University of Latvia, Institute of
Atomic physics and
Spectroscopy
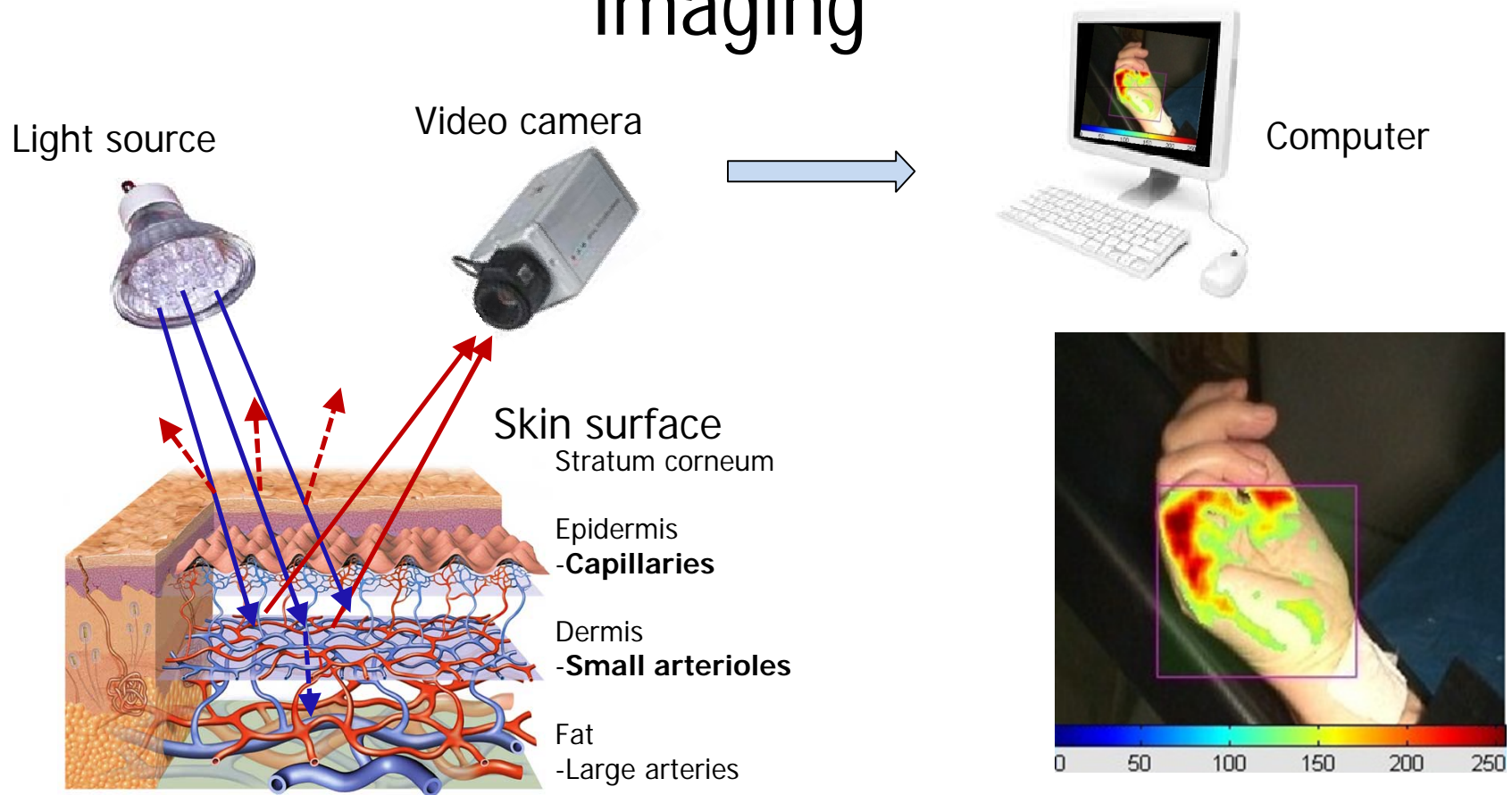Biophotonics laboratory

Portable remote photoplethysmography device for monitoring of blood volume changes with high temporal resolution

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The principle of photoplethysmography imaging

Light source

Video camera

Computer

Skin surface
Stratum corneum

Epidermis
-**Capillaries**

Dermis
-**Small arterioles**

Fat
-Large arteries

Photoplethysmography imaging is a non-contact technique for detection of skin blood volume pulsations using backscattered optical radiation.

Motivation

- There is a clinical need for simple inexpensive technique able to provide parametric circulation maps with high spatial resolution.

- Continuous monitoring of tissue microcirculation is important in some medical cases, such as surgery feedback, burn monitoring, control of regional anesthesia, skin reaction to external stimuli etc.

Motivation

- The main advantage of this technique is the contactless assessment of blood volume changes from human skin that can provide information about cardiovascular parameters:
  blood perfusion, heart rate and respiration rate.
- The technique requires light source and video camera that are distantly located from the skin surface.
- Near infrared radiation is suitable for rPPG measurements, due to relative high penetration depth in skin tissue.
- The video camera should be fast, with high sensitivity and dynamic range.
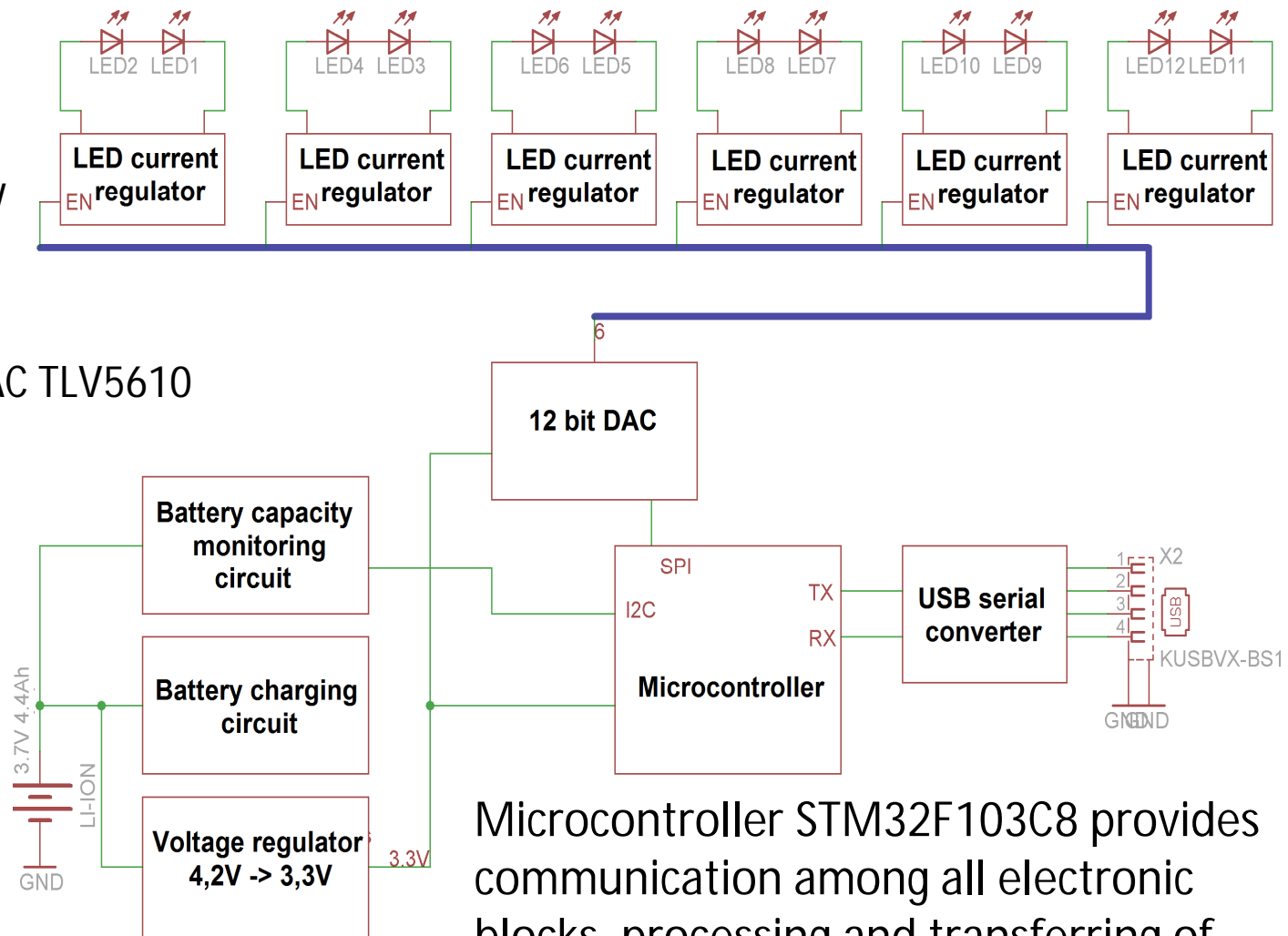
The device prototype

