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Quality observation of micro electro mechanic systems with the use of virtual instrumentation

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Abstract. The article deals with the control of the light level of four-colour RGBA LEDs for illumination of micro electro mechanic samples of a microscope while the methods of control of the light level are introduced and discussed first. In the next part of the article, four LED drivers for four-colour LEDs are selected. Furthermore, this article deals with the creation of the program for the colour mixing and the brightness control of the light emitted by LEDs, while the program itself is implemented in LabVIEW graphical programming software. System is dedicated for inspection tasks in mechatronic or industry applications, especially for microscopic items. Cooperation between virtual instrumentation and industrial application is also shown.

Introduction

The impact of new technologies produced and developed even more powerful and fuel-efficient LEDs that surpass the properties of filament lamps. They may be found in a wide range of applications from street lighting, through architectural lighting to light microscopy. The main purpose of this paper is light microscopy of micro electro mechanic systems (MEMS) such as microelectronic components, devices, machine components and micro switches. This microscope can also be used for detection of fast moving MEMS components in computers (Hard disc) and optical systems. An important feature of these light sources are small size and high power density. With the use of multicolour power LED, colour mixing of emitted light is possible to achieve the best contrast of image and surfaces details. LED diodes can be switched at high frequencies, because LED is electronic component with a small inertia. This feature is useful for detection of fast moving MEMS where the stroboscopic effect is used. For control of the LED diode suitable LED driver has to be used, so the constant current trough diode is ensured. For the scanning of the microscopic sample by video camera switching frequency is important parameter of LED drivers, by which the brightness of the LED diode is controlled.

Brightness control of a LED diode, electrical source

The construction of the PN junctions of a LED comprises two semiconductor materials, characterized by high purity. These materials are alloyed with the trace amounts of adequate materials. By their presence, either an excess of electrons (as the N-type materials) or on the contrary, the lack of them (P-type material) [1]. By attaching a DC voltage to the PN junction, recombination of each electron and hole occurs.

TABLE 1. Wavelenght, material and forward voltage of LEDs

	Red	Green	Blue
Wavelength [mm]	600-630	500-520	440-460
Material	ALGaInP	InGaN	InGaN
Forward voltage [V]	1.7-2	3.2	3.4-3.5

During the recombination of each electron-hole pair, a specific quantum of energy is released, which can be radiated out of the crystal. Electric power is converted directly to the light of a certain colour. Thanks to the latest technological processes, which ensure high product purity, the flexibility of production processes is increased. Therefore, the yellow, green, red and orange LEDs are produced by the same technology and their colour may be controlled by changing the size of the band gap [1].

LED electric model

As it is shown in Figure 2, LEDs are non-linear passive electronic components. In case of low voltage to a PN junction, diode is not conductive and does not emit light. If the voltage increases and reaches the threshold voltage, the LED current starts to rise sharply and causes light emitting. If the increase of voltage continues, LED is quickly overheated and can be destroyed. Therefore, it is necessary to connect a source of constant current [2]. The LED can be replaced with an equivalent circuit of the Zener diode and series resistance ESR. This model can be used as a load, which would replace the expensive LEDs in the development of a new power supply for LEDs. LEDs have besides ta series resistance also a dynamic resistance. Some manufacturers of LEDs indicate dynamic resistance in the data sheet, but in the most cases it is necessary to determine it from the volt-ampere characteristics. As it is shown in Figure 2, LEDs are non-linear passive electronic components. In case of low voltage to a PN junction, diode is not conductive and does not emit light. If the voltage increases and reaches the threshold voltage, the LED current starts to rise sharply and causes light emitting. If the increase of voltage continues, LED is quickly overheated and can be destroyed. Therefore, it is necessary to connect a source of constant current [2]. The LED can be replaced with an equivalent circuit of the Zener diode and series resistance ESR. This model can be used as a load, which would replace the expensive LEDs in the development of a new power supply for LEDs. LEDs have besides ta series resistance also a dynamic resistance. Some manufacturers of LEDs indicate dynamic resistance in the data sheet, but in the most cases it is necessary to determine it from the volt-ampere characteristics.

LED thermal model

This section is focused on a thermal model of the temperature control of a LED (Fig. 1). Thermal properties and operating temperature significantly influence the light output of a LED. For the optimal operation of LEDs, it is necessary to regulate the temperature of PN junction and remove the excess heat from its case to the surroundings through the cooler. Unless there is a sufficient heat dissipation from the LED, the chip temperature may increase to values that cause a drop-in efficiency and a significant reduction in its life time. Optimal operation of LEDs can be achieved by a good thermal design and suitable installation of LEDs' lighting. Thermal properties are analogous to electrical parameters of resistance, capacitance, voltage and current. The thermal resistance of a material is the ability to resist the transfer of a heat flow.

