Arduino-based photo- and fluorimeter for measurements on site

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Abstract

In the last decades many photometric assays were established for a wide range of parameters. Especially in areas where laboratory equipment is not available due to high cost and space requirements or where unstable parameters have to be determined quickly on site, the demand for inexpensive, portable photometers is high. Therefore, there has been a growing trend towards the use of smartphone-based analysis systems. However, since the size and arrangement of sensors in smartphones is constantly changing, the analysis systems have to be tailored to one specific smartphone model to be used and cannot be transferred to any other. In order to make such systems accessible to the general public, ubiquitous applicability is important. One solution is to use external sensors for light measurement. The output of measurement data can be done by a display, by smartphone or by a computer. To make on-site measurements possible, an arduino-based photo- and fluorimeter for less than 150 € was developed based on the photometer of the non-profit entrepreneurial company desklab. It consists of an Arduino microcontroller and a 3D printed housing. Absorption and fluorescence measurements are implemented using LEDs of specific wavelengths. A phototransistor serves as light sensor. The absorbed or emitted light is evaluated with the aid of a circuit that determines the discharge time of a capacitor via the phototransistor.

Measuring chamber design

- 3D printed (ABS plastic)
- overall dimensions L x W x H: 90 mm x 93 mm x 95 mm
- rotable wheel opposite the light sensor for alternation between LEDs with different wavelengths (1)
- Dual-beam sample excitation in a 90-degree angle to the light sensor (2)
- light sensor and UV-LEDs inserted by LED mounting clips for simple exchange
- cables guided into a bottom compartment (3)
- Covers for the UV-LEDs and the light sensor to keep out ambient light (4)
- circuit soldered on a circuit board and placed in the bottom compartment
- transparent matte labels in front of the light sensor for an even distribution of light

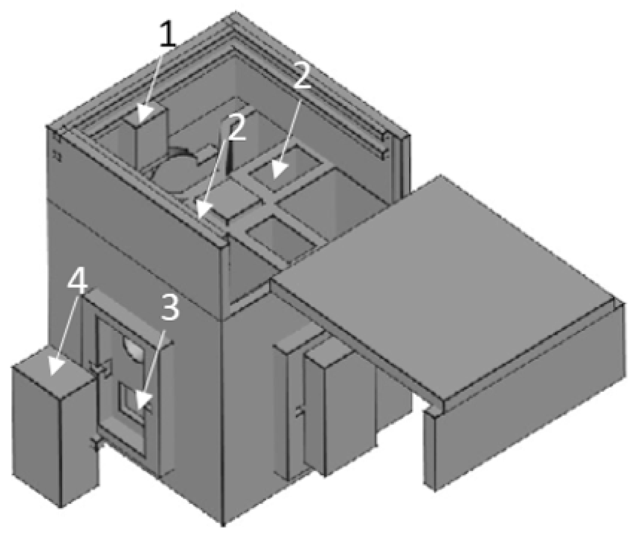

Fig. 1: CAD-model of the developed measuring chamber of the handheld photo- and fluorimeter.

Circuit design and program

- phototransistor as light sensor
- low sensitivity of the phototransistor in low light intensity region
  → circuit to enable measurement of weak light (see Fig. 2)
- phototransistor connected to a digital pin and in parallel to a capacitor
- digital pin as power source → capacitor charges up
- voltage removed from pin → capacitor discharges through the phototransistor due to photocurrent
- reading out applied voltage at digital pin → determine time for discharge of capacitor
- discharge time depends on photocurrent and therefore on light intensity at phototransistor,
  →discharge time = reference value for transmitted (photometer) or emitted (fluorimeter)

