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Optical spectrometer for measuring anti-Stokes luminescence initiated by single or double impulses

Svetlozar Nedev*, Ivaylo Gugov, Nikolay Saliyski

University of Chemical Technology and Metallurgy, 8 Kl. Ohridski, 1756 Sofia, Bulgaria

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ABSTRACT

A spectrometer with a data acquisition module for measuring light spectrum into the 330 -1000 nm range is built. The interface module produces periodical signals of single or double pulses with given width and duty cycle whish are used to control the light for illumination of the investigated material. The purpose of the spectrometer is to measure the light radiated from anti-Stokes phosphors which emission is a result of a sequential multiple photon absorption activated by these pulses.

Keywords: spectrometer, data acquisition, computer interface, anti-Stokes luminescence.

INTRODUCTION

The light emission in the visual range can be produced by absorption of infra red radiation in anti-Stokes phosphors [1]. They are used in night viewing devices. Such an emission is a result of a sequential multiple photon absorption [2]. This process can be initiated by IR-light diodes with an appropriate wavelength and intensity. The light intensity produced by a diode is limited by its maximum allowed current. It is possible to obtain higher intensity for a short time without diode damage, if the current is sequence of short pulses having high current value of each pulse, but low average current. The spectrometer described below is designed for investigation of such materials by their illumination with light pulses with given parameters.

EXPERIMENTAL

The spectrometer is designed to study the light spectra in range 330-1000 nm. The device consists of:

- spectrometer,
- interface module,
- computer.

An optical sketch of the spectrometer is shown in Fig. 1. This is a Littrow like mounting configuration. The light, which is analyzed, gains to the spectrometer entrance by an optical fiber. A slit with adjustable width, used to control the light intensity, is mounted at the spectrometer entrance. The rays are refracted by a lens, reflected from a mirror, diffracted by a diffraction grating and finally are focused by the same lens on an optical CCD array.

**Correspondence to: Svetlozar Nedev, University of Chemical Technology and Metallurgy, 8 Kl. Ohridski, Sofia 1756, Bulgaria, E-mail: nedev@uctm.edu*

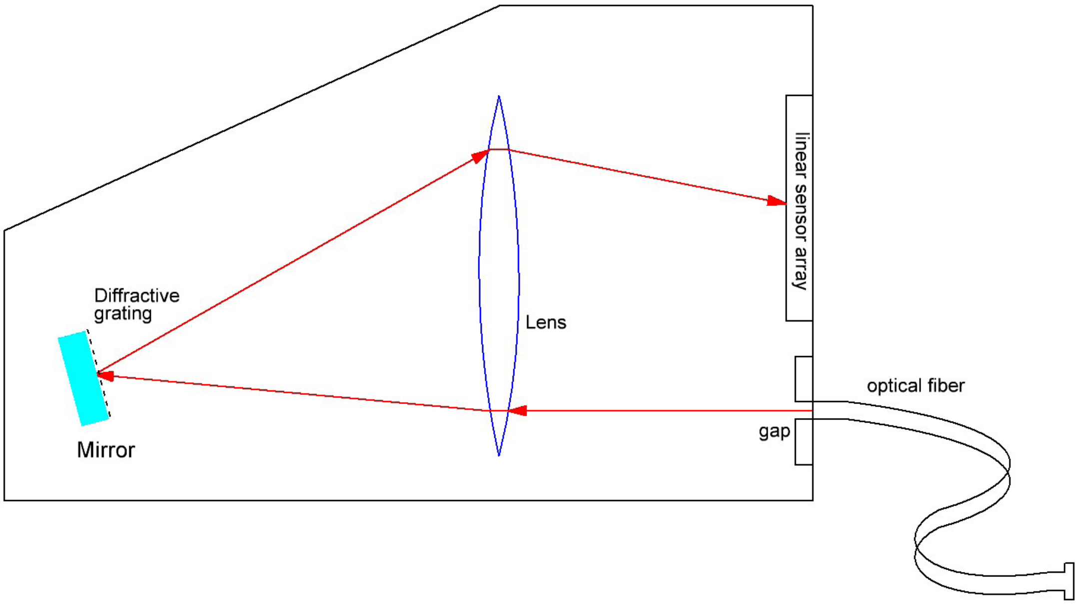

Fig. 1. Spectrometer optical diagram.