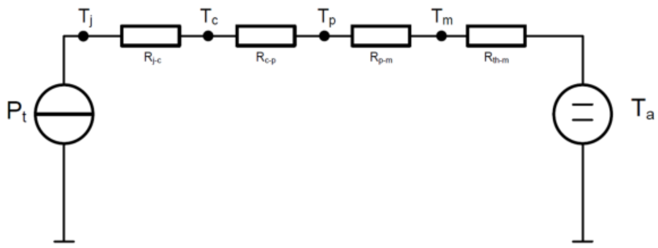

Fig. 1 Equivalent thermal circuit of the cooling [3]

If the material has a high thermal resistance, it transmits heat very slowly. Heat hardness is characterized by a thermal resistance, which is similar to the electrical resistance. The thermal calculation is made from a thermal model of the circuit elements. In the following figure (Fig. 1) there is shown the equivalent thermal circuit cooling, which is composed of the multiple thermal resistances [3], [4]. T_j is the temperature of the PN junction, T_c is the temperature of the case of the LED (PCB), T_p is the temperature of insulation pad, T_m is the temperature of the cooler and T_a is the temperature of the ambient. The thermal resistances are: R_{j-c} - the temperature resistance between PN junction and case, R_{c-p} - the temperature resistance of the circuit board, R_{p-m} - the temperature insulation pad and R_{th-m} - the temperature resistance of the cooler [3]. Thermal resistance represents the ability of a material to conduct heat. Under the influence of the thermal resistance, the one side of the material, by which the heat flow is entered, is heated to the temperature υ1 whereas the side of the material from the heat flow exits is taken to υ2 [5]. Thermal resistance is calculated as follows:

$$R_{\upsilon_{12}} = \frac{\upsilon_1 - \upsilon_2}{P}. \tag{1}$$

R_{tot} - total thermal resistance is calculated by adding the thermal resistance of the materials, that are in the direction of the heat transfer from the chip to the cooler. This temperature is emitted to ambient. LEDs convert the part of the received energy to heat and part to portion of the light. The following equation determines the power dissipation of a LED:

$$P_t = V_f \cdot I_f, \tag{2}$$

where U_f and I_f are RMS values of voltage and current flowing through the diode. The temperature difference is calculated as follows:

$$\Delta T = T_j - T_a = P_t \cdot R_{tot}. \tag{3}$$

Digital control of the brightness of a LED

Digital control of a LED’s brightness is based on the PWM modulation. LED is continuously switched on and switched off. This process must be fast enough so that the human eye d not register the blinking of a LED. In practice, PWM dimming frequencies in range of 400-1200 Hz are used. The control of brightness is realized by changing the PWM duty cycle. This method of dimming a LED does not fit into the machine industry or anywhere where it might occur a strobe effect. From Fig. 2 b.) it is clear, that the current which flows through a LED during the light emitting is always the same, only the mean value of the current is changed. This results in a constant colour temperature of the emitted light.

Design of the system for controlling the brightness of LEDs

LED lighting has been realized as a light for a desktop microscope Olympus, which is powered by the grid. Light control is implemented in a graphical programming software LabVIEW. Lighting control system for the microscope consists of the following blocks (Fig. 2).

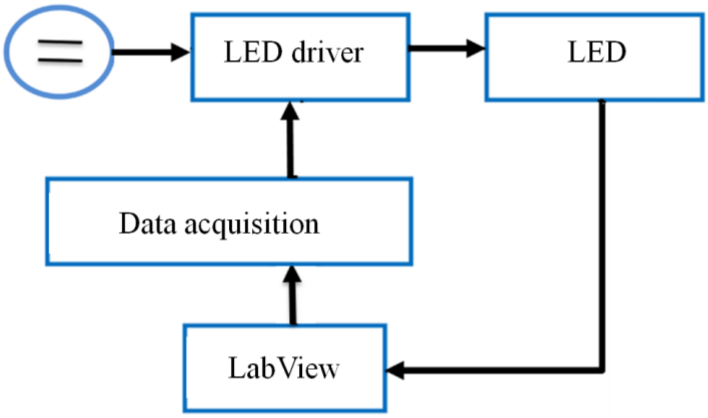

Fig. 2 Block diagram of the system

The light source for the microscope

As the light source the LED LZ4-00MA00 has been selected. It is a four-colour RGBA LED so that in addition to the three basic colours red, green and blue contains a fourth amber colour. This colour is used to obtain a lower colour temperature of white colour. The patented design has unique thermal and optical power. LED achieves high light output 10W.