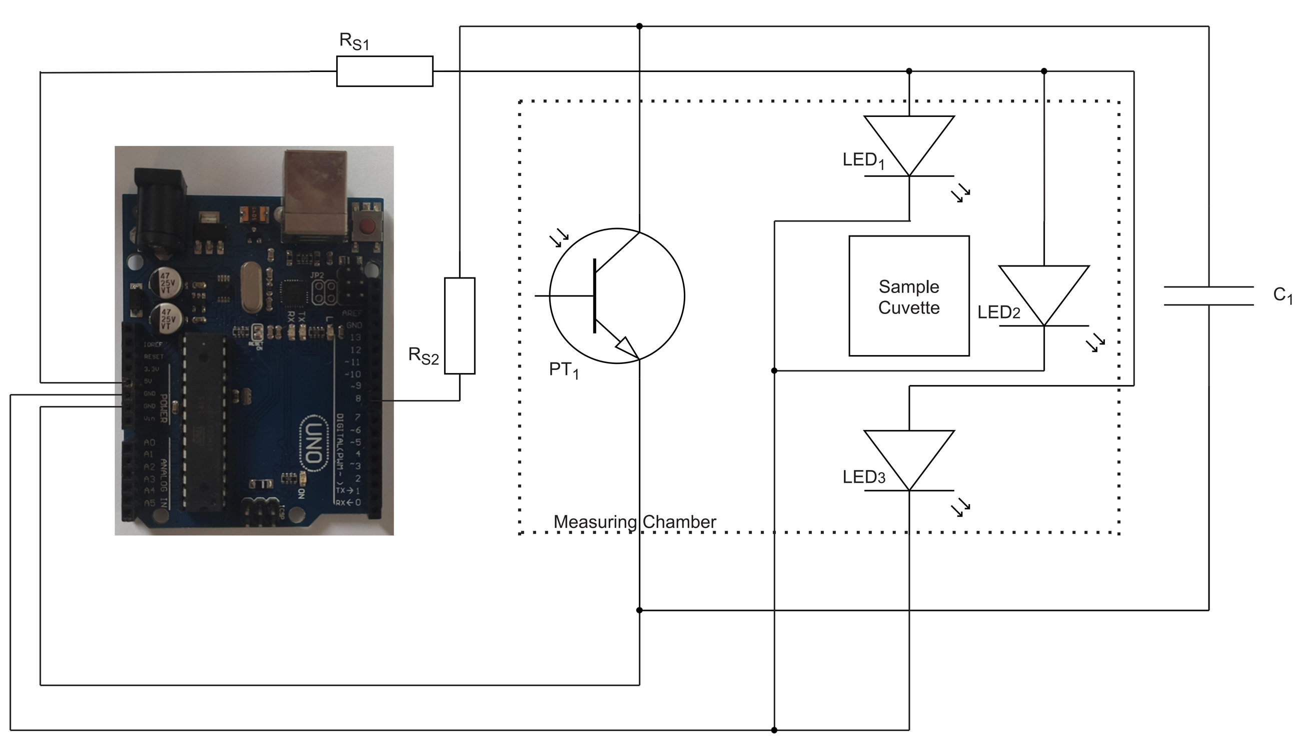

Fig. 2: Capacitor-circuit of the portable Arduino-based photo- and fluorimeter. The LEDs are connected to the 5V-power source and to the ground. The phototransistor and the capacitor are connected to the digital pin 8 and to the ground. RS1= series resistor for LEDs, 100 Ohm; RS2= series resistor for phototransistor-circuit, 1 kOhm, LED1 and LED3= LEDs in 90-degree angle for fluorescence measurements. LED2= LED in 0-degree angle for absorption measurement. PT1= phototransistor SFH300, C1= condenser, capacity 0.022 µF.

Validation of the measurment principle

- non-linear relationship between the ligth intensity and the photocurrent at the phototransistor
  →third-order calibration curves
- similar correlation coefficient with portable device and laboratory device
- Good overall agreement between portable device and laboratory devices for absorption (> 97%, see Fig. 3) und fluorescence (> 98%, see Fig. 4) measurements
  →measurement principle could be validated

Table 1: Correlation coefficients for measurements of concentrations of different analytes in aqueous solution with the portable photo- and fluorimeter in comparison with laboratory devices. *Due to a strong flattening of the calibration curve, no linear correlation was performed.

Analyte		Correlation coefficient		
		Laboratory spectrometer/ fluorimeter	Handheld photo- and fluorimeter	
			Linear calibration curve	Third-order calibration curve
Absorption measurements	Protein	0.9852 ± 0.0024	0.9763 ± 0.0057	0.9827 ± 0.0106
	Nitrate	0.9942 ± 0.0049	0.9871 ± 0.0025	0.9972 ± 0.0010
	Nitrite	0.9809 ± 0.0196	0.9912 ± 0.0113	0.9934 ± 0.0108
	Phosphate	0.9906 ± 0.0049*	0.9955 ± 0.0032	0.9997 ± 0.0002
	Ammonium	0.9902 ± 0,0167*	0,9890 ± 0,0078	0.9787 ± 0.0045
Fluorescence measurements	Calcofluor white	0.99536	*	0.99519
	roGFP2	0.99435	0.99612	0.99836

