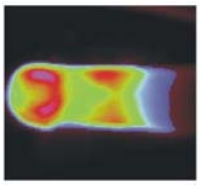
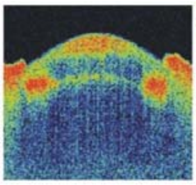
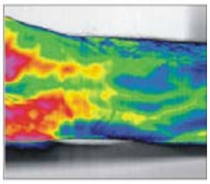
Applied Optoelectronics in Medicine

Aplikovaná optoelektronika v lékařství

Interdisciplinary course at the CTU Prague (P317APL-E, W, 4 credits)

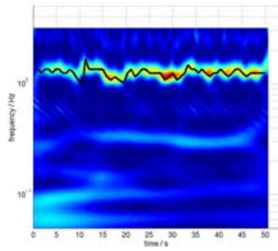


8. Optoelectronic sensor concepts for vascular diagnostics – part II
8. Optoelektronické koncepty pro vaskulární diagnostiku – část II

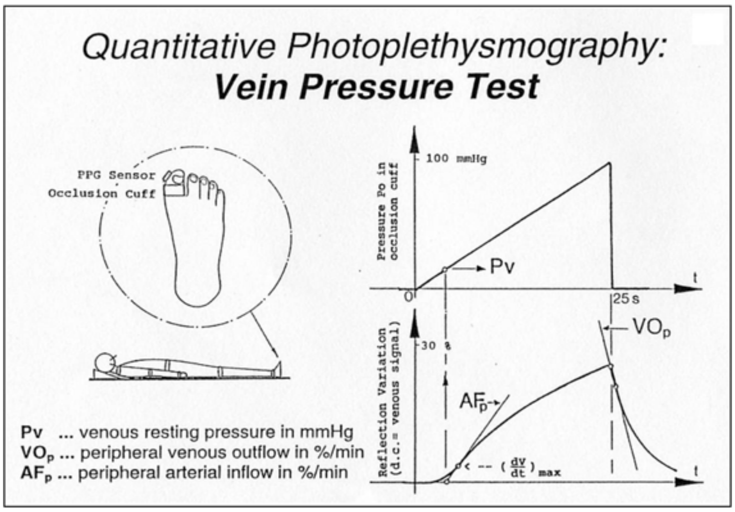
Learning aims of the eight AOM lecture

- PPG vein pressure test
- Arterial PPG tests
- What is behind the beat? Rhythmical phenomena in dermal blood perfusion
- Alternative fluidic experiment under microgravity






Noninvasive measurement of venous blood pressure



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Non-invasive measurement of venous blood pressure:
different pressure compartments

vis a tergo → P_V; venous blood flow →; vis a fronte → P_{Front}

$$P_V = P_{Vo} + P_{Hydr} + P_{Okkl} + P_{Front}$$

P_{Vo} ... venous resting pressure in horizontal position (physiological value ca. 10 mmHg)

$P_{Hydr} = \rho \cdot g \cdot h$ ... additional hydrostatic pressure
r … blood density (ca. 1.06 g/cm^3); g … gravity (9,81 m/s^2)
h … vertical distance from heart level to cuff level

P_{Okkl} ... additional pressure through outflow obstruction (e.g. DVT: 30 - 60 mmHg)

P_{Front} ... central venous pressure in right atrium (physiological value ca. 0 mmHg; in case of right heart insufficiency ca 20 - 40 mmHg)

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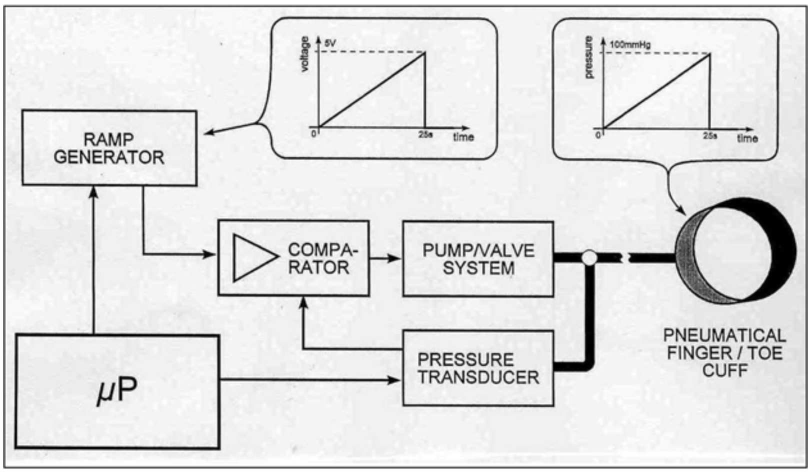
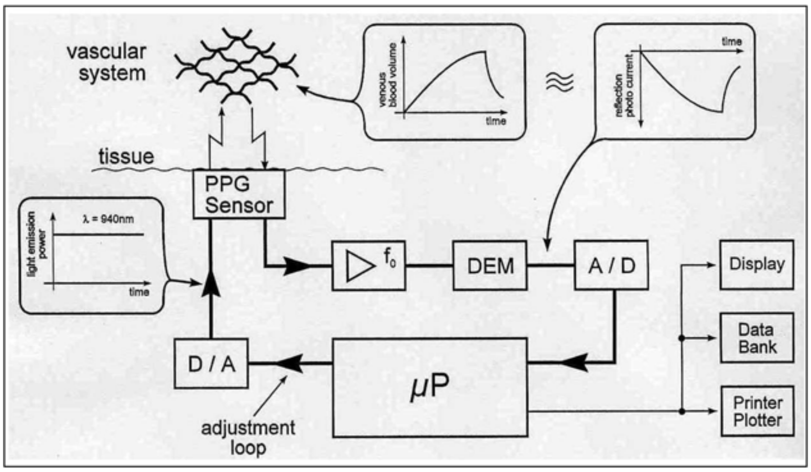
Non-invasive measurement of venous blood pressure:

Electro-pneumatic setup

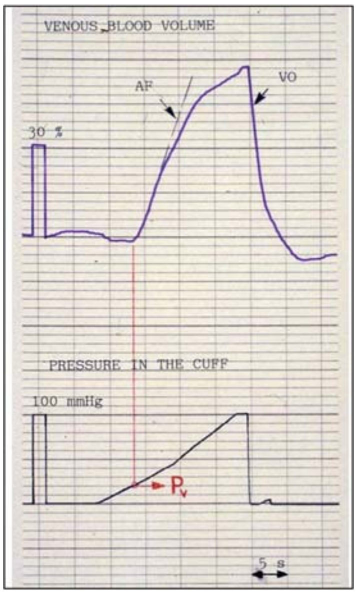


Non-invasive measurement of venous blood pressure:

Optoelectronic setup



Non-invasive measurement of resting venous blood pressure in the lower extremities