Our developed rPPG device consists of:

➢   twelve circullary oriented near-infrared   LED sources (760nm, radiation power of 400 mW, max operating current is 800mA);

➢   high-quality video camera (Ximea, non-cooled sCMOS, resolution 640x480, framerate 500 fr/s, 12-bit, USB-3);

➢   lens (Edmund Optics 3,5mm C-mount, wide low-distortion lens, 82,4°);

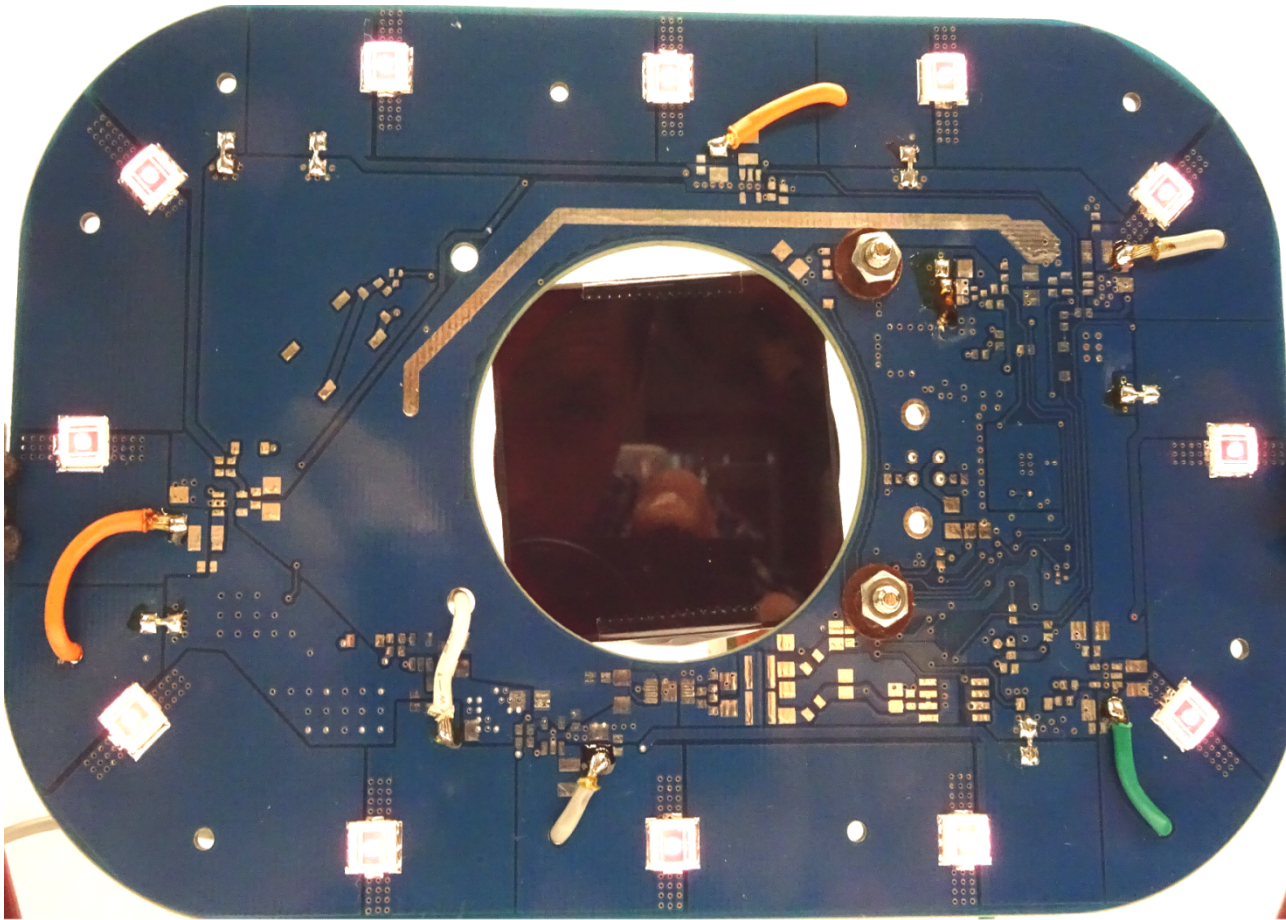➢   and on-board electronics.

The block-diagram of rPPG device

Diode driver TLV62565DBVT, it is 1,5 A high-efficiency voltage stepdown regulator.
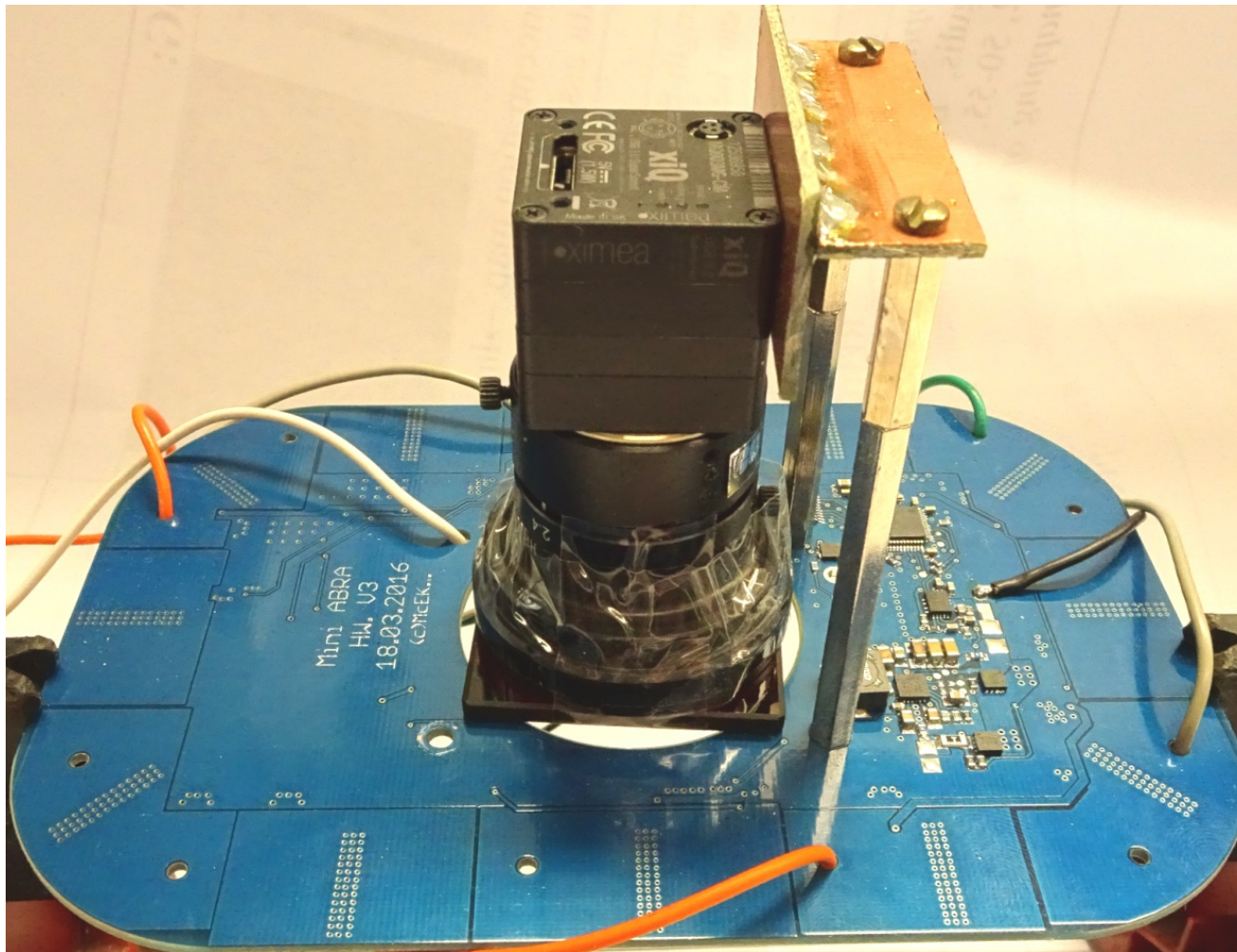
8-channel 12-bit DAC TLV5610

Microcontroller STM32F103C8 provides communication among all electronic blocks, processing and transferring of data.

