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MMEA WP 4.4.2
Low cost sensor platform based on LED technology

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Report Title: Low cost sensor platform based on LED technology

Key words: LED, SLD, LED lifetime, UV, NIR, LED characterization

Abstract

Efficient process monitoring, control and automation technology serves today very well in most high-end production processes but many small-medium scale processes are not well controlled because the measuring and monitoring sensors available today are too expensive for the purpose. Examples of applications in need for low cost yet reliable analytical sensors are many systems relating to energy and environment processes, bio refineries, waste water treatment processes, water quality measurements and environmental monitoring.

Work package 4.4.2 *Low cost sensor platform based on LED technology* aims to study Light Emitting Diode (LED) technology, supported by opto-electronic-mechanic engineering and integration, in order to develop a multi-use sensor platform, which reduces sensor cost significantly compared to existing on-line technology and which still meets the specific application related performance requirements. Thanks to wide range of available LED wavelengths from UV to IR, this research aims for technology suitable for large variety of analytical spectroscopy applications.

Firstly this task aims to develop and test modules, building blocks and technology which are useful for multiple applications. Secondly this work aims to develop sensor research prototypes and later during the five year program near product demonstrators to specific target specifications presented by participating industry.

Helsinki, month 20xx

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Terminology

CPLD = Complex Programmable Logic Device. Complexity and processing power between that of micro controller and FPGA.

CW = Continuous Wave. Continuous wave current = direct current

FPGA = Field-Programmable Gate Array. Complexity and processing power higher than CPLD.

DSP = Digital signal processor, a specialized microprocessor designed specifically for digital signal processing.

LED = Light Emitting Diode

NIR = Near Infrared (wavelength region 0.8…3 µm)

SLD = A frequently used acronym for the superluminescent diode (or superluminescent light-emitting diode = superluminescent LED) is SLD. The alternative acronym SLED is also sometimes used.

SW = Software

TO = TO-package. A type of metal can package for semiconductor devices. It is sealed hermetically to protect the device from environmental factors such as moisture and contaminants.

UI = User Interface

1 Introduction

Efficient process monitoring, control and automation technology serves today very well in most high-end production processes but many small-medium scale processes are not well controlled because the measuring and monitoring sensors available today are too expensive for the purpose. Examples of applications in need for low cost yet reliable analytical sensors are many systems relating to energy and environment processes, bio refineries, waste water treatment processes, water quality measurements and environmental monitoring.

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Firstly this task aims to develop and test modules, building blocks and technology which are useful for multiple applications. Secondly this work aims to develop sensor research prototypes and later during the five year program near product demonstrators to specific target specifications presented by participating industry.

Essential work package tasks were defined as *(1)* Generic development of LED array techniques which included component survey of the most suitable emitters and comparison between sensor platform concepts, *(2)* near infrared LED characterization at MIKES laboratory, *(3)* Generic development of cost effective sensor platform which included preliminary development of laboratory scale sensor setup optics, optomechanics and electronics and finally *(4)* Deep-UV LED lifetime testing.

2 LED survey

Work was started by doing a survey of available NIR LED and SLD components in the market today and considering what kind of parts are required in the platform. This mainly consists of updating of previously known supplier list and checking the availability of any new manufacturers. Electronics and signal processing needed in the sensor platform were also considered.

Developed system will be based on reflection measurement in the NIR wavelengths. Sensor needs to have at least comparable performance with the current lamp based systems. Interesting wavelengths are above 1.7 µm, for example 1.94 µm corresponds to absorption band of water, but shorter wavelength NIR devices are also included (>1.1 µm) in the survey. Electric modulation of the light source is desirable. This would mean no wearing mechanical parts like chopper wheel nor worn-out incandescent halogen bulbs. Intelligent connection (e.g. wireless, USB) between the sensor and the control UI is desired. Fabry-Perot filtering is not recommended in the early phase of the study.

2.1 Illumination source

LED based illumination source used in the low cost sensor platform could be one of the following options. Each of them has advantages and disadvantages which are explained.

1. Two or more single packaged LED sources. Light path combined with beam splitters.
2. Multiple LED sources assembled in the same hermetic package. No wavelength filtering.
3. Multiple LED sources assembled in the same hermetic package. At least one interference filter integrated inside the hermetic package.
4. Multiple LED sources assembled in the same hermetic package plus Fabry-Perot filter integrated inside or outside the package.

(1) Single packaged LEDs are easier and more inexpensive to assemble but the mutual temperature stabilization of the LED chips is more demanding. Moreover,

alignment of the beams of two or more separate illumination sources with dichroic filters or beam splitters result losses in the optical power.

(2) Multiple LEDs assembled in the same hermetic package without wavelength filtering is more compact solution and LED chips can be temperature regulated with the common thermoelectric cooler. Because LED chips can not be physically in the same space, multiple light beams need to be mixed which is usually achieved by mixing rod made of acryl plastic or glass. Optical power density per area is also decreased because LED chips are physically located on a larger area. Exclusion of wavelength filtering makes module simpler and more inexpensive but in many cases greatly complicates detection of substance of interest due to relatively wide emission bands of NIR LEDs.

(3) It would be better to utilize at least one interference filter in the certain wavelength of interest to narrow detected wavelength band width. Adding interference filter to LED module increases the cost and makes assembly more complicated. In many cases reference wavelength could be used without interference filter in order to lower cost of the module.

(4) Fabry-Perot filtering would offer continuous wavelength tunability, reasonably fast wavelength switching time (though measurement of wavelengths cannot be simultaneous!) and very narrow spectral band width. Fabry-Perot filter solution would be generic because it would offer practically any wavelength banc covered by the LEDs. However, certain application seldom requires high number of wavelength bands to be detected. Moreover, it is a rather expensive technique when integrated in the LED source and very challenging to assemble. Light beam needs to be collimated with high efficiency inside the LED package and stray light from illumination source must be practically zeroed to assure sufficient operation of Fabry-Perot filter element.

