USC University of Southern California

ECE 105: Introduction to Electrical Engineering

Lecture 13

Bio 3

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Pulse oximetry

ECG

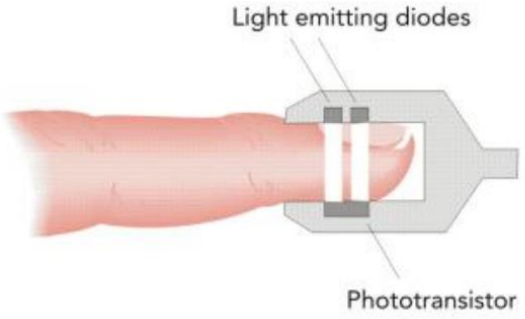
Pulse Ox

Respiration

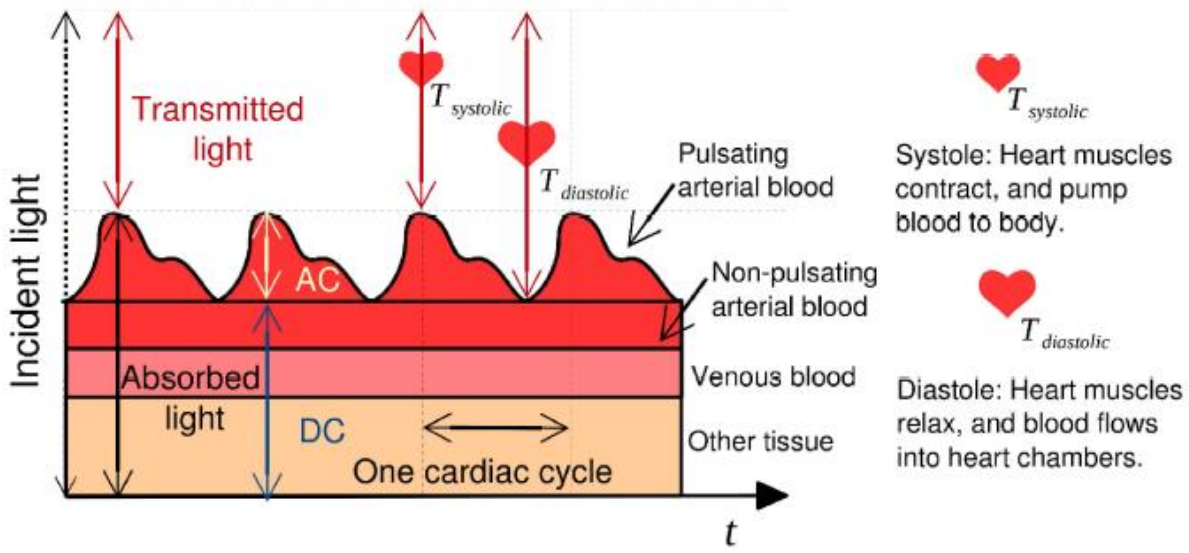
Blood Pressure

Temperature

- Pulse oximetry measures blood oxygenation. Using spectrophotometry of absorptivity of blood at two distinct wavelengths, blood oxygen saturation is quantified.
- Can detect hypoxemia, ie. lower than normal blood oxygenation.

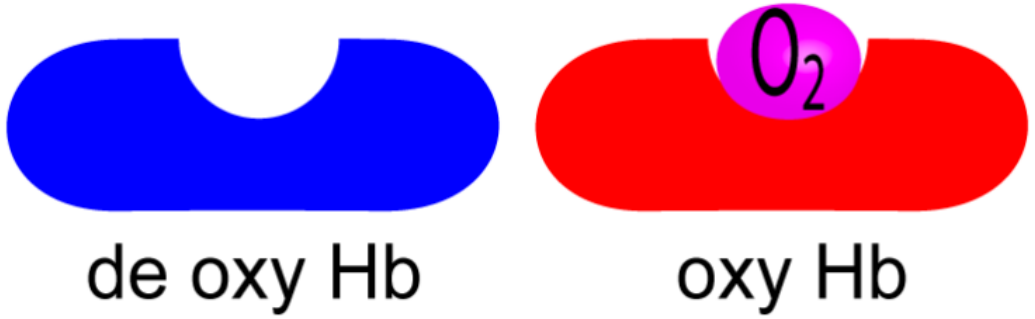


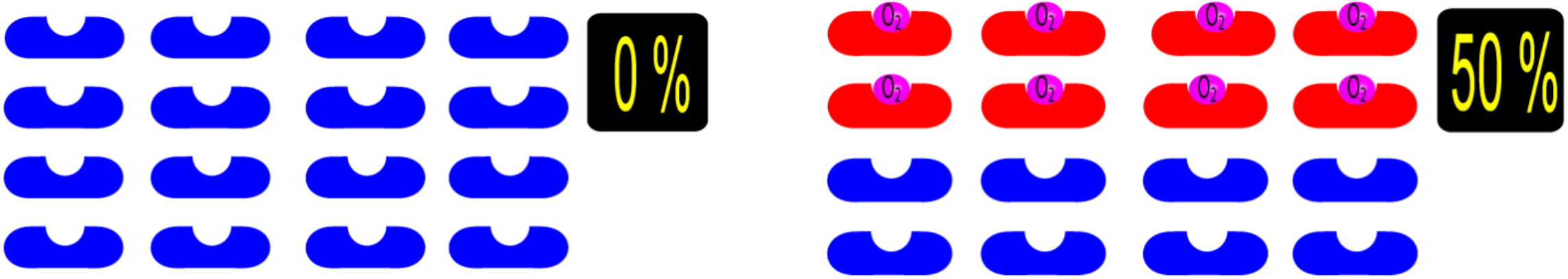
$$SO_2 = \frac{C_{HbO_2}}{C_{HbO_2} + C_{Hb}}$$



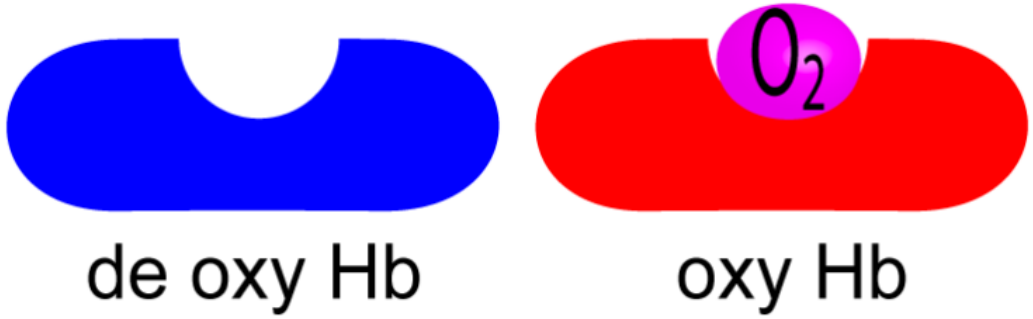
- SO_2 The saturation of oxygen in blood,
- C_{HbO_2} Concentration of oxygenated hemoglobin (HbO_2),
- C_{Hb} Concentration of deoxygenated hemoglobin (Hb).

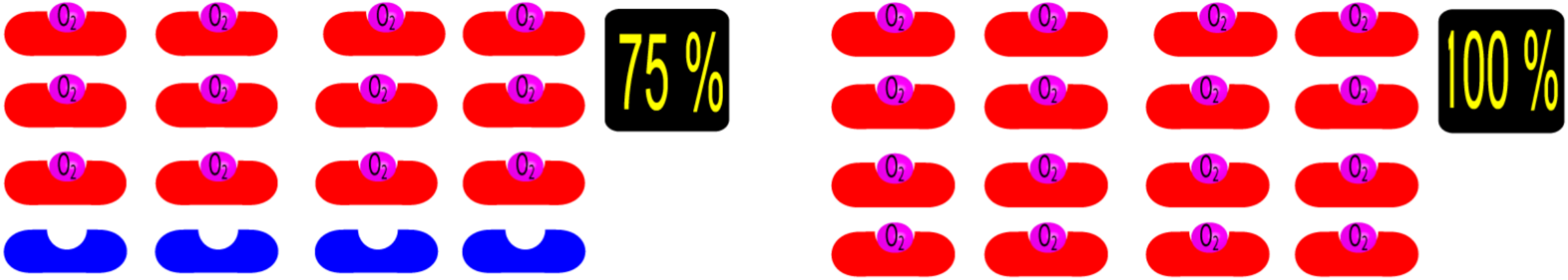
Oxy and deoxy-hemoglobin



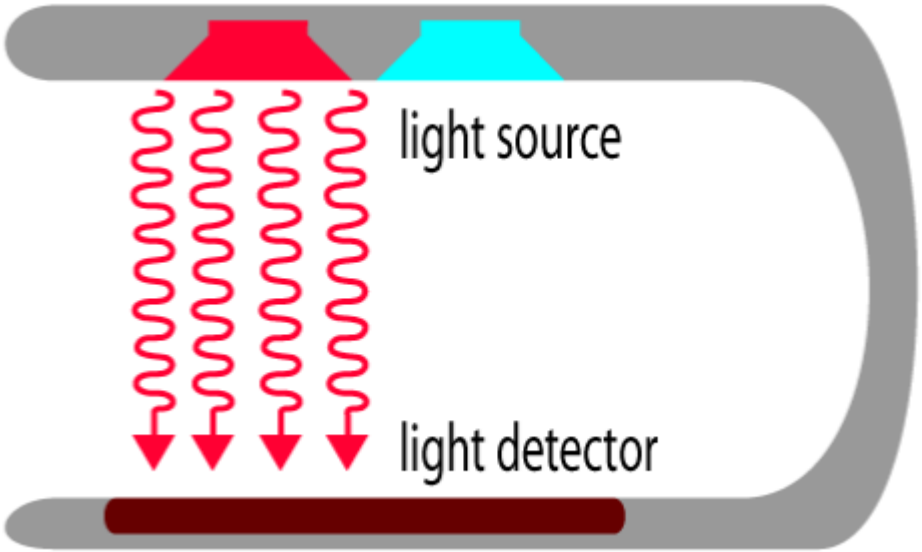


Oxy and deoxy-hemoglobin





Transmission-mode oximetry



How the transmitted light is changing

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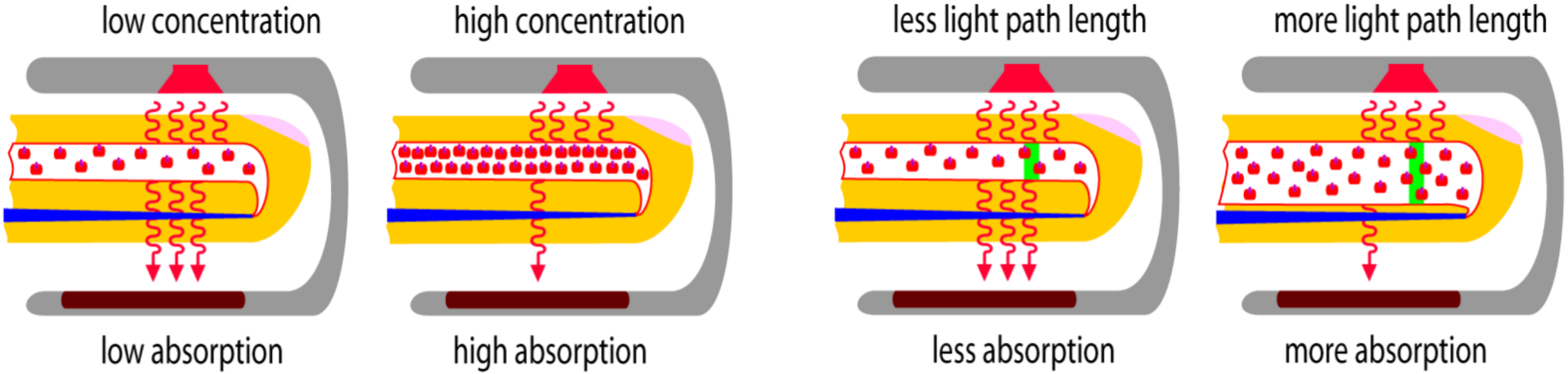
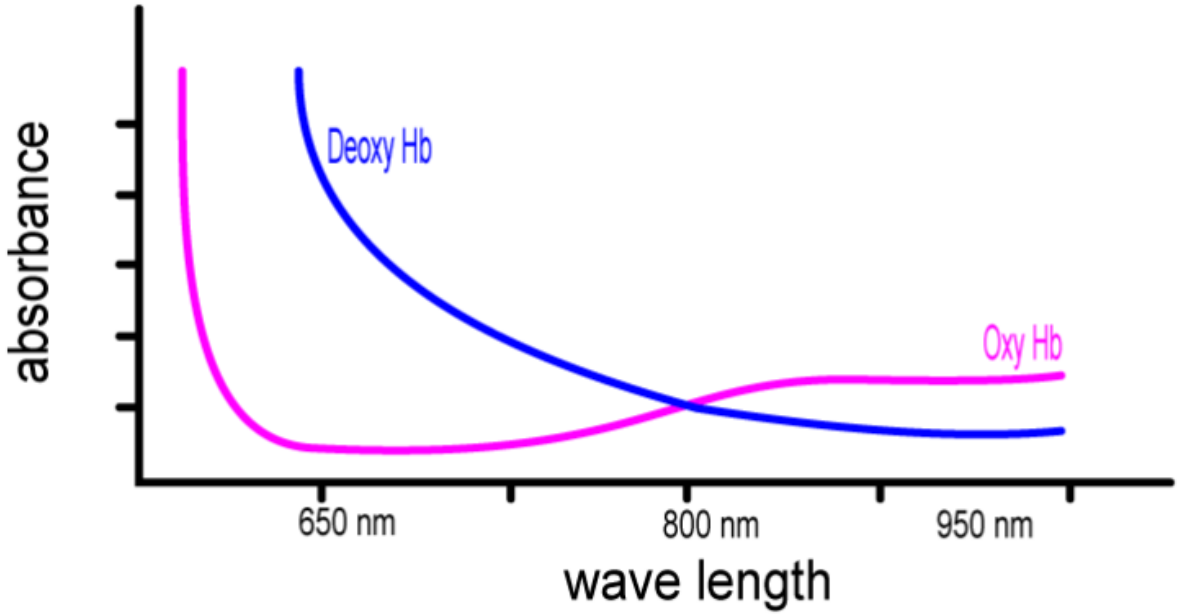
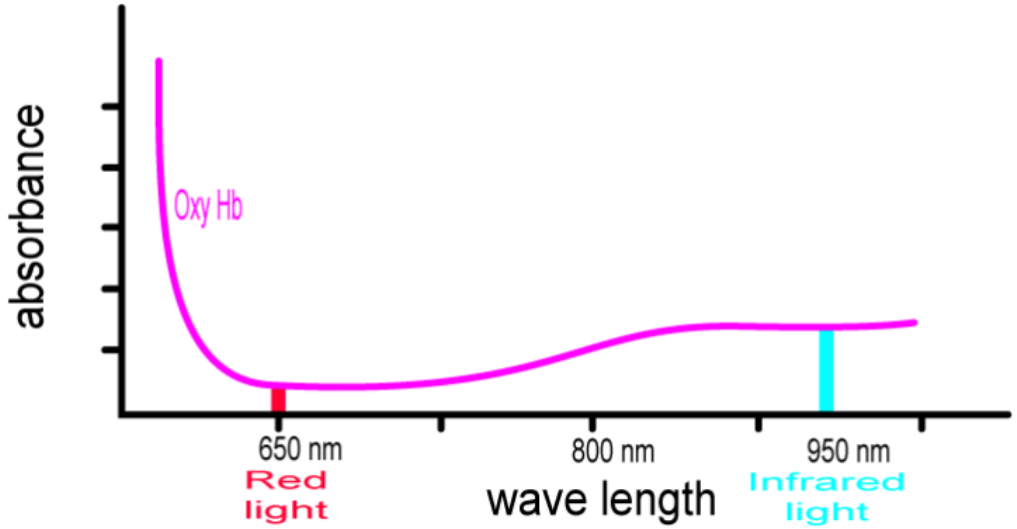
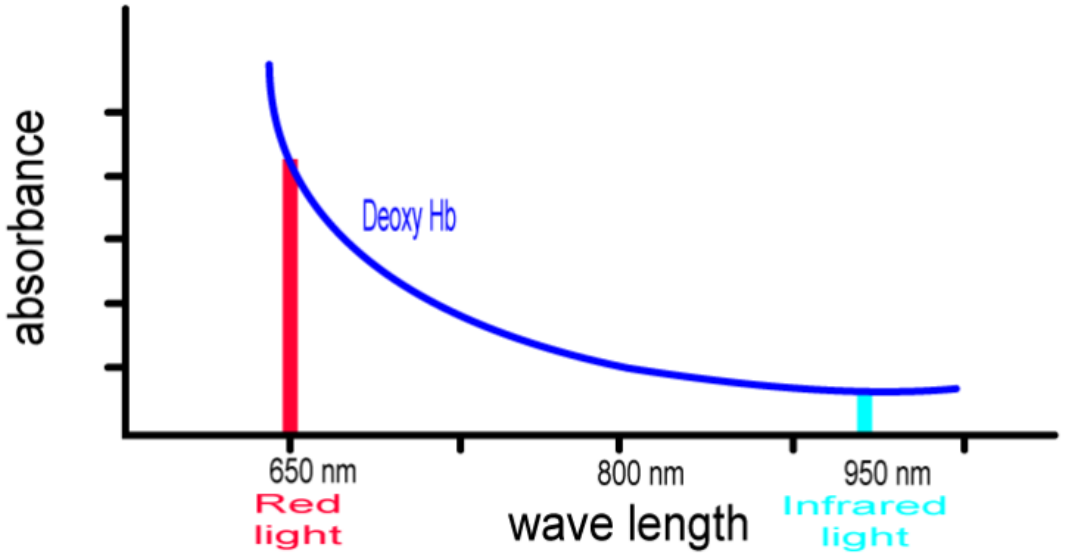