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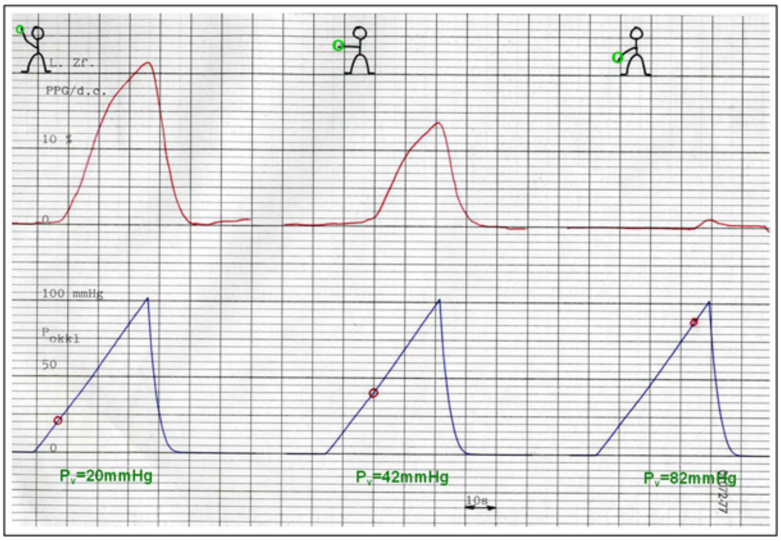
Non-invasive measurement of venous blood pressure



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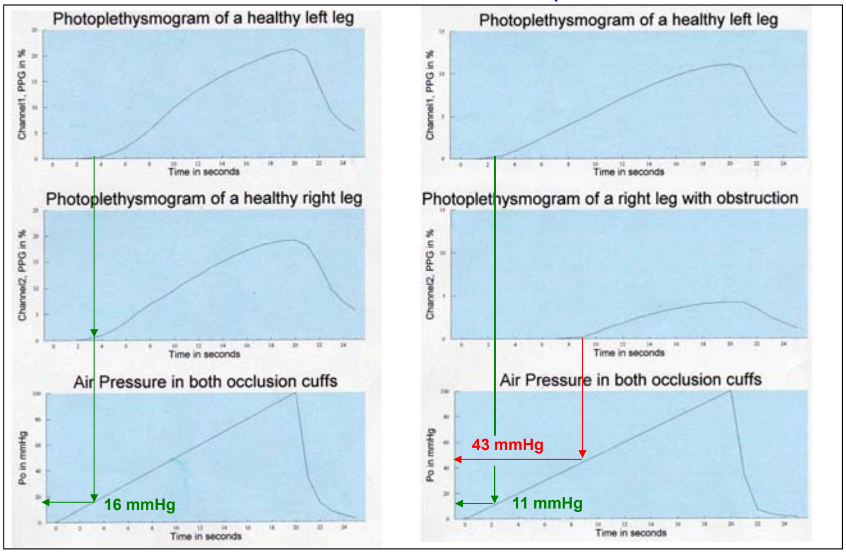
Non-invasive measurement of venous blood pressure: Bilateral test



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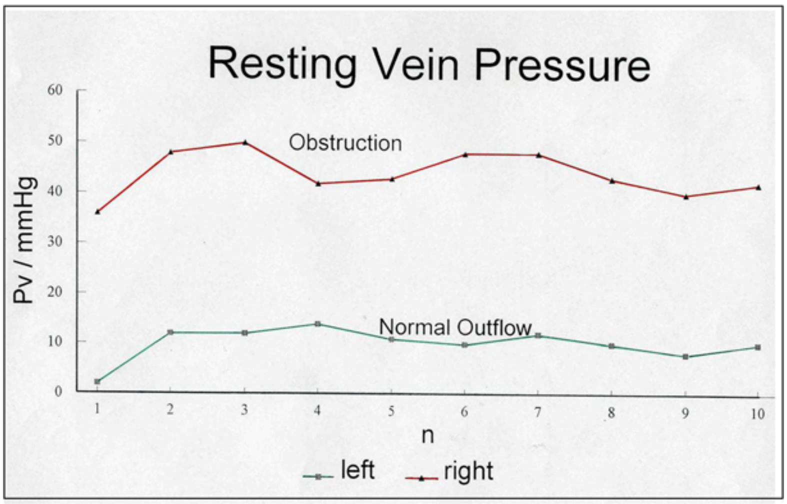
Non-invasive measurement of venous blood pressure: Reproducibility



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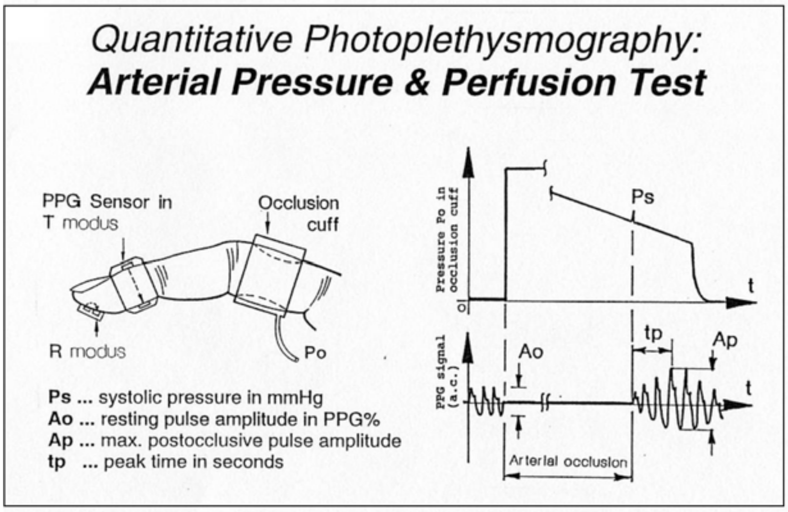
Non-invasive measurement of arterial blood pressure

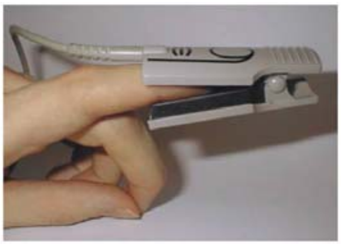
using optoelectronic sensor concept

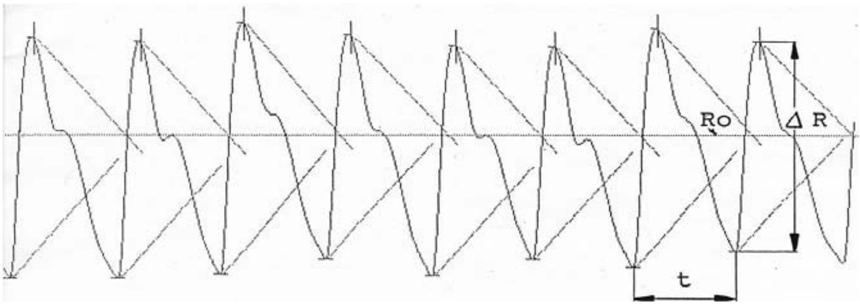


Photoplethysmographic registration of peripheral arterial blood volume pulse

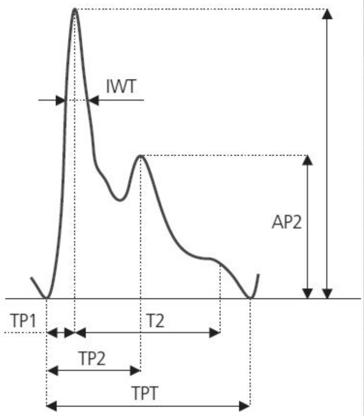
Different perfusion parameters can be calculated from the recorded time series, e.g. the so called tissue perfusion index TPI:

