# Development of a low-cost automated goniophotometer

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*Abstract:* - An automated goniophotometer was developed at the Photometry Laboratory of National Technical University of Athens. The construction of this apparatus permits the rotation of the light source around a fixed vertical axis as well as around a moveable horizontal axis. The combination of both the rotations and the use of special mechanical structures facilitate measurements in A, B and C-planes. The lamps of the luminaire are always in the burning position. The operation of the system is fully controlled by a personal computer, through an electronic controller. The motors for the rotation of the axes are connected to the controller. Two optical encoders connected also to the controller measure the position of the axes. A detector, connected to the analogue input of the controller measures the luminous intensity. The measuring procedure is very simple and user friendly, by means of the software, which was developed using Visual Basic in Windows 95 environment. The user defines only the plane, the range of the angles and the angle-step of rotation as well as the desired accuracy. Other parameters can also be defined whereas individual movements can be performed. The values of the angle and of the detector are continuously measured and transferred to the computer. The measured values are stored in a file and the diagram of the polar distribution of the luminous intensity is drawn when the rotation is finished

*Key-Words*: - Goniophotometer, luminous intensity, polar diagram, luminaire

## 1. Introduction

The use of goniophotometers with fixed vertical axis and moveable horizontal axis (Fig. 1) was quite common during the past decades. This type of apparatus is characterised by CIE [1] as "Goniophotometer with facility for turning the light source-Type 3". The luminaire in these goniophotometers is turned around its vertical and its horizontal axis. The photometer head is fixed. The measurements are made in C-planes or conical surfaces.

The advantage of this type of goniophotometer is the ability to operate in every laboratory with long length irrespective of its height and width. A short, close fitting room without windows and with no reflective walls is suitable. Another advantage is the absence of a deflecting mirror as it introduces polarisation error and selective reflection. Its alignment is also another source of errors.

A disadvantage of those goniophotometers is that the movement of the luminaire during the measurement can generate an error due to vibrations and air movements. Another more serious disadvantage is that the burning position of the lamp sometimes can not meet the requirements of the manufacturer.

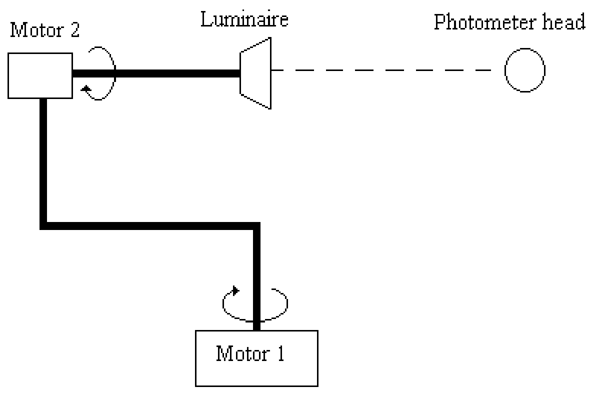


Fig. 1: Goniophotometer with rotating vertical axis and moveable horizontal axis.

A goniophotometer of the above type in the Laboratory of Photometry of National Technical University of Athens was manufactured in the late seventies. It had the facility for turning the light source with fixed vertical axis and moveable horizontal axis. The disadvantages of this goniophotometer and the old electronic control system were the reasons for total changes in this system. Considerable modification [2] was performed in the mechanical structure, so measurements in A-planes as well as in B-planes are possible. The modifications permit the position of the lamp to be always in burning position.

The operation of the system is controlled by a personal computer, through an electronic controller. A detector, connected to an analogue input of the controller measures the luminous intensity. Two optical encoders measure the angles of rotation. The measuring procedure is very simple and user friendly, by means of the software [3] which was developed using Visual Basic for Windows 95. The recording of the measurements permits the tasking from a lot of software package like Excel, Access, and Dbase for the calculation of the zonal distribution of luminous flux, the coefficient of utilisation etc.

