EE 4BD4 Lecture 19

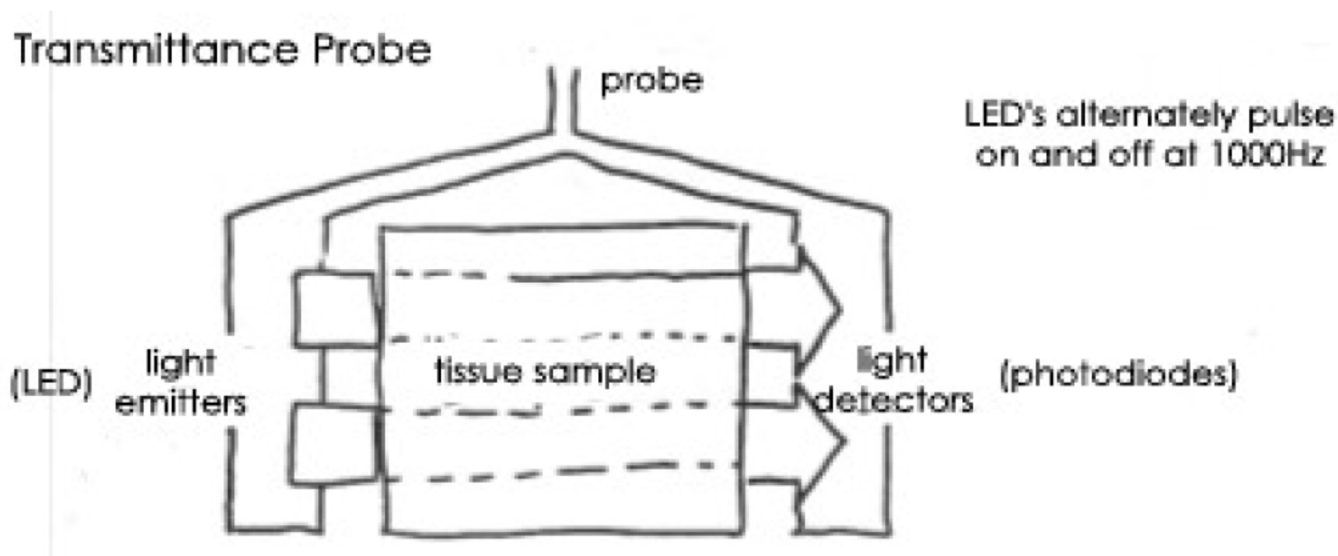
Pulse Oximeter

Utility

- Replace direct observation of blood oxygenation (pallor, cyanosis) or frequent arterial blood analysis
- Based on differential absorption of Red and Infrared light by oxygenated and deoxygenated hemoglobin
- Has become the standard instrument for SaO_2 measurement in the OR, PACU, NICU, ER, etc. and even the wards of a hospital
- $SaO_2 = O_2Hb/(O_2Hb+HHb)$
- First developed by Hewlett Packard in the middle 1970’s but is now a product of companies like Nellcor
- Relatively inexpensive with a typical monitor < $3000.

Instrumentation

- 2 LED's on one side of tissue 1 photodiode on other



Light Absorption by Hemoglobin

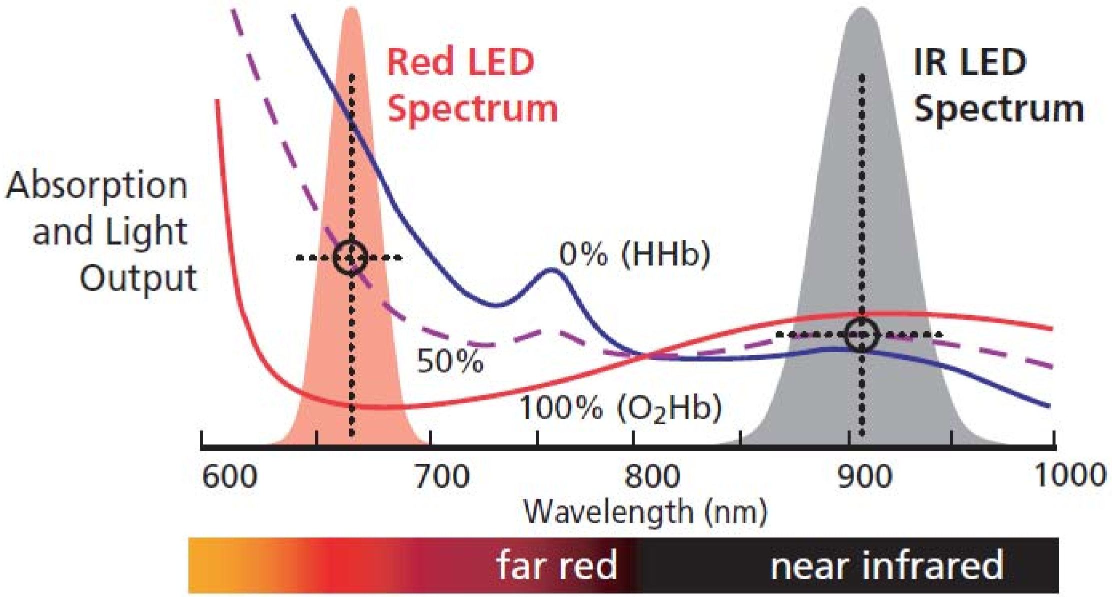


Figure 1
Overlay of typical LED-emitted light spectrum and relative light absorption spectra of oxygenated and deoxygenated hemoglobin. The dashed purple line indicates the spectra of 50%-saturated blood, with the relative absorbance in the red and IR indicated by the black circles.