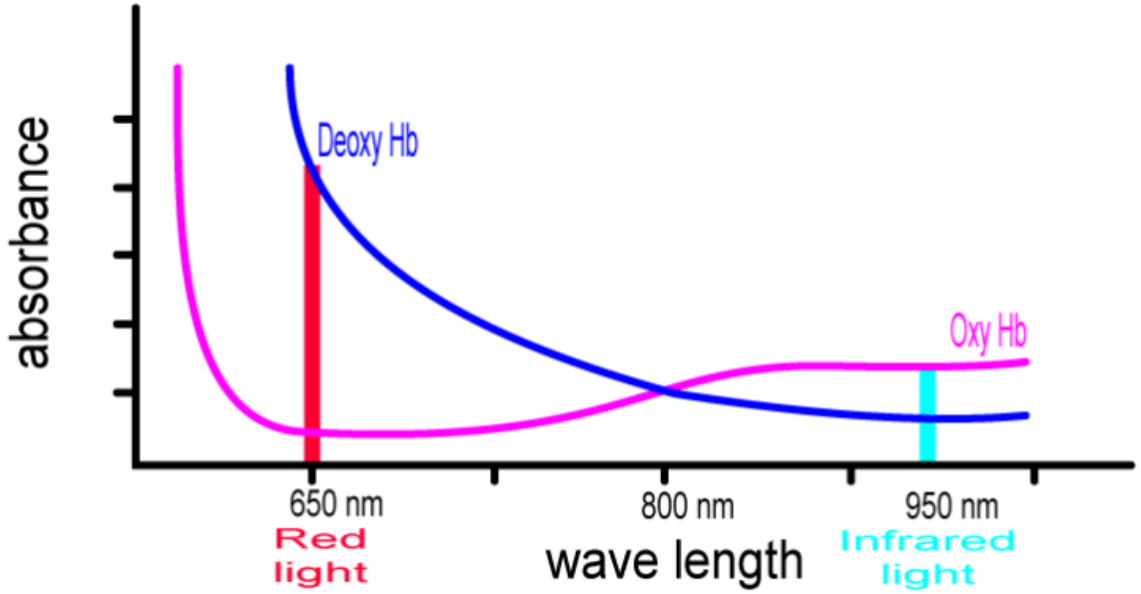
Oxy and de-oxy abs.



