

System for measuring a radiation pattern of the light source

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Abstrakt

Tato práce se zabývá návrhem systému pro měření vyzařovací charakteristiky zdroje světla. Zdroj světla je umístěn do úchytu, kterým lze v jeho ose otáčet krokovým motorem o 360°. Senzor pro měření výkonu světelného zdroje se nachází na otočném rameni, které může vykonávat pohyb v rozsahu větším jak 180°. Minimální krok, o který lze zdroj světla a rameno pootočit, je 0.9°. Ovládání krokových motorů je realizováno pomocí Arduino Mega 2560. Pro uživatele je vytvořeno GUI (Graphical User Interface) v jazyce Python, díky němuž je celý proces měření charakteristiky automatizován. Pro kalibraci přesného natočení zdroje světla je použit optický enkodér.

Klíčová slova

Vyzařovací charakteristika, Arduino Mega 2560, Python

1. Introduction

One of the important characteristic of the light source is its radiation pattern, also called a spatial radiation pattern or a spatial distribution of light. This characteristic gives us information about how much of the power in the form of light is emitted from the light source. The key role here has the location of the light source and a direction of its radiance, because the power is not distributed equally in its surroundings. Therefore, to achieve a radiation pattern, it is necessary to measure a power of emitted light in the main hemisphere of the light source.

How the radiation pattern looks like is given mainly by the type of the light source. For example, a LED's radiation pattern will differ from the radiation pattern of a regular bulb. The radiation pattern can be also shifted or changed by the light design. For example halogen lights are commonly found with the reflector design, where most of the light's power is focused onto the 30° beam.

A LED's radiation pattern can be seen in Fig. 1, where the y-axis is representing a relative intensity. As seen, this radiation pattern is symmetric about the y-axis, and most probably it will be also symmetric in any plane at the main axis of the light source.

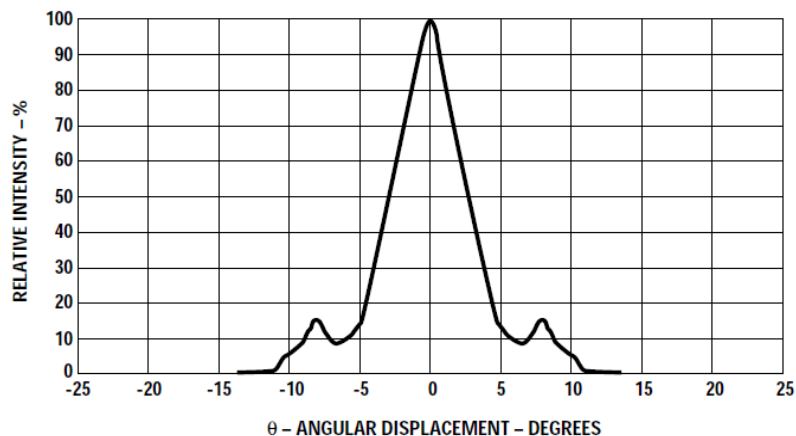


Figure 1. Representative spatial radiation pattern for 6° viewing angle lamps [1]

But for the light sources, where the radiation pattern is unknown, measurement has to be done in more than just one plane. For this purpose, a measuring system with a possibility of measurement of multiple planes (3D radiation pattern) has to be designed and built.

2. Design of a measurement system

The measurement system consists of mechanical and electrical components. These parts will be described in the next sections, followed by the description of the GUI (graphical user interface) created for an automated process of radiation pattern measurement.

2.1 Mechanical components

A model of the measurement system is shown in Fig. 2. The light source (1) is placed into the holder (2) supported with the ball bearing. It can be rotated up to 360° by the stepper motor (3) (temporarily visible in this figure). A sensor reading head (4) of the optical power meter system is located on the arm supported by the second ball bearing. This arm can be rotated more than 180° by the second stepper motor (5). Both stepper motors are controlled by *Arduino Mega 2560* (6). For calibration purposes, the rotating part of the second stepper motor is supplemented by an optical encoder (7). To be able to obtain information about the range of the wavelengths emitted by the light source, the measurement system is also equipped with the output to the spectrometer. The holder of the optical fiber ferrule is (8).

2.2 Electrical components

Overview of electrical wiring of the proposed method of measurement is shown in Fig. 3. The workstation (computer) is connected to two main devices – *Optical power meter system* and *Arduino Mega 2560*. *Arduino Mega* is an open source microcontroller board [2], in the past years commonly used platform for realizing an interactive projects. For our purposes it was extended with *RepRap Arduino Mega Pololu Shield*, also known as *RAMPS* (Fig. 4). This extension is primarily used as a controller for the low cost 3D printers. It also contains a *Pololu stepper driver board*, which in right configuration can drive up to 5 stepper motors.