TABLE 2. Luminous flux of all colours

luminous flux [lm]/colour	Red	Green	Blue	Amber
If=700mA	115	155	30	75
If=1000mA	160	200	40	95

RGBA LED Driver for LED diode LZ4-00MA00

Available RGBA driver is intended for low-power applications and therefore it is able to deliver a small amount of current to LEDs. For power applications there are available RGB LED drivers. The disadvantage of such types of the drivers is that they are capable of driving only three LEDs. That's why the RGBA monochrome LED driver was chosen a for each colour of the emitted light. For powering one LED, the topology type step-down converter was chosen. The best driver that meets the criteria of PWM brightness is LED driver LED 5000. The calculation of the circuit elements for step-down converter for LED 5000 is described in [9].

Software control of the LED brightness in graphical software LabVIEW

The aim of the program was to achieve control of LEDs' brightness by PWM adjustment. As the LED contains 4 colours (RGBA), the brightness control has been done for all colours consequently and thus the brightness control of the white light is acquired. Another requirement was to independently control the brightness of each LED and colour mixing based on the additive model. The platform Arduino Nano is used as the control card. Arduino Nano is a platform with ATmega328 microcontroller. Arduino is used as the measuring card communicating with LabVIEW via USB interface. Arduino Nano has fourteen digital input-output pins and eight analogue inputs. Arduino is able to communicate with the following interfaces: SPI, I2C, USB. Arduino is able to deliver up to 40 mA current to each pin. The communication between LabVIEW and Arduino can be done using two interfaces LIFA and LINX. For interfacing Arduino with LabVIEW, a newer version of LINX is chosen as LIFA is unsupported. To establish communication, the add-on LabVIEW VI package manager, which is an open-source, needs to be downloaded and installed. VI package manager itself has implemented more installation interfaces. One of them is referred to the LIFA, which is still used even though it is unsupported [8].

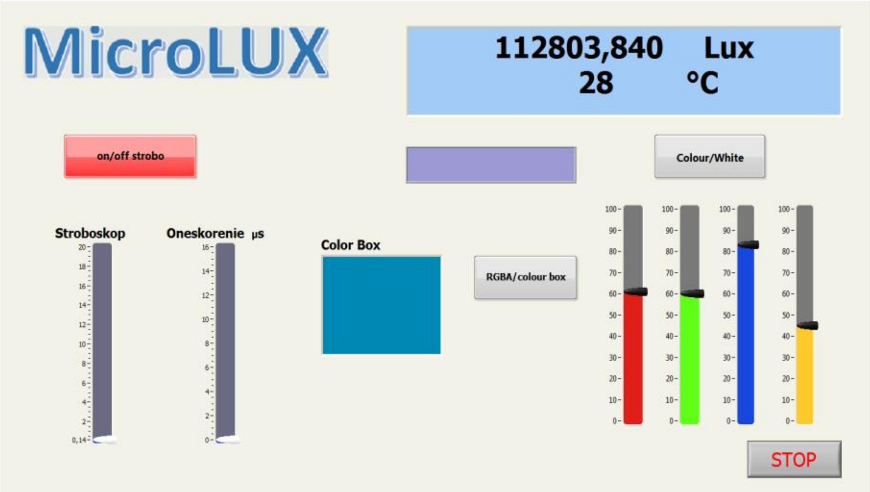

Fig. 3 Control panel

The main program loop

Prior to the main loop of the program the COM port Arduino is conducted. The main loop of the program consists of an infinite while loop where the *Case* structure is integrated, which can acquire two states: true and false. If the case structure acquires true state, it performs part of the program which controls the intensity of light emitted white light. If the case structure acquires false state, it performs part of the program which controls the light intensity of each colour separately. In either case, the adjusted PWM is in range of 0-255.

Front panel in the LabVIEW

The front panel of GUI (Fig. 3) consists of the sliders that adjust the brightness and also the indicator window. Switching between the mixture of colours and the light intensity control of white colour is realized by a switch *colours/white*. By clicking this button, the colour mixing panel is replaced by a panel dimmable white colour and vice versa. By pressing the button *RGBA /Colour box*, the specific colour from colour palette is chosen or the colour can be manually set by the RGBA sliders.