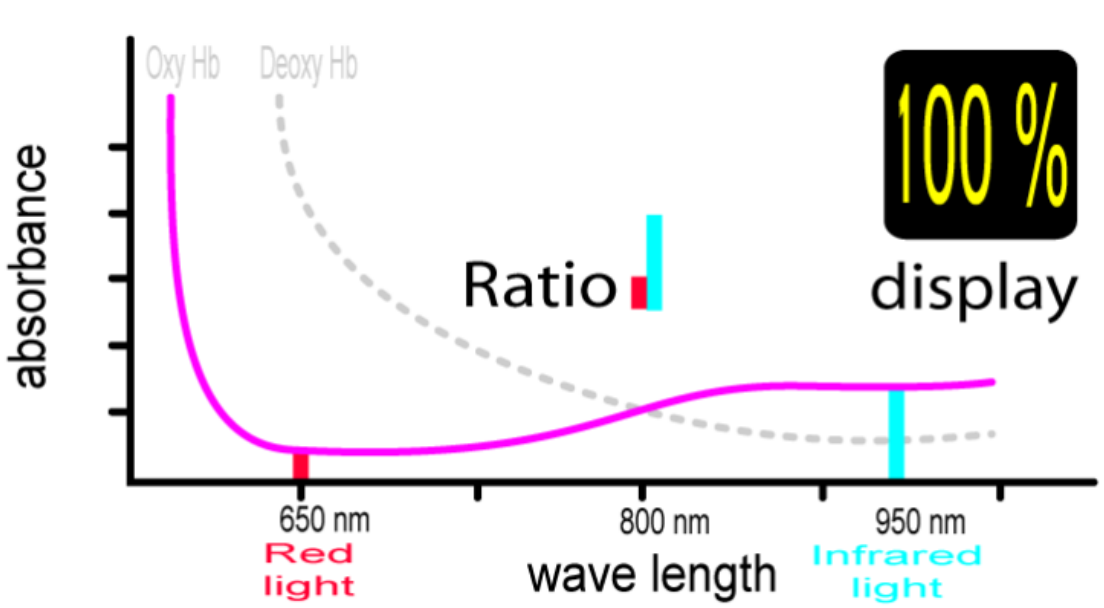
Why do we need two lights

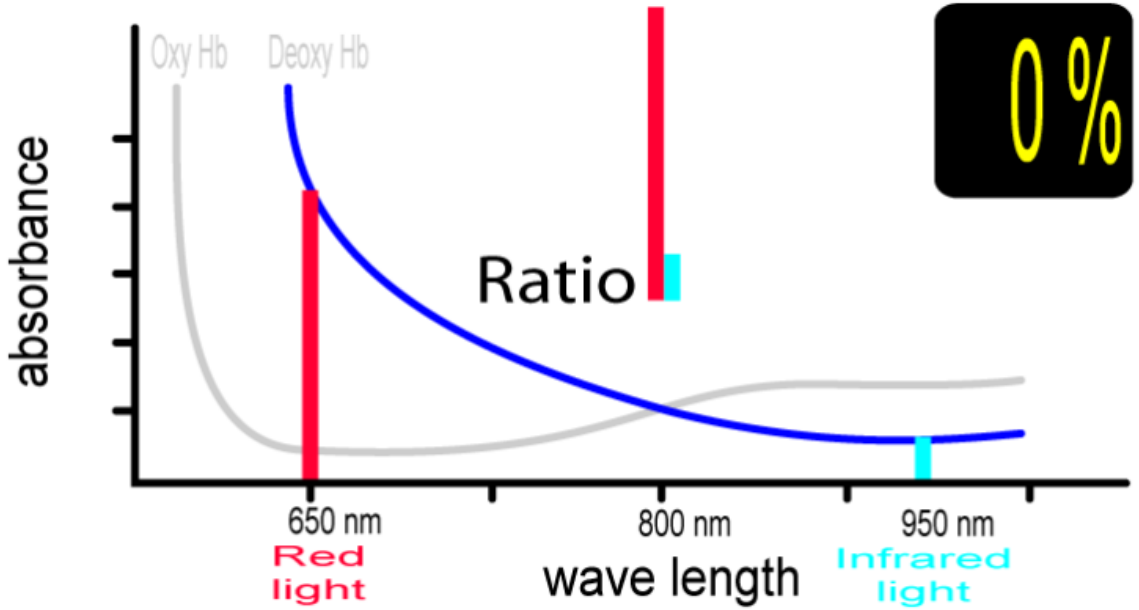


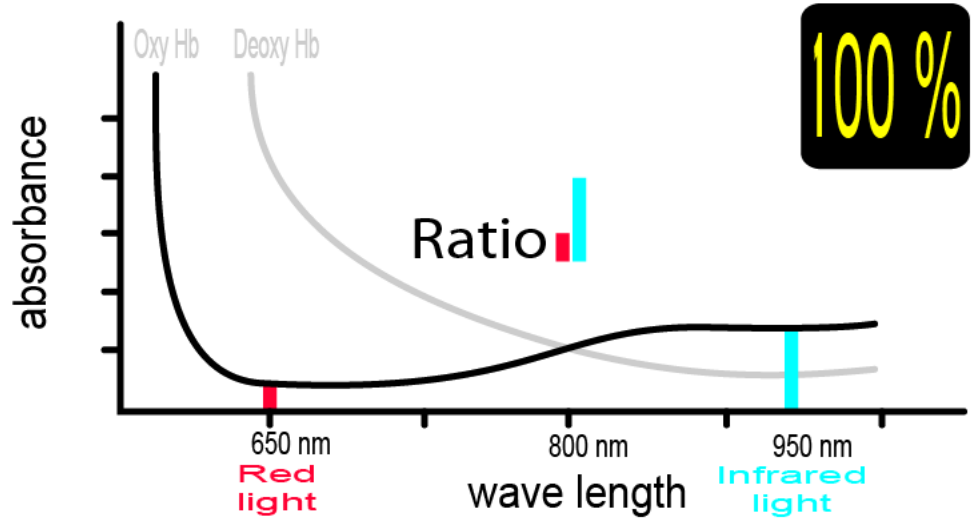




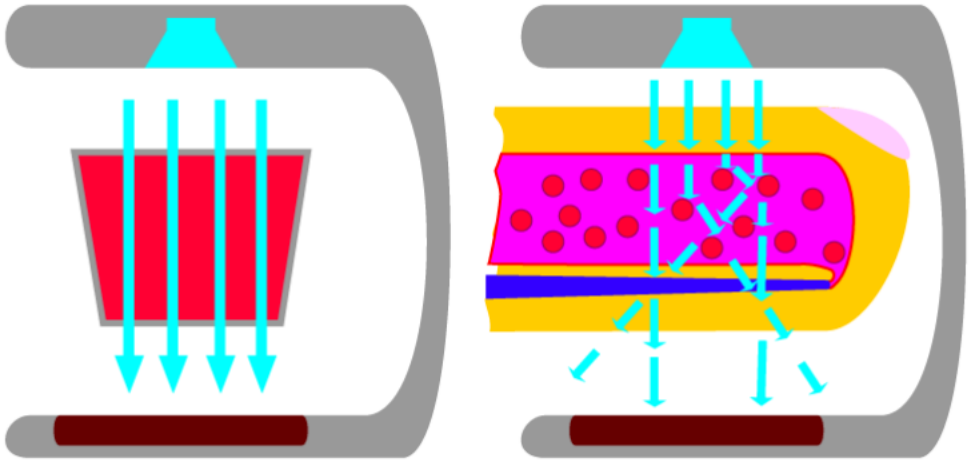
Change in ratio = change in oxygenation

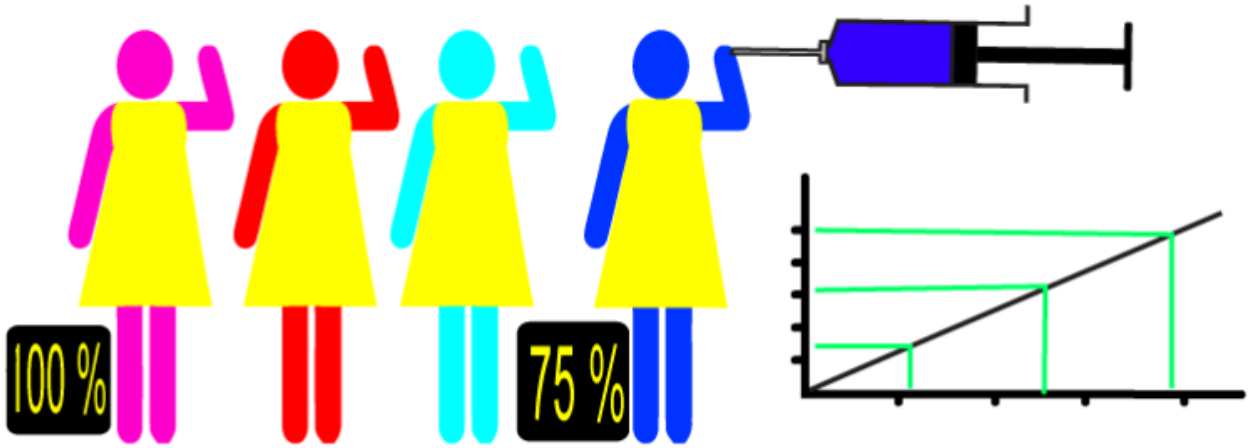




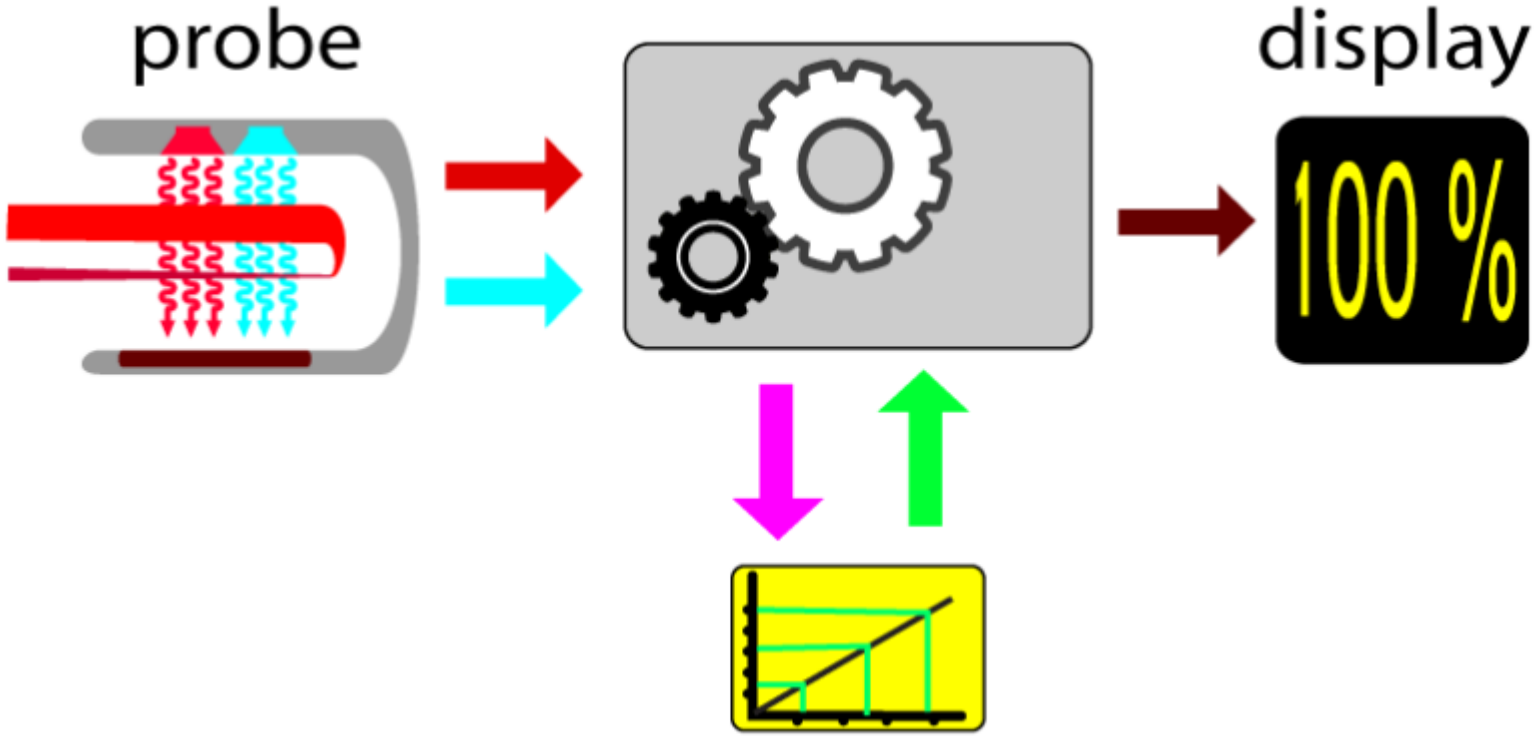


Need for empirical calibration

