ASSESSMENT OF BLOOD FLOW USING LASER DOPPLER FLOW METER

Aim:

To understand the working principle of LDF and its application in the assessment of flow

Objectives:

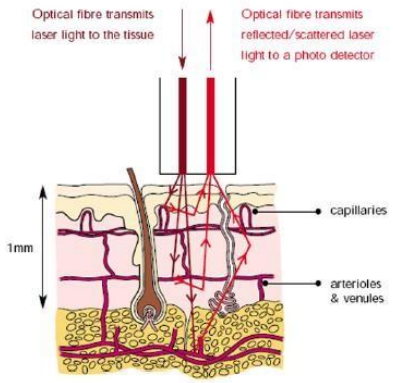
- To estimate the level of blood flow using laser doppler flowmeter method
- To analyse the variation in estimation based on the measurement site
- To determine the effective of venous occlusion and temperature on blood flow

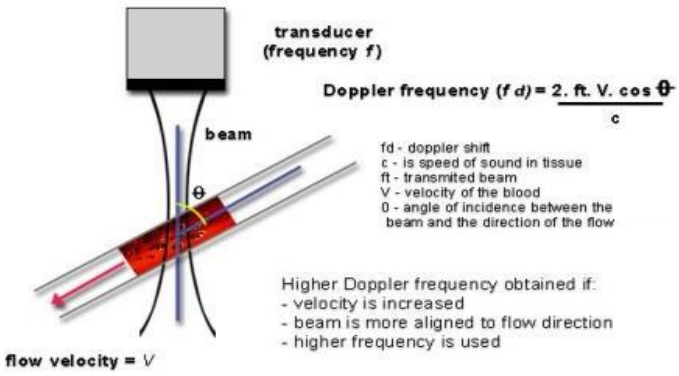
Introduction:

Adequate perfusion via microcirculatory network is essential for the integrity of tissue and organ functions. Measurement and analysis of microcirculation is vital in proper functioning of cell and tissue Non-invasive assessment of microcirculatory impairments can aid the physician in early disease diagnosis and can also be used to provide quantitative assessment of effects of a given treatment for a particular disease. Cutaneous microcirculation measurement has gained research interest in the recent past mainly due to the advancement of non-invasive techniques for blood flow monitoring. Laser Doppler flowmetry is one modality of laser based non- invasive techniques for monitoring microcirculation.S

Principle of operation:

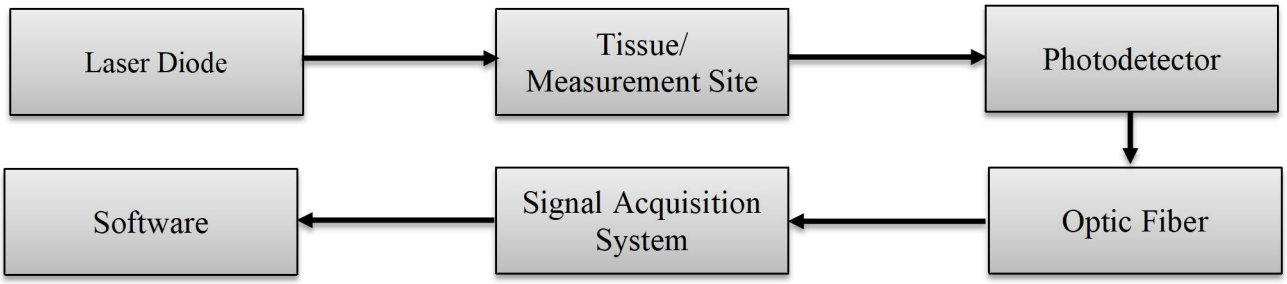
A Laser Doppler Flow Meter (LDF) is a device used to measure the velocity of blood flow in tissue. It works on the principle of the Doppler effect, which involves the change in frequency of light when it is scattered by moving red blood cells.