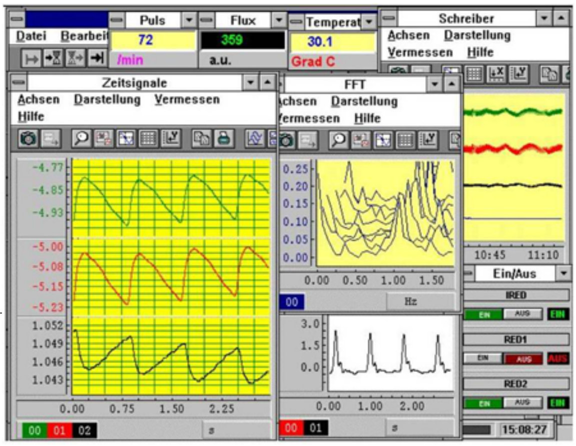
$$TPI = \frac{\Delta R}{t \cdot R_0}$$





Analysis of the peripheral arterial blood volume pulse

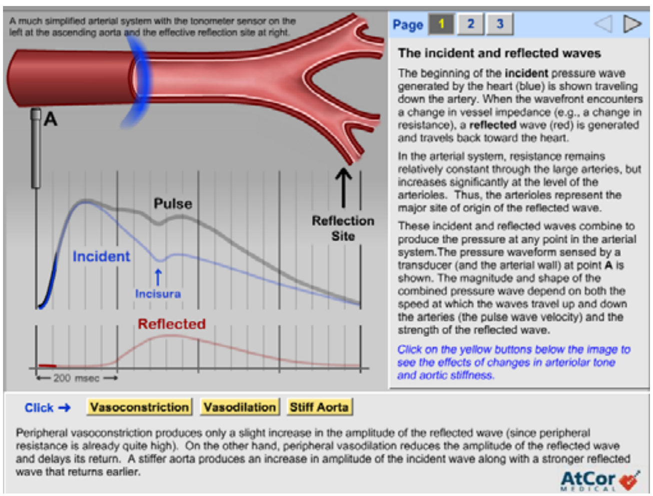




> *Remember:*
>
> *Beat to beat wave form analysis of blood volume pulse, its variability and other rhythmical perfusion patterns characterize peripheral vascular status and are diagnostically relevant.*

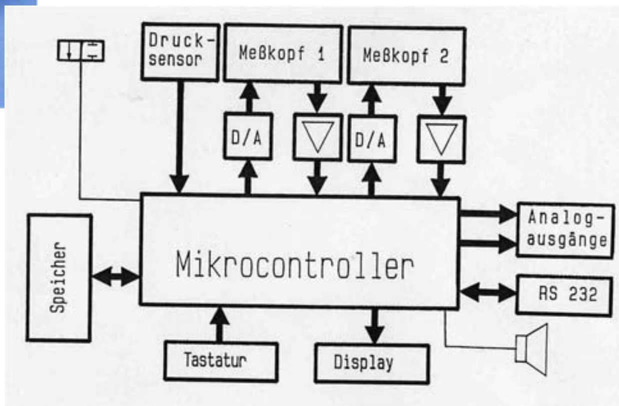
Modelling arterial pulse qantities

Video



Non-invasive measurement of arterial blood pressure

using combined optoelectronic and electro-pneumatic sensor concept



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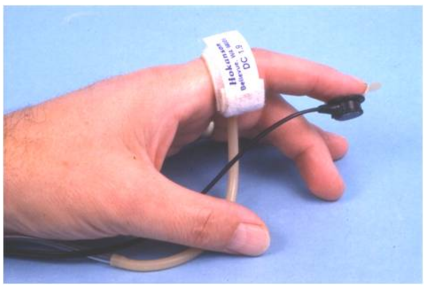
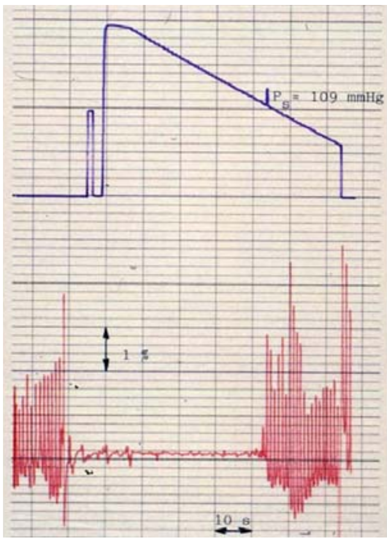
Non-invasive measurement of arterial blood pressure

using combined optoelectronic and electro-pneumatic sensor concept





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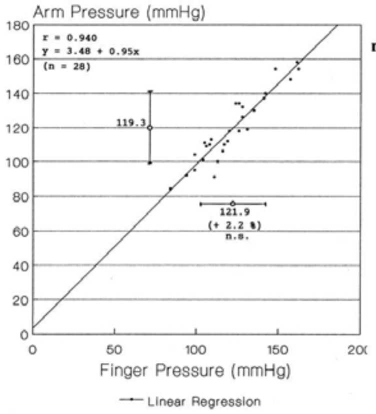
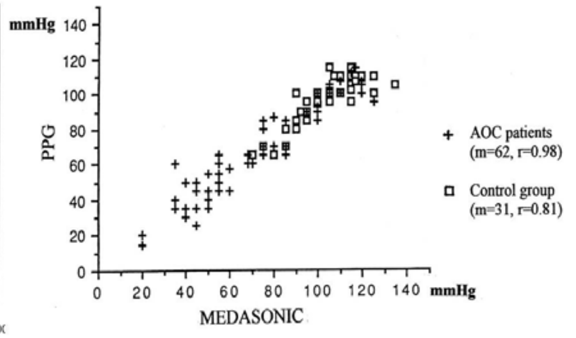
Non-invasive measurement of arterial blood pressure

using combined optoelectronic and electro-pneumatic sensor concept

Important for diagnosis of peripheral vascular status:
Segmental blood pressure studies





Healthy controls: Pressure values in comparison **Measuring systems in comparison: pressure assessment on toes**

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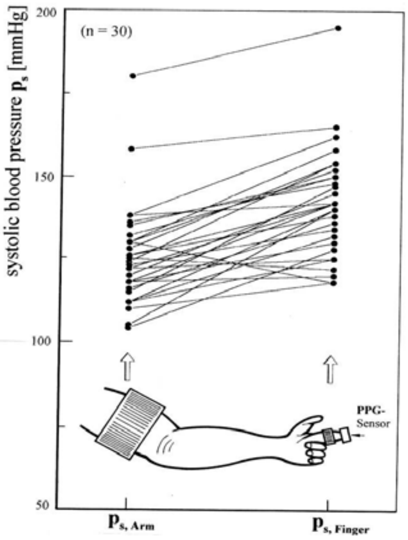
Non-invasive measurement of arterial blood pressure

using combined optoelectronic and electro-pneumatic sensor concept

Important for diagnosis of peripheral vascular status:
Segmental blood pressure studies