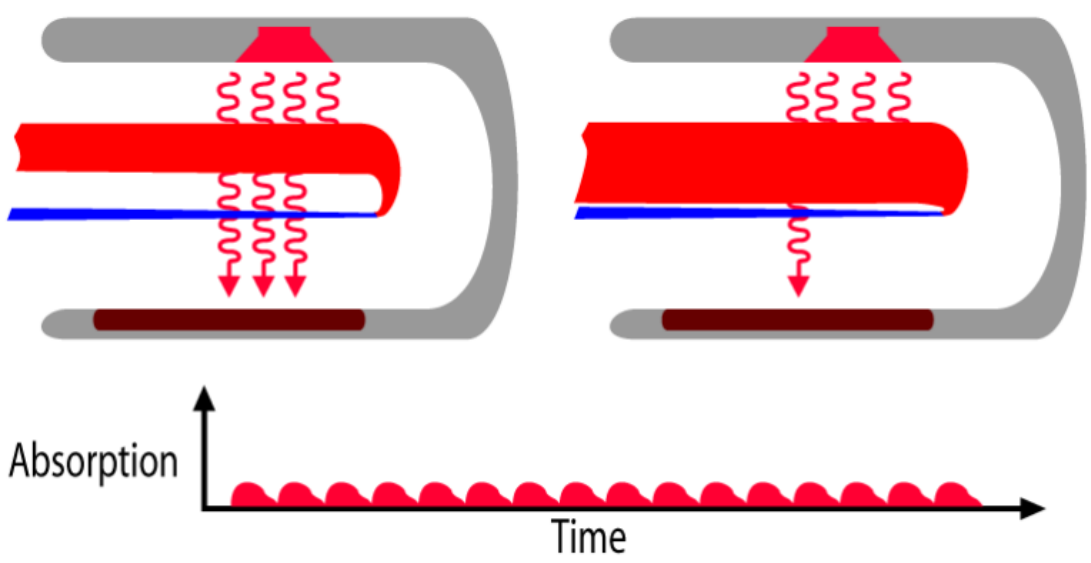


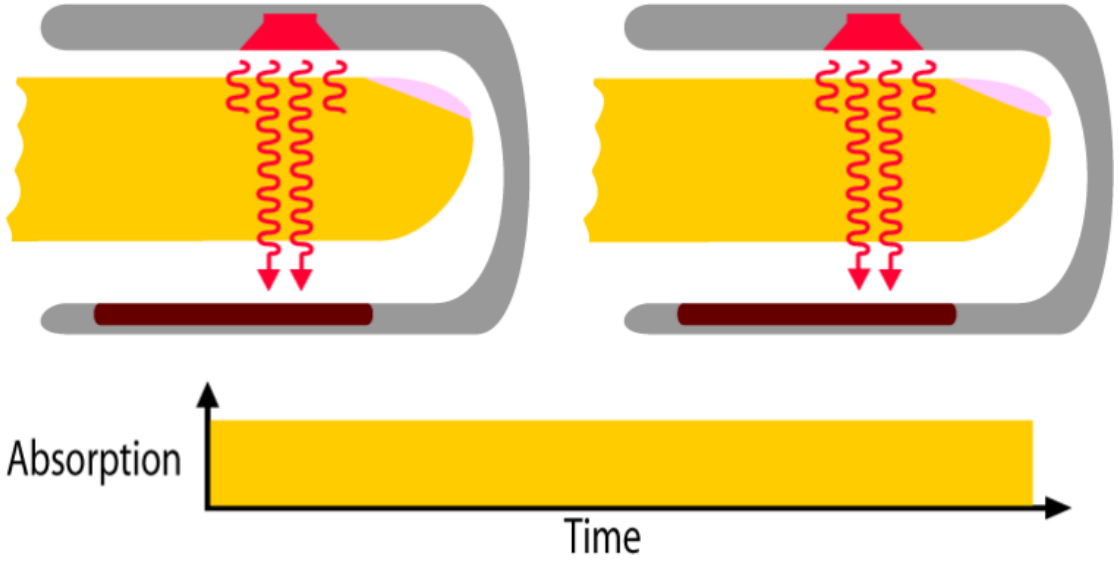


Data collection flow



AC and DC part of the signal





AC and DC part

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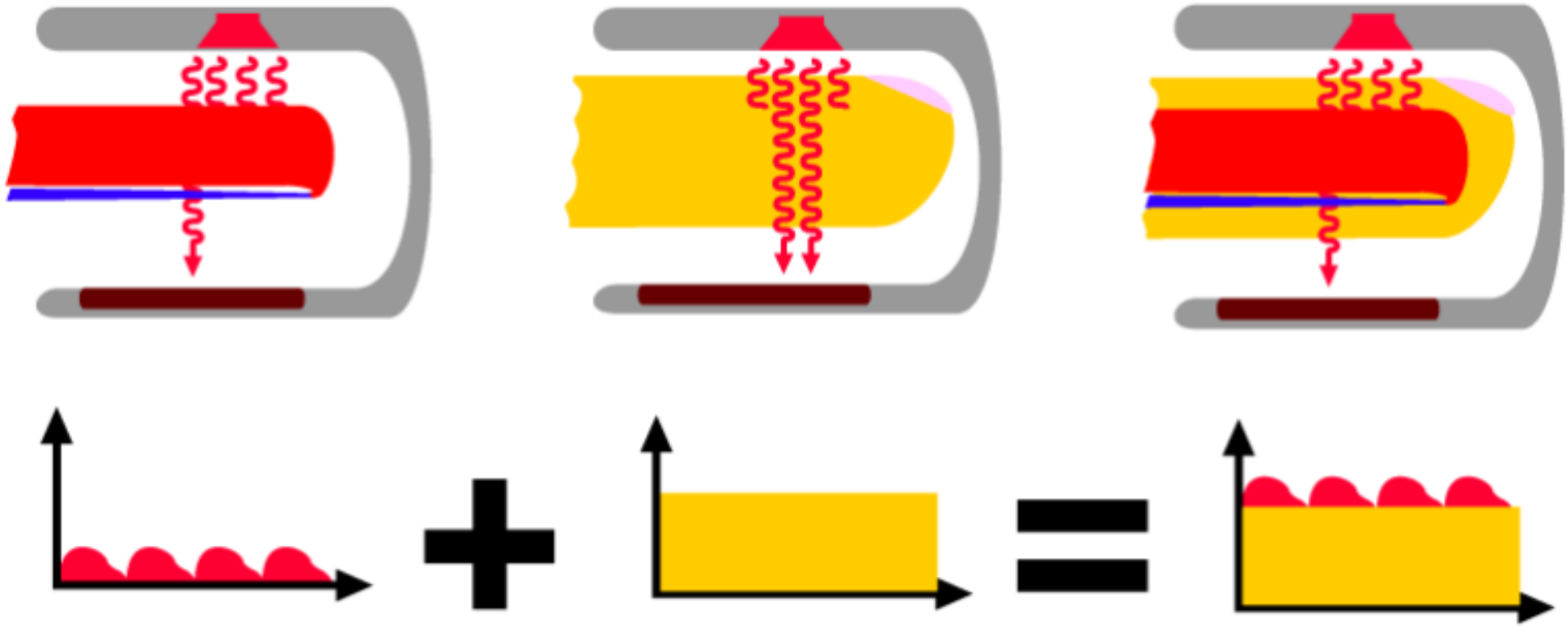
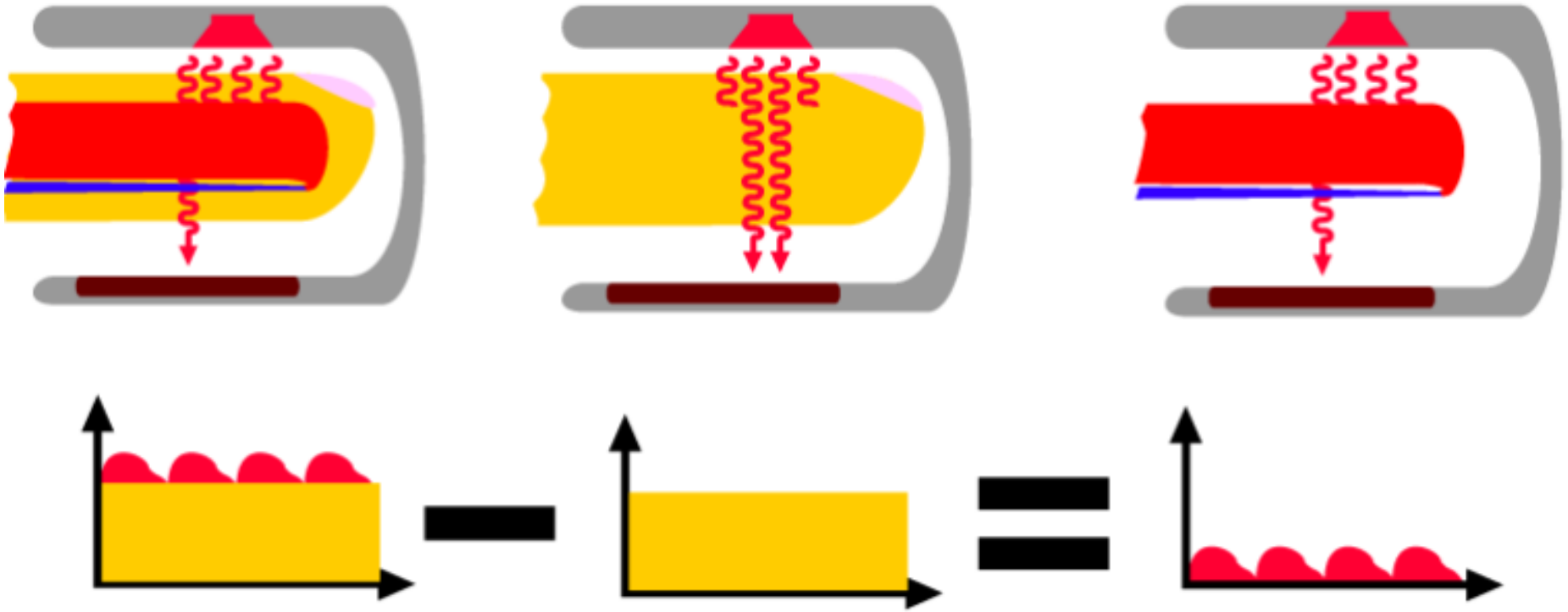
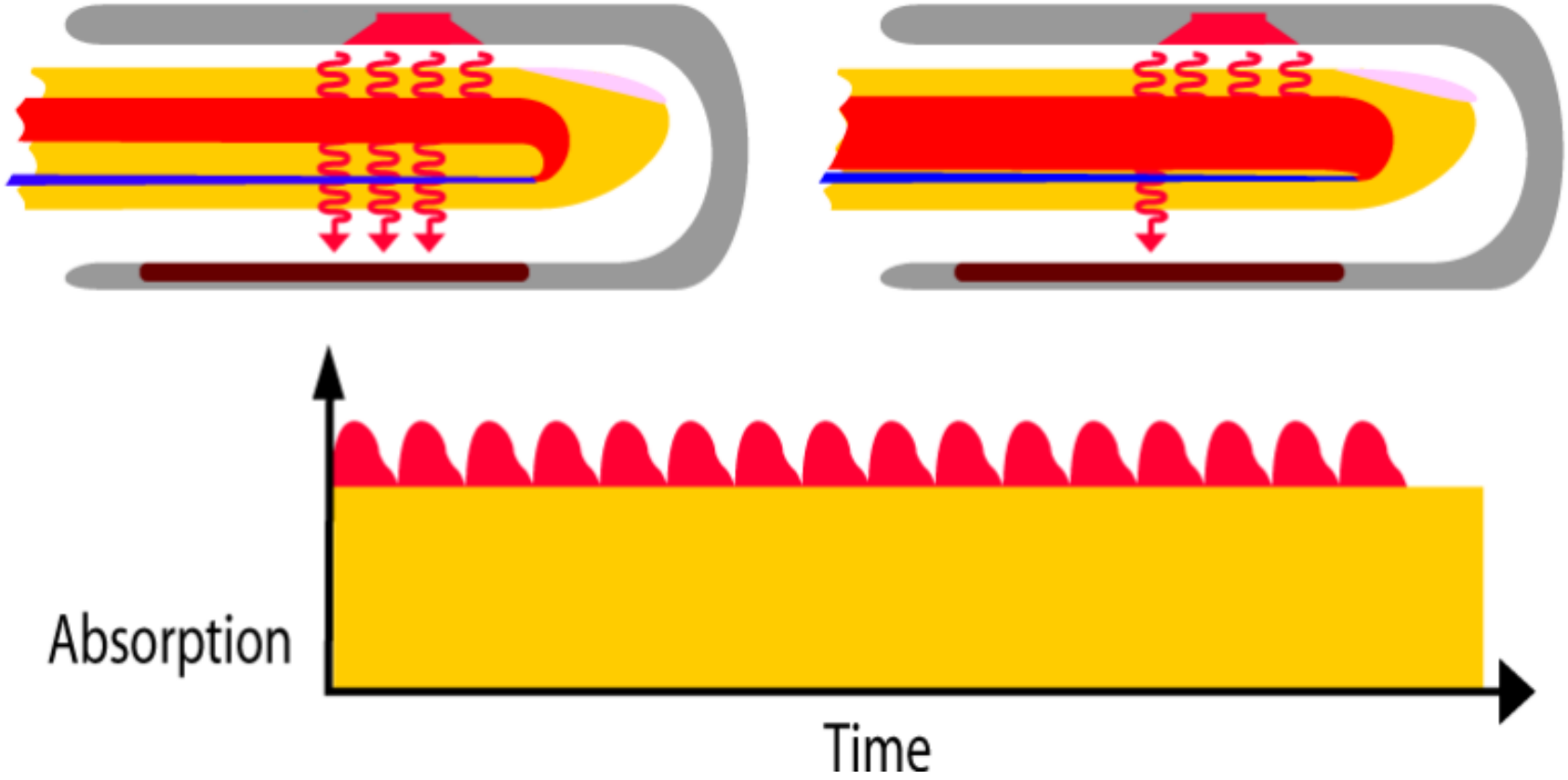


