Requirements and design of a fluidic circuit for optical measurements on non-hemolyzed human blood

B. Redmer, J. Albrecht, I. Dibbern, C. Stark, F. Fiedler, B. Nestler

Medical Sensors- and Devices Laboratory, Lübeck University of Applied Sciences (FHL), Lübeck, Germany

Introduction

- An optical measurement setup for the concentration determination of clinically relevant hemoglobin derivatives in non-hemolyzed human blood is currently under development.
- Optical properties depend on the flow behavior of the sample [1].
- Deposits, clumping and any changes of the sample constitution have to be minimized and a stable flow profile provided in the optical focus.

Objectives

- Construction of a fluidic circuit that fulfills the specific requirements of optical measurements on non-hemolyzed blood.
- Reduction of flow pulsation and a flow between 0.4 and 2 ml/min for wall shear rates from 200 to 1000 s^{-1} for stable optical properties [2, 3].
- Development of an economical flow cell, because custom designs are expensive and can not easily be replaced if they are clogged with blood.

Results

Fluidic circuit

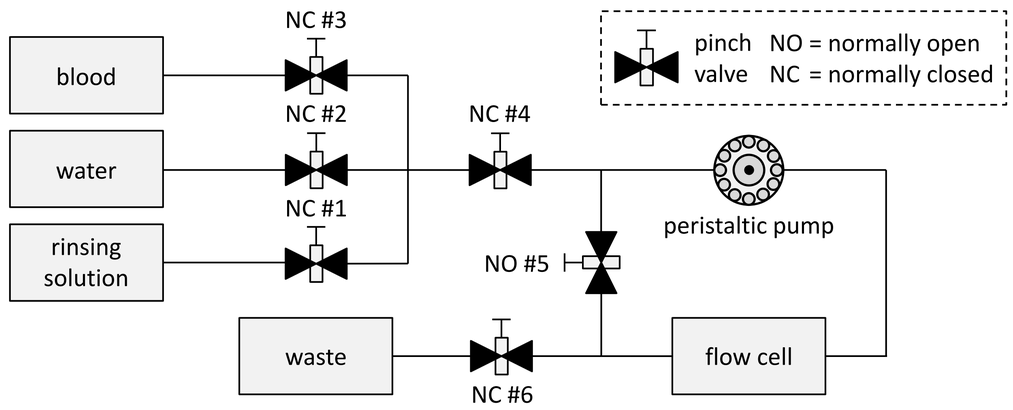
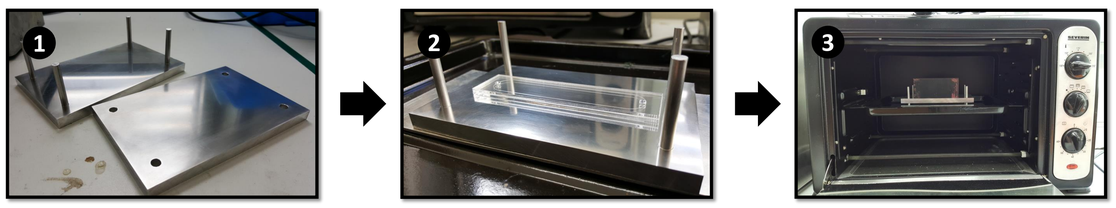


Fig. 1 – Schematic diagram of the constructed fluidic circuit. It allows a remote controlled automation of several processes, e.g. sample insertion, circulation or cleaning the circuit.

- Built up of six pinch valves and a peristaltic pump.
- Developed software allows to control the valves individually via USB.
- An Arduino serves as interface between software and hardware.
- Possibility of sample circulation lowers necessary sample volume.

Flow cell



a) Polished aluminium plates

Abrasive paper with 400 grit, followed by 2000 grit and finally aluminium polishing paste.

b) Flow cell PMMA layers

Middle layer is PMMA film. All components were cut with a CO_2 laser.

c) Thermal bonding procedure

1 hour at 160 °C and ≈11 MPa.

Fig. 2 – Process to build an economic flow cell from PMMA.

- Channel width is 20 mm and height approximately 175 µm.
- Total external dimensions of flow cell without connected tubings are 120 mm x 30 mm x 4.175 mm.