Remember:

By physiological conditions is $p_{s,\,Finger} \geq p_{s,\,Arm}$



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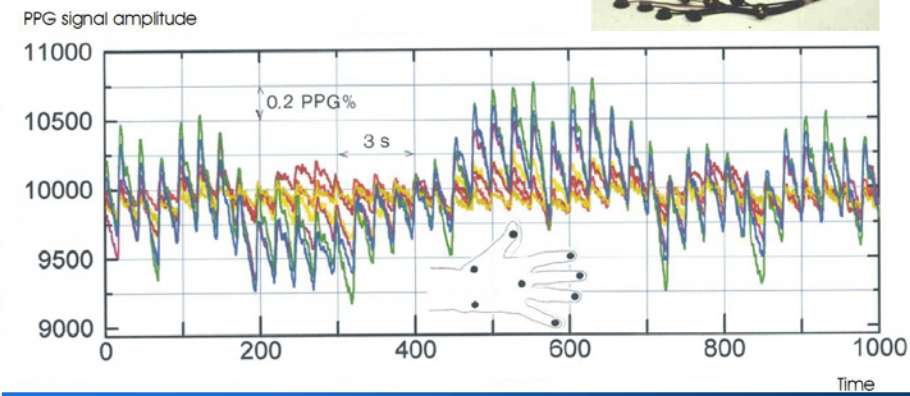
Multi channel Photoplethysmography:

Detection & analysis of rhythmical phenomena in skin perfusion. Using multi channel PPG we found different rhythmical perfusion changes in different skin areas at the same time.



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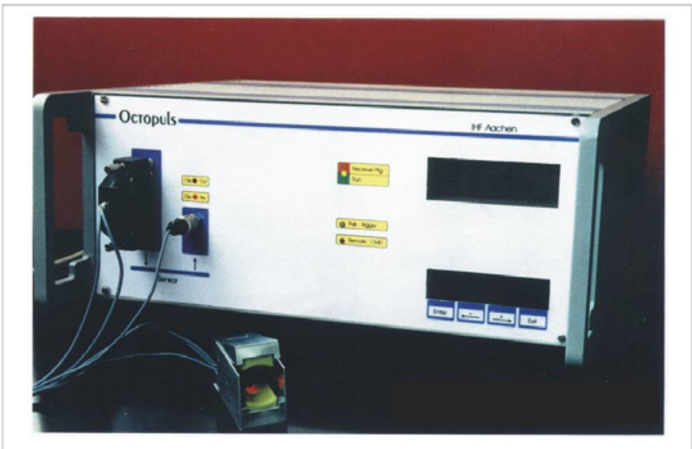
Multi wavelength / multi channel Photoplethysmography



Kanal	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
λ/nm	630	655	700	730	770	830	880	940
Typ	CR12 R	CR12 HR	CR10 IRB	CR10 IRC	CR10 IRD	CR10 IRF	CR10 IRG	CR10 IRK

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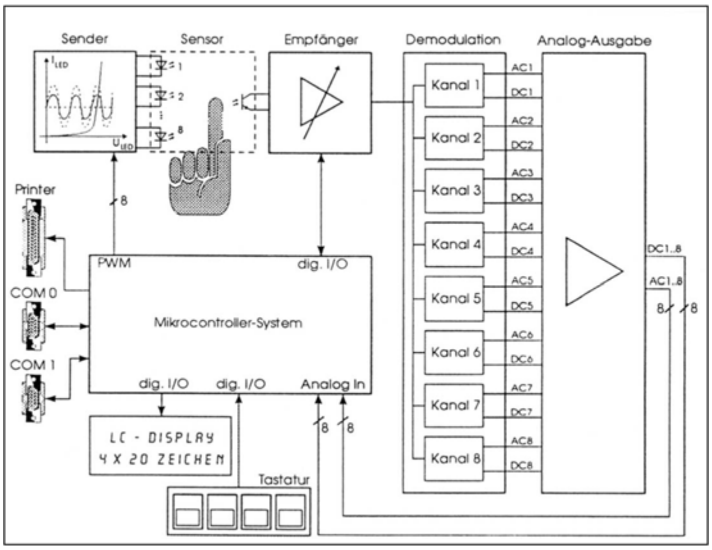
Multi wavelength / multi channel Photoplethysmography



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Application of multi wavelength Photoplethysmography:

transcutaneous measurement of tissue oxygen saturation (pulse oximetry)

The simplest non-invasive, optical assessment of oxygen saturation assumes a mixture of (only) two blood components: reduced haemoglobin (RHb) and oxygenated haemoglobin (O_2Hb):

$$SaO_2 = \frac{cO_2Hb}{cRHb + cO_2Hb} \qquad R_x = \frac{AC_r / DC_r}{AC_{ir} / DC_{ir}}$$

Using this definition the (relative) oxygen saturation of the tissue can be assessed from the AC and DC part of the signal. In experimental use the amplitudes R_x of these signal compartments are measured by two wavelengths: **660 nm** (r) and **940 nm** (ir).
Two analytical approximations are described in the literature:

a) Assessment according to MEYAPPAN (Int. J. Clin. Monit.&Comp. 1990):

$$SaO_2 = \frac{A - R_x}{B - C \cdot R_x} \cdot 100\%$$ with A = 3,4; B = 3,1074; C = 0,3983 .

b) Assessment according to RUSCH et al., (Comput. Biol. Med. 26/1996 ,pp.143)

$$SaO_2 = (A - B \cdot R_x)\%$$ with A = 110 und B = 25 .

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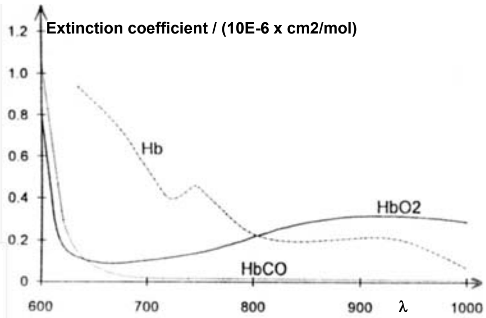
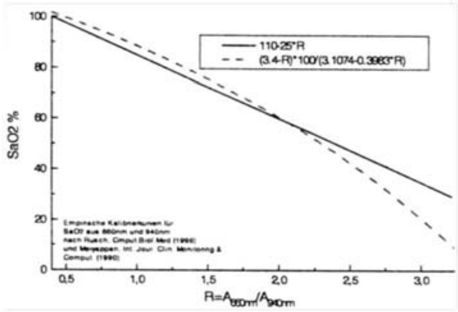
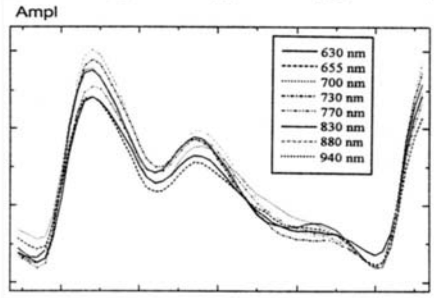
Application of multi wavelength Photoplethysmography:

transcutaneous measurement of tissue saturation with oxygen (pulse oximetry)







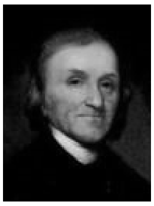
On the importance of oxygen saturation in the blood ...