The graphs you will see in your demoboard

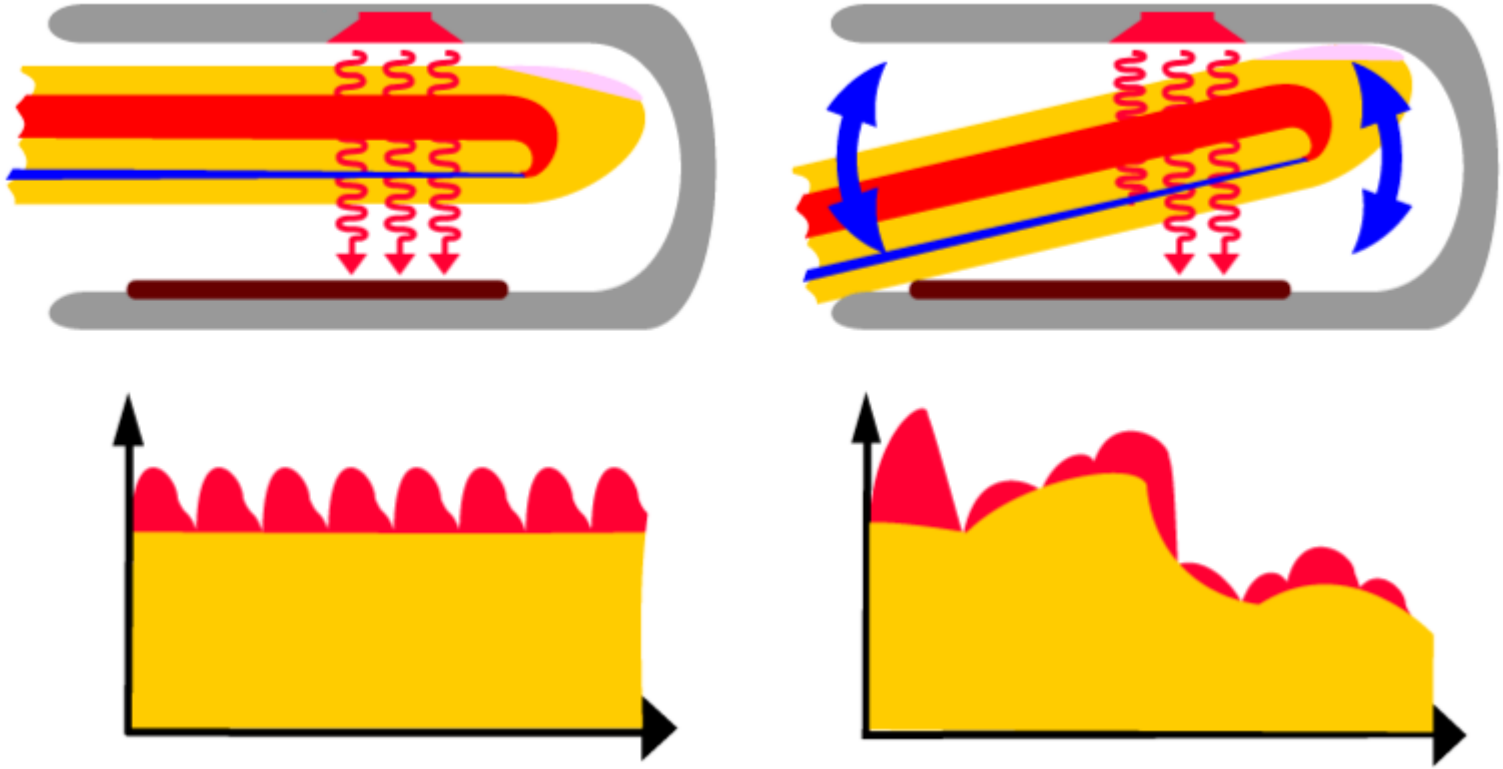


Pulsatile signal

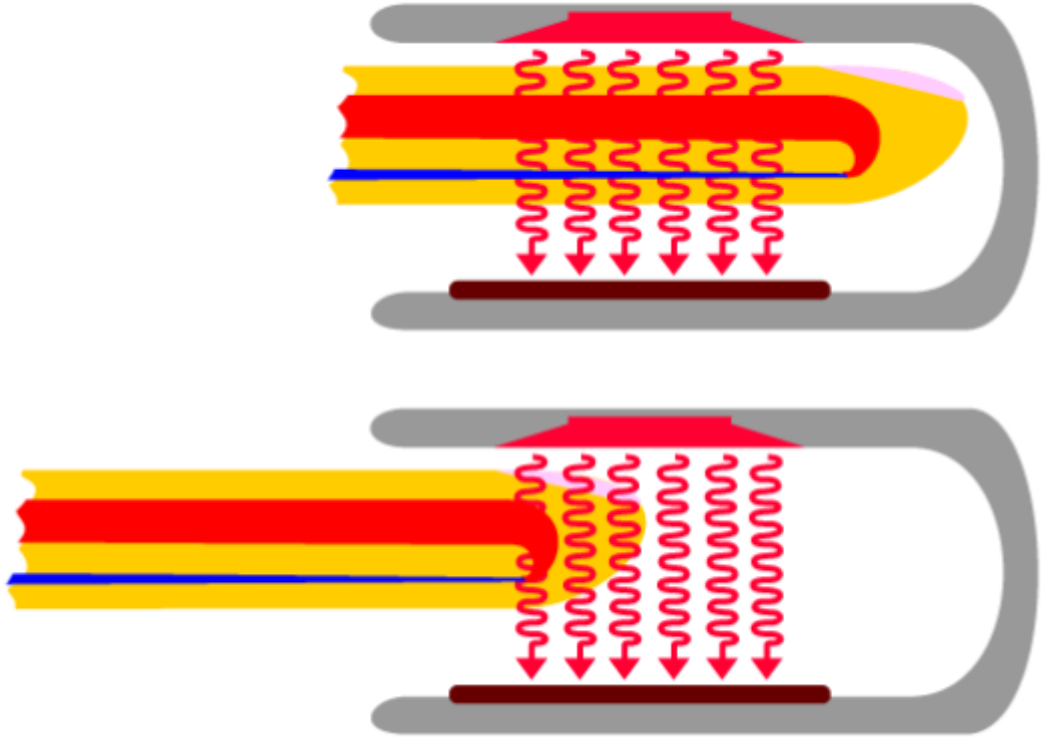


The portion of the AC part is very small

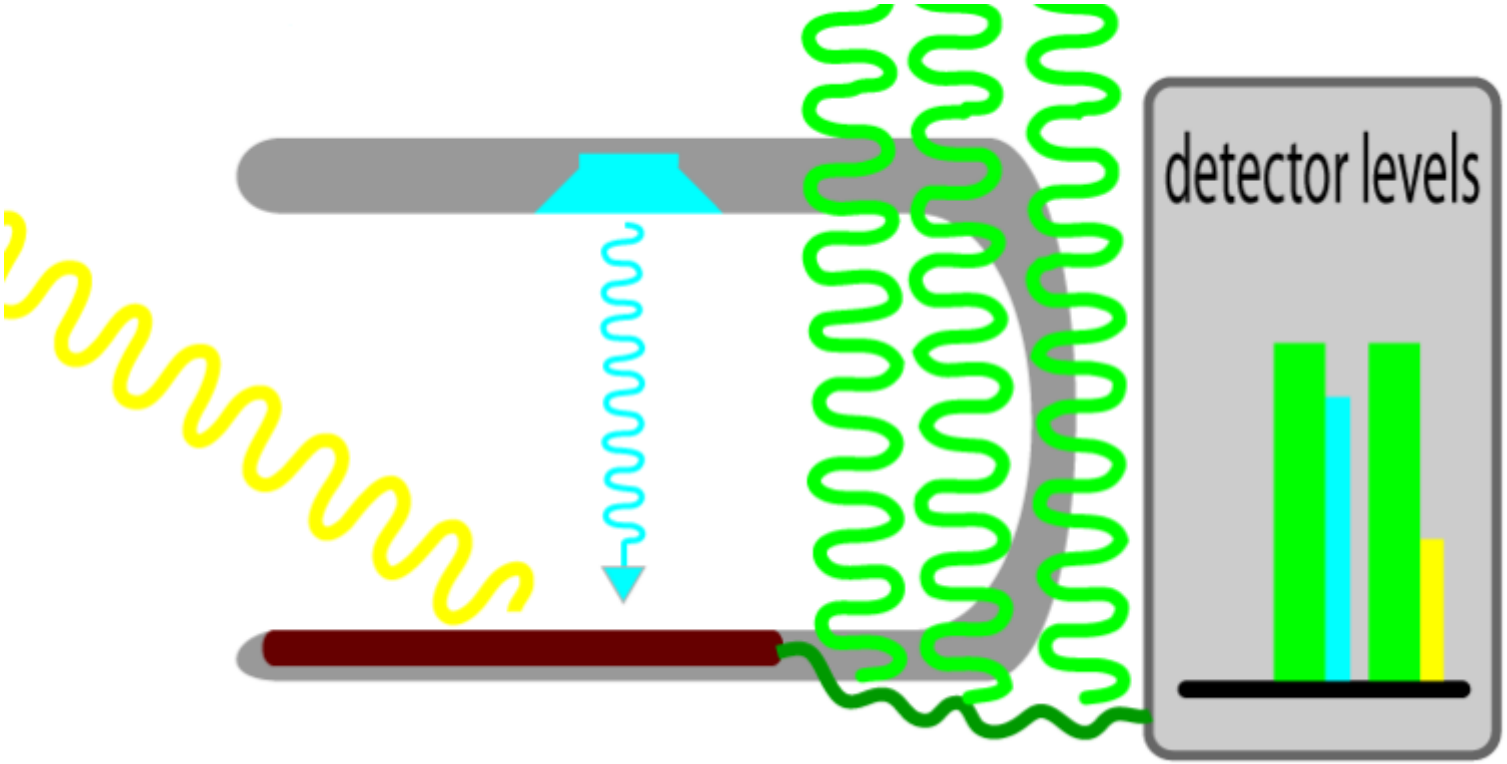
Source of drift



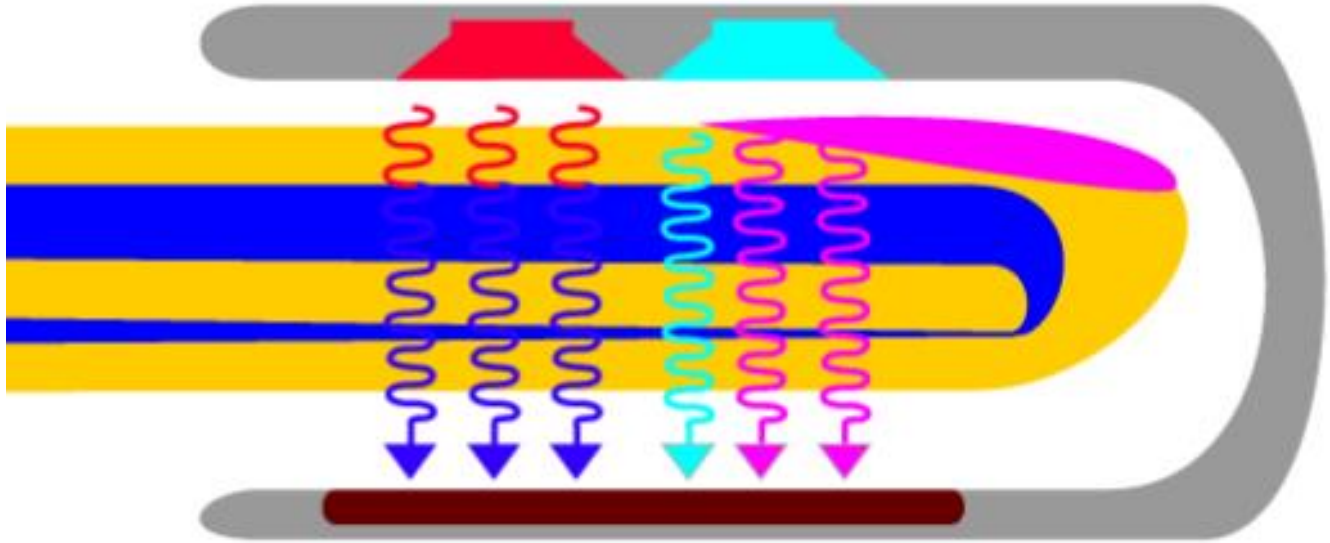
Optical shunting – photodiode gets saturated



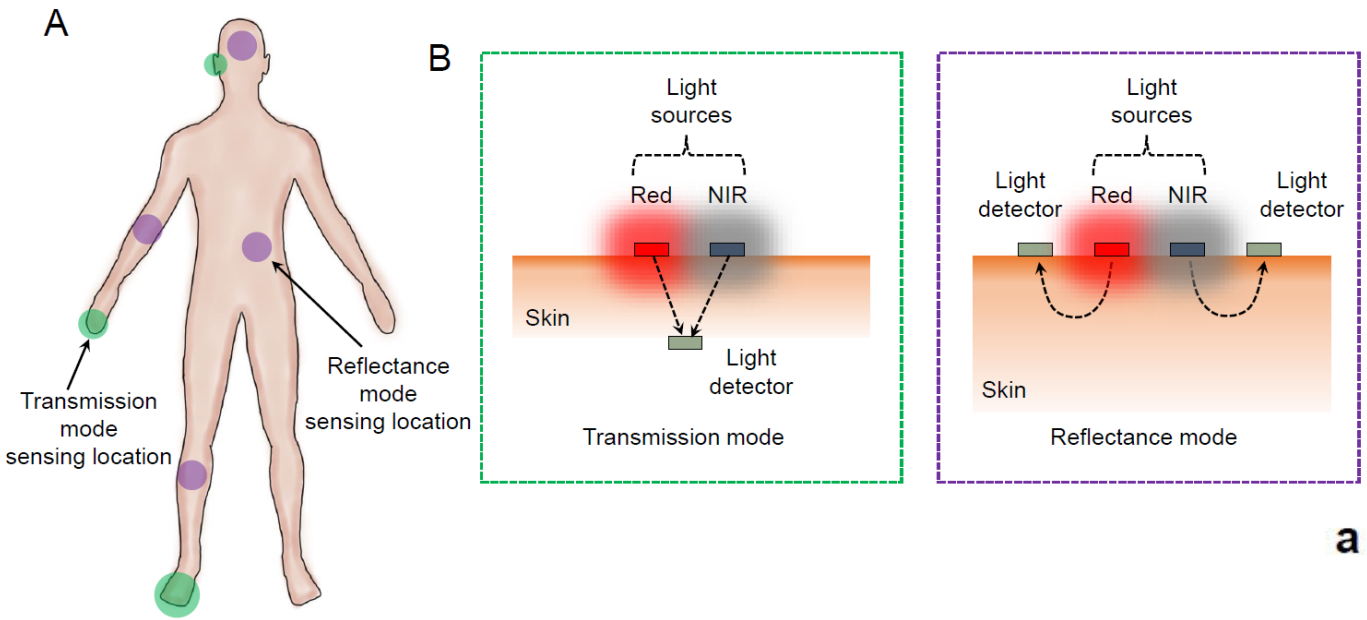
EM noise



Nail polish

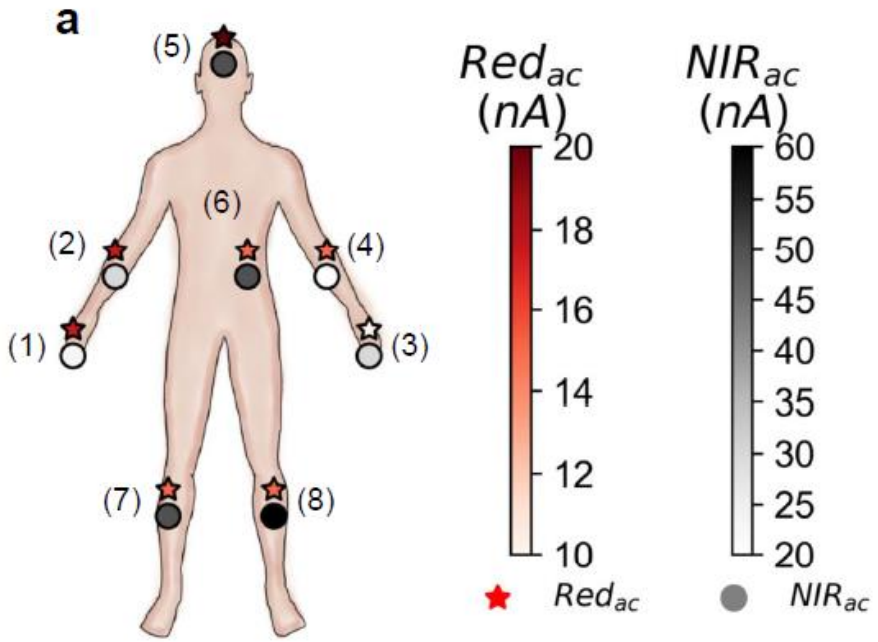


Transmission vs. reflectance oximetry

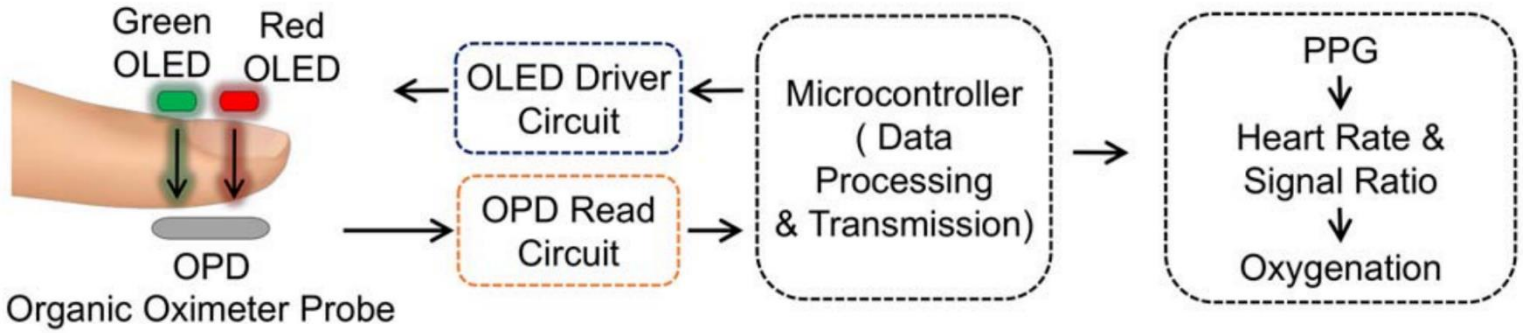


- Transmission-mode pulse oximetry is limited only to tissues that can be transilluminated, such as the earlobes and the fingers.
- If reflected light is used as the signal, the sensor can be used beyond the conventional sensing locations.

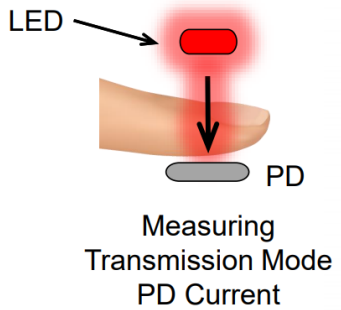
- AC signal is the highest at the forehead for both Red and NIR channels.
- Arms provide mid-range AC amplitude, while signal strength is low in the legs and chest area.
- Forehead is the best location for reflectance pulse oximetry.