Light Absorption by Tissue and Fluids

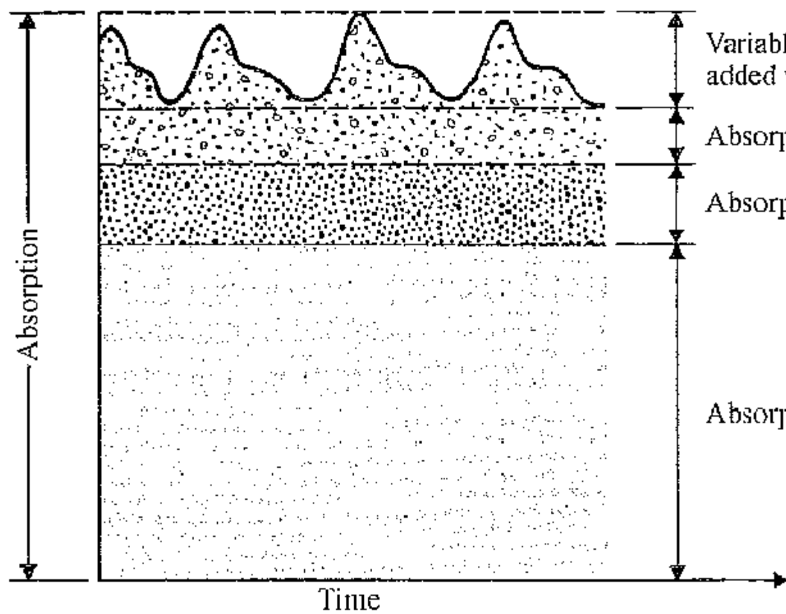


Figure 10.19 The pulse oximeter analyzes the light absorption at two wavelengths of only the pulse-added volume of oxygenated arterial blood. [From Y. M. Mendelson, "Blood gas measurement, transcutaneous,"in J. G. Webster (ed.), *Encyclopedia of Medical Devices and Instrumentation.* New York: Wiley, 1988, pp. 448–459. Used by permission.]

Relative Signal Effects

- Only pulsatile signal is retained (represents arterial blood only) by the equivalent of high pass filtering the signal or subtracting the constant baseline representing absorption by tissues and fluids that don't change volume or characteristics over time
- At High SaO_2 red light is absorbed much less by haemoglobin so pulse height due to red is small while that of IR is higher (i.e. there is less effect on the received signal due to pressure pulse).
- The reverse is true for low SaO_2