Gas exchange: Oxygen (O_2) < --- > Carbon dioxide (CO_2)

Oxygenium (from the Greek roots **ὀξύς** (oxys = acid, literally "sharp," from the taste of acids) and -**γενής** (-genēs) (producer, literally begetter) is the element with atomic number 8 and represented by the symbol **O**.

When and by whom oxygen was discovered?

Carl Wilhelm SCHEELE
(1742 - 1786)
1771

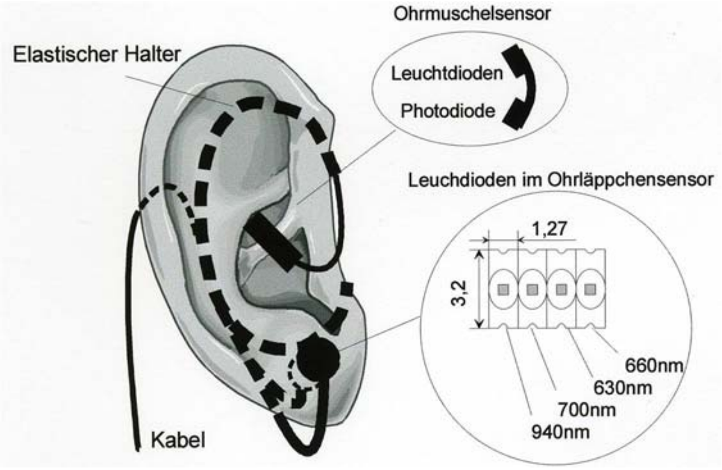


Joseph PRIESLEY
(1733 - 1804)
1774

Antoine Laurent de LAVOISIER
(1743 - 1794)
1779

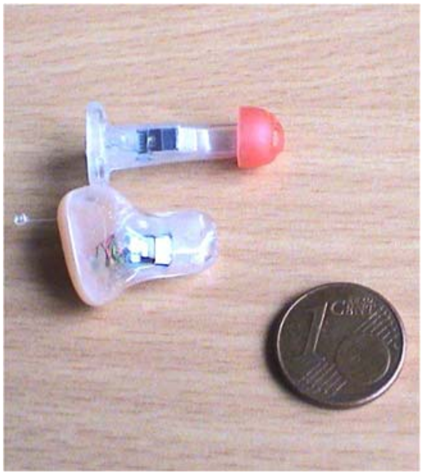
Application example:

Optoelectronic sensor concepts for preventive long-term Monitoring (24/7 of vital signs



Actual R&D program (BMBF-Verbundprojekt IN-MONIT und LAVIMO):

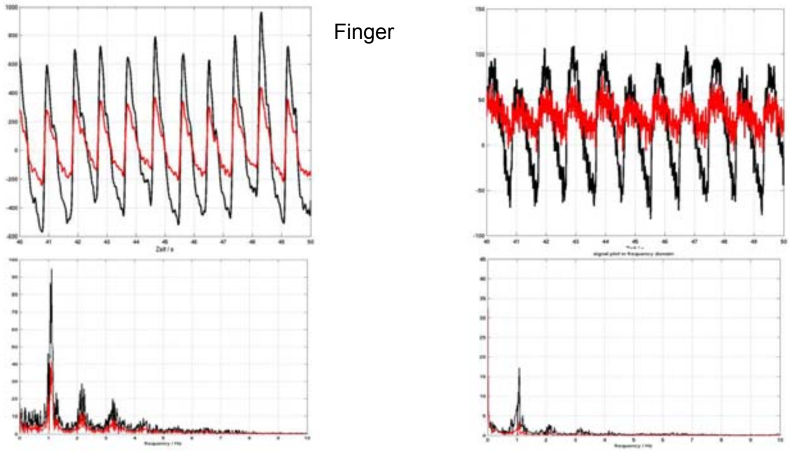
In-ear-implemented system for preventive monitoring of cardiovascular function in patients at risk



Actual R&D program (BMBF-Verbundprojekt IN-MONIT und LAVIMO):

In-ear-implemented system for preventive monitoring of cardiovascular function in patients at risk

Results 2008



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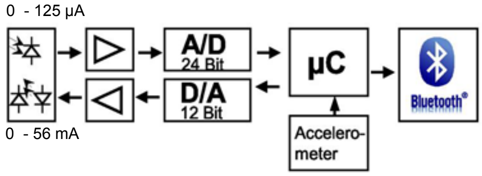
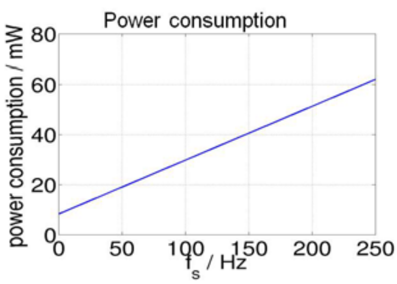
Actual R&D program (BMBF-Verbundprojekt IN-MONIT und LAVIMO):

In-ear-implemented system for preventive monitoring of cardiovascular function in patients at risk

Results 2013



System parameters
- drivers 2 LED in time multiplex
- photo detector current: 0 – 125 mA
- ambient light suppression
- sampling rate up to 200 Hz
- photoplethysmogram with 24 Bit resolution
- future proof connection to PC via USB or Bluetooth
- power consumption (excl. Bluetooth) typ. 50 mW
- size: 85 mm (L) x 45 mm (W) x 15 mm (H)
- weight: 50 g



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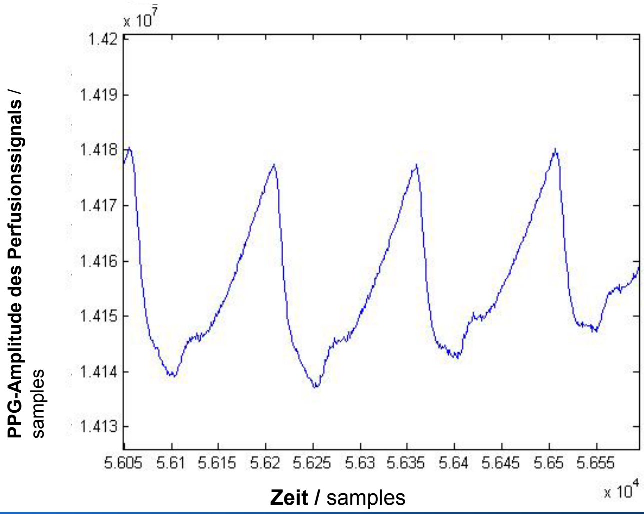
Actual R&D program (BMBF-Verbundprojekt IN-MONIT und LAVIMO):