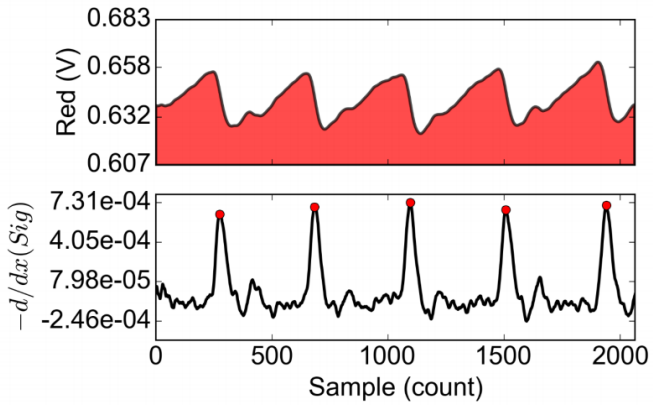


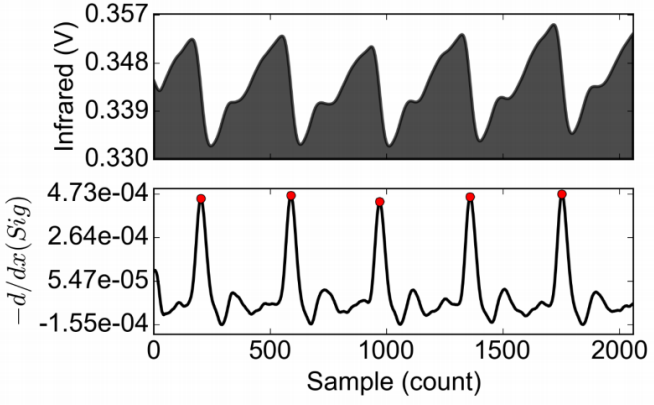
Oximeter readout circuit



Calculating oxygen saturation

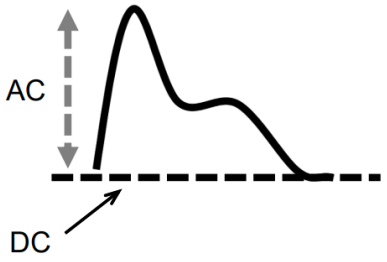


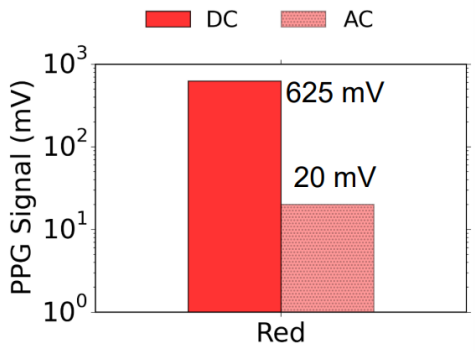


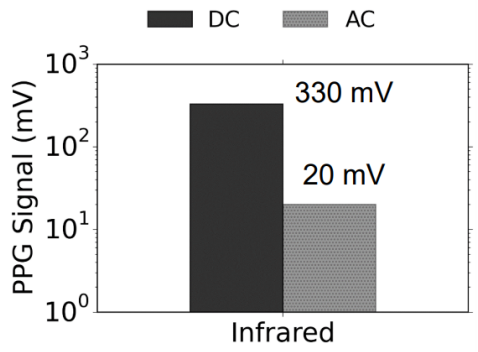


$$R = \frac{AC_{rd}/DC_{rd}}{AC_{ir}/DC_{ir}}$$

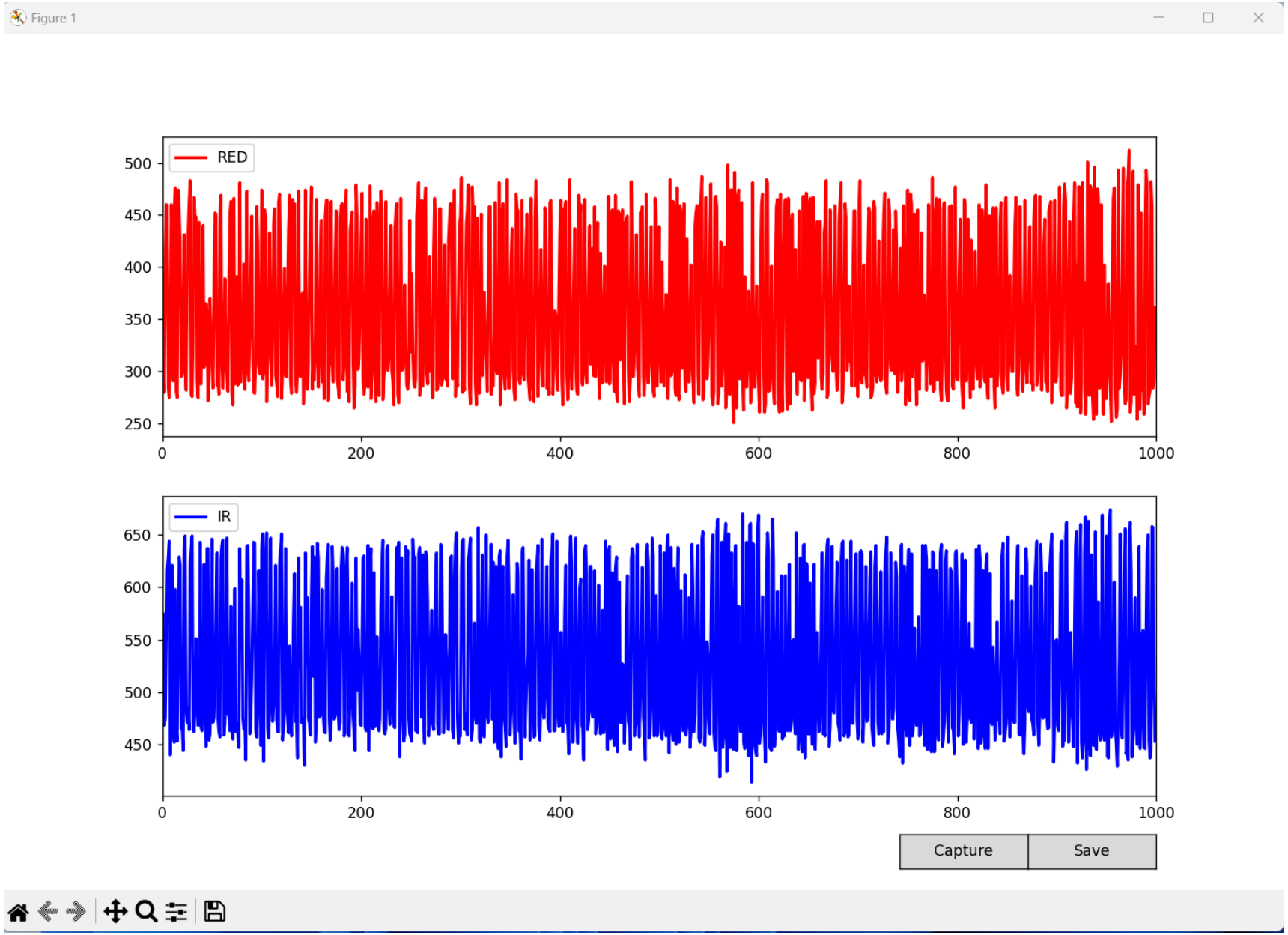
$$R = \frac{20mV/625mV}{20mV/330mV} = .528$$