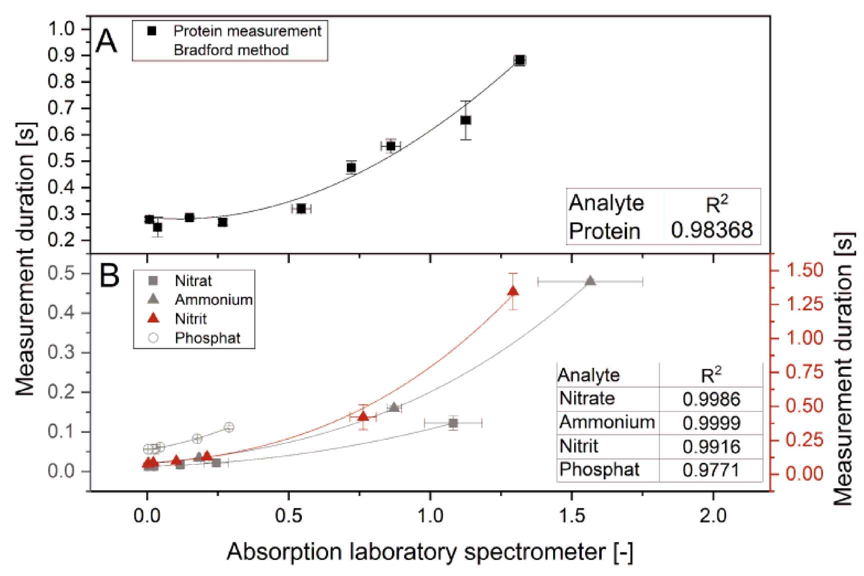

Fig. 3: The overall agreement of the portable photometer and a laboratory spectrometer, presented by a third-order correlation. A: Overall agreement for the protein measurement after the Bradford method. B: Overall agreement for the ion measurement with the help of an aquarium lab kit.

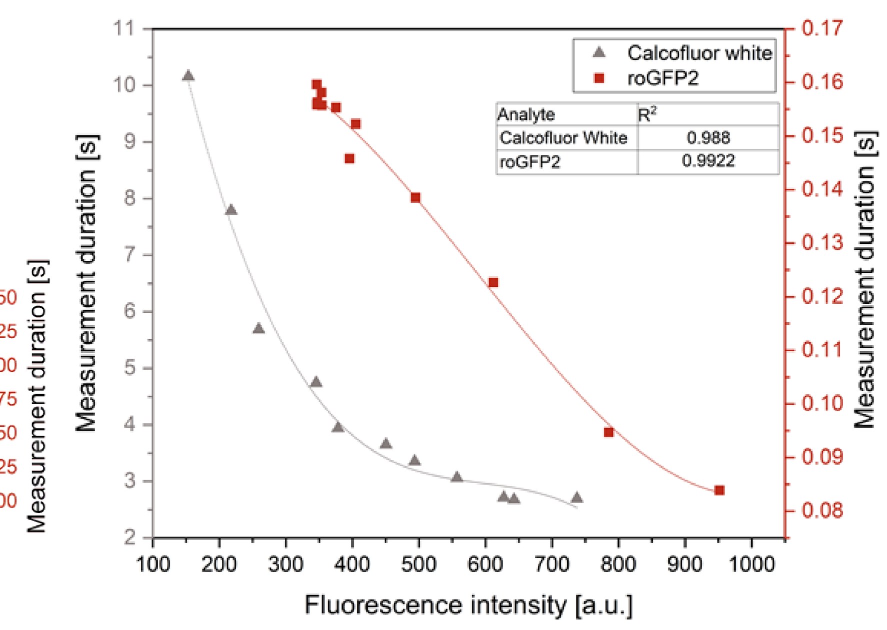

Fig. 4: The overall agreement of the portable fluorimeter and a laboratory fluorimeter, presented by a third-order correlation. The standards were excicated with light of a wavelength of 355 nm for calcofluor white and 488 nm for roGFP2. Fluorescence light was measured with a laboratory fluorimeter at a wavelength of 430 nm for calcofluor white and 488 nm for roGFP2.

Conclusion and outlook

A portable Arduino-based photo- and fluorimeter has been developed. The device is based on a capacitor circuit, which is developed to correlate the time to discharge a capacitor with the help of the photo current of a phototransistor with the analyte concentration. Validation experiments showed a third-order relationship between the measurement duration and the analyte concentration. The correlation coeffitients of the measurements were above 0.97. In the future, the developed device will be used in wine analysis and the biotechnology industry. Simple protocols for the determination of important parameters of wine, such as histamine concentration in wine or wine color, will be developed. In addition, the usability of the device as a nephelometer will be tested.

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