1. Laser Light Emission: A laser diode emits coherent light that is directed onto the tissue. The laser light typically has a wavelength in the near-infrared range to penetrate the tissue.
2. Interaction with Blood Cells: The laser light penetrates the tissue and interacts with moving red blood cells. Some of the light is scattered by these cells.
3. Doppler Shift: When the light is scattered by moving red blood cells, its frequency is shifted due to the Doppler effect. The frequency shift Δf is proportional to the velocity of the blood cells.
4. Detection: The scattered light, including the Doppler-shifted light, is collected by photodetectors.
5. Signal Processing: The collected light is analyzed to detect the frequency shift. This analysis can be done using methods such as Fast Fourier Transform (FFT) to obtain the velocity spectrum of the blood flow.
6. Blood Flow Calculation: The velocity information obtained from the Doppler shift is used to

calculate the blood flow. Blood flow can be expressed as a perfusion unit (e.g., ml/min/100g of tissue).



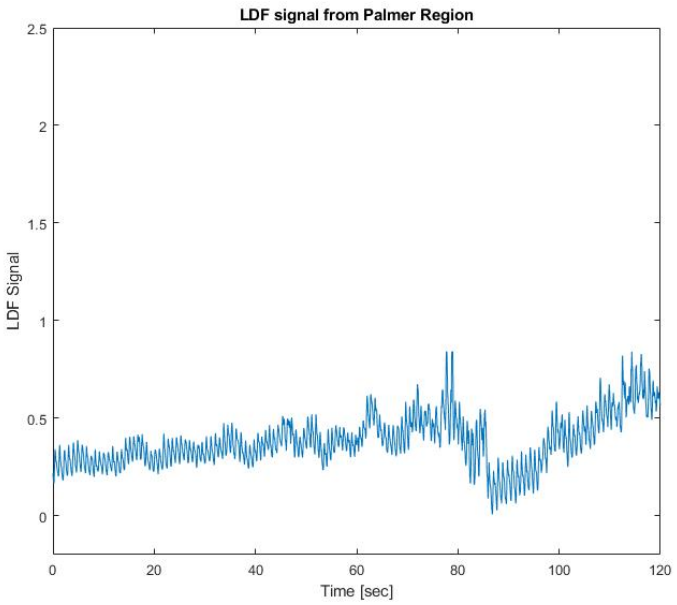
Block Diagram of Laser Doppler Flow Meter:

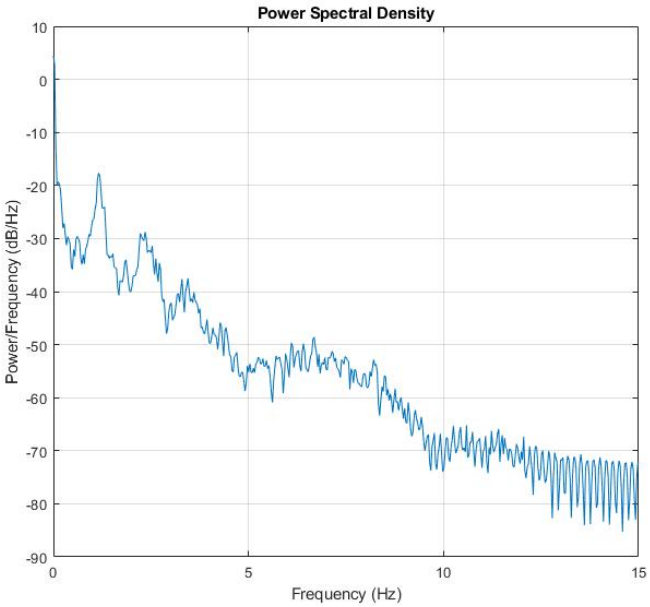
1. Laser Diode: Emits a coherent near infrared (NIR) beam with a wavelength of 830 nm directed toward the tissue. It is fitted into a probe that also contains the detector.
2. Tissue/Measurement Site: The part of the body where the blood flow measurement is being made. The laser light penetrates the tissue and interacts with blood cells.
3. Photodetector: Detect the backscattered light, including the Doppler-shifted components. It is fitted in the same probe as the laser diode.
4. Optic Fiber: Transmits the received signal from the detector into the data acquisition system.
5. Signal Acquisition system: Receives the optical information and preprocess it converts it into numerical data.
6. Software: It's used to visualize and manipulate the data.