In-ear-implemented system for preventive monitoring of cardiovascular function in patients at risk

Results 2013

Hypoxy study
Proband 1,
Rohdaten PPG IR



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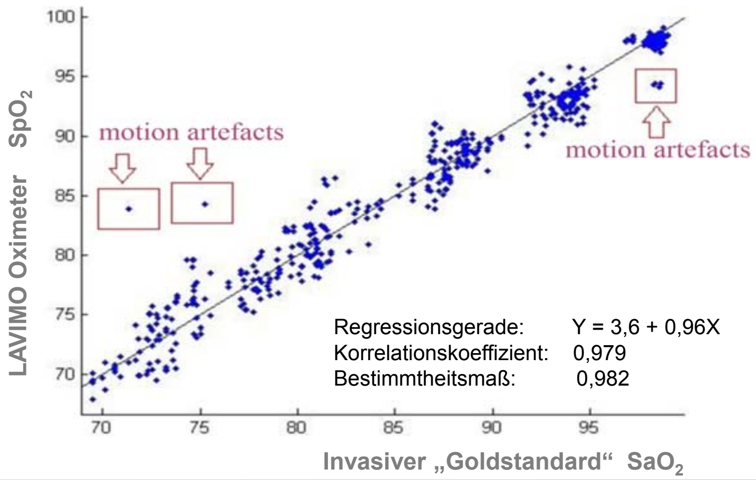
Actual R&D program (BMBF-Verbundprojekt IN-MONIT und LAVIMO):

In-ear-implemented system for preventive monitoring of cardiovascular function in patients at risk

Results 2013



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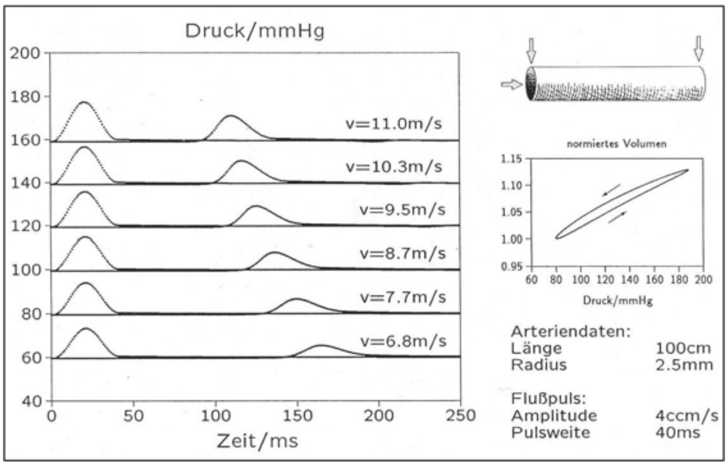
Non-invasive measurement of arterial blood pressure
using optoelectronic sensor concept

Further idea:
Measurement of pulse wave velocity for monitoring of arterial pressure changes

$$c_p \approx r \cdot \sqrt{\frac{E}{\rho}} \approx p$$



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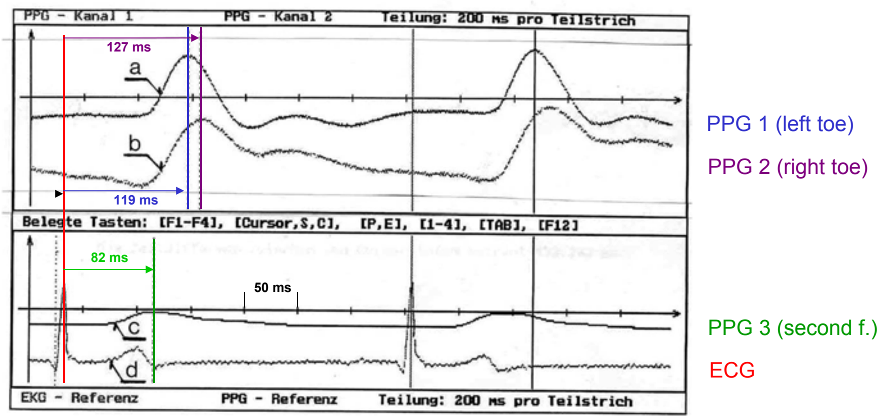
Further idea:
Measurement of pulse wave velocity for monitoring of arterial pressure changes



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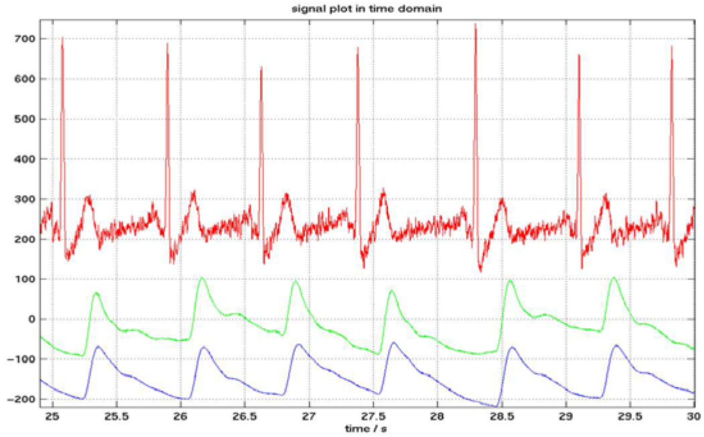
Non-invasive measurement of arterial blood pressure
using optoelectronic sensor concept

Further idea:
Measurement of pulse wave velocity for monitoring of arterial pressure changes

Typical results: simultaneous ECG and PPG registration



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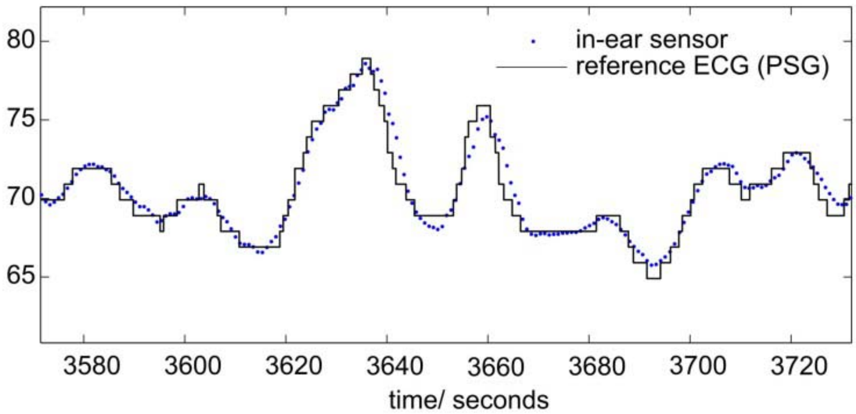
Non-invasive monitoring of heart rate variability (HRV)



Comparison of heart rate (HR, blue dots) derived from the PPG sensor and from polysomnography (ECG, black solid line)

From: Venema, B. et al: Evaluating Innovative In-Ear Pulse Oximetry for Unobtrusive Cardiovascular and Pulmonary Monitoring During Sleep. IEEE Journal of Translational Engineering in Health and Medicine, Vol. 1 (2013), Digital Object Identifier 10.1109/JTEHM.2013.2277870