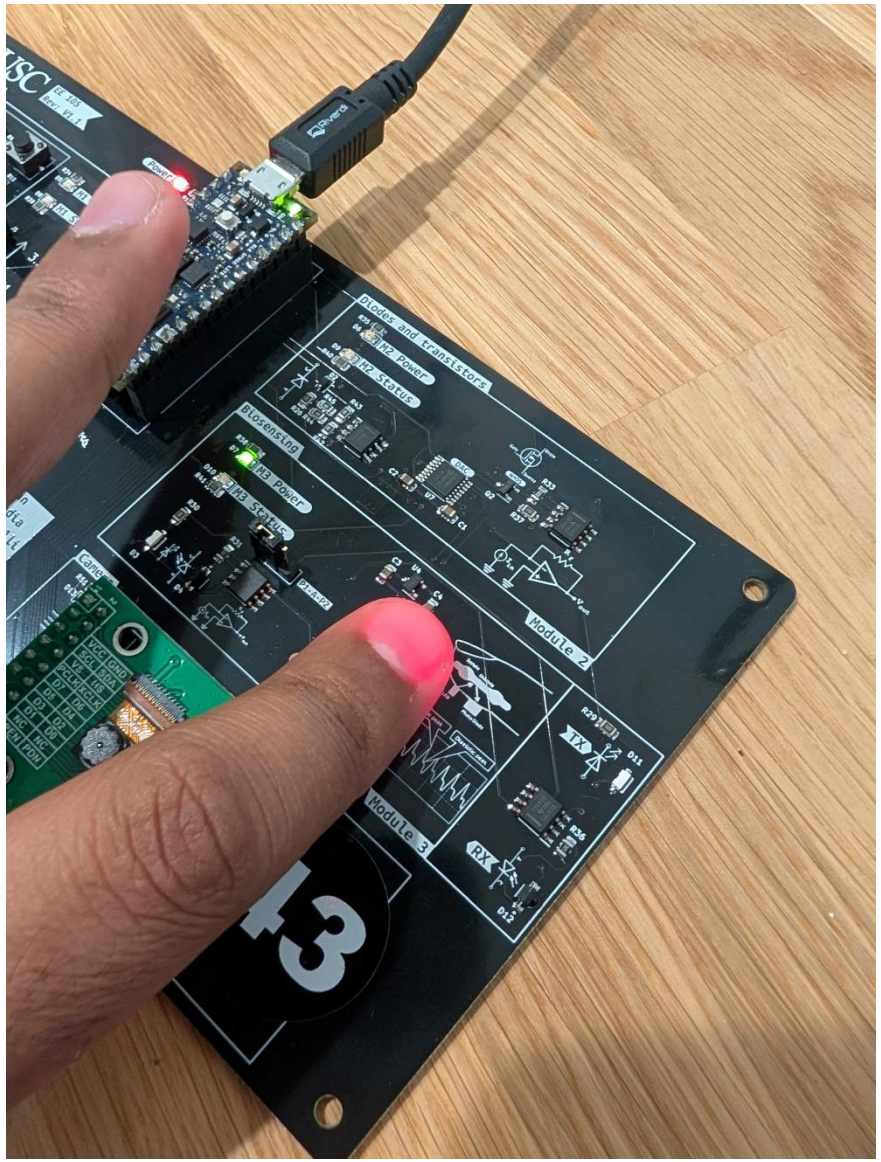


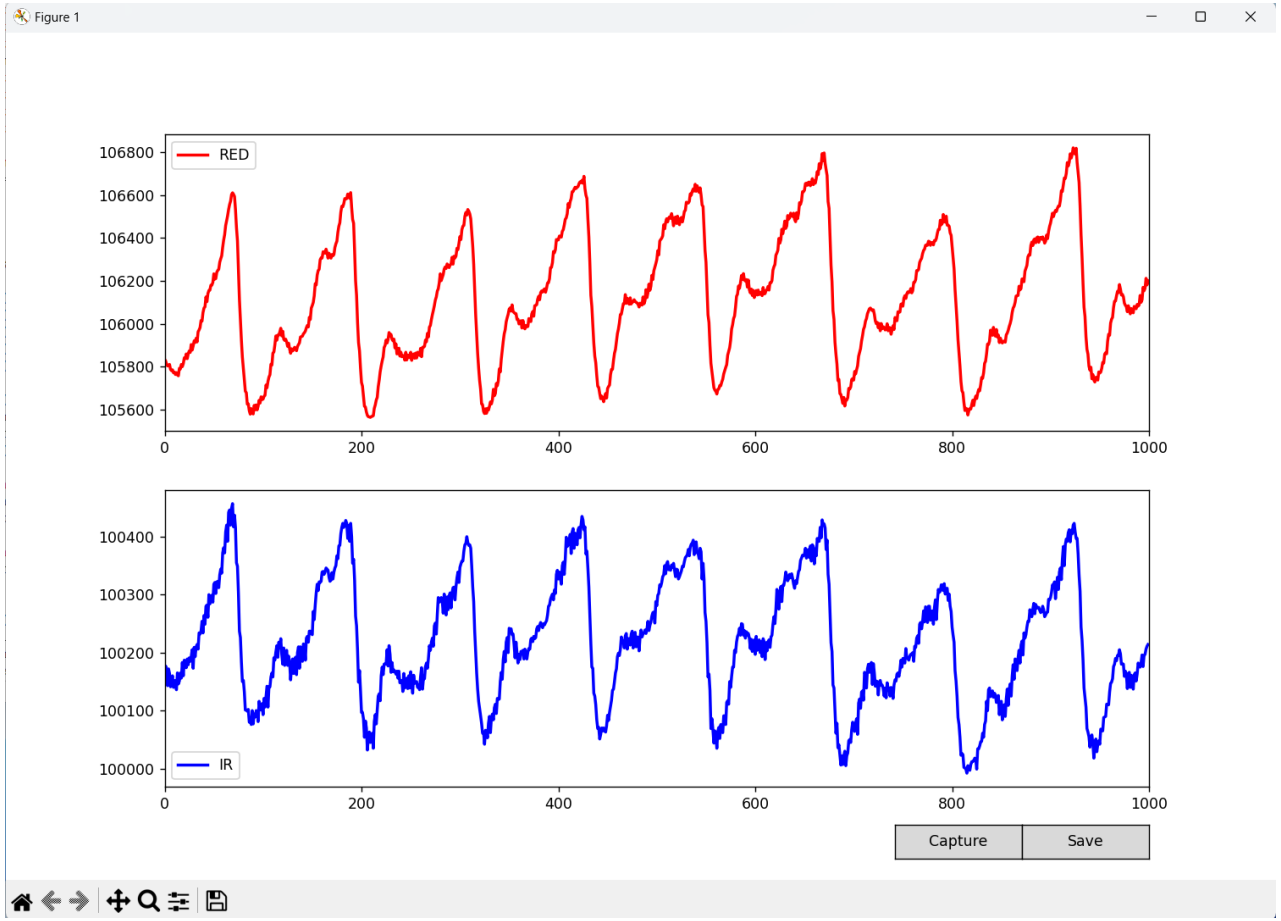


Press capture

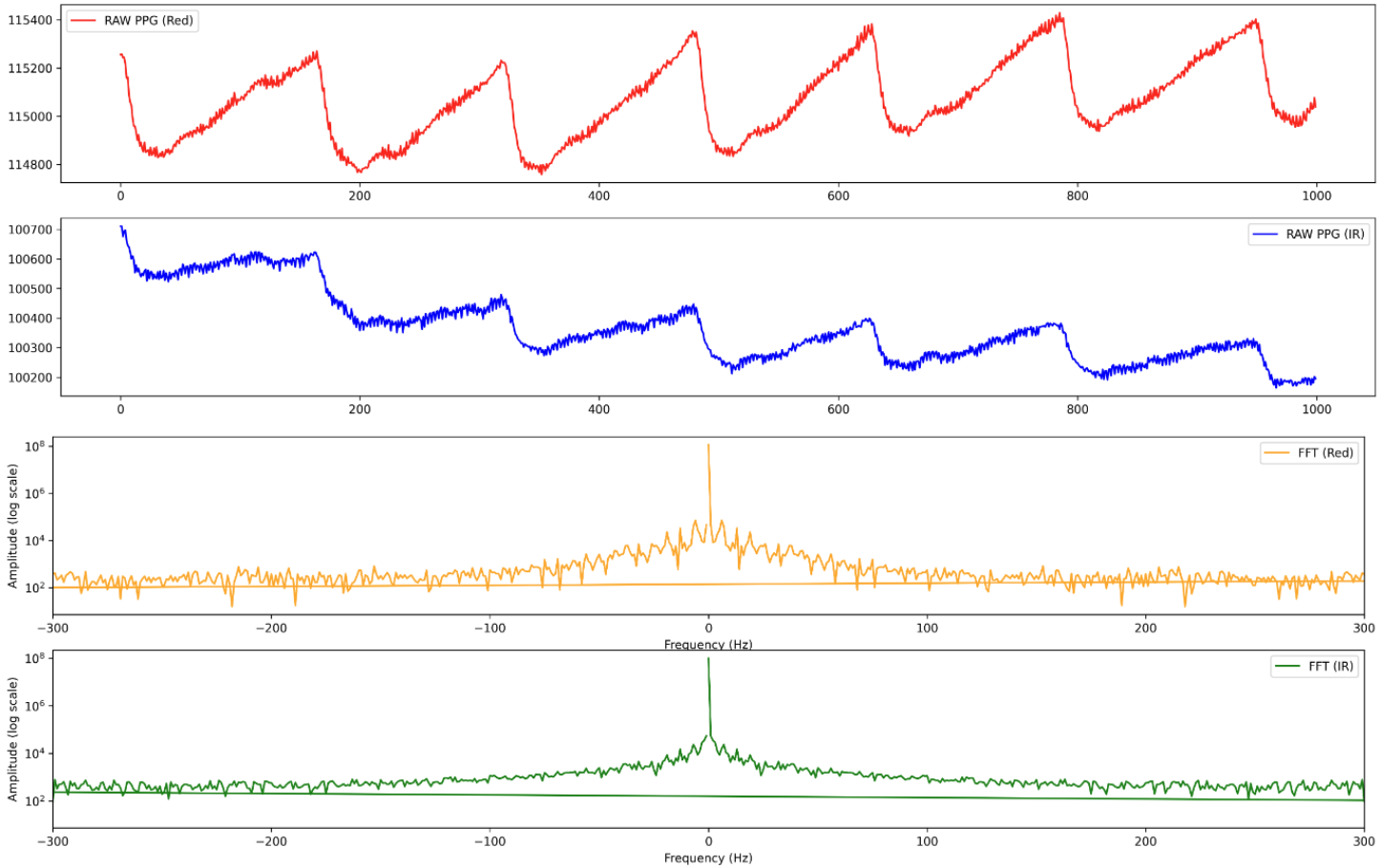


Keep your finger gently on the sensor

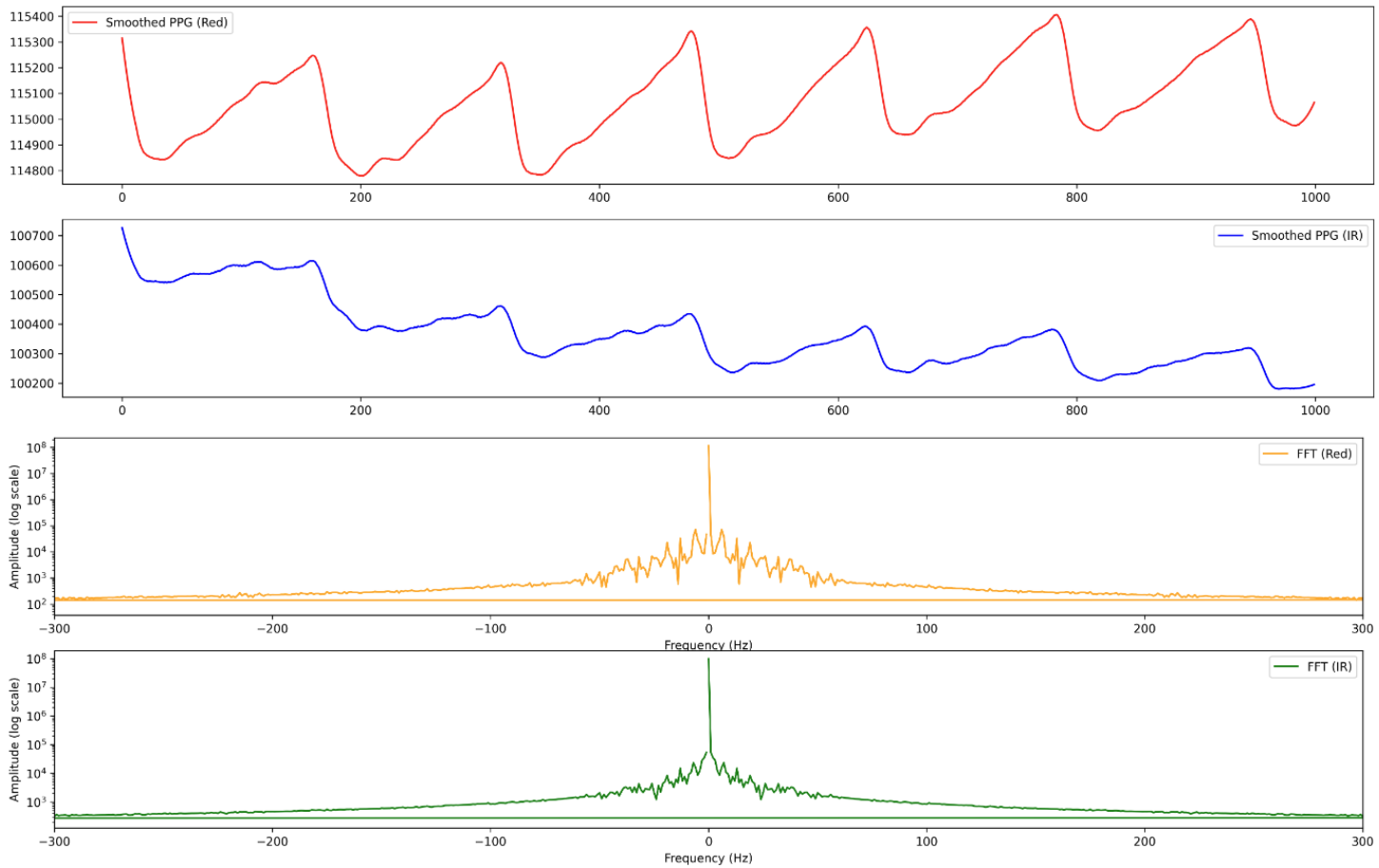




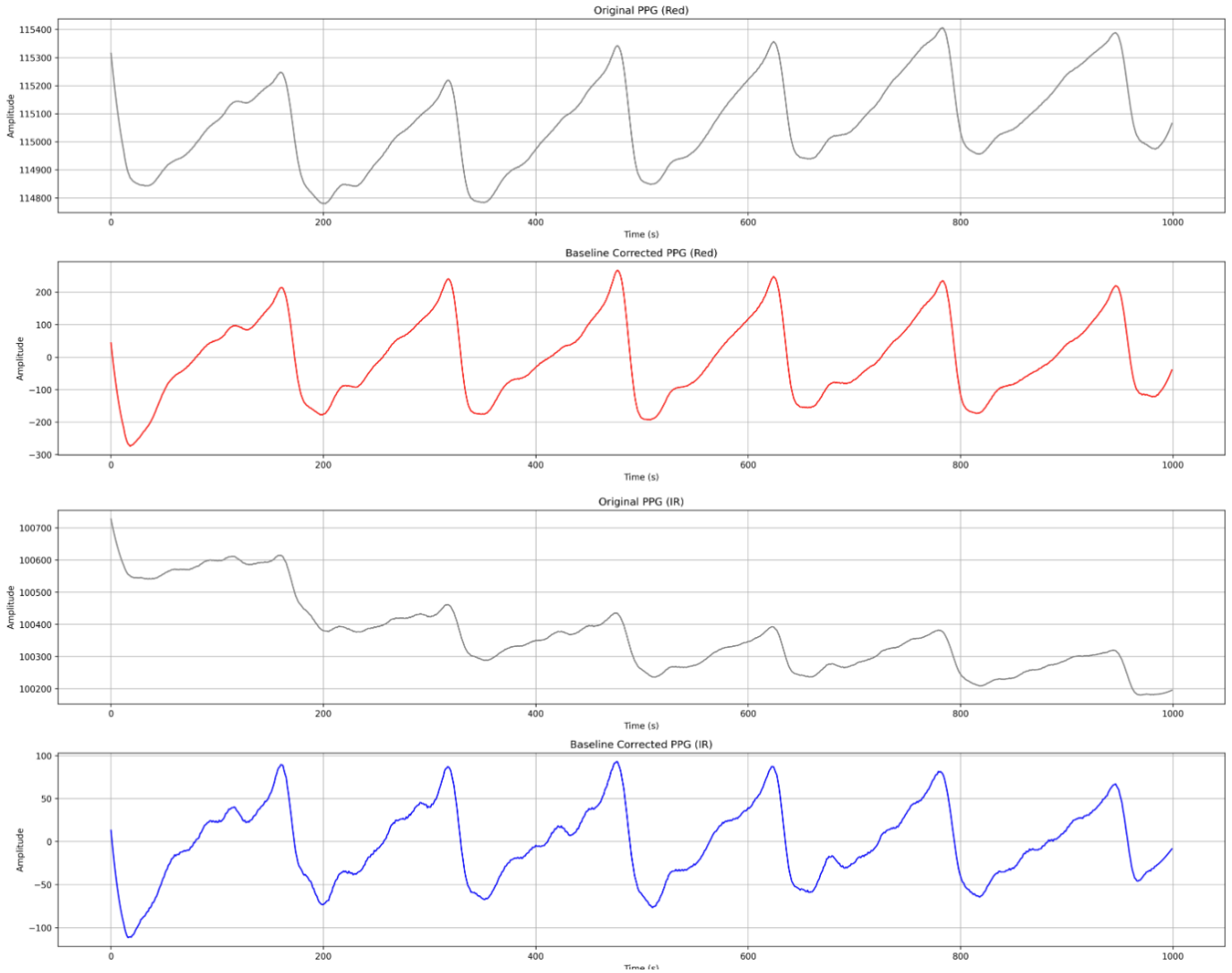
Going back to the PPG data collected



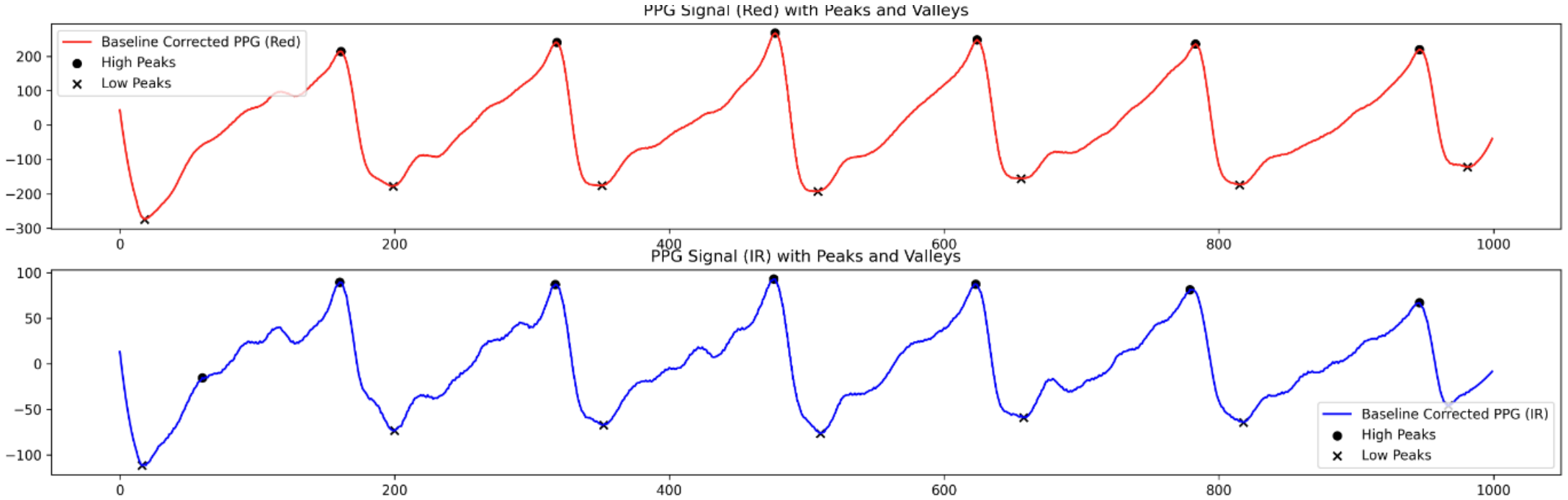
Smoothing


Smoothed PPG (Red)
115400
115300
115200
115100
115000
114900
114800
0
200
400
600
800
1000
Smoothed PPG (IR)
100700
100600
100500
100400
100300
100200
FFT (Red)
Amplitude (log scale)
Frequency (Hz)
−300
−200
−100
100
200
300
FFT (IR)