The device prototype

The size of board is 100mm x 150mm with 46mm hole in the middle where C-mount lens of the camera is located.
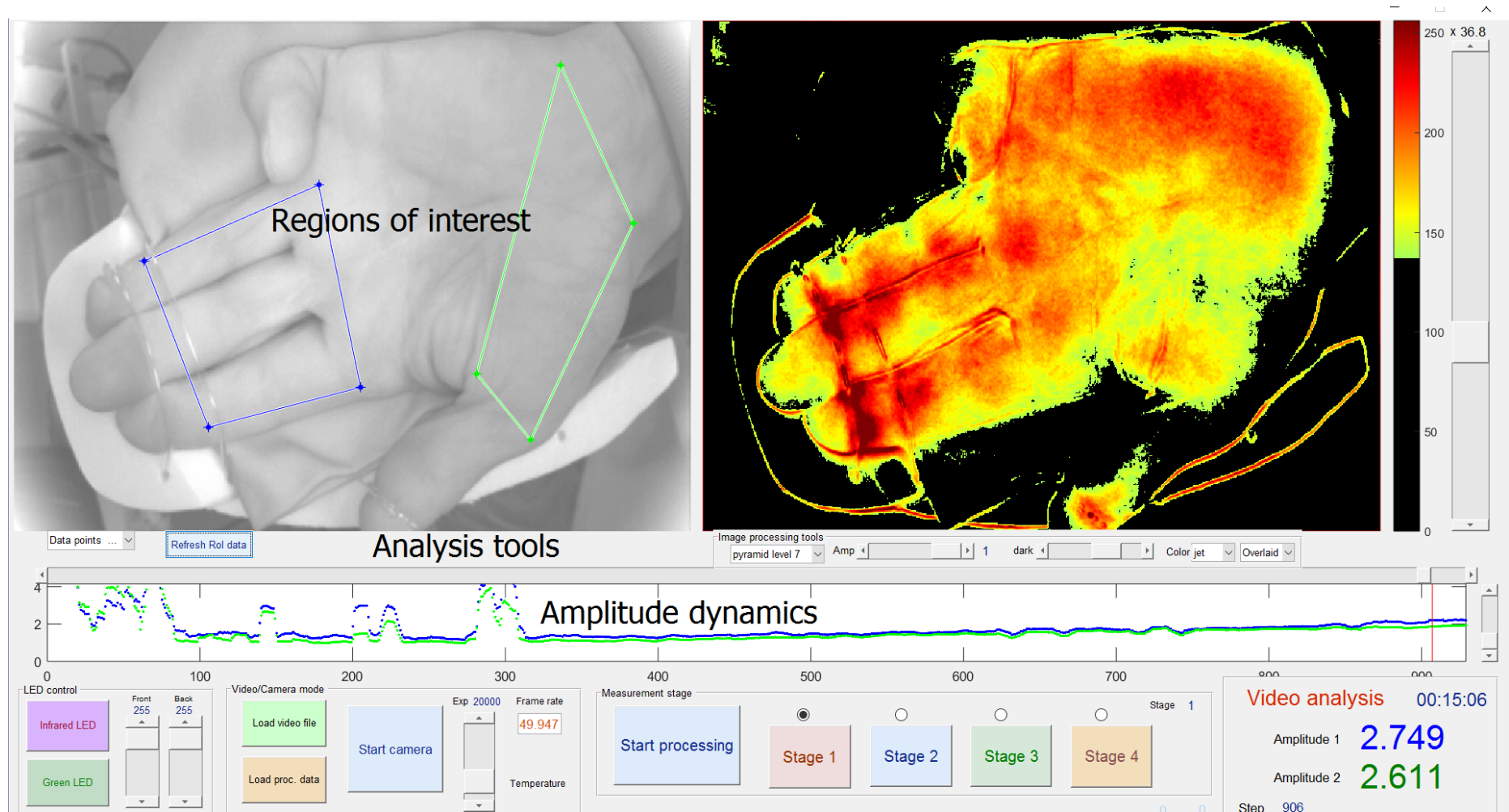
The device prototype

PCB
heatsink
and camera
with optics
and IR
filter.
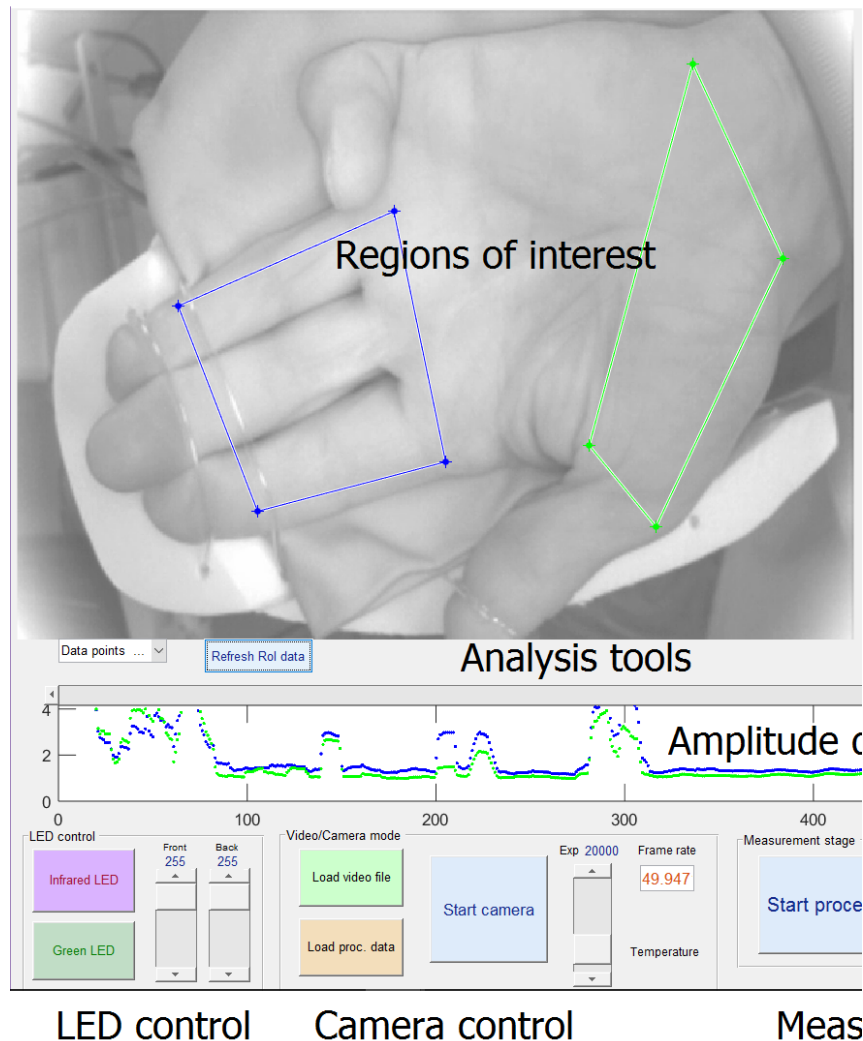
The software

Video frame window

rPPG image map

Regions of interest

Analysis tools

Amplitude dynamics

LED control   Camera control   Measurement stage buttons   Status

Signal processing

Video frame window

Regions of interest

Analysis tools

Amplitude

LED control   Camera control   Meas

- To extract remote PPG signals from skin, the several regions of interest were manually selected over the skin image. Then the averaged pixel values were calculated from every frame of video within each regions of interest . As a result, the set of PPG signals were found.