**2. Planes of rotation**

The goniophotometer before the changes had the following possibilities:

- Turning the horizontal axis of the light source by the stepping motor No.2. Measurements of the luminous intensity were made in the appropriate C-planes. The photemetric centre of the measured luminaire was constant. The orientation of the luminaire to the photometer head was only changing.
- Rotating of the vertical axis by the stepping motor No.1, for variation of the angle $\gamma$ of the selected C-plane. The position of the measured luminaire was constant at the photometric centre. The angle $\gamma$ was only changing

A shoring-base for the luminaire was manufactured and attached to the arm that is the assumed horizontal axis of the goniophotometer. The luminaire now is placed on the arm and the longitudinal axis of the luminaire is the same with the horizontal axis of the goniophotometer (Fig. 2). The role of the goniophotometer axes are inverted now and the possible movements are the following:

- Rotation of the vertical axis, by the motor No.1, for the selection of the A-plane.
- Rotation of the horizontal axis, by the motor No.2, for the change of the angle $\alpha$ at the selected A-plane. The position of the measured luminaire is constant with reference the photometric centre. The angle $\alpha$ is only changing.

The luminaire in Fig. 2 is placed with its longitudinal axis perpendicular to the line that connects the photometer head with the geometrical centre of the luminaire. Rotating the horizontal axis by the motor No.2, the polar distribution of luminous intensity in $A_0$-plane is measured.

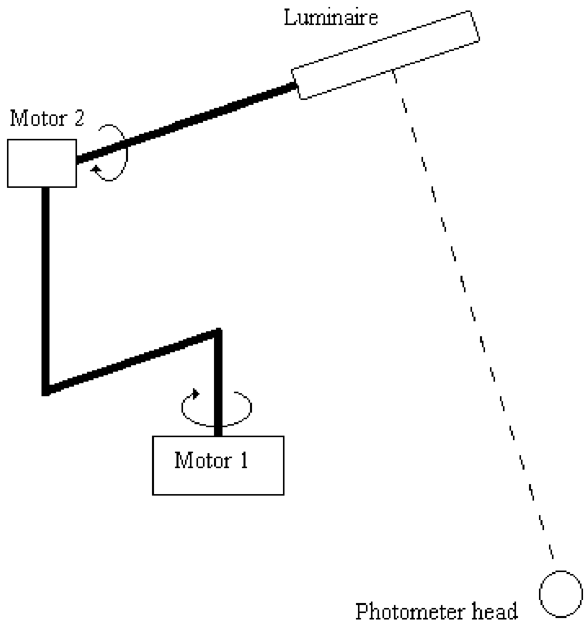


Fig. 2: Modification for measurements in A-planes (here in $A_0$-plane).

For the measurement of the polar distribution in the other A-planes the vertical axis of the system is turned to the selected plane and the distribution of the luminous intensity is measured by rotating the horizontal axis.

It should be noticed that the lamps of the luminaire are always at the burning position.

For the measurement of the zonal distribution in B-planes a mechanical system was constructed with cog-wheel that converts the rotation of the horizontal axis (motor No.2) to an inclination of the luminaire on the vertical direction (up or down) as it is shown in Fig. 3. The possible movements of the luminaire with this system are the following:

- Rotation of motor No.2 that causes the inclination of the luminaire to the selected B-plane.
- Rotation of the vertical axis by the motor No.1 for change of angle β in the selected B-plane. The position of the measured luminaire is constant at the photometric centre. The angle β is only changing.

It is obvious that the lamps are always at the burning position.

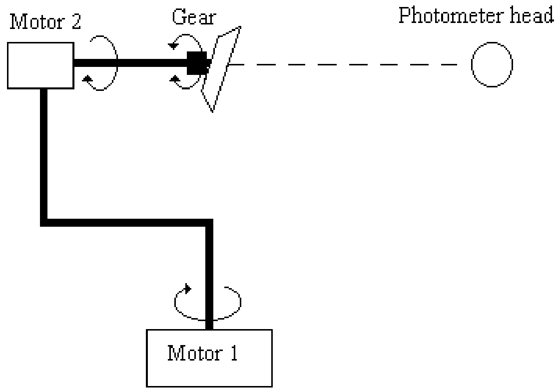


Fig. 3: Modification for measurements in B-planes.

