**Physics in Modern Medicine** **Winter 2025**

**Homework #3**

**Chapter 3 – Lasers in Medicine**

**Questions**

Q3.5 Since the chief pigment in the endometrial tissue is blood, a good choice of laser would be one that is in the blue portion of the spectrum and one that would be inappropriate would be a laser whose output is in the red portion of the spectrum. An appropriate choice for the laser would be something in the $400nm - 600nm$ range, say an Argon laser or maybe a copper vapor. An inappropriate choice for the laser would be lasers whose wavelength is in the $600nm$ and larger range, say He-Ne, Krypton, ruby and any IR laser.

Q3.7 a. To use a laser as a surgical tool, you need to know the absorption properties of the tissues that will be operated on, the penetration depth for the laser, the power density, and the mode of operation of the laser.

b. The tissue's absorption spectrum should be known in order to select the appropriate laser. The concentration of absorbing molecules should also be known since this will determine the penetration depth.

Q3.9 Excimer lasers, which are ultraviolet lasers, are used in photorefractive surgery because the cornea is transparent to any visible light, such as that in the argon laser. The cornea is a good absorber of UV radiation. The retina on the other hand has many blood vessels and to target these in a surgery one would want the argon laser since it operates in the blue-green portion of the EM spectrum and would be preferentially absorbed by the red blood cells here.

**Problems**

3P.5

a. To achieve a power density of $80\frac{mW}{cm^2}$ with a 1W CW laser, you would need a spot size given through (Eq. 3.7) $I = \frac{P}{\pi r^2}$, where $I$ is the power density (or intensity) and $P$ is the power. Solving for the spot radius, $r$, we get:

$$r = \sqrt{\frac{P}{\pi I}} = \sqrt{\frac{1W}{\pi \times 80 \times 10^{-3}\frac{W}{cm^2}}} = 2cm.$$

b. The intensity is the power per unit area and the power is the energy per unit time. Thus, the exposure time would be given by the energy per unit area divided by the intensity. We define the energy per unit area the fluence $F$.The exposure time would be given by:

$$I = \frac{P}{A} = \frac{E}{tA} \rightarrow t = \frac{E/A}{I} = \frac{F}{I} = \left[\frac{100\frac{J}{cm^2}}{80\times10^{-3}\frac{W}{cm^2}}\right] \times \frac{1min}{60s} = 20.8min \sim 21min$$

This is within a reasonable time limit for a therapeutic procedure.

c. The goals would be to maximize absorption for the photosensitizer, in this case phthalocyanine, and at the same time to minimize hemoglobin absorption, which is not specific to tumors. Since phthalocyanine has an absorption peak and hemoglobin absorbs relatively weakly at the region between $600nm$ to $720\ nm$, the red gold vapor laser ($630nm$), Krypton laser ($676.4nm$), and dye laser operating in this wavelength range would be reasonable choices. The helium-neon laser has a good match, but in fact the powers achievable tend to be too low for this use. The ruby laser is a similarly good wavelength match, but the pulsed operation is not desirable in this application.

d. The reason lasers are a good choice involves both their spatial coherence, necessary because of the need for relatively high power densities over a small region of tissue, and their temporal coherence, which is important to guarantee that the power density delivered is concentrated at the absorption peak of the photosensitizer, while avoiding high levels of absorption by other body tissues, such as blood. The very similar absorption properties of hemoglobin and many photosensitizers especially make the latter criterion highly important.