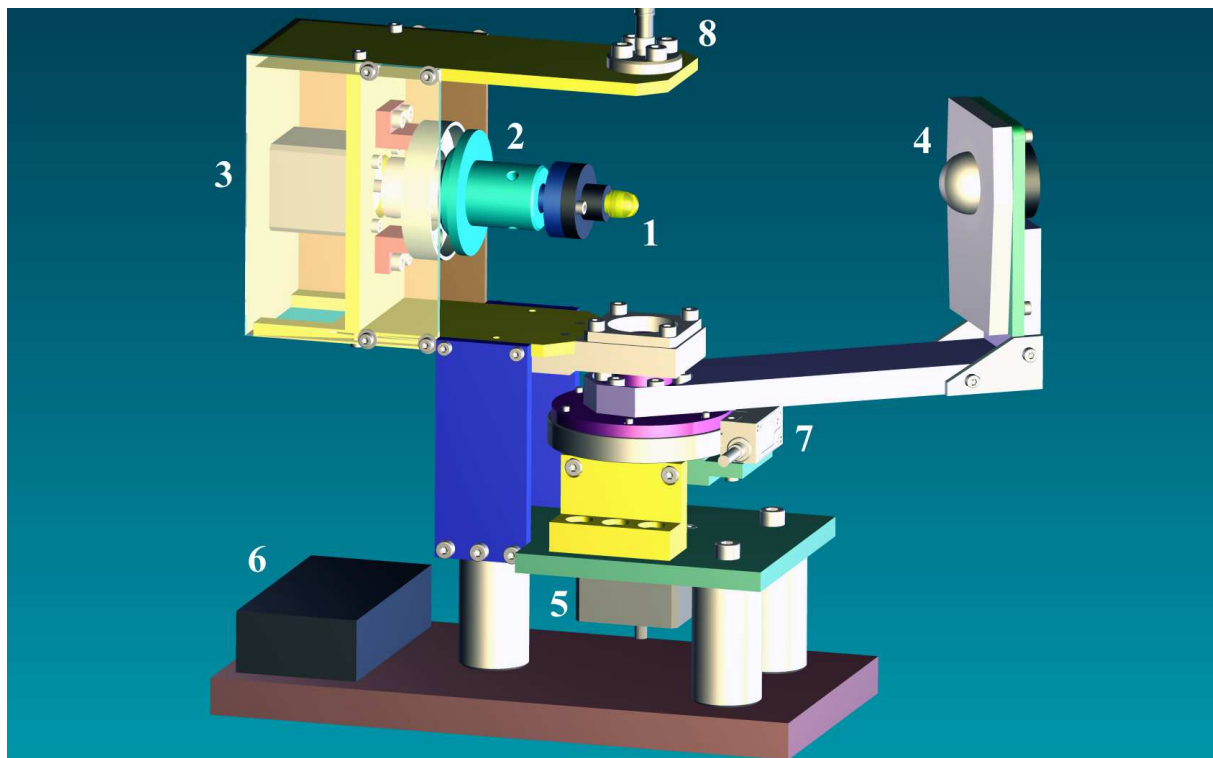


Figure 2. System for measuring a radiation pattern of the light source [1]