Signal processing

- To extract fast varying component (PPG AC), digital bandpass 2nd order Butterworth filter is applied with frequency range 0.3-6Hz (within the heartbeat frequency range).
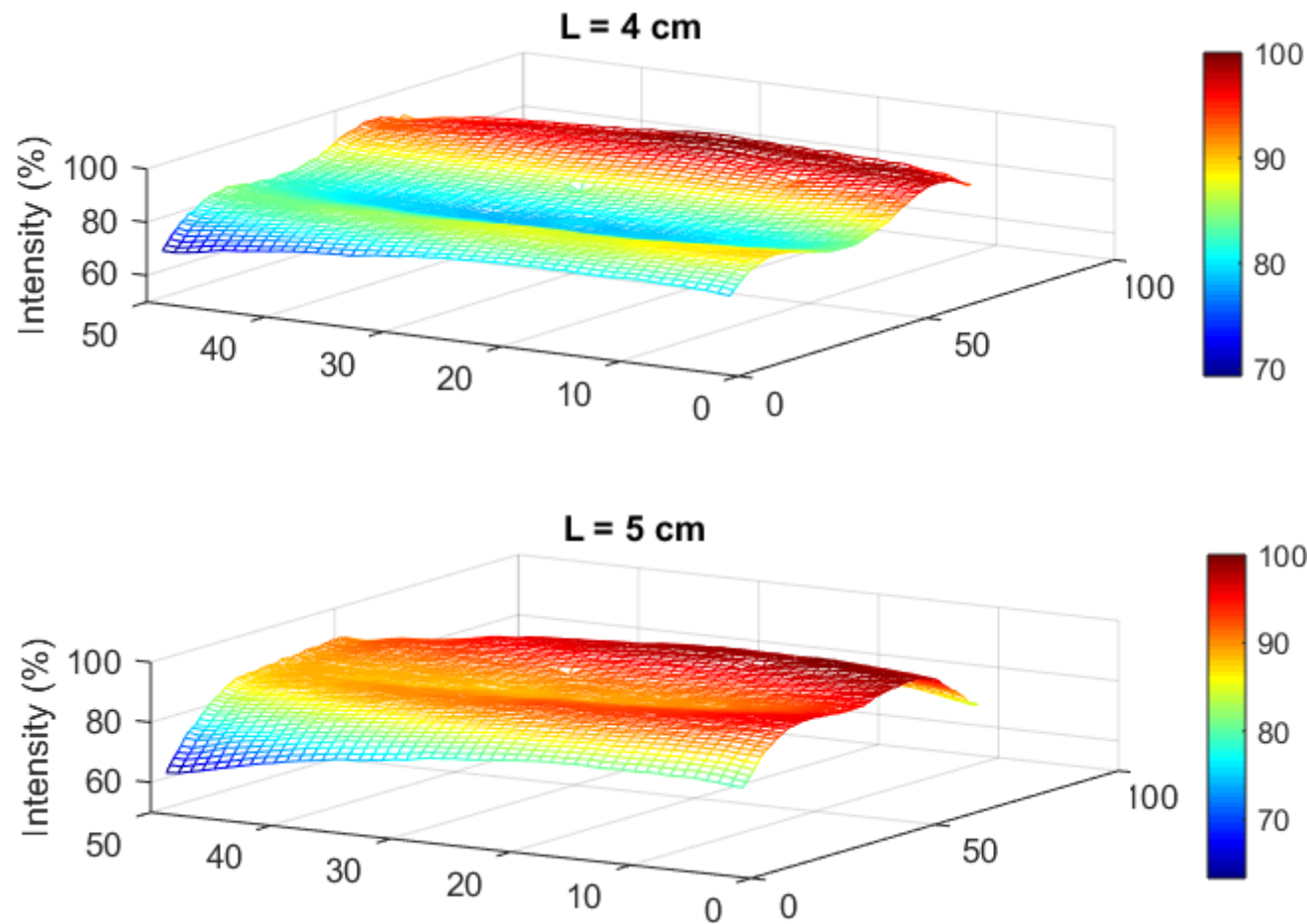

rPPG image map
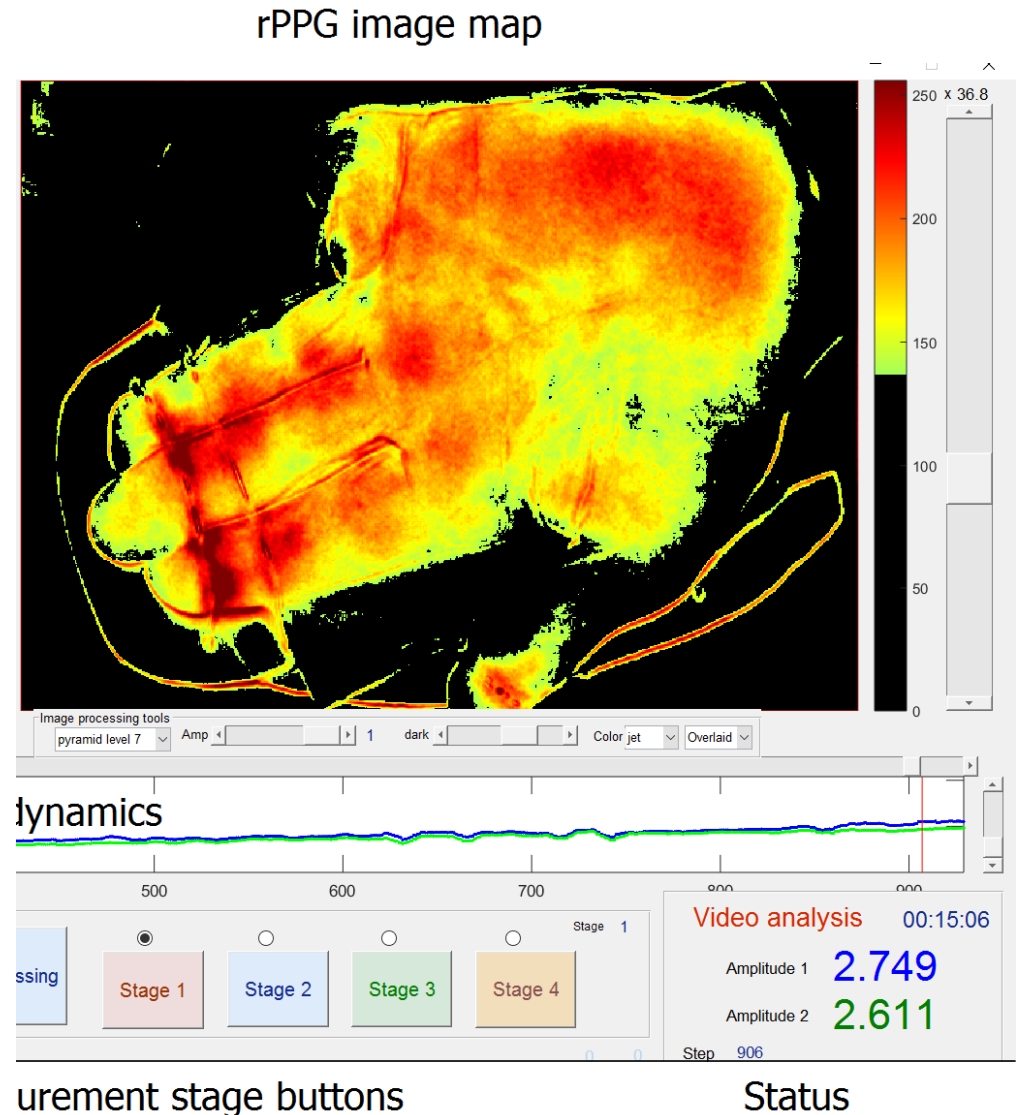
RESULTS

Three tests of prototype device were performed:
    1) the uniformity of LED illuminator;
    2) the performance of camera sensor;
    3) the quality of photoplethysmogram measured by device.

Light distribution uniformity

L = 4 cm

L = 5 cm

Light intensity plots acquired by camera at four distances (4cm, 5cm, 6cm and 7cm) to the object. At near distances the shape is similar to toroidal.