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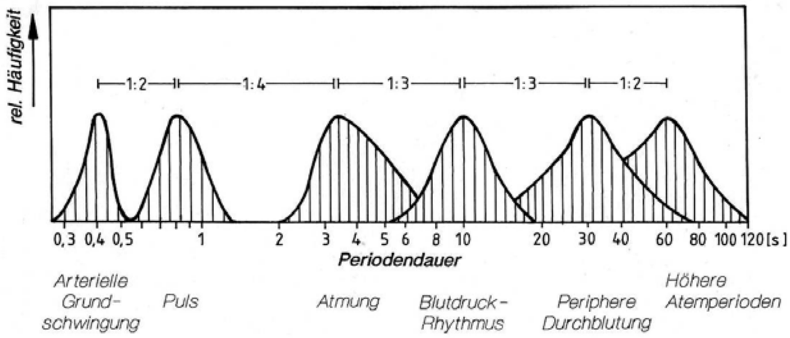
Non-invasive measurement of arterial blood pressure

using optoelectronic sensor concept

Further idea:
Analysis of rhythmical phenomena in skin perfusion for monitoring of pressure changes

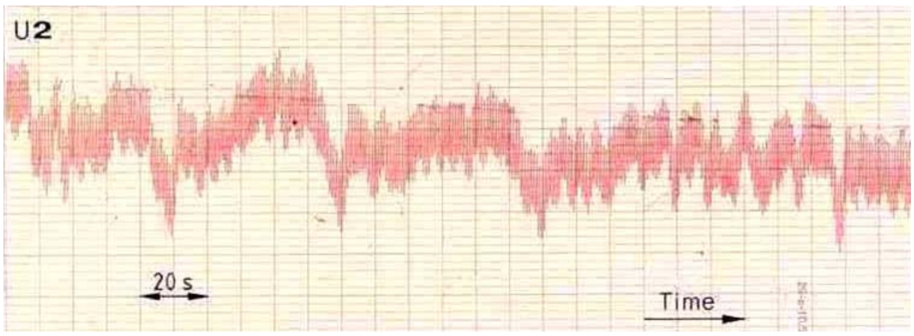


„Rhythms are a basic phenomenon in all physiological systems. They cover an enormous range of frequencies with periods from the order of milliseconds up to some years”.
(Haken et al., Springer Verlag, 1992)

Non-invasive measurement of dermal perfusion dynamics

using optoelectronic sensor concept

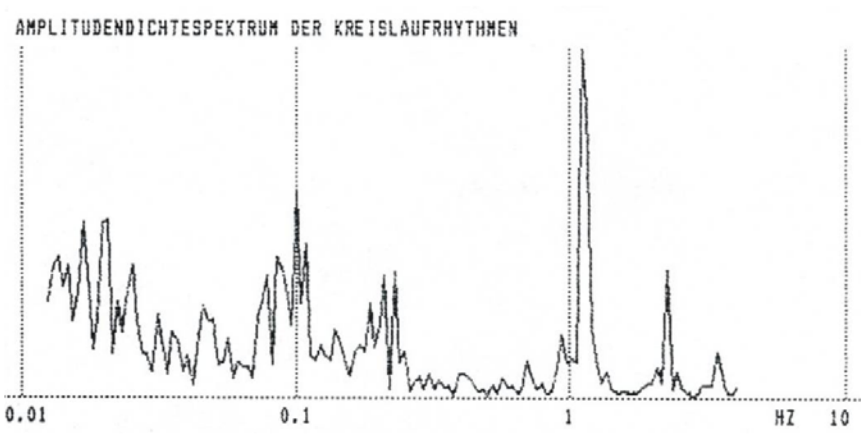
“Historical results” 1: Visualisation in time domain a. D. 1984



Optical (PPG) monitoring of skin perfusion exhibits a rich spectrum of rhythmical patterns including components around 1 Hz due to heart pulse, breathing periodicity and periodic low frequency components at around 0.1 down to 0.01 Hz.
(Blazek et al., Oldenburg Verlag 1984)

Non-invasive measurement of dermal perfusion dynamics
using optoelectronic sensor concept

“Historical results” 1: Visualisation in the frequency domain a. D. 1984



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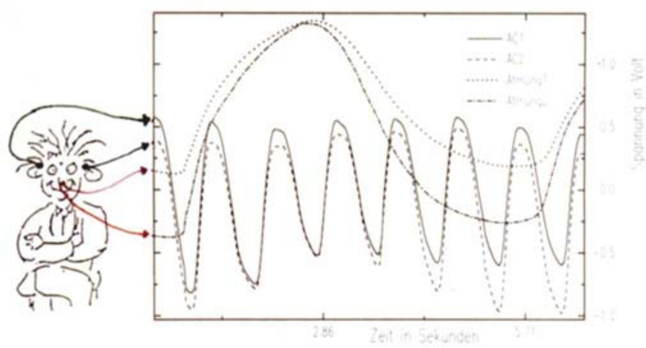
Non-invasive measurement of dermal perfusion dynamics
using optoelectronic sensor concept

“Historical results” 2: Registrations during YOGA

(Indo-German Project “Studies of neurological induced skin perfusion changes using optical sensors”, 1996-1998)



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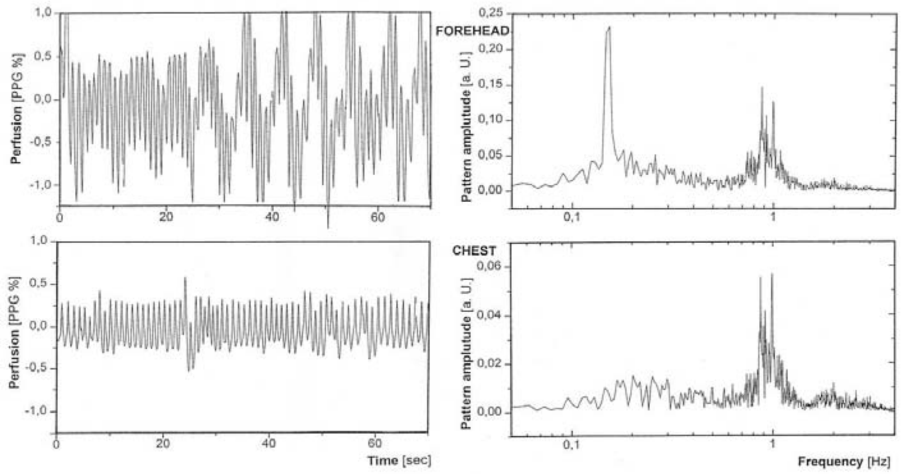
“Historical results” 2: Registrations during YOGA

(Indo-German Project “Studies of neurological induced skin perfusion changes using optical sensors”, 1996-1998)