It is highly recommended that in all of the previous cases 1–4 each LED chip is equipped with microlens to improve the collimation of light beam. This of course adds to the cost of the module.

2.2 Sensor electronics and signal processing concepts

Complete sensor platform also requires detection element, electronics and parts for the signal processing in addition to light source. Table 1 gathers suggestion of sensor platforms of different cost levels: from very low to medium/high cost. Cost level is roughly estimated in batches of 100 units manufactured. Each cost level proposes illumination source configuration 1–4 specified in the previous chapter 2.1. Sensor needs to be remote controlled via PC so no user interface on the sensor itself. Temperature drift compensation of electronic components is something that needs to be considered.

Table 1. Suggestions of sensor platforms of different cost level

Very low cost	
• On / off modulation of LEDs	• Speed: slow (≈1 s)
• Maximum of 3 wavelengths	• Measurement of temperature, no Peltier cooling, SW compensation
• 1 detector	• Multiple sensor connectivity via serial bus to control PC
• Time division measurement, no need for precision timings	• **Cost: 50 € + LEDs + detector (100 pcs)**
• No need for high processing power. Micro controller (16-bit) or CPLD is sufficient.	• **Illumination source (1) or (2)***
Low cost	
• Fast measurement of 2–4 fixed wavelengths	• Speed: ≈10 ms
• 1 detector	• Multiple sensor connectivity via serial bus or Ethernet to control PC
• Temperature stabilized LEDs	• **Cost: 300 € + LEDs + detector (100 pcs)**
• Time or frequency division measurement	• **Illumination source (2) or (3)***
• One concentration detection → several micro controllers, CPLDs or FPGA	
High cost	
• 8 LEDs with or without Fabry-Perot filtering	• Speed ≈10 ms (measurement time depends on how many wavelengths are scanned with Fabry-Perot filter)
• Measures continuous spectrum	• Peltier stablized LEDs
• Frequency division measurement	• Optical feedback monitoring of LEDs to compensate LED dimming
• Simultaneous multiple concentration detection	• Multiple sensor connectivity via Ethernet or wireless to control PC
• High precision	• **Cost: 1000 € + LEDs + Fabry-Perot + detector (100 pcs)**
• Need for high processing power → FPGA, DSP or both	• **Illumination source (3) or (4)***

*) Illumination sources: (1) single packaged LEDs, (2) multiple LEDs in same package, (3) multiple LEDs and interference filter, (4) multiple LEDs and Fabry-Perot filtering.

2.3 Suppliers

2.3.1 LED

Many LED sources above the 1700 nm wavelength range appear to originate from the same source in Russia: IBSG and Physimpex/Ioffe LED. These both enterprises are related to Ioffe Physico-Technical Institute located in St. Petersburg, Russia. IBSG was established in the early 90’s by the group of researchers previously working in Ioffe and Physimpex is a spin-off company of Ioffe. Some of the other distributors of these LEDs appear to be Roithner LaserTechnik, Laser2000 and Scitech Instruments all located in Europe. IBSG appears to be the only producer with full-line of LEDs in the 1.8 – 2.4 µm range. Physimpex also produces 1.9 and 2.1 µm LEDs but most of their products are in the 3 – 7 µm wavelength range. IGM Instruments (also from Russia) is previously known to be supplier of optically pumped LEDs among others in the 1.9–2.0 µm wavelength range. Company develops, produces and sells instruments and equipment for the monitoring of gaseous and liquid media.

Table 2 gathers information about these LED suppliers. Shorter wavelength (<1700 nm) LED suppliers are also included in the table.

Rikola Ltd supplies LEDs in the 1020 – 1675 nm wavelength range. LEDs can be obtained in standard TO packages or custom modules can be developed. LED chips packaged by Rikola originate from Research Institute for Technical Physics and Materials Science (MFA) in Hungary.

Marubeni America Corporation offers very high output NIR illuminators which are based on 60 InGaAsP diode chips in single package. These illuminators can be driven with electric power up to 5.5 W (800 mA CW) as long as the thermal management is taken care of. According to datasheets Marubani LEDs have notably higher total radiated power (60 mW) than typical IR LED. This of course is due to 60 chips in the same package. Downside must be that the combined emitting area is rather large. Three wavelengths available are 1200, 1450 and 1550 nm. Same LEDs appear to be available also from Muevo-Technik in Germany.

VTT has previous experience with IBSG and Physimpex companies and have purchased several samples and batches of bare chips which were assembled as custom LED arrays by VTT and Rikola Ltd, spin-off company of VTT. IBSG offers two kind of chip layouts: one with standard circular contact pad and the other is a flip-chip design were electrical contacts are below the chip. Main advantage of this design is free top surface which gives higher total optical power because top surface of chip is free from contacts. However, flip-chip design requires submount where the chip is mounted and is more expensive.