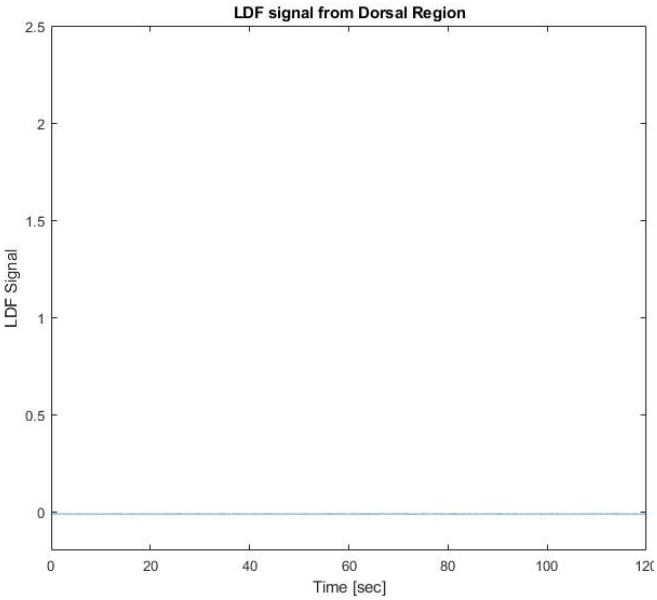
Methodology:

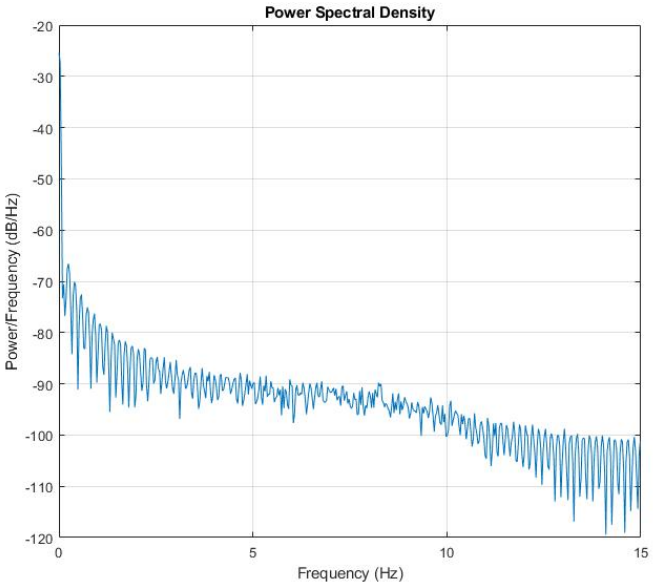
1. Understand the LDF system and its components
2. LDF measurements for static and dynamic flow
    a. Check LDF signal from a static surface
    b. Record LDF for palm, dorsum, forearm, and fingertip (2min duration) under normal flow
3. Occlusion studies – Apply pressure cuff in upper arm and then record LDF signal before and after applying pressure
4. Thermal hyperemia studies - Analysis of LDF signal due to local changes in skin surface temperature