Concentration of the Head

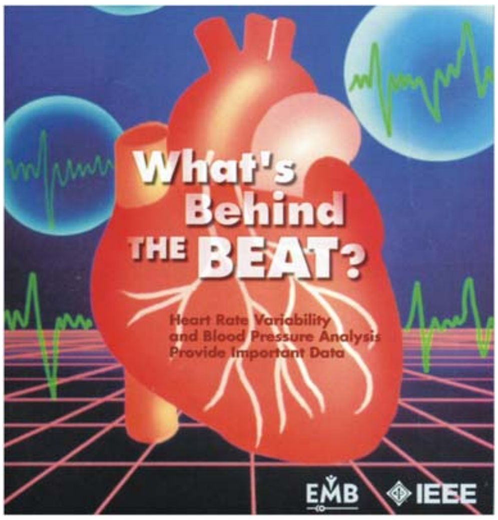


Non-invasive measurement of dermal perfusion dynamics

using optoelectronic sensor concept

IEEE ENGINEERING IN MEDICINE AND BIOLOGY
MAGAZINE

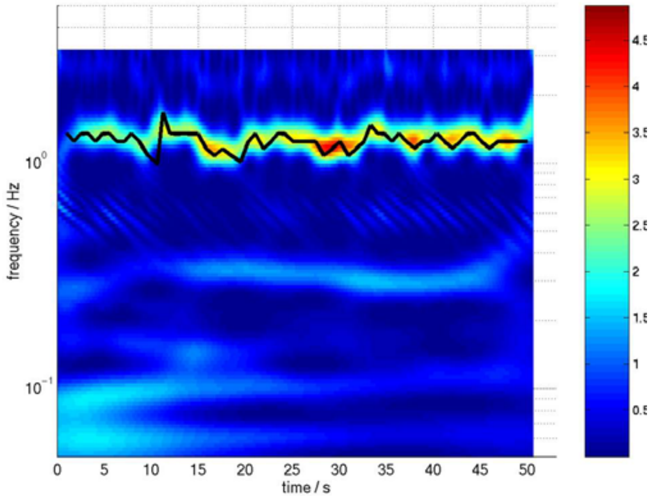
Volume 20
Number 2
March/April 2001



Non-invasive measurement of dermal perfusion dynamics
using optoelectronic sensor concept

Non-invasive measurement of dermal perfusion dynamics
using optoelectronic sensor concept

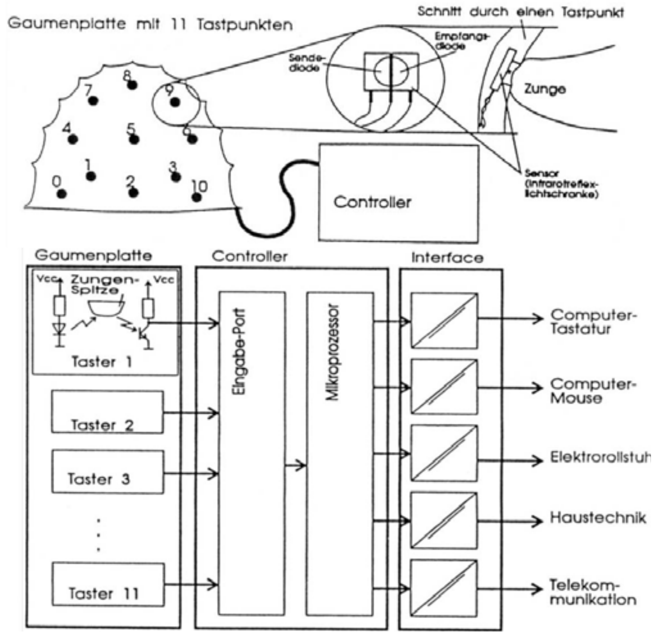
Correlation of wavelet spectrum and beat to beat analysis of the peripheral PPG signal



Innovative application example:

Optoelectronic reflection sensor as a biosensitive interface for paraplegics

11 Reflexionssensoren SFH 900-X der Firma Siemens



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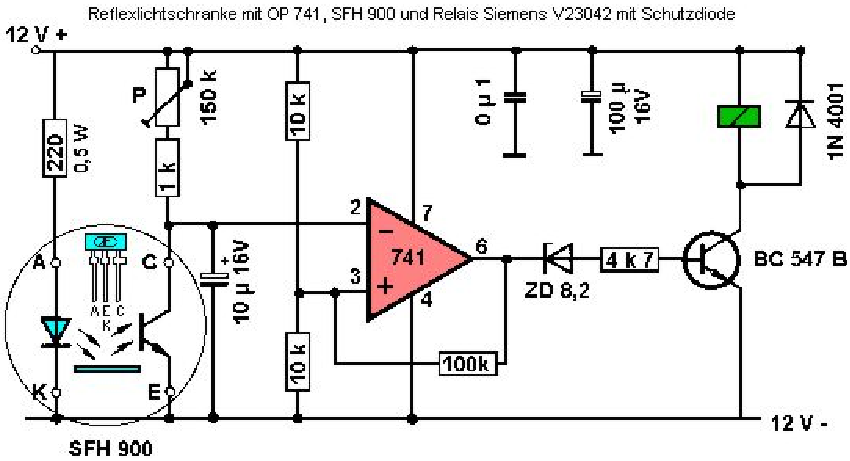
Innovative application example

Optoelectronic reflection sensor as a biosensitive interface for paraplegics



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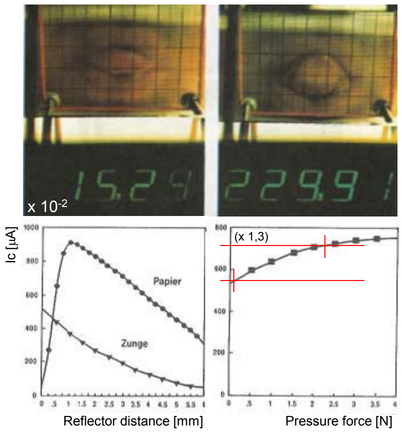
Innovative application example

Optoelectronic reflection sensor as a biosensitive interface for paraplegics

Appearace feature: 1) Position and distance

2) Contact pressure



SCHMITT, W., RÜTTEN, W., BLAZEK, V.: Optical sensors as biosensitive transducers for application in the rehabilitation of handicapped persons. In: Schultz-Ehrenburg, U., Blazek, V. (Eds.).: Advances in computer-aided noninvasive vascular diagnostics. VDI-Verlag Düsseldorf, 1994, S. 121-127

Human hemodynamics under hyper- und microgravity

Experiment for the 7th and 8th German parabolic flight campaign:

Rapid fluid shifts along the body axis in humans during parabolic flights

Partner: Center of the Space Medicine Berlin, Charité, University Berlin (Prof. H. C. Gunga)
Institute of High Frequency Technology, Aachen University RWTH (Prof. V. Blazek)

Management: DLR, German Aerospace Center, Space Management Bonn

weightlessness.swf

Alternative fluidic experiment under hyper-and microgravity

Video

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Citát pro osmou přednášku / Quotation of the lecture 8:

"When planning for a year, plant corn. When planning for a decade, plant trees. When planning for life, train and educate people"

管仲

Guan ZHONG (725 BC - 645 BC)
famous Chinese minister of state.
Chinese proverb

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