As a light sensor the linear array TSL210 [3] is used. This array has been used successfully in optical measurements [4]. It has 640 photodiodes with 125 μm center to center pixel spacing. The photocurrent, generated on each pixel is integrated, and as a result the voltage obtained is proportional to the light intensity and to the time of integration. The spectral response of the photodiodes is given in Fig. 2. The wavelength

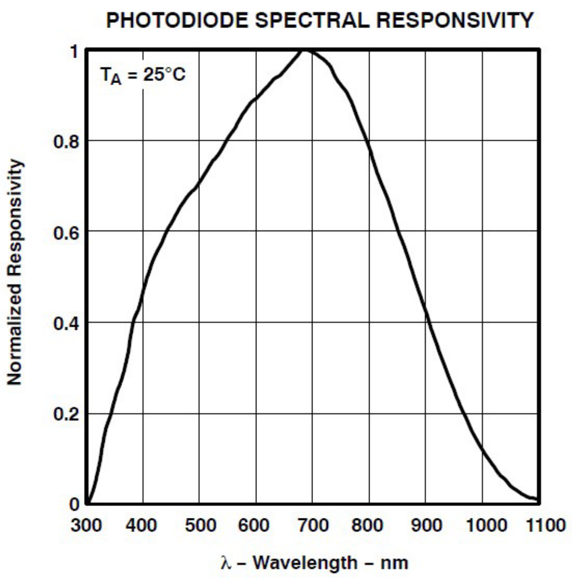

Fig. 2. Photodiodes spectral responsivity.

range of the spectrometer is determined by this curve. The serial mode of a connection of the sensor is used in this application. In this mode the voltage of each pixel is shifted to the output by a clock signal sequence until all pixels are read.

The interface module is designed for illumination control and data transfer. Its circuit diagram is given in Fig. 3. It is supplied by 6 - 12 V DC adaptor. The module has one PCB connector, used to program the microcontroller or to connect the optical array, located into the spectrometer, one 9 pin Canon connector used to feed the diodes which illuminate the sample and cable which ends with a 9 pin female Canon connector for serial interface to computer.

An 8 bit Atmel's microcontroller ATtiny26 was used to control the work of the module:

- 2 pins to communicate with a computer at maximum baud rate of 57600,
- 2 pins to show the mode of operation on two-colored LED diode,
- 3 pins to control and to read the optical array TSL210,
- 2 pins used as a differential ADC inputs to measure the collector current,
- 1 pin to control the current of the outer illuminating diodes.