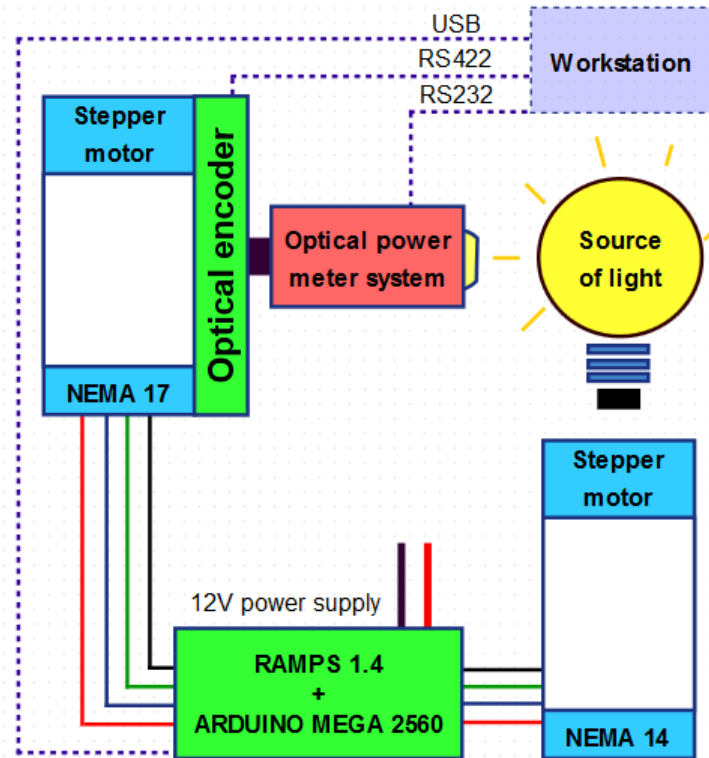


Figure 3. Overview of electrical wiring

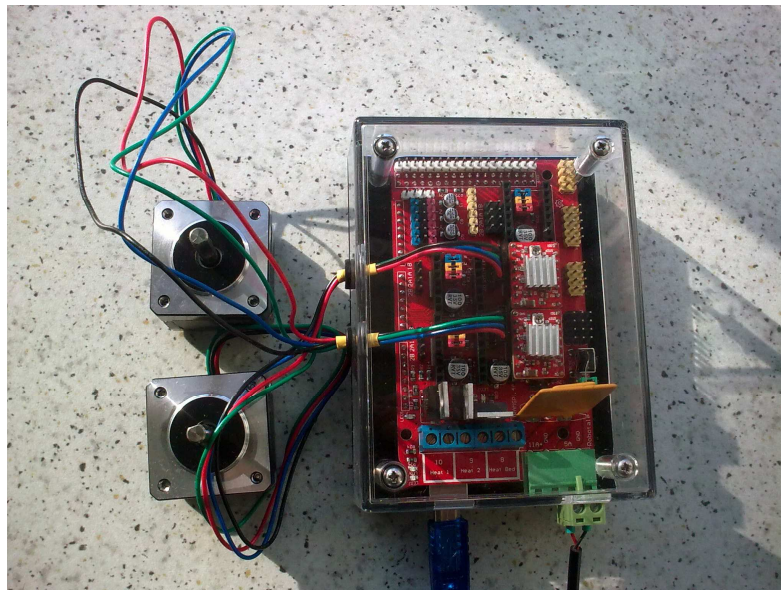


Figure 4. Arduino Mega 2560 with RAMPS and stepper motors

The stepper motor has very small requirements for torque. It was decided to use *NEMA 14* and *NEMA 17*, which are also used in 3D printers. In our application, a step angle value is a decisive factor. For this motor it is $1,8^\circ$ per one step. It is possible to find stepper motors with smaller step, but it is not necessary, due to hardware technique called “micro stepping”. With this technique, realized by *RAMPS* and *Pololu stepper driver*, it is possible to divide one full step by 2, 4, 8 or 16. Therefore the $1,8^\circ$ step can be divided up to 16 steps, resulting in a value of $0,1125^\circ$ for 1 micro step. Although, we should remember there are imperfections in coils, and this number may vary slightly.

Due to these and other reasons, measurement system is supplemented by the *SiGNUM™*

RESM rotary (angle) encoder system with the 1 μ m resolution (which is $5.47'' \approx 0.00152^\circ$). It can be used to verify accuracy of the measurement system and also to help with the settings of stepper motors, as explained later.

The second main device is the sensor reading head of the optical power meter system (*Thorlabs Instrumentation S120B*). It is connected to workstation via RS232 and for the communication it is using one of the IEEE standards. It is sending data to workstation about a current measured power level as described in chapter 2.3.

Arduino Mega 2560 can be programmed using the Arduino development environment. Because the software code used by Arduino is usually under the GPL (General Public License), it was decided to use already created firmware with codename “Marlin” [3]. It belongs to one of the firmware used for RAMPS for 3D printers and other purposes. Only a few parameters were changed, such as a removal of temperature sensors and setting a speed for stepper motors to make it more suitable for our application. This firmware also contains a library for communication with workstation, which is used to receive commands for required stepper motor position.

Because the “Marlin” code is used with applying a linear movement in 3D printer applications, program constants of stepper motors have to be calibrated for our application. This is the second main reason, why the optical encoder is also attached to the measurement system.

2.3 Graphical user interface

Graphical user interface (GUI) is realized using Python language. The application window is shown in Fig. 5. The program is communicating with Arduino and optical power meter system using COM ports, which are opened in the beginning of the program. Program is using special set of characters (defined by manufacturer and publisher) sent to each device via serial and USB port (virtual COM port). Their meaning is described in [3] for the Arduino with RAMPS and in the manual for a selected optical power meter system.