Table 2. Suppliers of the LED sources

LEDs >1700 nm

Supplier	**Wavelength range (nm)**	**Package type**
IBSG (Russia)	1600 – 2400, 2800 – 4600	TO, TO cooled, reflectors, wafers, chips
Physimpex (Ioffe LED) (Russia)	1900 – 7000	Screw, TO cooled, wafers, chips
Roithner LaserTechnik (Austria)	1650 – 5000	
Laser2000 (GER)	1850 – 4450	TO, reflector
Scitech Instruments (UK)	1900 – 4700	Screw
Dora Texas Corp. (USA)	1600 – 2300,	TO, TO cooled
	2800 – 4600	
IGM Instruments (Russia) ?	1950?	Optically pumped LEDs

LEDs <1700 nm

Supplier	**Wavelength range (nm)**	**Package type**
Rikola Ltd. (FI)	1020 – 1675	TO, custom
MFA (Hungary)	1020 – 1675	wafers, chips
Epitex (Japan)	375 – 1550	TO, plastic
Hamamatsu (SWE, Japan)	670 – 1650	TO
Muevo-Technik (GER)	375 – 1550	TO
Roithner LaserTechnik (Austria)	360 – 1720	TO
Marubeni America Corp.	1200, 1450, 1550	TO

2.3.2 Superluminescent LED

Superluminescent LEDs are optoelectronic semiconductor devices which emit broadband optical radiation based on superluminescence. SLDs are similar to laser diodes in terms of construction. Devices have an electrically driven p-n junction like LEDs and an optical waveguide but no optical feedback which prevents lasering. Optical feedback in the structure is considered harmful because it can lead to undesired structures in the optical spectrum and to spectral narrowing. This is usually prevented by tilting the facets relative to the waveguide and with anti-reflection coatings. External optical feedback is also harmful and is typically prevented by angle polished fibre connections. Some SLD devices may even be permanently damaged by optical feedback. Like laser diodes SLDs are very sensitive to electrostatic discharges and current spikes typically caused by careless handling or ill-designed driver electronics [1, 2].

Typical output power levels are in the range from a few milliwatts to some tens of milliwatts and some devices reach the 100 milliwatt level. The optical bandwidth of an SLD is usually some tens of nanometers which is much narrower than LEDs in the same wavelength range. SLDs are commonly fibre-coupled or fibre pigtailed. Most SLD sources available emit starting from 650 nm (red) and ending in 1600 nm range. Table 3 gathers several suppliers and wavelength range available. SLD sources above the 1600 nm wavelength range appear to be very rare and only few commercial devices were found. Typically SLD devices are enclosed in the butterfly or DIL type packages which require mount which is practically a heat sink with D-sub connector. Some manufacturers like Superlum also offer these devices in the TO or TOW type packages.

The two longer wavelength SLD devices found emit in 1990 ±20 nm and 2125 ±50 nm wavelengths. 1990 nm device is manufactured by Frankfurt Laser Company and the 2125 nm by B&WTek. Frankfurt Laser Company's SLD device can output power 3–5 mW according to datasheet whereas B&WTek's device is rated 1 mW. B&WTek device is enclosed in the rather large sized benchtop housing which includes the precision current source, temperature stabilization and the fibre connector. Frankfurt Laser Company offers 1990 nm device in the C-mount compatible package.

Table 3. Suppliers of the SLD sources

Supplier	Wavelength range (nm)	Optical output power (mW)
Frankfurt Laser Company	1180–1610, 1990	up to 25, 3–5 @ 1990 nm
B&WTek	670–2125*	0.5–50, 1 @ 2125 nm
Exalos	650–1600	
(also from amsTechnologies Germany/UK)		
DenseLight	800–1690	
Superlum	650–1620	
Power Technology Inc.	680–1610	
QPhotonics	375–1537	
Amonics	680–1620	
Thorlabs	1280, 1310, 1325 or 1550	
Hamamatsu	830	

*) Further inquiries revealed that B&WTek's 2125 nm SLD source is no longer available though it is still advertised in the internet site and datasheet.

2.4 Recommended NIR sources

Table 4 has is a brief list of components which were found interesting and should be further evaluated or at least requests for quotations and availability should be made.

Table 4. List of interesting sources

LEDs < 1700 nm

- Marubeni America Corp. (USA) / Muevo-Technik (GER). High output, multiple chips in a package. Interesting wavelengths are 1200, 1450 and 1550 nm
- Wafers/chips directly from MFA (Hungary) in collaboration with Rikola Ltd.

LEDs > 1700 nm

- Roithner LaserTechnik (Austria). Large selection of sources.
- Ioffe. Wafers/chips directly from Russia.

SLDs

- Frankfurt Laser Company's FNPL-1990-03 (1990 nm)
- B&WTek's SLD18A (2125 nm)

Marubeni's NIR LEDs are available through European distributor starting at 360 USD/pc for 5 pcs, 300 USD/pc >10 pcs and 245 USD/pc >50 pcs.

B&WTek's SLD18A 2125 nm would have been interesting component but according to B&WTek's Finnish distributor this light source is not available. Only B&WTek SLD source available is the 1310 nm device. Frankfurt Laser Company's FNPL-1990-03 is available at cost of 7800 €. Device is available in standard housing in free-space or fibre coupled configurations. Optional TEC cooling is available. Cooling with different housing and/or fibre coupled are more expensive. Power supply is also available with temperature controller and mount.

3 LED characterization

A setup was characterized for spectral radiant flux measurements of LEDs at the Metrology Research Institute of Aalto University. The plan was that the setup will be used to characterize an 8-LED array source (developed in VTT's Tekes funded HANSKA project) in the 1100–1700 nm near-infrared wavelength range. A manuscript will be prepared for publication during the project based on the results of the characterization.

3.1 Measurement setup for spectral radiant flux of LEDs

The setup is shown in Figure 1. It is based on a 30-cm integrating sphere and a spectroradiometer. The integrating sphere was originally designed for luminous flux measurements of LEDs within the visible wavelength range of 360–830 nm using a photometer head with $V(\lambda)$-weighting [3]. The setup allows measurement of low- and high-power LEDs in both 2π and 4π geometries. Depending on the measurement geometry, the test-LED is attached to the sphere using either an aperture or a holder.