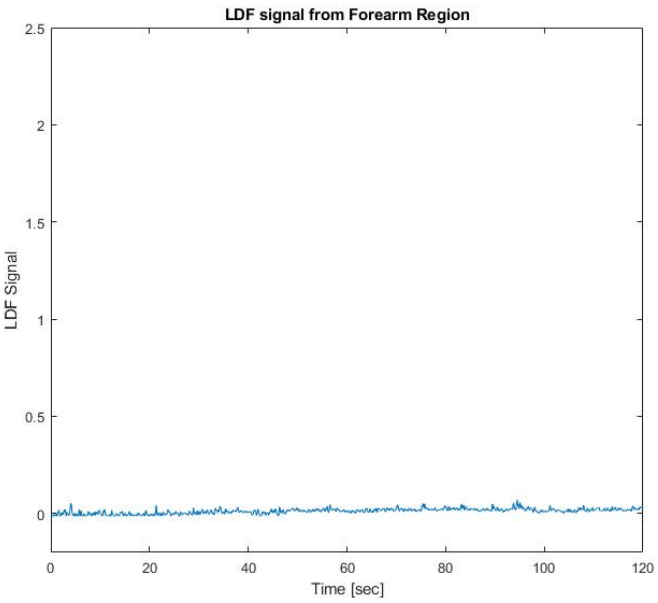
Results:

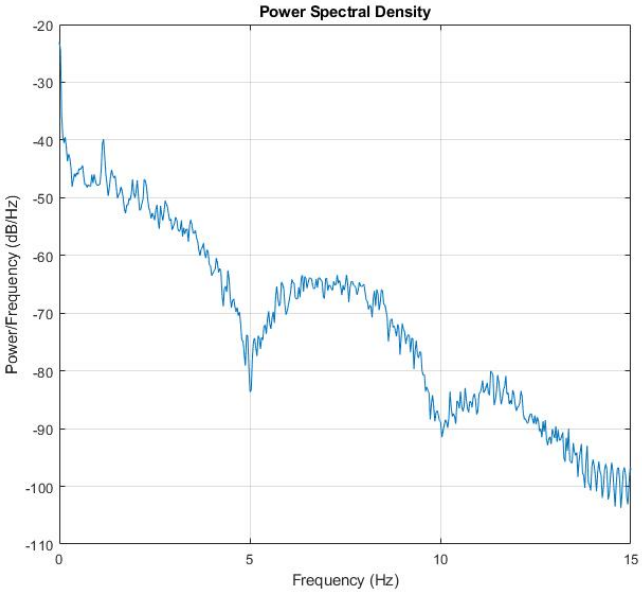

LDF signal from Palmer Region
LDF Signal
Time [sec]

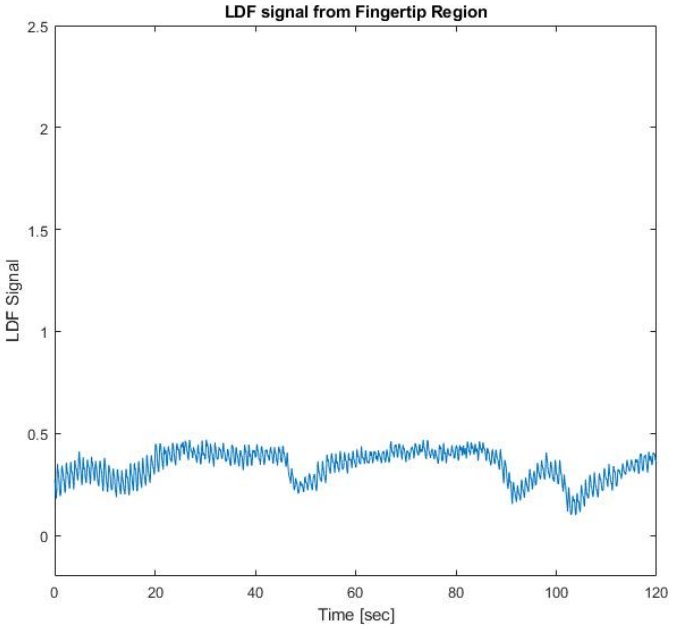

Power Spectral Density
Power/Frequency (dB/Hz)
Frequency (Hz)