Pulsatile Waveforms

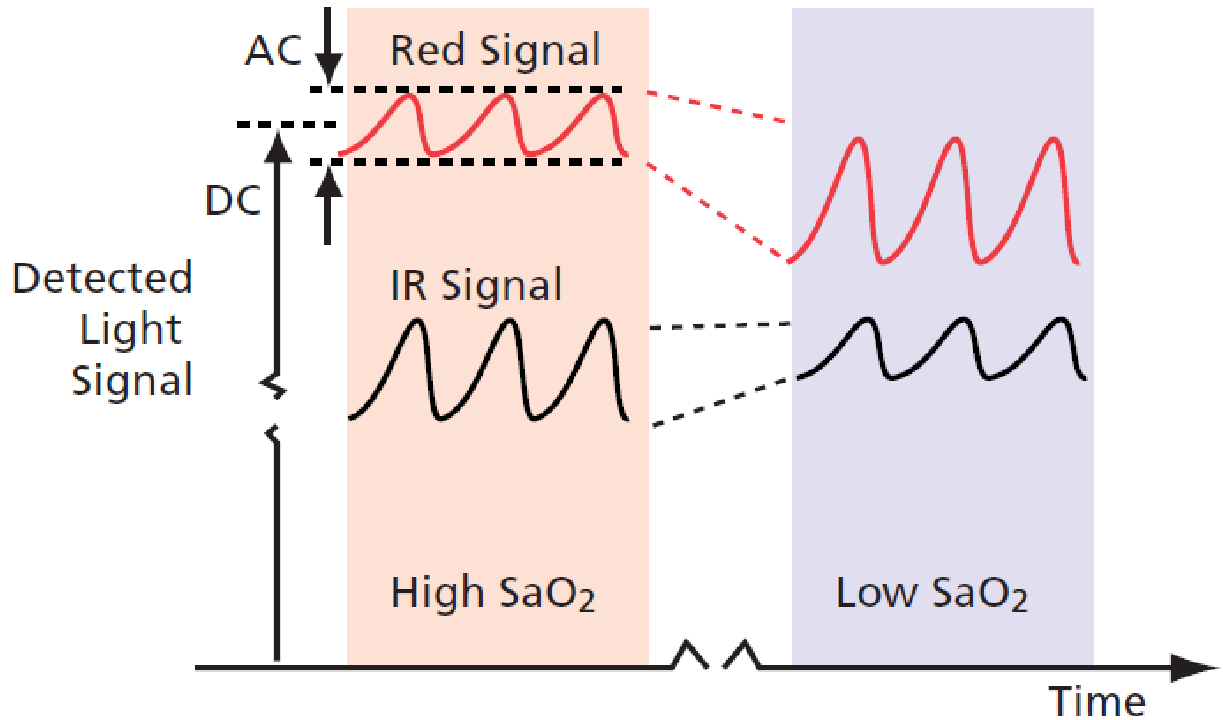


Figure 2
Red and IR light signals at high and low arterial oxygen saturation. At high saturation, the red "pulse amplitude" (AC/DC) is smaller than in the IR. At low saturation, the ratio of relative amplitudes is reversed.

Calibration Curves

- Ratio of Red to IR absorption R = ΔR/ΔIR is used to calculate SaO_2
- $SaO_2 = K_1R^2 + K_2R + K_3$ where K_1, K_2 and K_3 are constants
- LED's pulse on and off at 1 kHz
- Resulting SaO_2 averaged over 6 or 3 sec
- Updated .67 or .33 sec
- Accurate within 1% and can replace chemical sensor tests

Calibration Curves

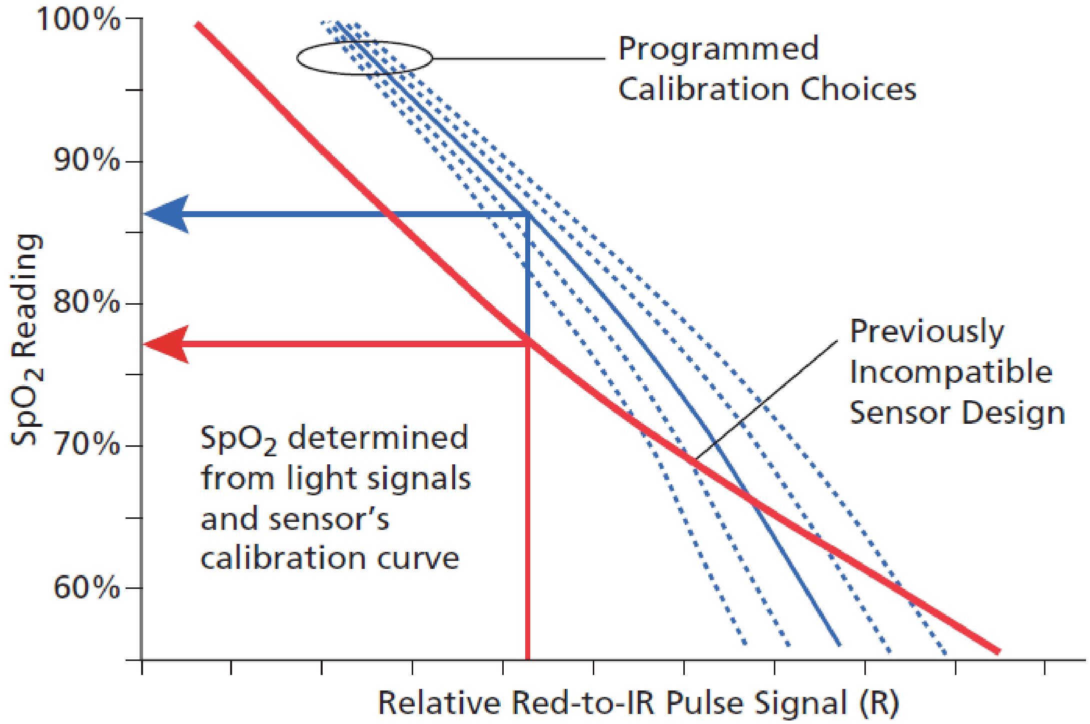


Figure 3

The blue lines depict the one or more calibration curves programmed into earlier-generation monitors, while the red line indicates a calibration required of a hypothetical new sensor. Such a design would be incompatible with these earlier monitors, since none of the blue curves could provide accurate SpO_2 values for the sensor's signals.

Design Considerations

- Eliminate effect of background light by measuring output when LED's are off
- Effect of skin colour and thickness on signal quality (autogaining or increasing LED power)
- Poor perfusion resulting in small pulsatile component
- Plethysmogram display for signal quality and to give pulse rate
- Interference from motion of probe, ambient light, EM from electrosurgical unit
- Levels of certain substances in blood can cause erroneous SaO_2 (elevated levels of carboxyhemoglobin, methemoglobin levels, etc.