Experimental observation of microelectronic components

In Fig. 4, there is shown a sample of miniature ribbon cable of CD drive. Quality of ribbon cable can be reviewed from Fig. 4. An important parameter for evaluating the quality of ribbon cable is the resistance of conductive paths. Another parameter is the dielectric strength of two neighbouring conducting paths. Both cases of considering the quality of ribbon cable are based on the edge contrast of the observed sample. The best contrast is achieved by using of a colour exposition. In Fig. 4, there are shown samples with different colour exposition.

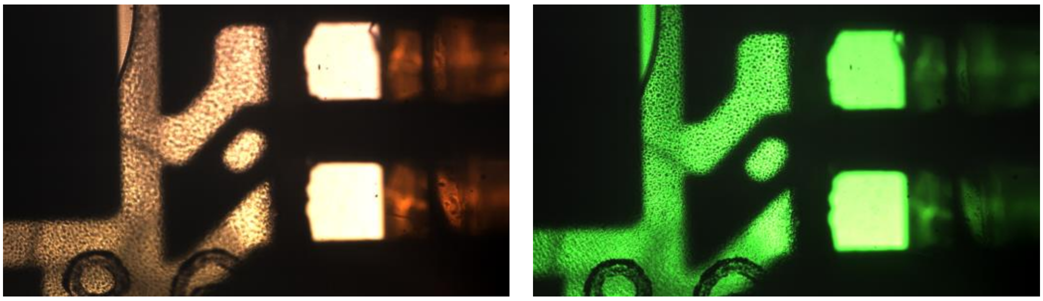

Fig. 4 Ribbon cable of CD ROM drive

Detail accuracy visibility is also demonstrated under the various wavelengths and lighting conditions.

Quality of micro-gears is crucial for many micro-mechanic applications. With our system we took some experimental inspection of gears under variable lighting conditions. Gears were ca. 3 mm in diameter. In Fig. 5 we can see the damage of gear tooth.

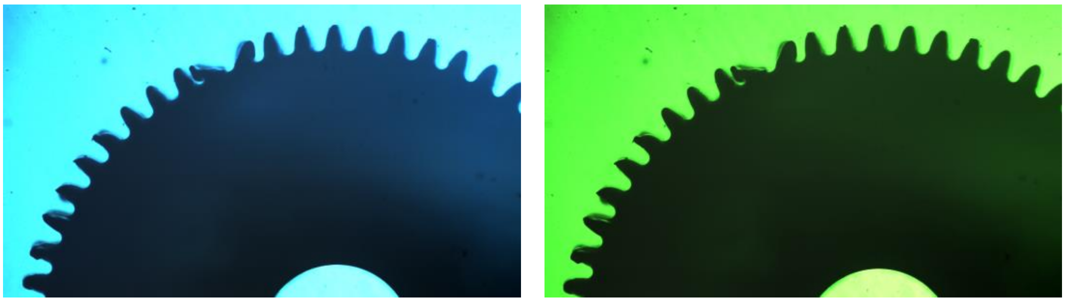

Fig. 5 Micro-gear with damaged tooth

Entire system was implemented to the light microscopy Olympus CX21 and images were acquired via high-speed CMOS colour camera Basler A504kc (Fig. 6).

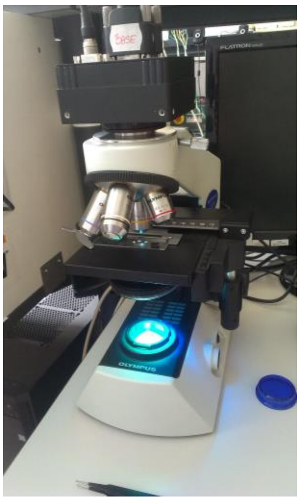

Fig. 6 Workstation with microscope and camera

Conclusions

In the paper we proposed a solution for inspection of a micro mechanical parts. During the work we declared a cooperation between virtual instrumentation and mechatronic system. The system is modular with open architecture and user can easily change anyone of the integrated parts (e.g. replacement of camera, replacement of microscope or LED module based on requirements of industrial task). The system can be immediately implemented to industry or it can be also used for educational purposes. Usage of virtual instrumentation and resulting automated approach to industry solutions decreases human faults in many jobs and follows the world trends.

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