5.4 MEDICAL APPLICATIONS OF LASERS

The highly collimated beam of a laser can be further focused to a microscopic dot of extremely high energy density. This makes it useful as a cutting and cauterizing instrument. Lasers are used for photocoagulation of the retina to halt retinal hemorrhaging and for the tacking of retinal tears. Higher power lasers are used after cataract surgery if the supportive membrane surrounding the implanted lens becomes milky. Photo disruption of the membrane often can cause it to draw back like a shade, almost instantly restoring vision. A focused laser can act as an extremely sharp scalpel for delicate surgery, cauterizing as it cuts. ("Cauterizing" refers to long-standing medical practices of using a hot instrument or a high frequency electrical probe to singe the tissue around an incision, sealing off tiny blood vessels to stop bleeding.) The cauterizing action is particularly important for surgical procedures in blood-rich tissue such as the liver. Lasers have been used to make incisions half a micron wide, compared to about 80 microns for the diameter of a human hair.

Medicine has two prime objectives; first to detect disease at an early stage before it becomes difficult to manage and second, to treat it with high selectivity and precision without any adverse effect on uninvolved tissues. Lasers are playing a very important role in the pursuit of both these objectives. Due to their remarkable properties, lasers have made possible ultraprecise, minimally invasive surgery with reduced patient trauma and hospitalization time. The use of lasers in surgery is, by now, well established and spans virtually the entire range of disciplines: ophthalmology, gynaecology, ENT, cardiovascular diseases, urology, oncology, etc. The use of lasers for biomedical imaging and diagnostics and for phototherapy using photo activated drugs is receiving considerable current attention and is expected to have profound influence on the quality of health care.

Laser spectroscopic techniques have the promise to provide sensitive, inside, near real time diagnosis with biochemical information on the disease. These developments have the potential to change the way medical diagnosis is presently perceived. Instead of a means of solving an already known clinical problem, the diagnosis may in future screen people for problems that may potentially exist. Further, any potential risk factor so detected can be corrected with high selectivity by the use of drugs that are activated by light. Because these drugs are inert, until photo excited by radiation with the right wavelength, the clinician can target the tissue selectively by exercising the control on light exposure (only the tissue exposed to both drug and light will be affected). A good example is the fast-developing photodynamic therapy of cancer.

There are indications that selective photo excitation of native chromophores in the tissue may also lead to therapeutic effects.

LASER AND TISSUE INTERACTIVE

Light Tissue Interactions

Radiative and non-radiative relaxation. Imagine an excited molecule that is alone, without any other nearby molecules to interact with. In this case, two things could happen. First, the energy gained by absorbing the photon, and initially stored in one mode, will begin to be shared out between all the modes in anon-radiative process of intramolecular redistribution until the molecule is in equilibrium (according to the equipartition theorem). However, the molecule could also jump abruptly to a lower energy state by emitting a photon.

If the radioactive life time of the molecule is shorter than the redistribution time, then it is likely that a photon will be emitted before the process of intra molecular redistribution has completed.

As some redistribution will always take place before a photon is emitted, the energy of there radiated photon will always be lower than the absorbed photon. There are two possible radioactive processes: fluorescence and phosphorescence. During fluorescence there is a transition from a state to a similar state, eg. singlet-singlet, and is typically fast (ns or shorter).Phosphorescence occurs after an intramolecularinter-system crossing has taken place, so the transition accompanying the radiation typically involves a change from a triplet to a singlet state which is much less likely to occur (according to quantum mechanics), and so the radiation is of lower energy and occurs over a much longer timescale (ms, seconds or even longer). All mechanisms that are not radiative are by default non radiative.

Photochemical reactions.

When the light absorption gives rise to an electronic transition, the more energetic electron will, on average, orbit the nuclei at a greater distance. As the attractive nuclear force falls rapidly with distance, the electron will be less tightly bound, and will be able to form a chemical bond with another molecule more readily. This is the basis of photochemistry.

Thermalisation, collisional relaxation

While an excited molecule is undergoing intra molecular redistribution it might collide with another molecule. Some of the vibrational energy in the excited molecule will transferred to the colliding molecule as translational kinetic energy. Molecular translational kinetic energy is what appears at a macroscopic level as a temperature rise so leads to photo thermal effects. This process of collisional relaxation will there by thermalize the absorbed photon energy in a matter of picoseconds, although the resulting macroscopic thermal effects occur over very much longer timescales (ms to s).