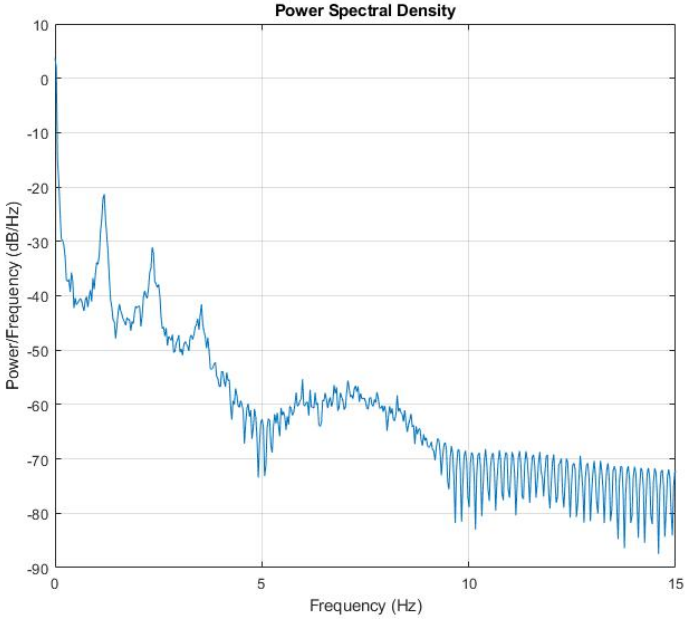

LDF signal from Dorsal Region
LDF Signal
Time [sec]

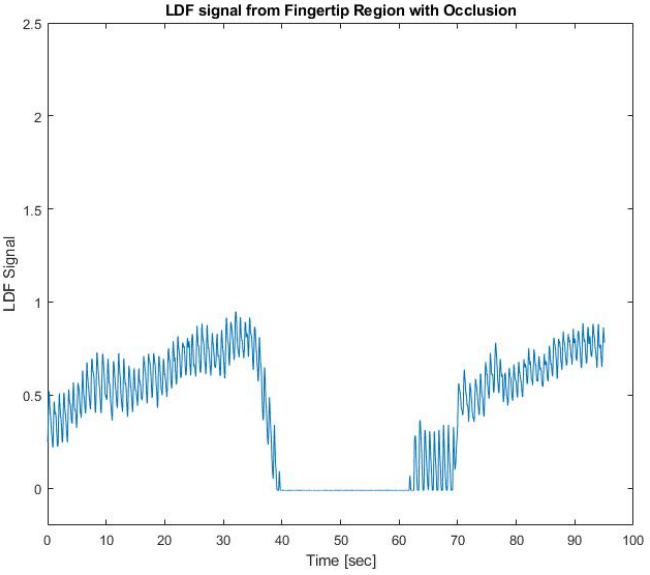

Power Spectral Density
Power/Frequency (dB/Hz)
Frequency (Hz)

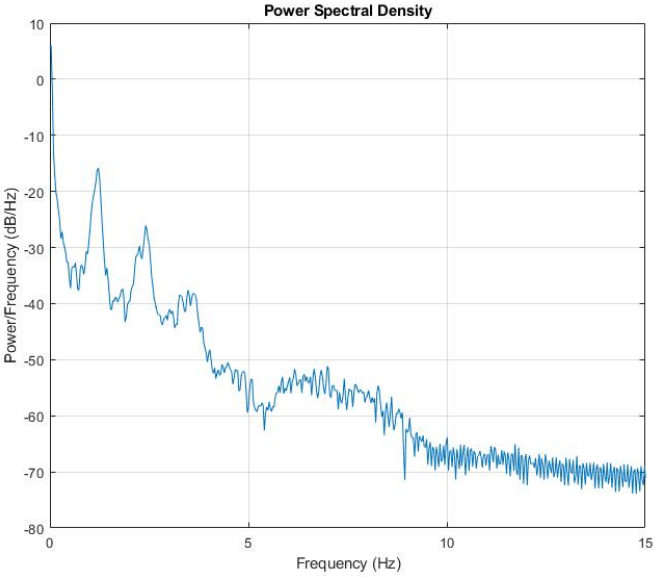

LDF signal from Forearm Region
LDF Signal
Time [sec]