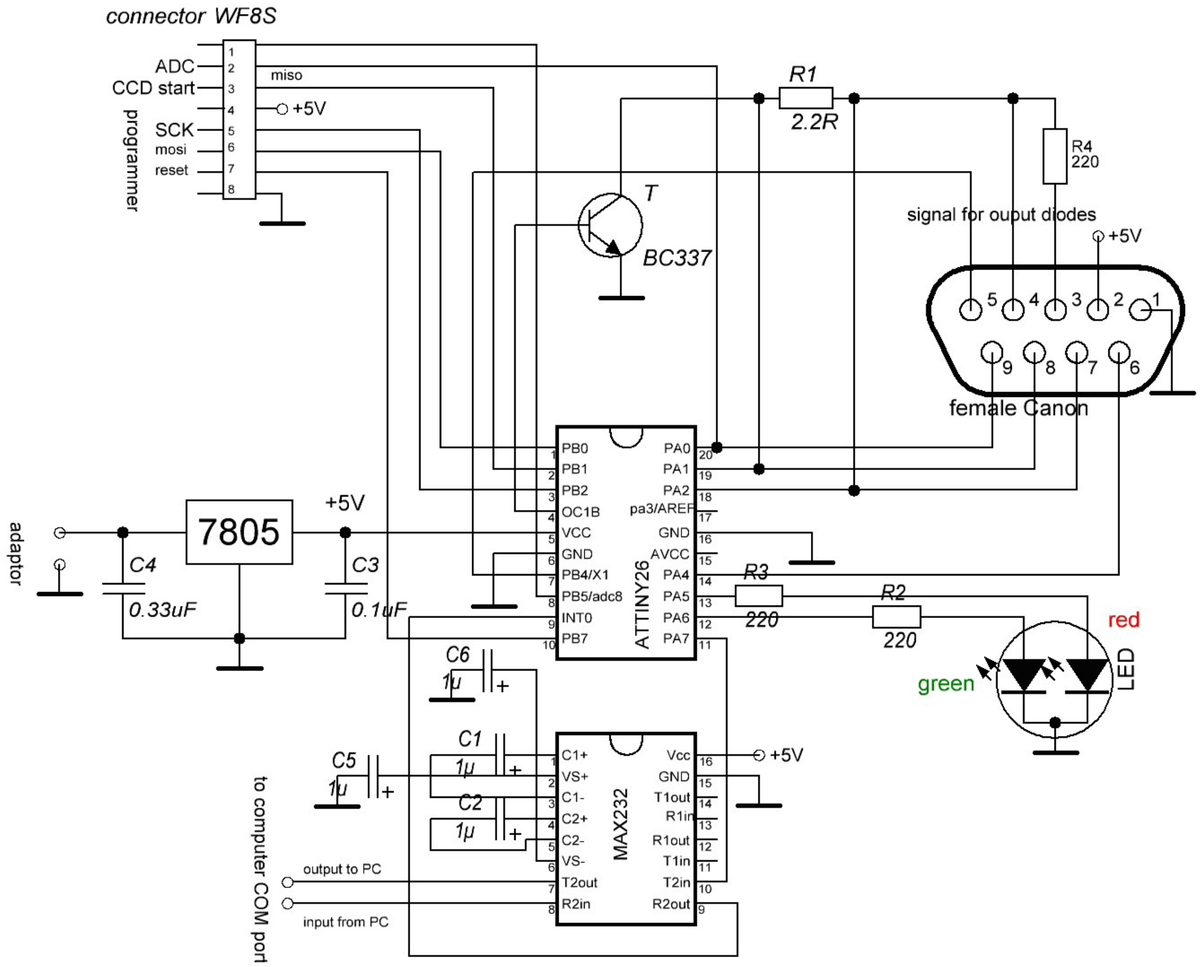

Fig. 3. Circuit schematic diagram of the interface module.

The microcontroller works at 8 MHz from internal oscillator. It has 10 bits analog to digital converters (ADC), which allows to pick up and covert in a digital number the output voltage of the optical array or to measure the voltage on the resistor R1 (see Fig. 3) which is proportional to the transistor collector current. ATtiny26 has timers which can be programmed at different frequencies to generate pulse width modulated (PWM) signals. We used OCB1 pin as a PWM output to control the collector current of a NPN transistor. The current trough the transistor can be modulated in wide range at different steps from 125 ns to 2.048 ms with duty cycle from 1 to 255. The integrated circuit Max232 converts the TTL levels into RS232 levels.

The spectrometer works under control of two programs:

- a master program working on PC under Windows operational system,
- a slave program for ATtiny26.

The master program is written in DELPHI object Pascal. All parameters for illumination control: choice of the pulse mode, pulse duration, duty cycle and the time of integration can by adjusted using friendly interface. One of the COM ports of the computer is used for communication with the interface module.

Two types of pulses can be chosen:

- single pulses with duty cycle from 1 to 255 and duration from 32 µm to 32 ms,
- double pulses with the same duty range and a given time between the two pulses.

When the measurements are started, the microcontroller reads the CCD array and sends the data to PC. Each series of data from 640 photodi-