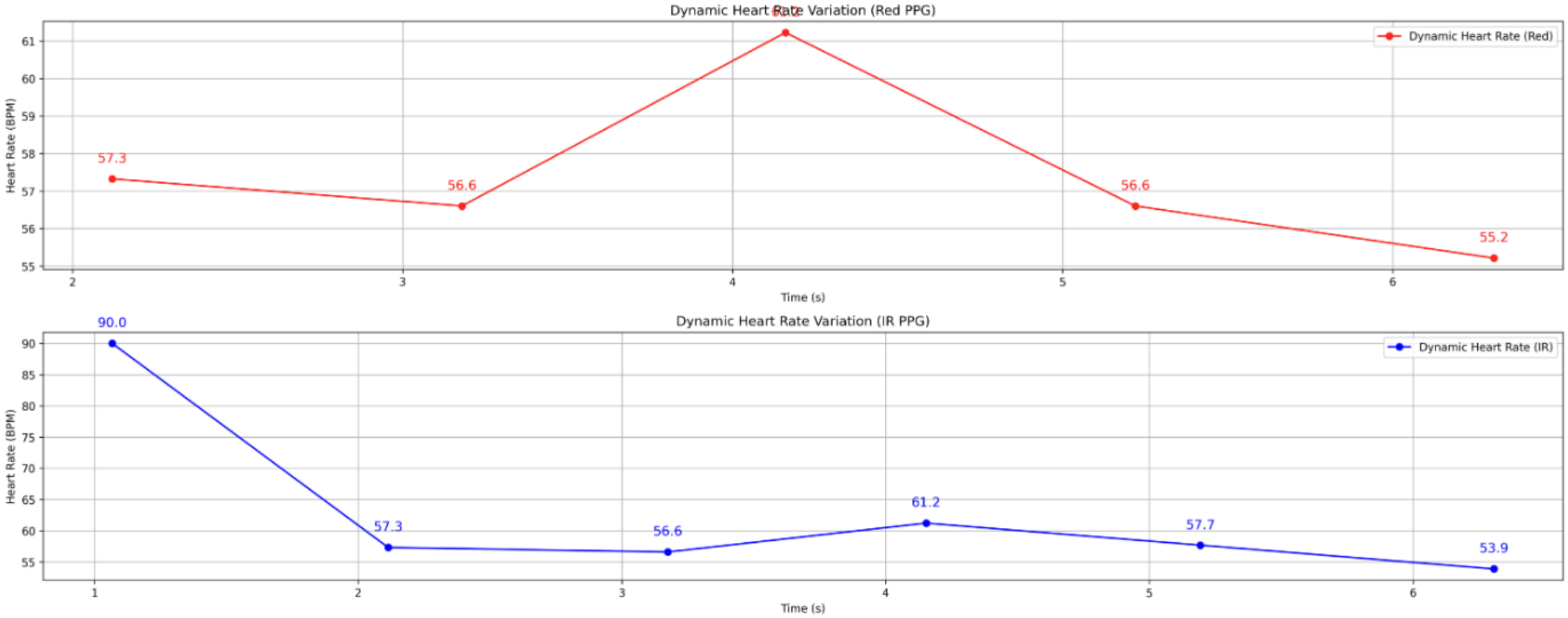
Drift correction



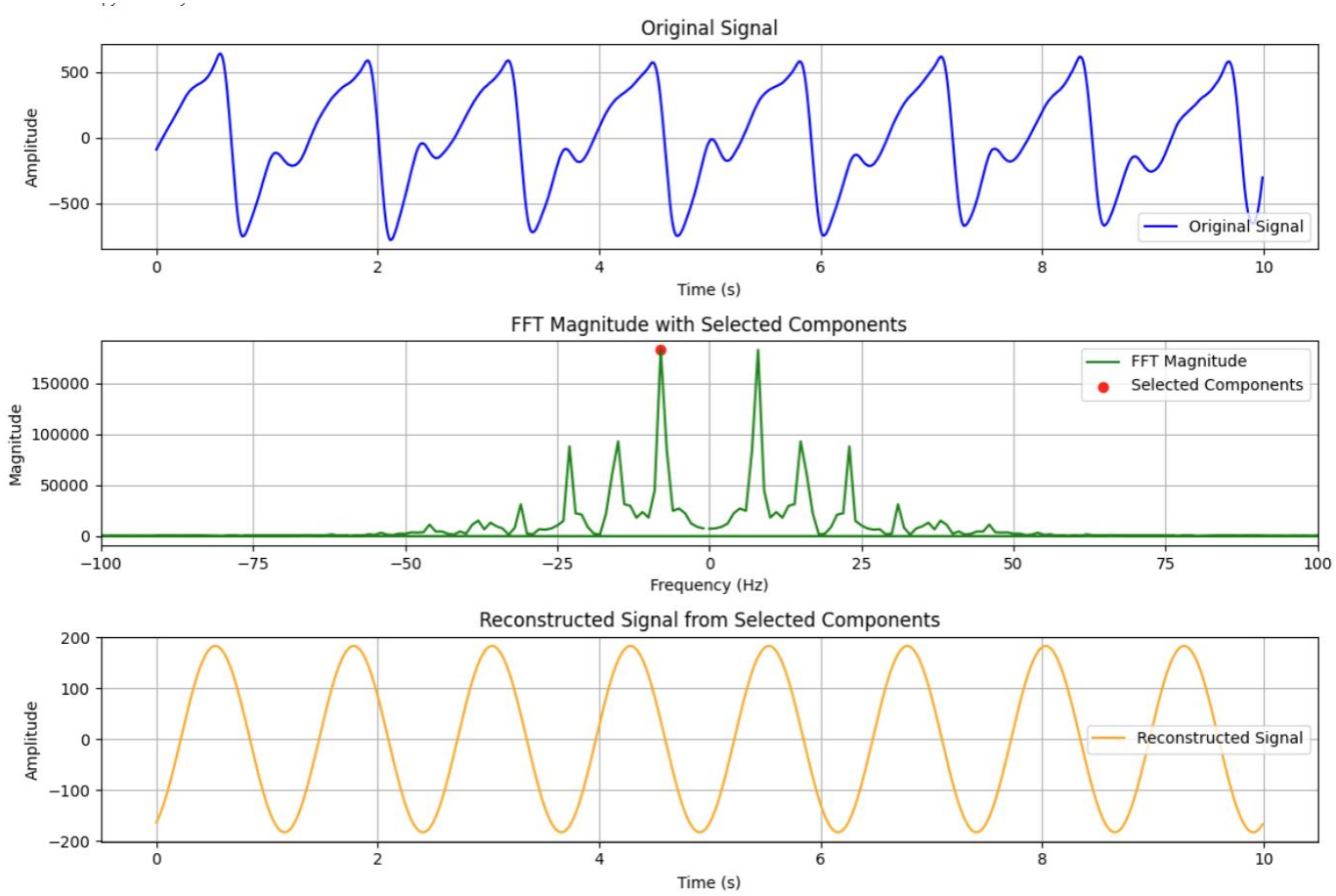
Peak detection



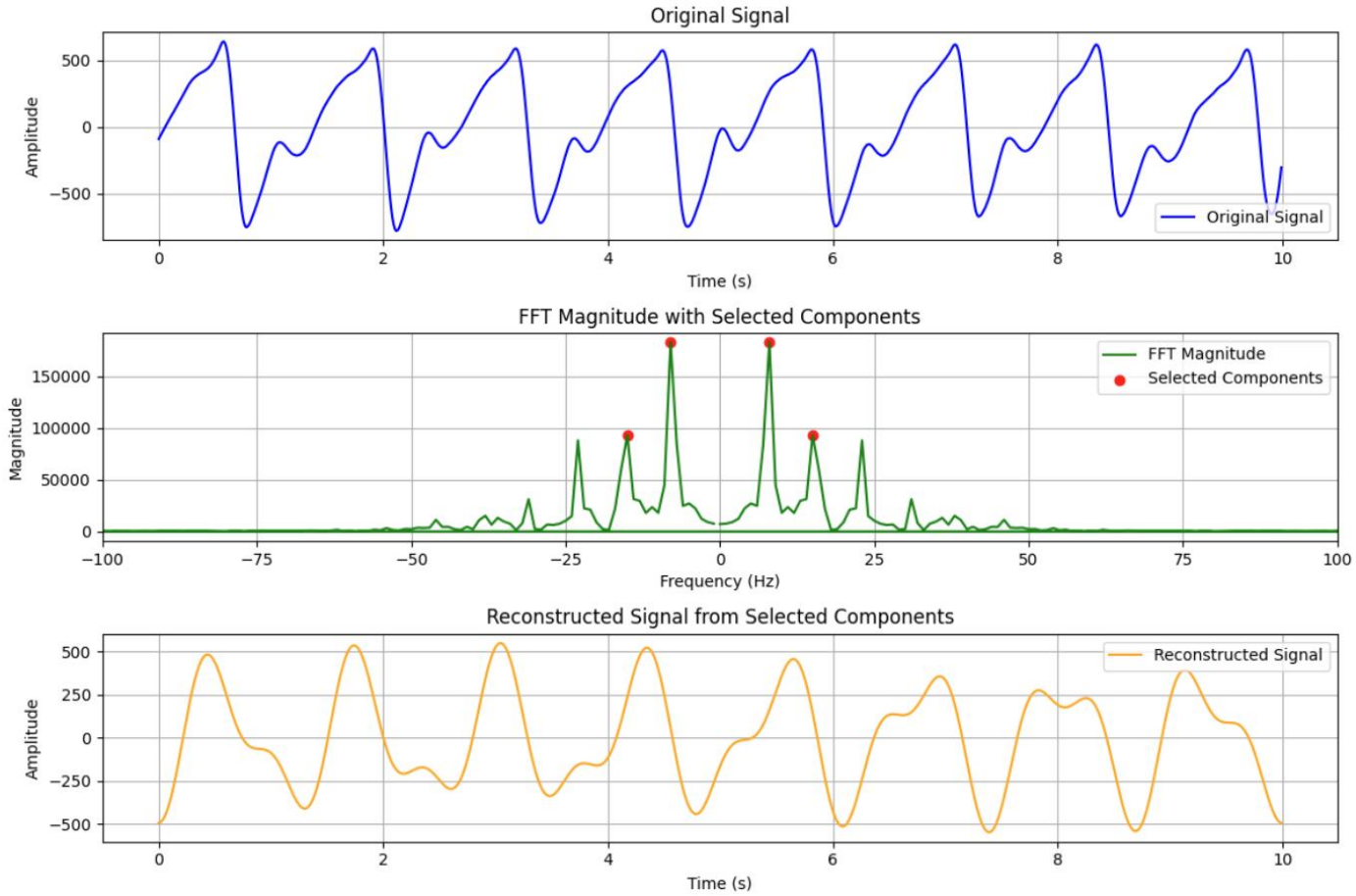
Heart rate


Dynamic Heart Rate Variation (Red PPG)
Dynamic Heart Rate (Red)
Heart Rate (BPM)
Time (s)
57.3
56.6
56.6
55.2
Dynamic Heart Rate Variation (IR PPG)
Dynamic Heart Rate (IR)
Heart Rate (BPM)
Time (s)
90.0
57.3
56.6
61.2
57.7
53.9

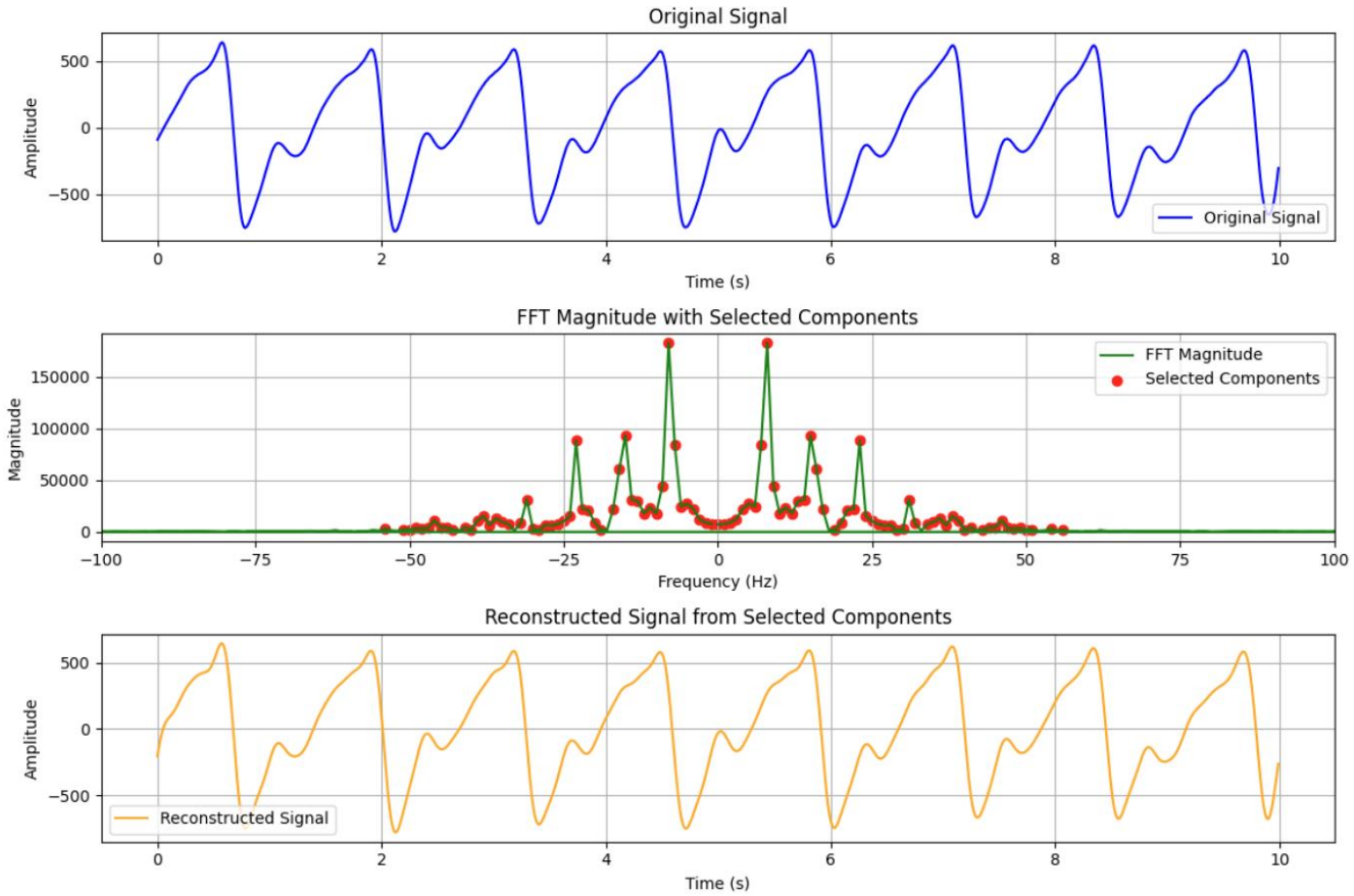
Using single component to find heart rate



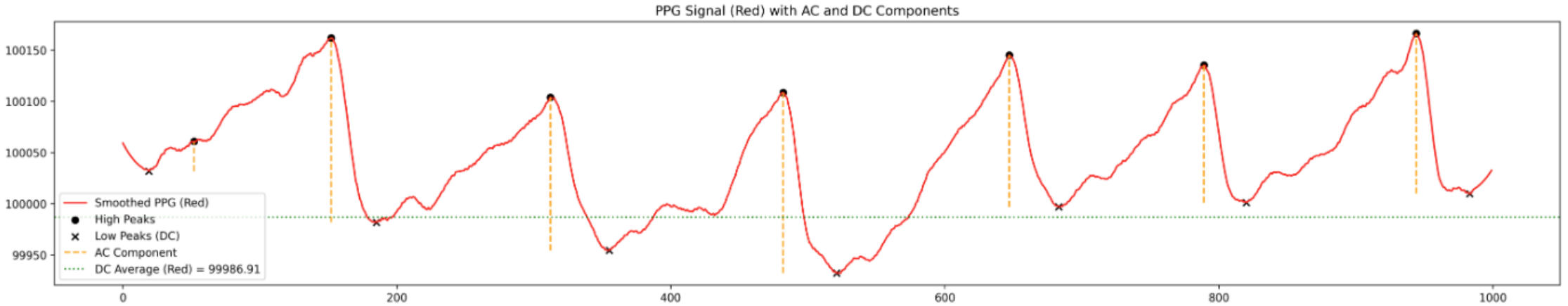
4 components in the PPG signal – signal loss

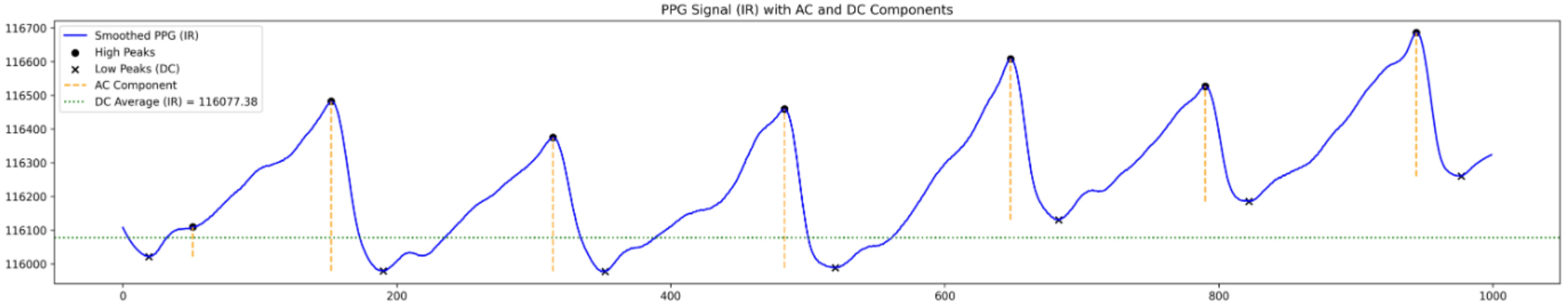


Taking all the components provides the original signal



Ratio of the ratios






```
(Red PPG Signal) DC Average: 99986.91, AC Average: 139.15
(IR PPG Signal) DC Average: 116077.38, AC Average: 386.22
Red signal ratio (red_ac/red_dc): 0.0013916875411345753
IR signal ratio (ir_ac/ir_dc): 0.0033272520894769473
Ratio of Ratios (Red ratio/ IR ratio): 0.4182693416997304
```

SpO2 calculation

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