Light distribution uniformity
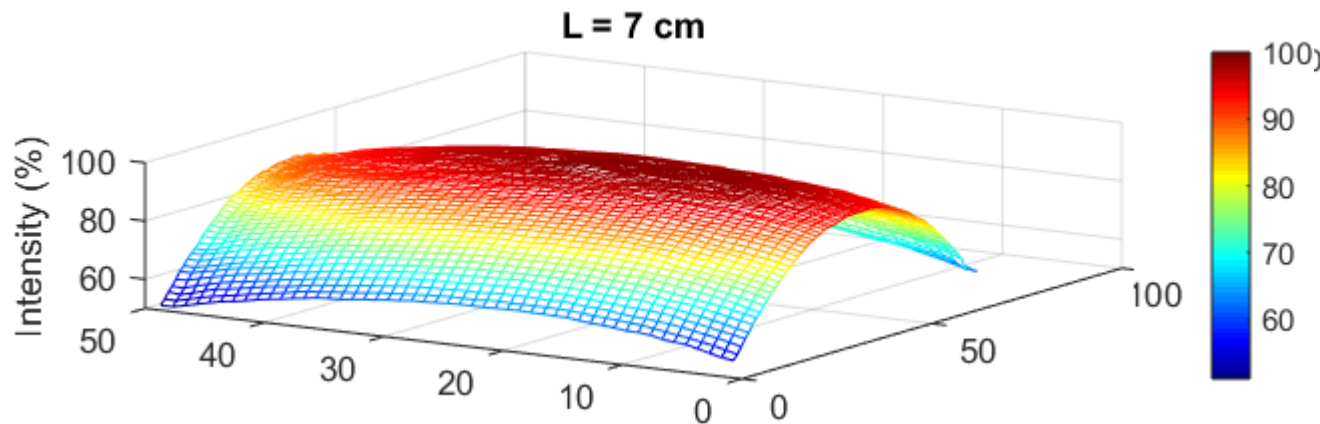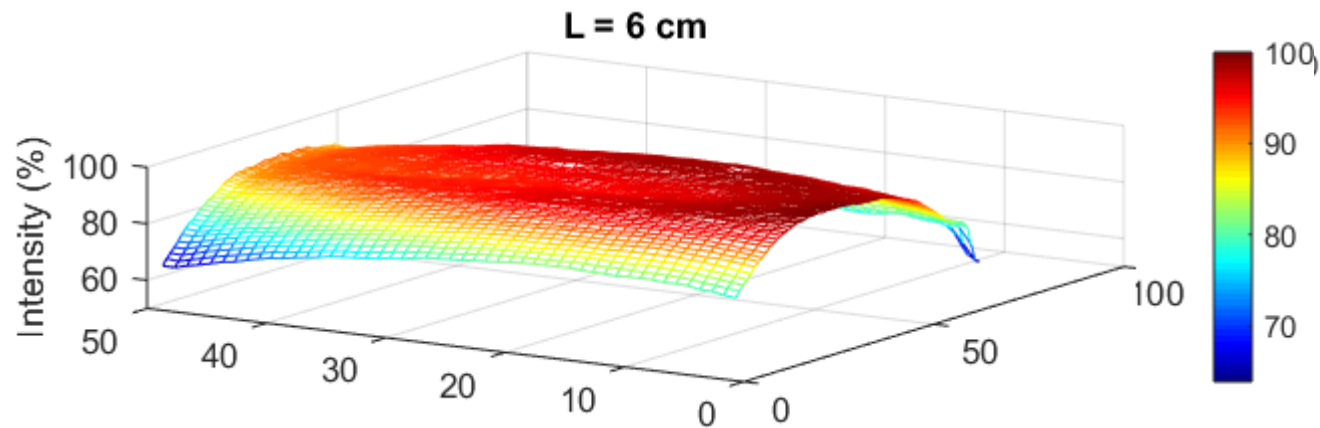
As distance increases, shape becomes rounder. The non-uniformility of light-field is determined by both light sources and small abberations of camera lens.

The performance of camera sensor
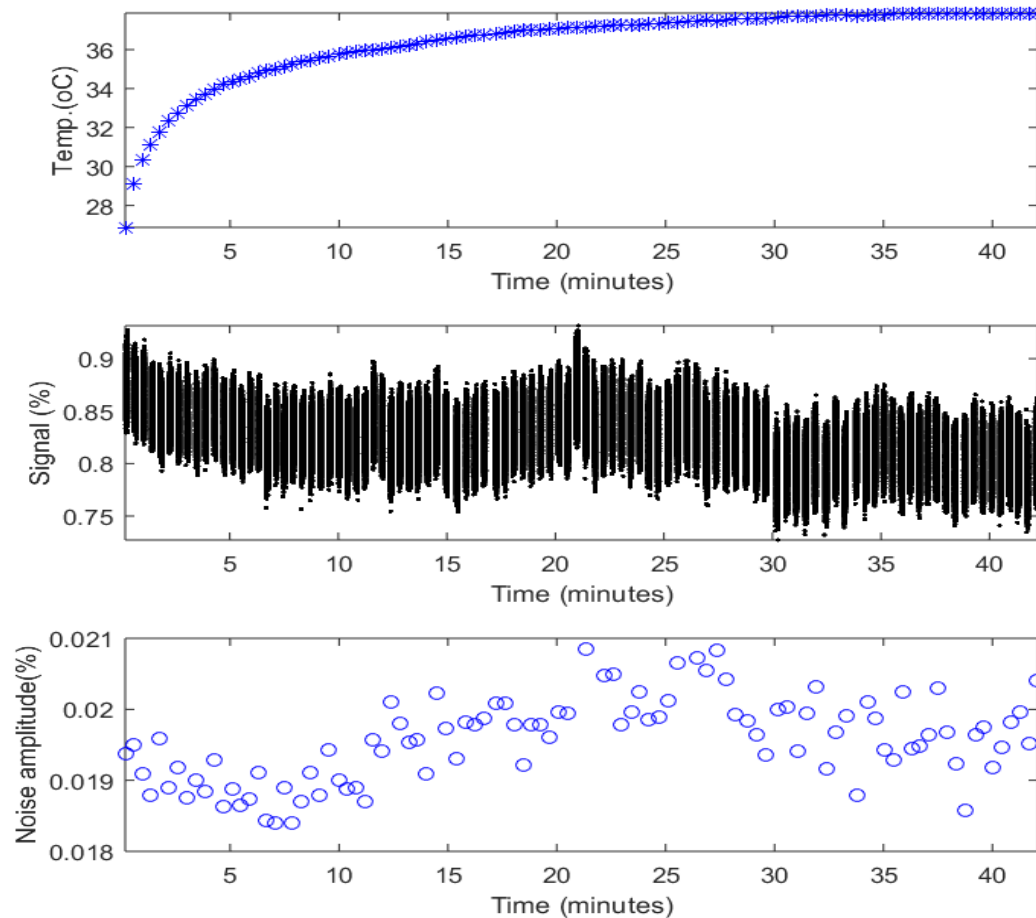

Camera sensor testing:
- The camera was switched on in dark conditions at 42 minutes.
- The temperature of camera sensor and dark signal was measured every 25 seconds.
- The temperature was increased rapidly at first few minutes and then becomes stable.
- The amplitude of noise increased by small amount.
- The performance tests showed that the level of dark-noise can be considered as low.

# The screenshot of video with five regions of interest
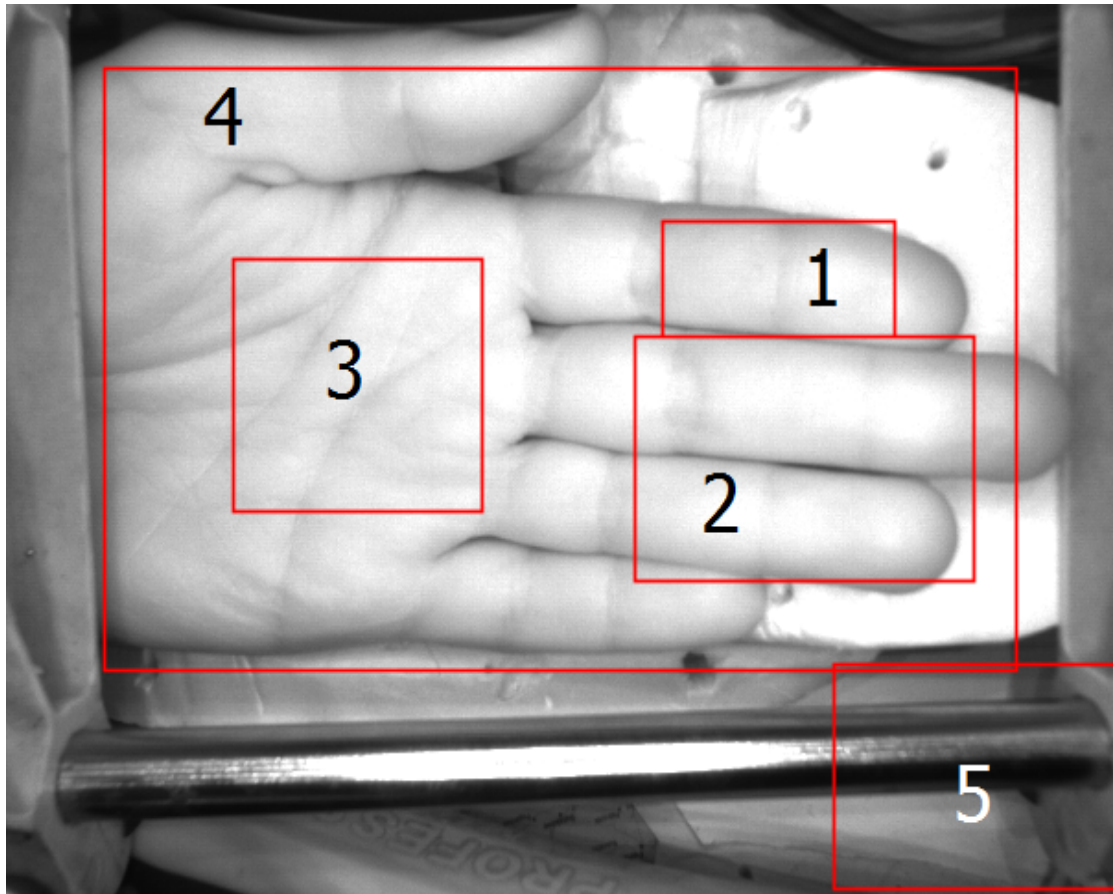
1-2 – three middle fingers,
3 – the central part of palm,
4 – the whole palm,
5 – the table.