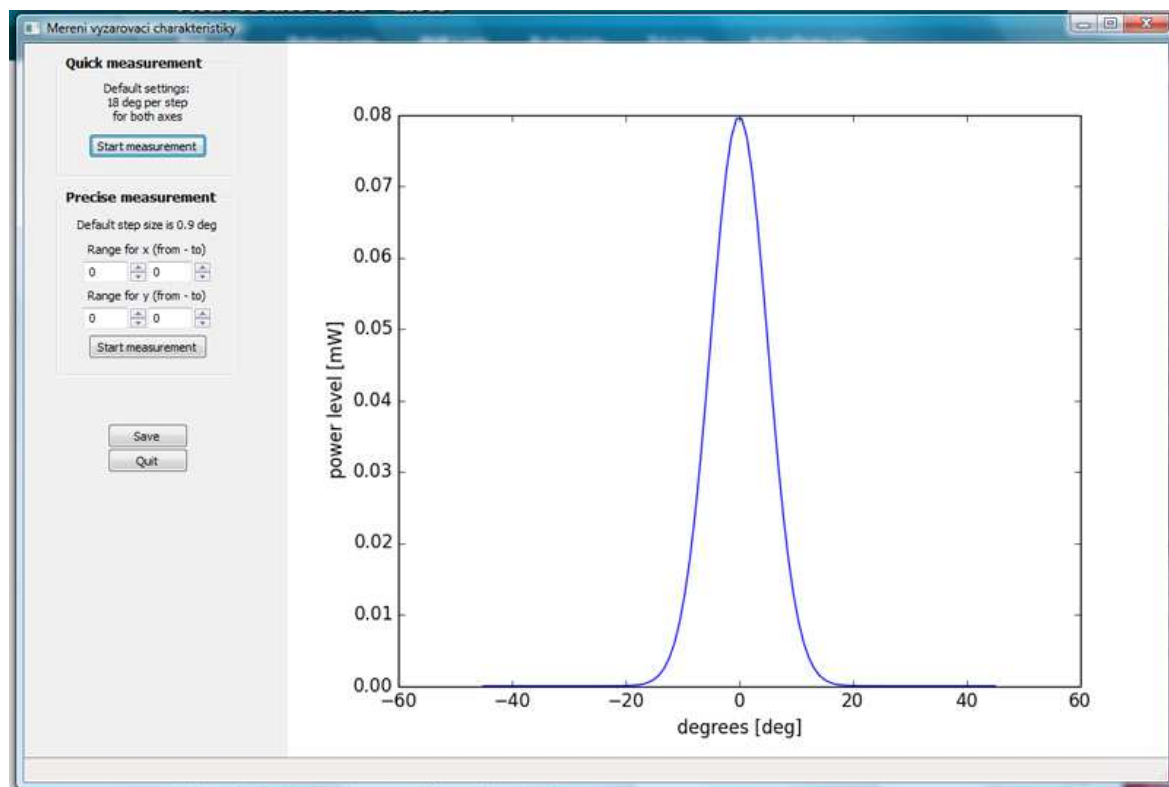


Figure 5. Graphical user interface (GUI) with an artificial sample of measurement

Through the GUI, the user has a choice of a rough measurement (one step angle for measurement is 18°) or a precise measurement (one step angle for measurement is $0,9^\circ$). These values can be easily changed in the future, the only limiting factor is the one mentioned above (the smallest micro step is $0,1125^\circ$).

In the first designed mode, it is possible to measure whole radiation angle using the automatic mode, where the position of the source of the light is slightly moved, and after every movement ($0,9^\circ$ or 18°) workstation sends request to optical power meter system for the actual power level. The received response is written to the measurement table and also into a graph. In the second mode user can manually set the position of the light and make a measurement by himself in selected limits. After measurement, obtained data can be saved to a file.

3. Conclusions

The measurement system has been introduced to reader. Its mechanical and electrical components have been described, as well the graphical user interface. Difficulties with the precise measurement had been examined and solutions were proposed. With the current design it is possible to measure a 3D radiation pattern of the light source with a single step of 0.9° within range of the main hemisphere of the light source. Output to the spectrometer for the informational measurement of the wavelength of the light is available as well.

The proposed design is currently in production and practical results will be available in a few weeks. Authors are planning to show these results in some of the upcoming international conference.

References

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