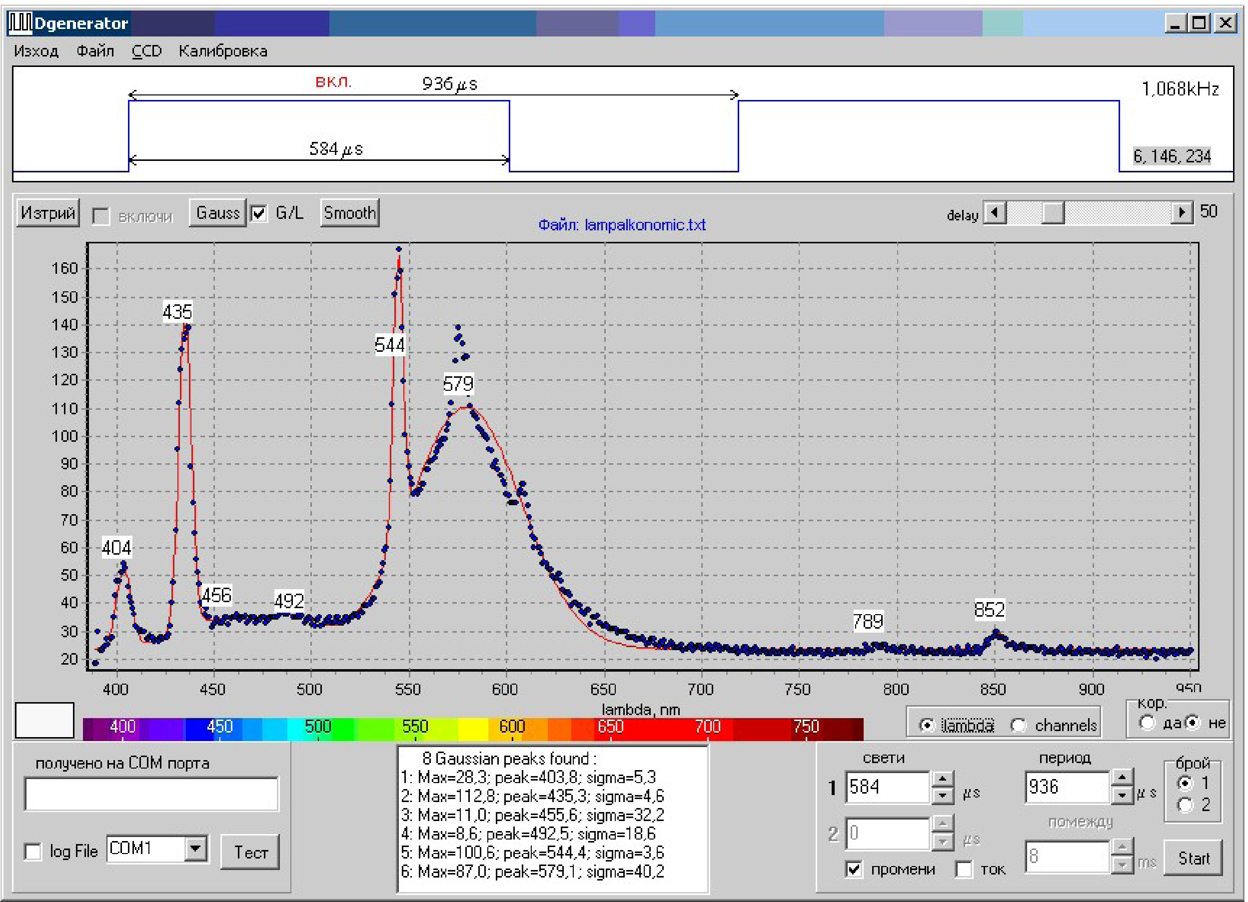

Fig. 4. The master program for spectrometer control with measured "economic" fluorescent lamp spectrum shown by blue dots. The red line is a fit with constant background plus six Gaussians.

odes is immediately shown on the screen together with the average over the last three series.

The program gives a possibility to fit the spectrum using sum of Gauss or Lorentz curves and constant background (red line in Fig. 4) or to save the data as a text file for better fitting and further analysis.

The source code for the microcontroller is written in C. It uses software UART (because ATtiny26 has no hardware serial interface) to communicate with the computer. The program generates an output PWM signal with given characteristics.

The microcontroller initiates the array output cycle and reads the voltage of each of 640 pixels converting it to 10 bits number. According TSL210 datasheet [3] this number is sum of two terms: a constant, defined by the output voltage for dark condition and a number proportional to the light intensity and the integration time. The integration time is the time between two output cycles.

The state of the microcontroller: data transfer, single pulses, double pulses, test of the serial interface, is visualized with different colors by a two colored LED diode.

CONCLUSIONS

A spectrometer with a data acquisition module for measuring light spectrum into the range 330 -1000 nm is built. The interface module produces periodical signals of single or double pulses with given width and duty cycle whish are used to control the light for illumination of the investigated material. The purpose of the spectrometer is to measure the light activated by such pulses.

Acknowledgements

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