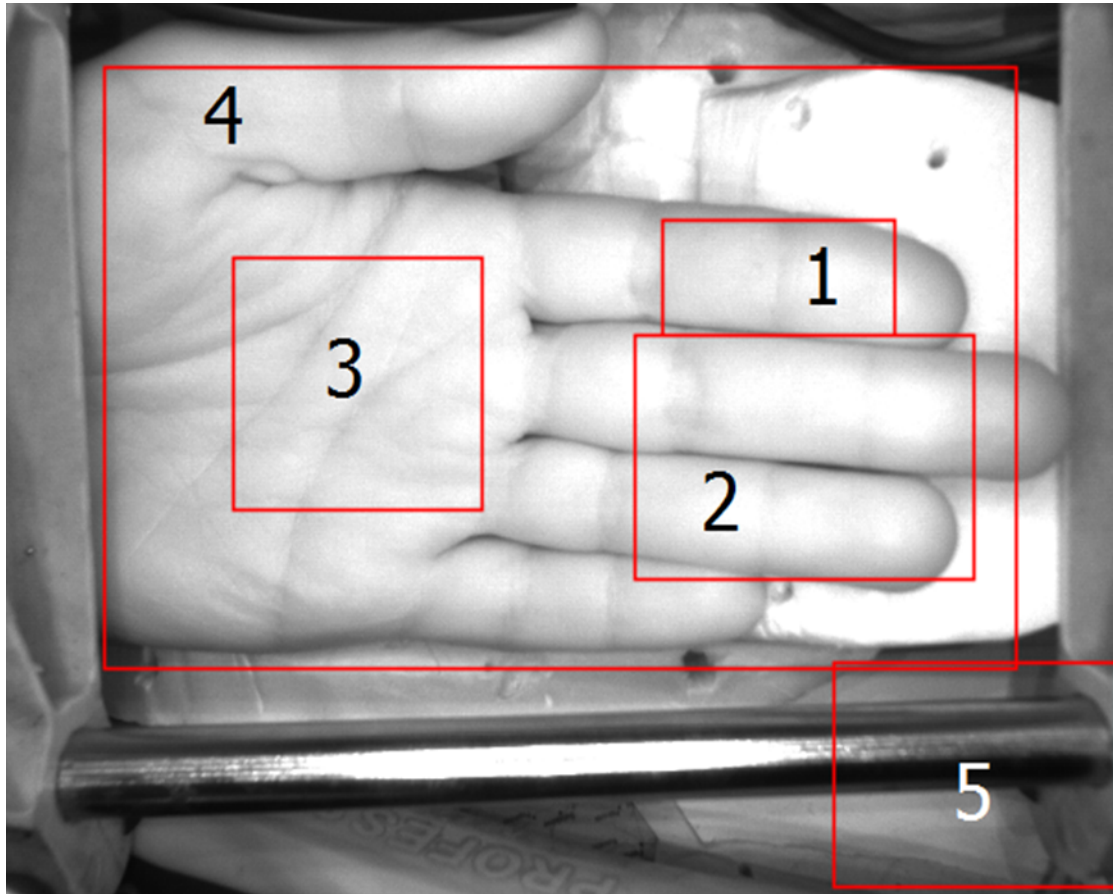# The quality of photoplethysmogram measured by device

RAW PPG Signal

Filtered PPG signal, AC component, zoomed
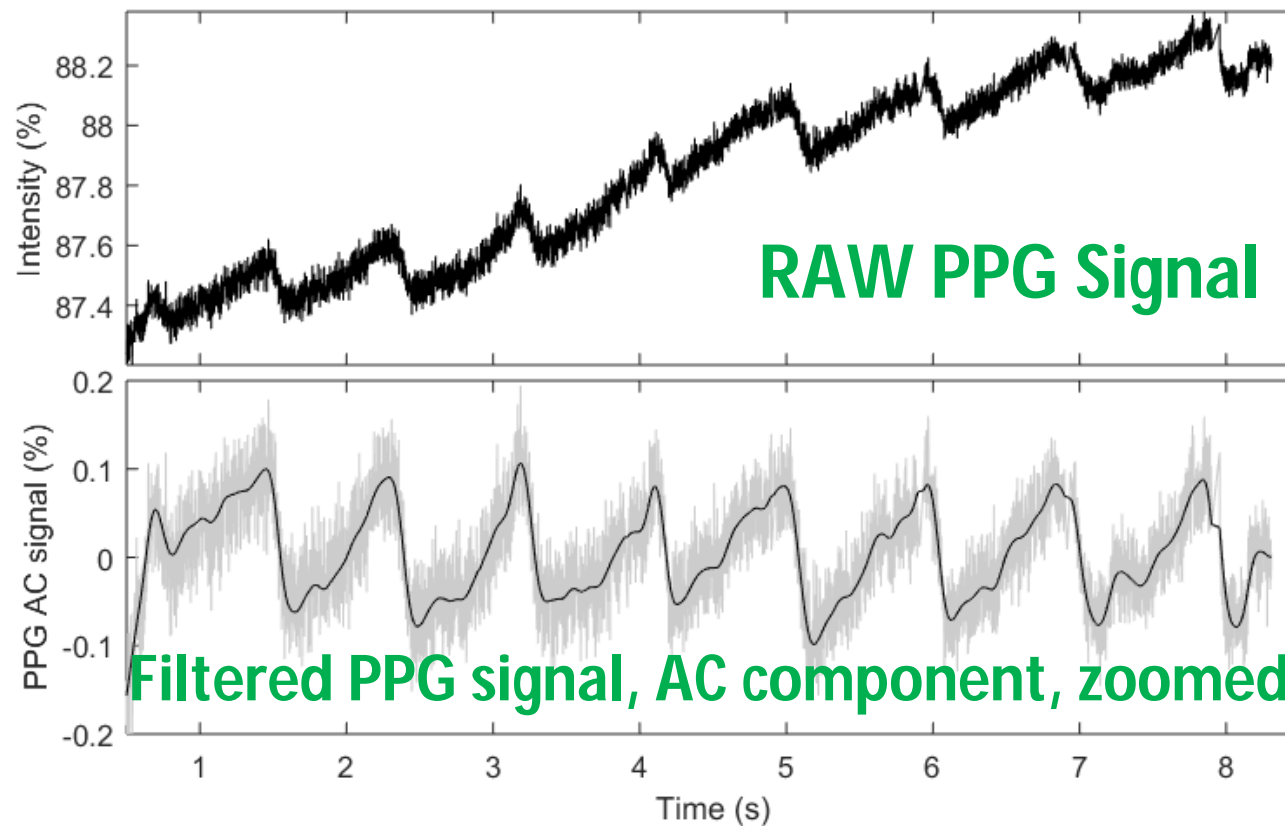
Signal from region of interest - 1 middle finger.