The measurement range of the setup was extended from visible to both UV- and NIR-wavelength ranges by combining the integrating sphere with a Bentham DTMc300 spectroradiometer. The device consists of a double monochromator, chopper input, lock-in amplifier and two temperature controlled detectors. For wavelength range of 250–850 nm, a photomultiplier tube (PMT) is used, whereas the wavelength range of 850–2200 nm is covered with an extended InGaAs-detector. Both detectors are actively cooled to obtain a temperature of -20 °C. The optical fibre of the spectroradiometer is coupled to the integrating sphere using a Bentham D7-diffuser head to obtain a good cosine response for the radiant flux measurement. The sphere is coated using $BaSO_4$ paint with 97 % reflectance. The direct exposure of the diffuser is blocked by using a baffle between the test-LED and the diffuser head. An auxiliary LED is used for measuring the self-absorption or self-reflection of the test-LED. For this corrective measurement, an LED of the same type as the test-LED is typically used. More details about the characterization of the setup can be found in [3].

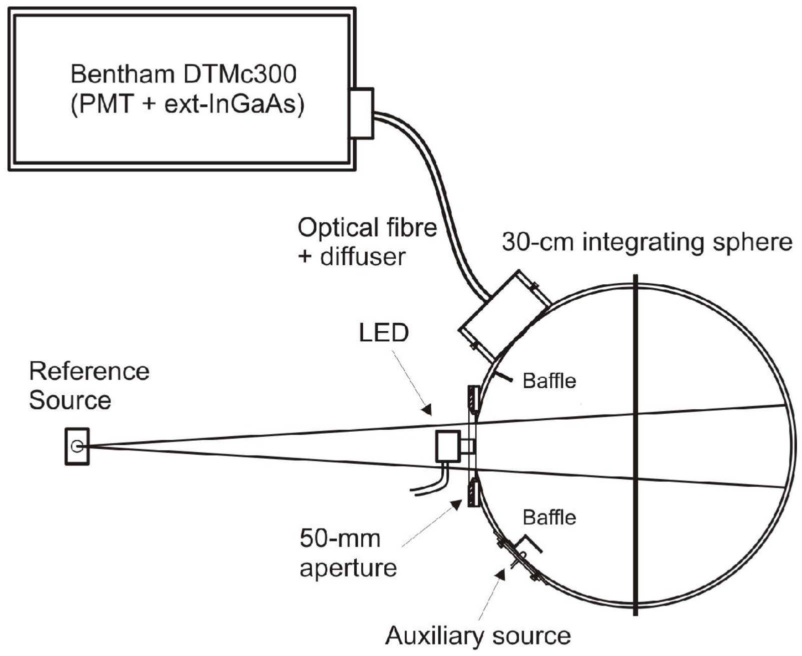

Figure 1. Measurement setup for LED spectral radiant flux.

3.2 Characterization of the measurement setup

The measurement setup was characterized using a 1-kW spectral irradiance standard lamp of type Osram Sylvania FEL-S.T6 at a distance of 500-mm from the entrance of the sphere. During the calibration, the sphere was equipped with a 50-mm precision input aperture. The wavelength range of 250–850 nm was calibrated using a bandwidth and a step of 1 nm, whereas the wavelength range of 850–2200 nm was calibrated with a bandwidth and a step of 10 nm. The integration time in the measurement was 3 seconds for the PMT and 10 seconds for the extended InGaAs detector. The measured radiant flux responsivity of the measurement setup is presented in Figure 2. The obtained wavelength range of the calibration is 250–2100 nm, depending on the power level of the test source. However, it can be seen that the PMT gives almost 3 orders of magnitude more signal than the extended InGaAs detector.

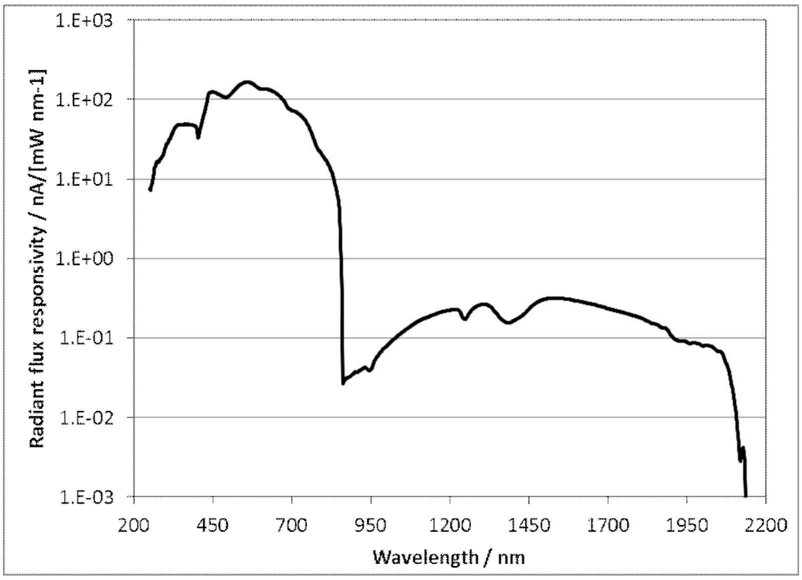

Figure 2. Radiant flux responsivity of the measurement setup.

3.3 Test measurements

The spectral radiant flux calibration of the system was verified by measuring a couple of high-power LEDs in the visible wavelength range by using both the photometer and the spectroradiometer as the detector. The lower wavelength range has been tested earlier using a couple of low-power UV-LEDs between 350 nm and 400 nm.

For testing the extended InGaAs detector, a selection of NIR-LEDs in the wavelength range of 1050–1550 nm were acquired from Thorlabs. The reported radiant flux values of the LEDs were 2.5 mW on average, when driven with 20 mA of current. During the test measurements, the temperature of the LEDs was stabilized at 25 °C using a temperature controlled LED-holder. It was found that the power levels of the test-LEDs were not high enough that they could be measured, even when driven with near maximum rated current of 100 mA, or by increasing the integration time of the amplifiers. For a couple of LEDs, the signal was found close to the noise floor but still too low to be measured. In order to obtain more signal, the optical fibre and diffuser were replaced with focusing radiance optics. In addition, the 30-cm integrating sphere was replaced by a 20-cm gold-coated sphere. With these modifications, the signals of the LEDs could be measured, but only near their peak wavelengths.