Flow pulsation

- Modification of the peristaltic pump to reduce flow pulsation:
  - Increased roll count from 6 to 12
  - Use of phase-shifted tubings

Tab. 1 – Compared pump configurations

number of rolls	phase-shifted tubings
6	no
12	no
12	yes

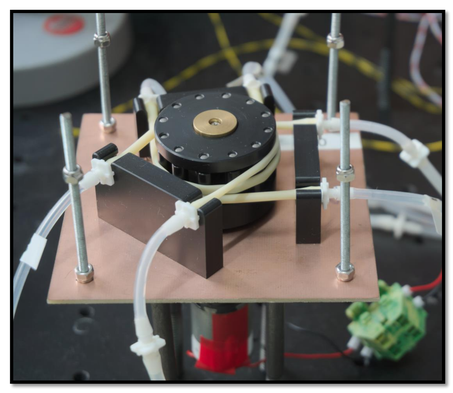


Fig. 3 – Peristaltic pump with phase-shifted tubings and head with 12 rolls.

- Flow rate was measured using a Sensirion LG16 flow sensor and compared against transmission measurements on whole blood.
- The peristaltic pump is driven by a DC motor with 20 RPM at 5 V.

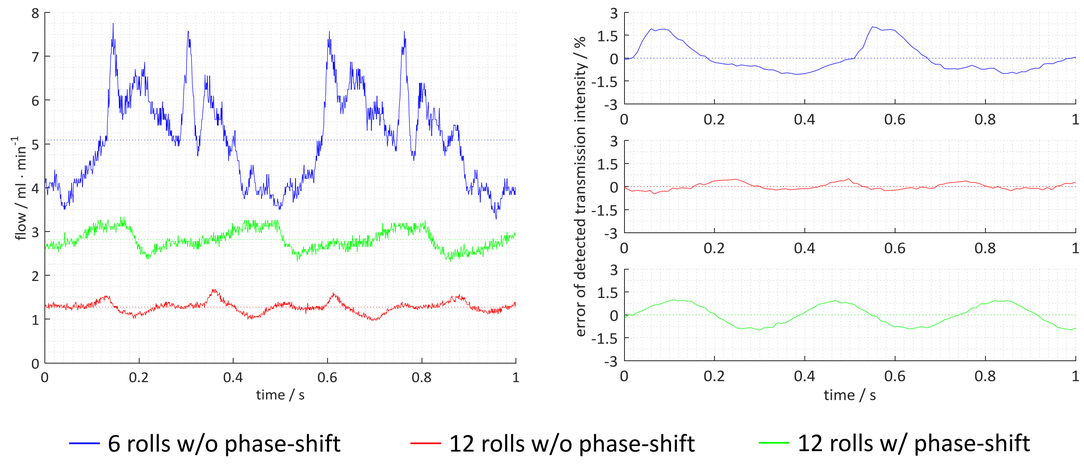


Fig. 4 – Flow rate of water at different pump configurations measured with a Sensirion LG16 flow sensor at 1 ms sampling time.

Fig. 5 – Variation of the detected transmission intensity of whole blood in the spectral range from 400 to 1000 nm, normalized to the mean detected intensity at 10 ms integration time.

- Without modification of the peristaltic pump, a large pulsation can be seen, which is clearly visible in optical measurements.
- Increased roll count and phase-shifted tubings change the mean flow rate, but do not necessarily lead to a lower pulsation.

Outlook

- Improvement of flow cell quality, e.g. through surface pre-treatment.
- Implementation of a control loop to further reduce flow pulsation.

References

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[3] André Roggan, Moritz Friebel, Klaus Dörschel, Andreas Hahn, and Gerhard Müller, "Optical properties of circulating human blood in the wavelength range 400-2500 nm", Journal of Biomedical Optics, Vol. 4, No. 1, January 1999.

Corresponding author

Benjamin Redmer, M.Sc.
Medical Sensors- and Devices Laboratory
Lübeck University of Applied Sciences (FHL)
Mönkhofer Weg 239
23562 Lübeck, Germany
benjamin.redmer@fh-luebeck.de

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