The quality of photoplethysmogram measured by device

RAW PPG Signal

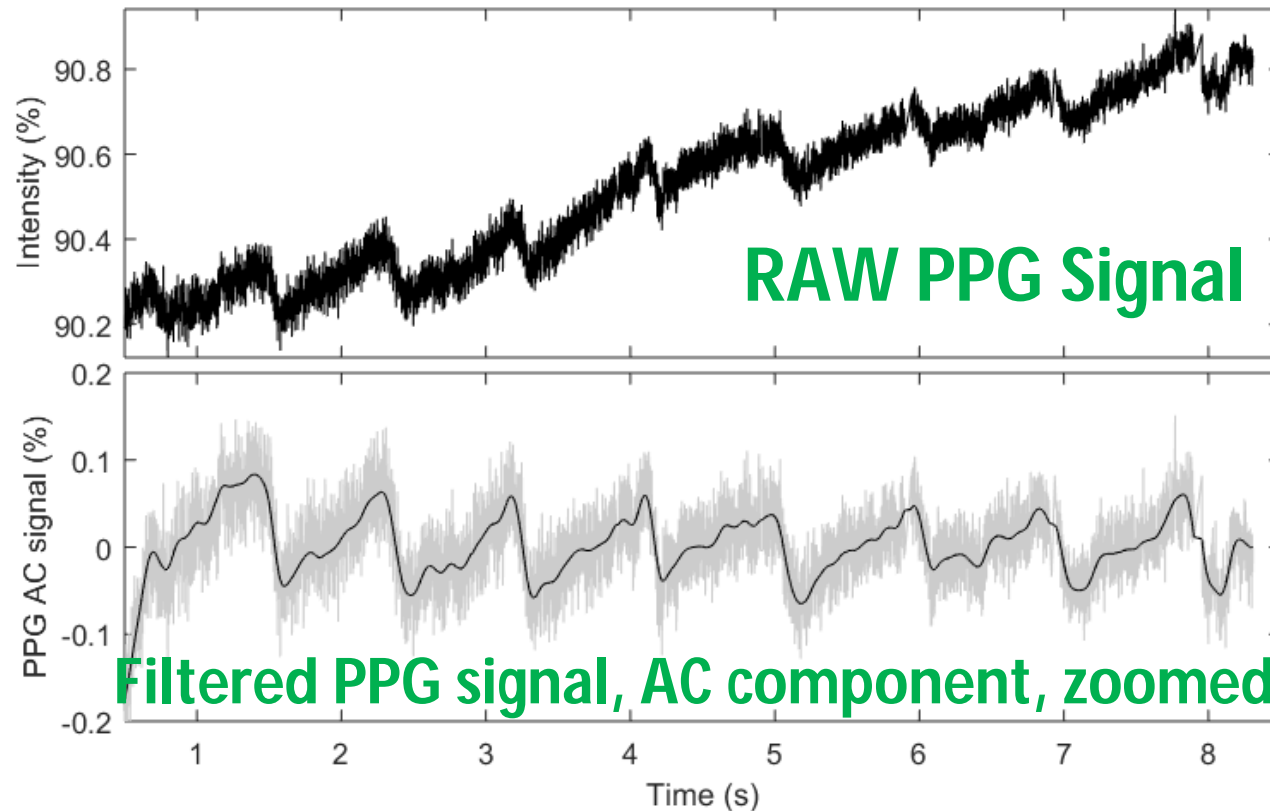**Filtered PPG signal, AC component, zoomed**
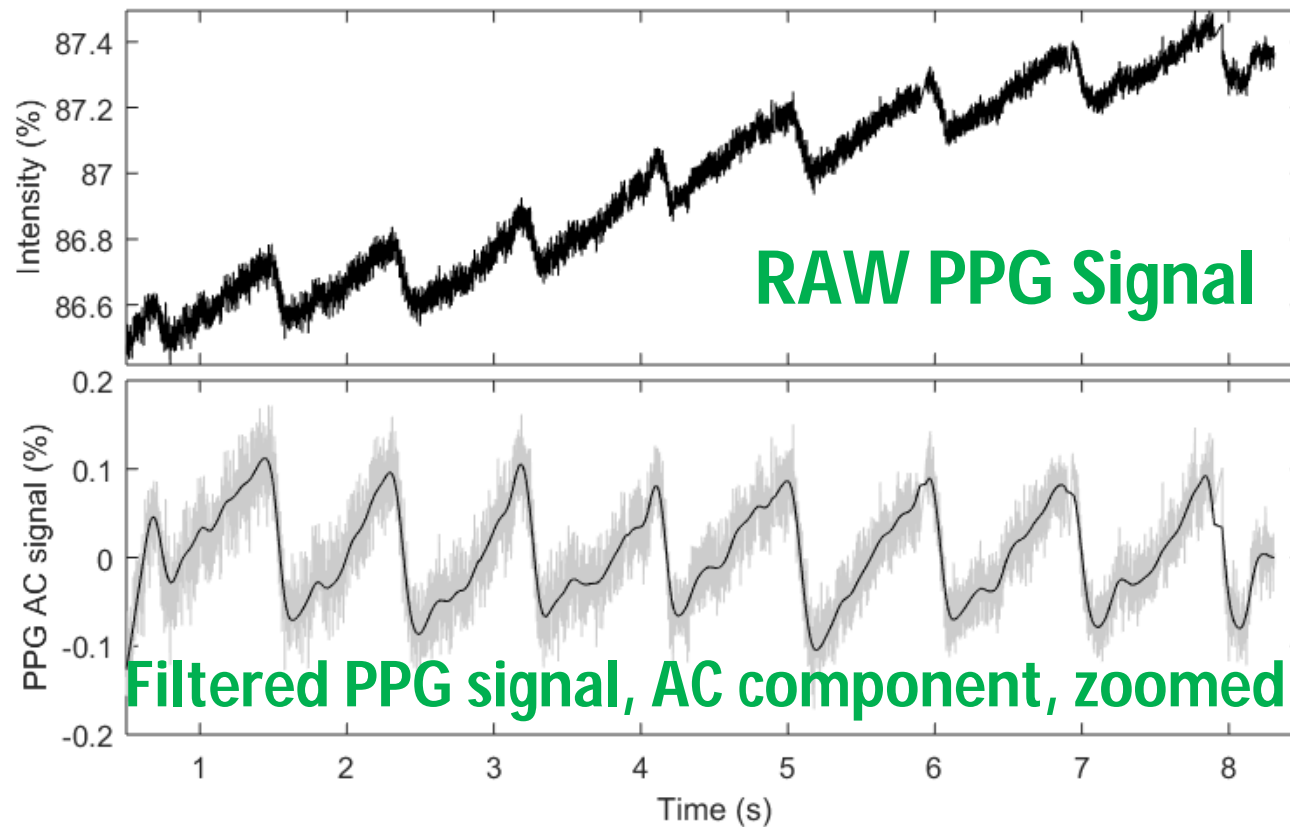
Signal from region of interest - 2 two middle fingers
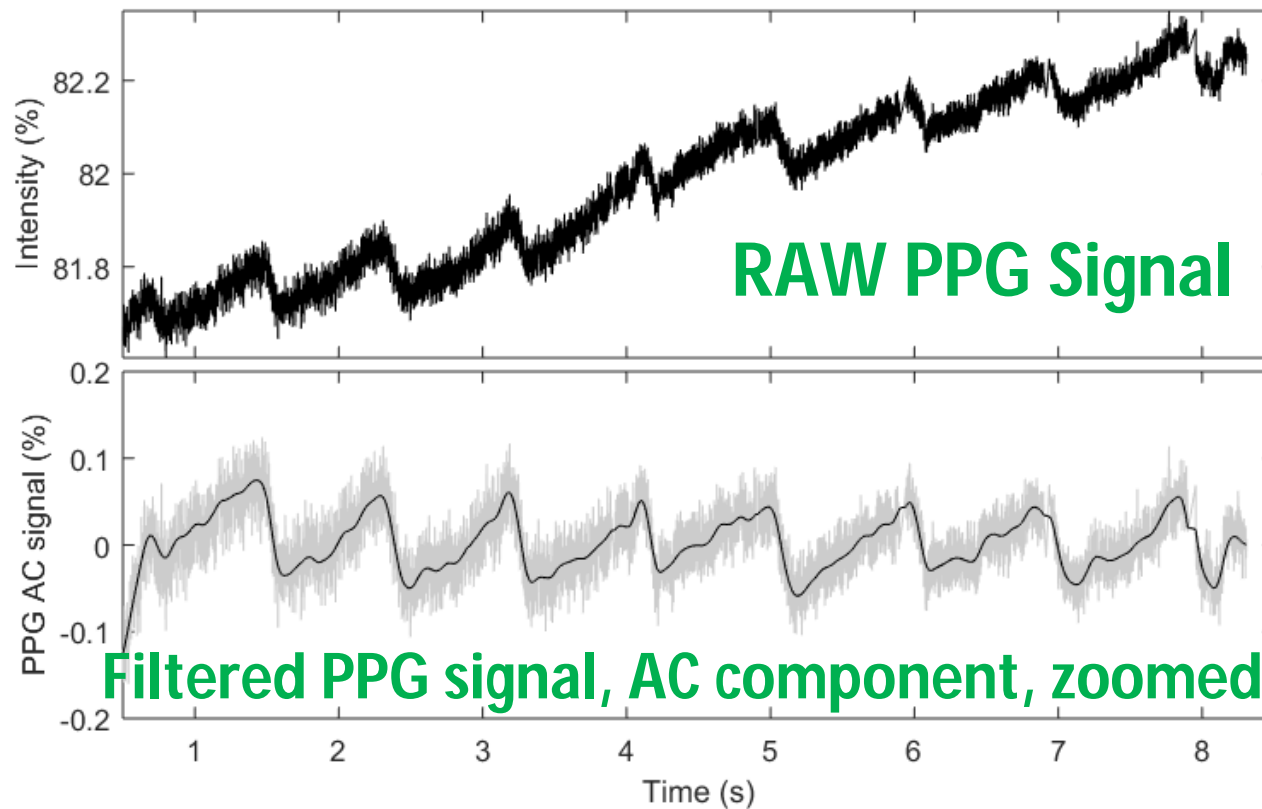
The quality of photoplethysmogram measured by device

Signal from region of interest - 3 the central part of palm.