The test measurements show that measurements of NIR-LEDs would require either a much smaller integrating sphere input for the spectroradiometer or a high-power NIR-LED module consisting of a large matrix of LEDs instead of a single LED-component. According to the calibration measurement, the sensitivity of the PMT works really well for UV- and visible single LED-components.

4 UV LED lifetime evaluation

Patch of deep UV LEDs was evaluated and small-scale lifetime test was started in the project. LEDs are manufactured by US based Sensors Electronic Technology Inc. (SET) which is practically sole supplier of <300 nm deep UV LEDs in the world. Deep UV LEDs have greatly developed in the recent years but there are still uncertainties like component lifetime. This information is not widely specified by the manufacturer but discussions with SET experts and studying of the scientific papers reveal that lifetime can be as short as few hundred hours in CW operation. Pulsing of LED will increase the lifetime but how much. Moreover, when integrating UV LEDs to online process instrument a real concern is how these UV light sources will endure elevated ambient temperature which is common to many industrial environments.

4.1 Setup

Small-scale lifetime test was performed for twelve LEDs, all from SET. LED model was chosen to be UVTOP 255 nm (type UVTOP255TO39HS) which is especially very challenging component due its very short wavelength. LED is shown in Figure 3.

Figure 3. SET Inc UVTOP 255 nm LED. TO39-packaged with hemispherical lens.

Lifetime of these components is specified to be ca. 300 hours in CW operation. For comparison components from same manufacturer above 280 nm have lifetime expectancy of few thousands hours.

Two groups of six LEDs were arranged: one would be kept in room temperature (22–23 ºC) and the other group in elevated temperature of 40 ºC. This temperature was achieved by placing LEDs in a Arctest ARC150 weather test chamber shown in Figure 4. LEDs were pulsed at 1 kHz. Both LED groups had two duty cycles: 1 and 10 %, each group having three LEDs. One LED was excluded from the test and was kept unused in its box. This LED was a reference LED whose only aging mechanism was storage time.

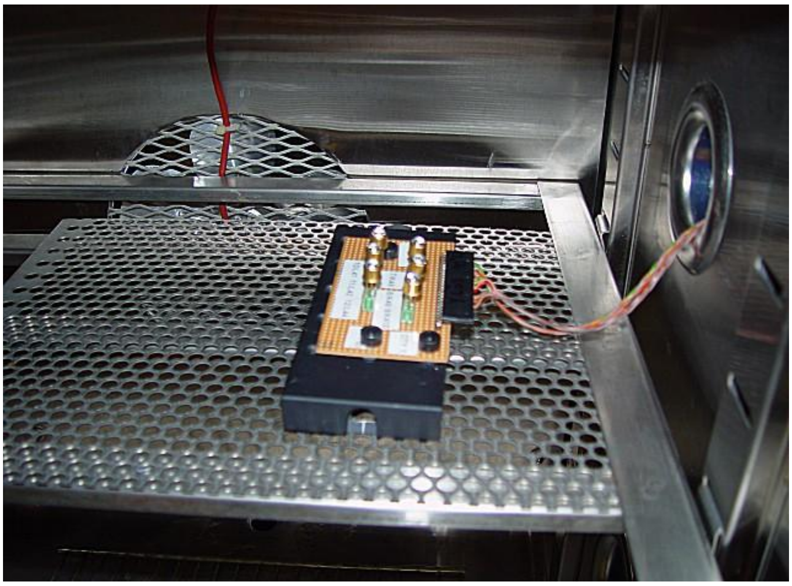

Figure 4. Patch of 6 LEDs in test chamber at elevated temperature of 40ºC.

Planned test period is estimated to be one year but preliminary results can already be analyzed and estimated after few months when test data is accumulated. Due to experiments rather long time scale and also difficulties driving several LEDs with different duty cycles using laboratory power supplies, it was necessary to build custom LED driving electronics for the experiment.

Optical power of LEDs was measured before the test and periodically monitored during the experiment. Test procedure means that LED are taken out of test environment and measured in laboratory. After measurement LEDs are put back to test bench. Optical power meter used was Melles Griot broad band meter which is able to measure wavelengths down to 200 nm. During the test it is expected that the optical power will decrease in exponentially. Spectra of all the LEDs were measured in the beginning and will also be measured after test. This will reveal possible changes in the spectrum shape. Tec5 UV spectrometer and integrating sphere setup was used in the spectral measurements. Reference spectrum was measured from calibrated and NIST traceable deuterium UV light source.

Table 4. Test parameters during the lifetime experiment

Parameter	Value
Temperature (ºC)	6 LEDs at room temperature (22–23 ºC) and 6 LEDs at 40 ºC
LED pulsing	1 kHz. Duty cycles 1 and 10 %
LED current (pulsed)	20 mA
Monitoring of LED optical power periodically during the experiment	Test current 20 mA CW.

4.2 LED pulsing electronics

A suitable commercial LED driving unit couldn't be found so the LED driving electronics were designed for the experiment. The LEDs were planned to be driven similarly in groups of three so the LED driving electronics were designed according to that and a commercial Atmel AVR-MT128 controller was chosen to control the designed electronics. LED driving circuit enables independent adjustment of each LED's current. Altium Designer 10 software was used to design to LED driver circuit and layout. AVR-MT128 Controller was chosen because it has been used for similar purposes before and the needed software code for LED driving was therefore already designed and required only minor editing. AVR generates pulses for the each LED group. The designed LED driver and the AVR-MT128 Controller are shown in Figures 5 and 6.