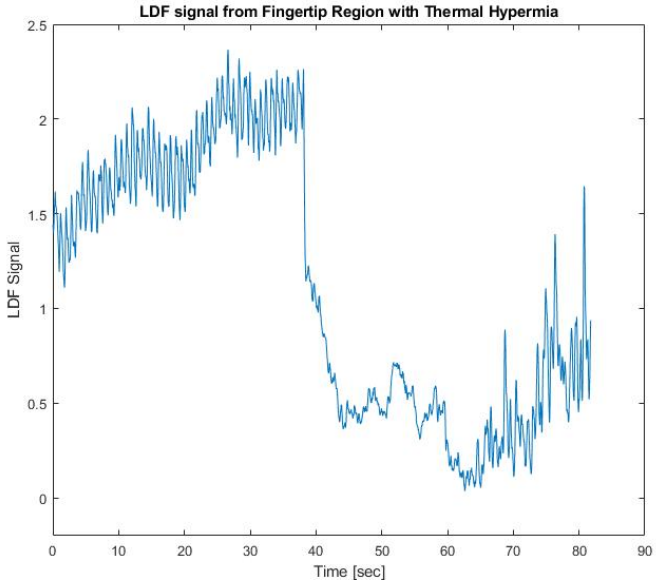

Power Spectral Density
Power/Frequency (dB/Hz)
Frequency (Hz)

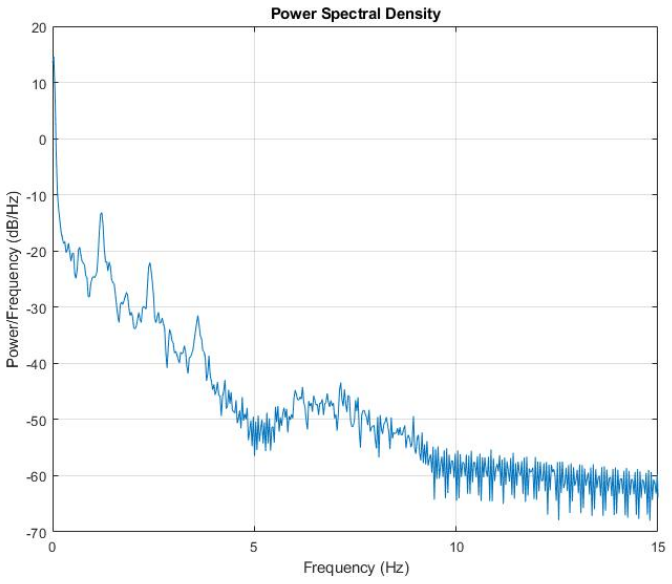

LDF signal from Fingertip Region
LDF Signal
Time [sec]


Power Spectral Density
Power/Frequency (dB/Hz)
Frequency (Hz)


LDF signal from Fingertip Region with Occlusion
LDF Signal
Time [sec]


Power Spectral Density
Power/Frequency (dB/Hz)
Frequency (Hz)


LDF signal from Fingertip Region with Thermal Hypermia
LDF Signal
Time [sec]


Power Spectral Density
Power/Frequency (dB/Hz)
Frequency (Hz)