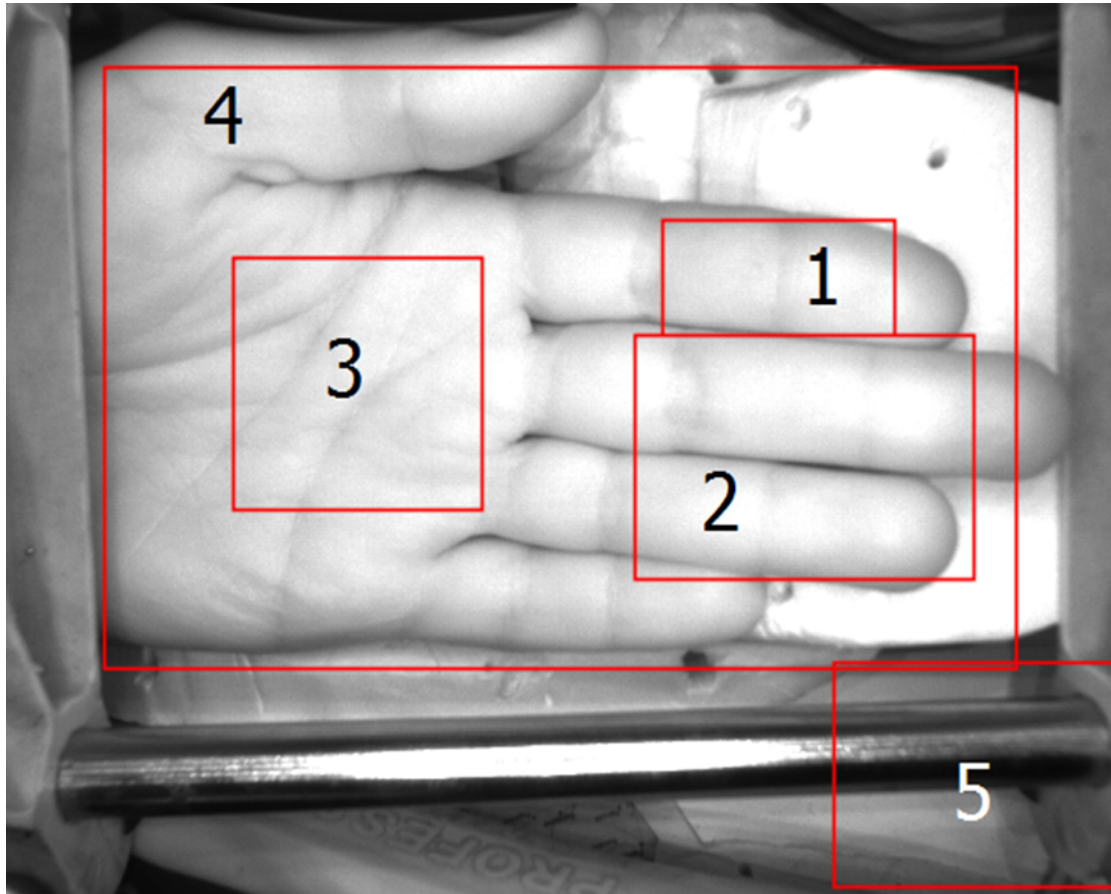# The quality of photoplethysmogram measured by device

RAW PPG Signal

Filtered PPG signal, AC component, zoomed

Signal from region of interest - 3 the central part of palm.

The quality of photoplethysmogram measured by device

RAW PPG Signal

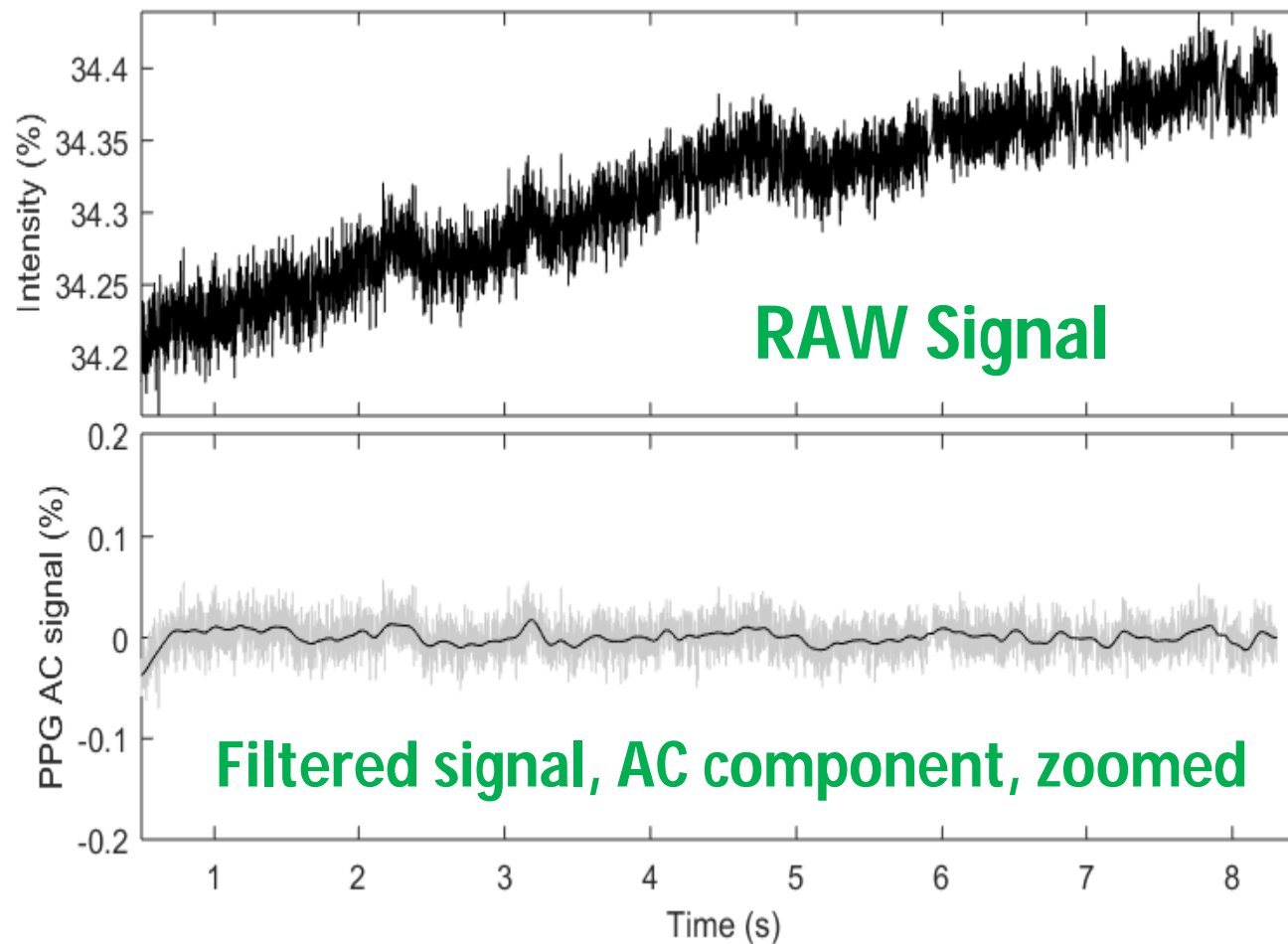**Filtered PPG signal, AC component, zoomed**

Signal from region of interest - 4 the whole palm.

The quality of photoplethysmogram measured by device

Signal from region of interest - 5

The quality of photoplethysmogram measured by device

RAW Signal

Filtered signal, AC component, zoomed

Signal from region of interest - 5 showed only noise.

CONCLUSION

- The developed prototype device was successfully tested and showed good performance results.
- It is able to provide uniform illumination for human skin to provide high quality photoplethysmogram data.
- The blood volume signals detected by device showed high temporal resolution with ability to see higher order pulse waves.
- The prototype device showed high signal/noise level and could be used for monitoring of human blood volume changes in palm.

ACKNOWLEDGMENT

Thank you!