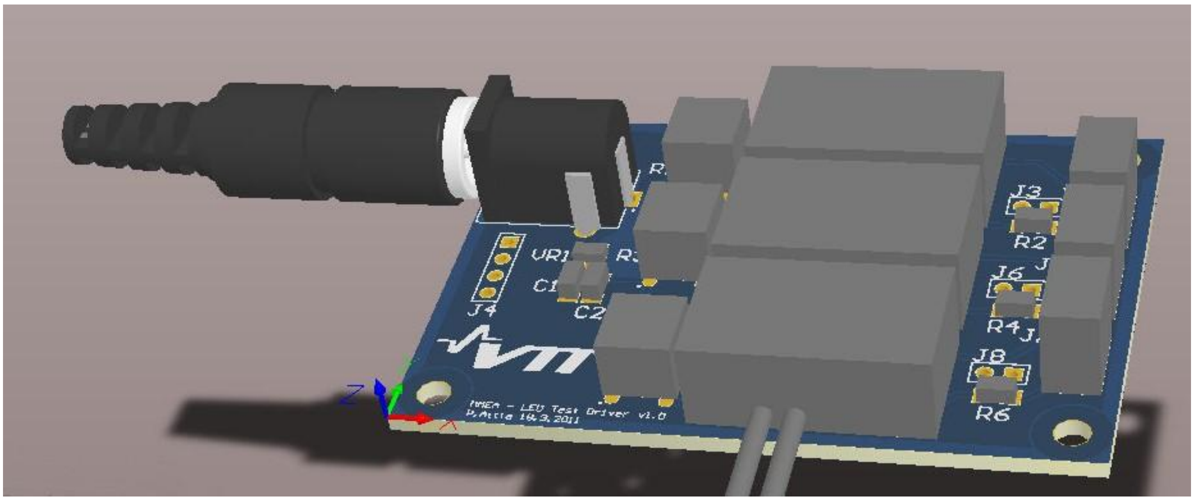

Figure 5. LED driver 3D model in Altium Designer 10 software.

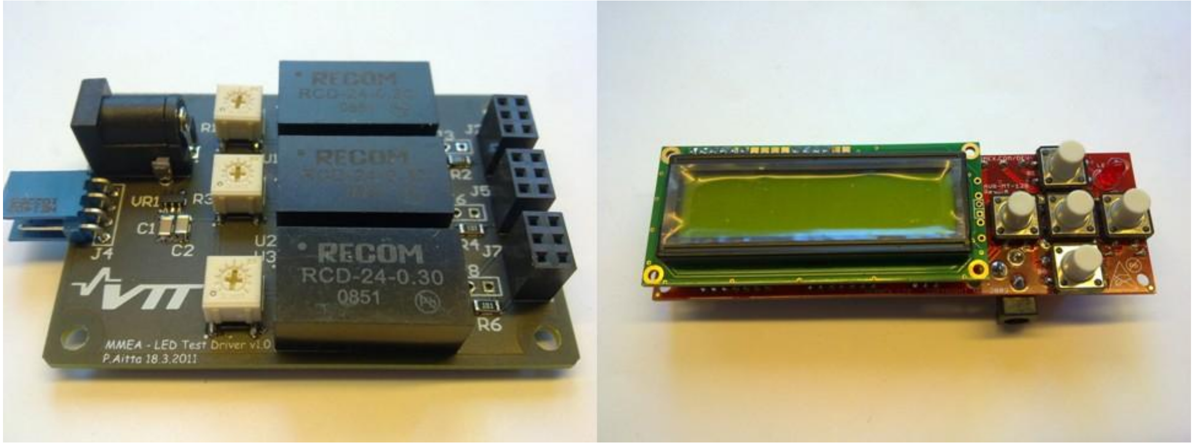

Figure 6: On the left side one LED Driver and on the right side AVR-MT128 Controller

4.3 Preliminary results

Lifetime testing will continue for a year but some good estimates can be done after few months when data is accumulated and aging curve starts to shape up. Somewhat surprisingly preliminary results indicate rather steep decrease of LED brightness already during the first month. Figures 7 and 8 show results after a month and a half for two groups of six LEDs held in room temperature and in 40 ºC. Y-axis of the plot is normalized LED brightness. In many instances LED lifetime can be defined as a time period where LED brightness decreases to 50 % of the initial level.

The two used duty cycles, 1 and 10 %, are clearly distinguishable in Figure 7. Brightness of 1 % LEDs has dropped to approx. 80 % level and 10 % LEDs down to 65 % level after a month. Early predictions (dotted line) indicate that 1 % LEDs could reach 50 % level already after five months whereas it only takes ca. three months for 10 % LEDs.

The situation is not so clear for LEDs held in elevated temperature of 40 ºC. For this batch of six LEDs brightness has dropped to approx. 70–78 % level and there is no clear division between 1 % and 10 % duty cycle LEDs. Curves are even interleaving, that is LED with 1 % duty cycle has weakened more than LED with 10 % duty cycle. This is surprising also because LEDs were operated in higher ambient temperature and yet some of them seem to have come through better than LEDs in room temperature. One of the LEDs held in 40 ºC temperature (blue curve in Figure 8) seems to be failing already after 1.5 months. It’s brightness has dropped down 85 % from its initial level.

Predictions assume that LEDs continue to loose brightness at the same level as during the first month. Reference value indicates that there has not been any deterioration with the reference LED as expected. Final results will be reported later on the second research year.