Code:

```
close all, clear, clc
load('ldf.mat')
figure
plot(x_palmer,y_palmer)
ylim([-0.2 2.5])
title('LDF signal from Palmer Region');
xlabel('Time [sec]');
ylabel('LDF Signal');
figure
SPECTRAL_ANALYSIS(x_palmer,y_palmer)
figure
plot(x_dorsal,y_dorsal)
ylim([-0.2 2.5])
title('LDF signal from Dorsal Region');
xlabel('Time [sec]');
ylabel('LDF Signal');
figure
SPECTRAL_ANALYSIS(x_dorsal,y_dorsal)
figure
plot(x_forearm,y_forearm)
ylim([-0.2 2.5])
title('LDF signal from Forearm Region');
xlabel('Time [sec]');
ylabel('LDF Signal');
figure
SPECTRAL_ANALYSIS(x_forearm,y_forearm)
figure
plot(x_fingertip,y_fingertip)
ylim([-0.2 2.5])
title('LDF signal from Fingertip Region');
xlabel('Time [sec]');
ylabel('LDF Signal');
figure
SPECTRAL_ANALYSIS(x_fingertip,y_fingertip)
figure
plot(x_occlusion,y_occlusion)
ylim([-0.2 2.5])
title('LDF signal from Fingertip Region with Occlusion');
xlabel('Time [sec]');
ylabel('LDF Signal');
figure
SPECTRAL_ANALYSIS(x_occlusion,y_occlusion)
figure
plot(x_thermal,y_thermal)
ylim([-0.2 2.5])
title('LDF signal from Fingertip Region with Thermal Hypermia');
xlabel('Time [sec]');
ylabel('LDF Signal');
figure
SPECTRAL_ANALYSIS(x_thermal,y_thermal)

function SPECTRAL_ANALYSIS(x,y)
t = x; % Assuming the first column is time
signal = y; % Assuming the second column is the signal
% Preprocess the data (filtering)
fs = 1000; % Sampling frequency in Hz (adjust to your actual sampling rate)
fc = 10; % Cutoff frequency in Hz
[b, a] = butter(4, fc/(fs/2)); % 4th order Butterworth low-pass filter
```

```
filtered_signal = filtfilt(b, a, signal);
% Compute the FFT
N = length(filtered_signal); % Length of the signal
Y = fft(filtered_signal); % Compute the FFT
Y = Y(1:N/2+1); % Take the positive frequencies
f = (0:N/2)*fs/N; % Frequency vector

% Plot the Power Spectral Density (PSD)
[pxx, f] = pwelch(filtered_signal, [], [], [], fs);
plot(f, 10*log10(pxx)); % Plot in dB/Hz
title('Power Spectral Density');
xlim([0 15])
xlabel('Frequency (Hz)');
ylabel('Power/Frequency (dB/Hz)');
grid on;
```

Conclusion:

1. When using a Laser Doppler Blood Flowmeter (LDF) in different regions of the hand and forearm, the measurements can vary significantly due to differences in tissue composition, blood supply, and vascular architecture in these regions.

   In terms of measurement sensitivity: Fingertip (high sensitivity due to dense capillary network) > Palmar Hand (high due to rich blood supply) > Palmar Forearm (moderate, deeper vessels) > Dorsal Hand (lower, fewer vessels)

2. When blood flow is obstructed in the forearm by inflating a blood pressure cuff, several effects can be observed in the Laser Doppler Blood Flow measurements at the fingertip:

   - Reduced Blood Flow: As the cuff inflates and occludes the brachial artery, blood flow to the forearm and hand, including the fingertip, will be significantly reduced or completely stopped depending on the cuff pressure.
   - Immediate Measurement Drop: The LDF will detect a sharp decrease in blood flow at the fingertip almost immediately after the occlusion starts. This is because the supply of fresh blood to the fingertip is cut off. As the cuff deflates, the blood flow values go back to normal.

3. When the palm of the hand is exposed to an IR (infrared) lamp, increasing its surface temperature, thermal hyperemia, the increase in blood flow to a tissue or organ, occurs. the following effects on Laser Doppler Blood Flow measurements at the fingertip can be expected:
   - Vasodilation: The increase in surface temperature causes vasodilation of the blood vessels in the palm, including the fingertip. This dilation is mediated by various factors, including the release of nitric oxide and other vasodilators. Vasodilation increases blood flow.
   - Increased Blood Flow: The LDF at the fingertip will measure an increase in blood flow due to the thermal-induced vasodilation. This increased blood flow will result in higher perfusion values. The values will go back to normal after the heat source is turn off as the blood carries the excess heat away from the palm.