused to 20 μm)	10^{26}
Laserbeam (1 mW, He-Ne)	10^{21}
Bright sunlight on earth	10^{18}
Indoor light level	10^{16}
Twilight	10^{14}
Moonlight on earth	10^{12}
Starlight on earth	10^{10}

Table 1.2.1: The mean photon flflux density for some common sources

The visible part is only a small part of the overall electromagnetic spectrum (see Figure 1.2.1). The results we will derive are however generally valid for electromagnetic waves of any frequency.