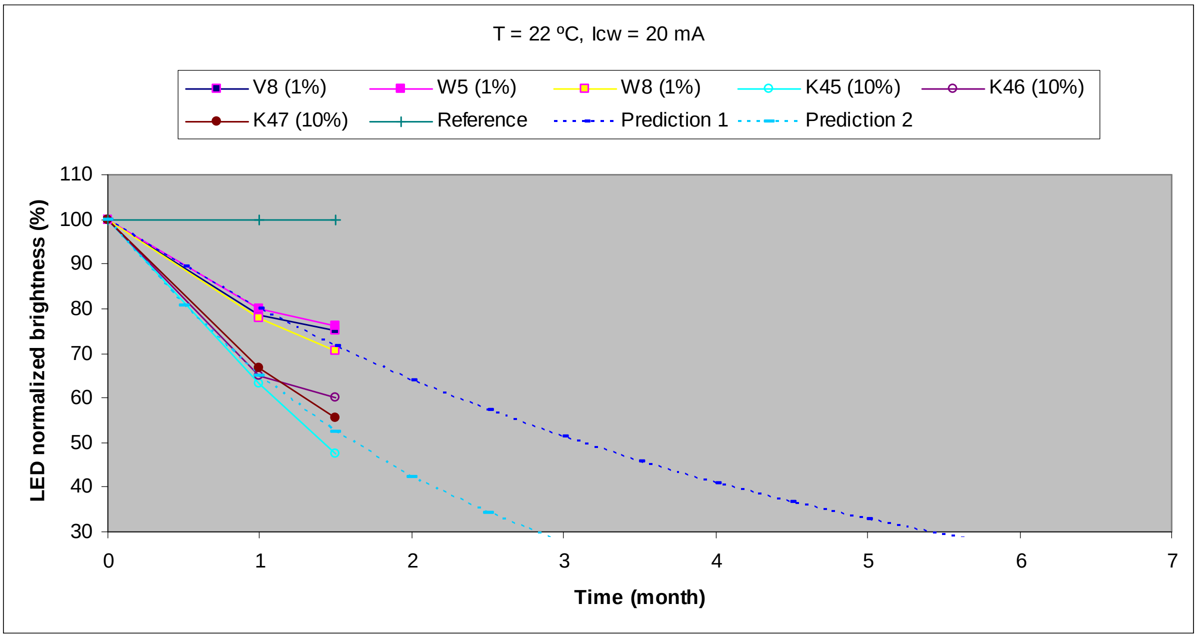

Figure 7. Preliminary results of the lifetime experiment in room temperature.

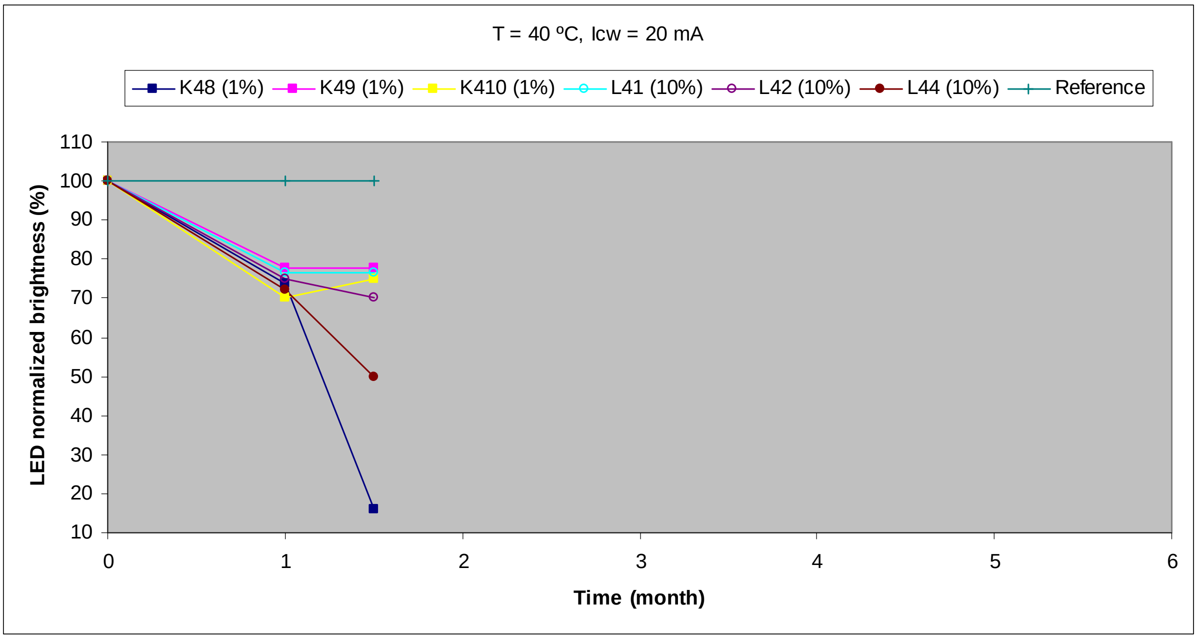

Figure 8. Preliminary results of the lifetime experiment in 40 ºC.

5 Laboratory demonstrator

Laboratory grade demonstrator device is being prepared based on diffuse reflectance measurement in NIR wavelengths. Setup required planning and simulation of optics and some mechanical structures as well as new improved smaller sized electronics. Light source could either be 8-LED array developed in the TEKES funded HANSKA project or SLD illumination source. VTT has SLD sources which cover wavelengths around 1300 and 1450 nm. These SLD sources can be operated either in CW mode or with analog or digital modulation.

At the present moment, design developed is a hand held device which utilizes two SLD light sources (1300 and 1450 nm). First demonstrator device design is illustrated in Figures 9 and 10. Optical parts (two off axis mirrors) and the standard InGaAs detector are in the hand held part of the device (blue part). Battery back is used as a power source for the components and it is accommodated into the backpack together with SLD illumination sources (black part). Wiring and optical fibres are placed in the protective hose which connects the hand held device and the backpack. Measuring distance of the device is 100 mm and measuring range ca. ±40 mm.

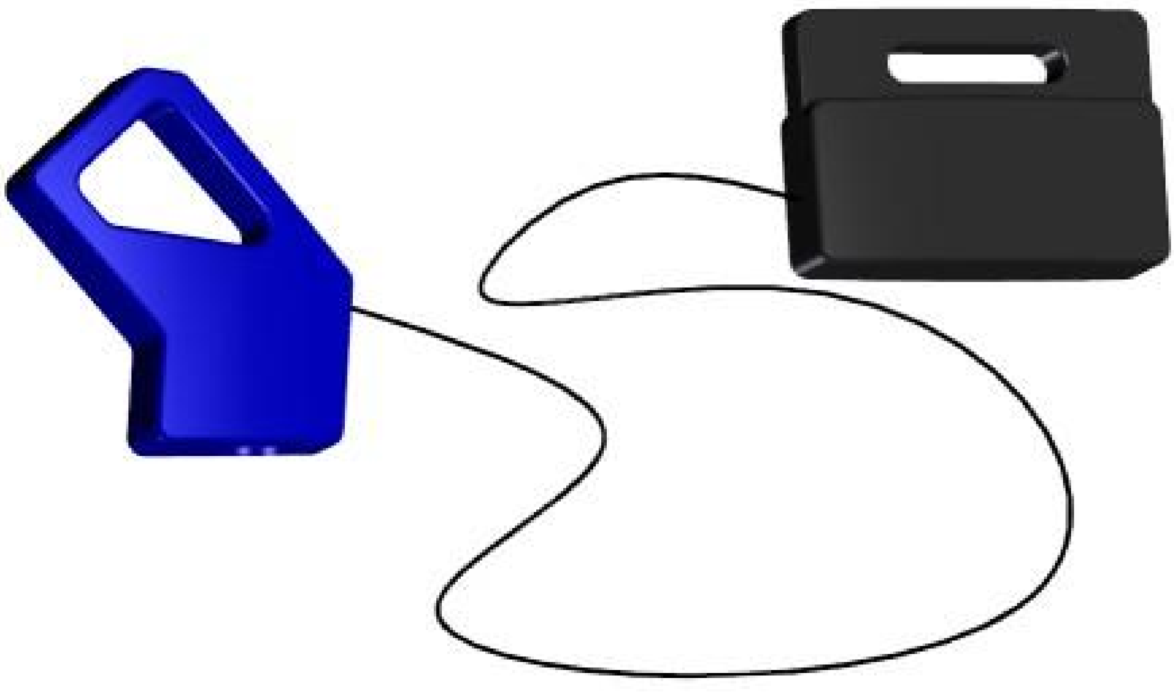

Figure 9. First hand held demonstrator device utilizing SLD illumination sources. Fiber coupled SLD sources are inside the black housing together with battery pack. Hand held sensor head itself is on the left.

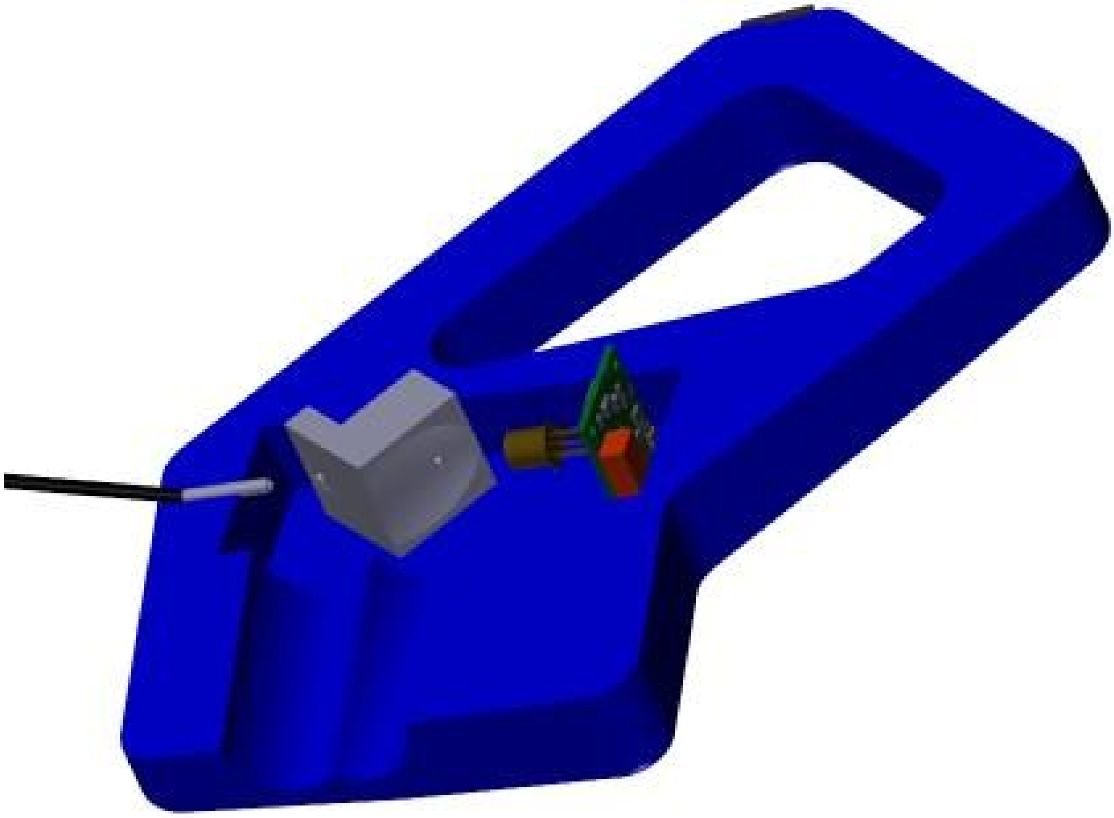

Figure 10. Illustration of hand held sensor head revealing the optics and the detector.

6 References

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