## 3. Electronic system

An electronic controller that is connected to the serial port of the personal computer controls the goniophotometer. The controller consists of a CPU card, a master peripheral card, a motherboard, an analogue-to-digital converter and an analogue/digital multiplexer. The controller is connected to the serial port of a personal computer. All the commands to the stepping motors are executed from the computer through the controller. The measurements are also transferred to the computer. The block diagram of the electronic system is shown in Fig. 4.

Two D.C. stepping motors perform the rotation of the goniophotometer axes. Two angle encoders of 10.000 pulses/360$^o$ control the angle of rotation of the axes. Therefore, the minimum angle that can be generated and measured with this system is 0,036°. The controller receives digital signals (commands) from the user of personal computer which are converted to analogue ones (pulses) and transmitted to the stepping motors.

A photometer head measures the luminous intensity. Its output is amplified and next is connected to the analogue input of the controller. This signal is converted to digital by the analogue-to-digital converter and finally is transferred to the personal computer.

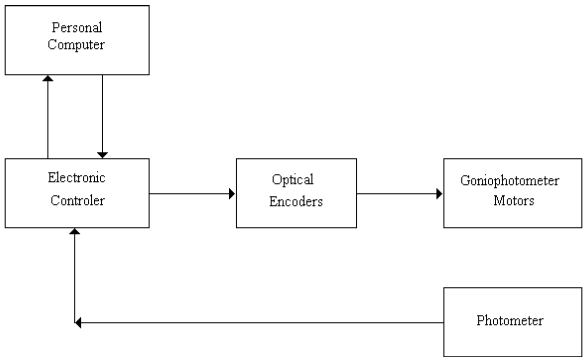


Fig. 4: The electronic circuit.

## 4. Software

The software package [4, 5] that has been developed provides the ability to execute the movements of the arm of the goniophotometer and locate the position of the luminaire. The most significant ability of the system is the automation of the measurements with the least contribution of the user.

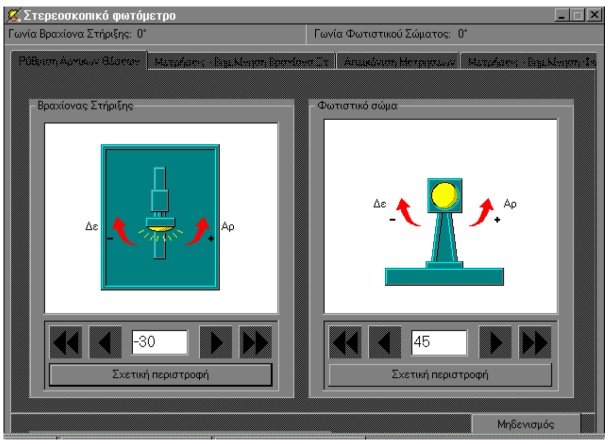


Fig. 5: Individual rotations defined by the user.

The first display of the software package (Fig. 5) is divided in two parts, one part for each axis (motor) of the goniophotometer. The user can rotate each axis around a specific angle. The user can select slow (⏵ or ⏴) or fast (⏵⏵ or ⏴⏴) rotation using the respective keys. A simplified picture of the axes on the display permits a user-friendly operation of the programme.

The second display of the software (Fig. 6) is used for the definition of the input parameters of the measurement procedure. The user can select the range of the angle of rotation, the angle-step and the type of polar diagram. By default, there are three types of polar diagrams: 0°...90°, -90°...+90°, 0°...180°. The angle step can be defined as short as the resolution (0,036°) of the angle-encoders permit.

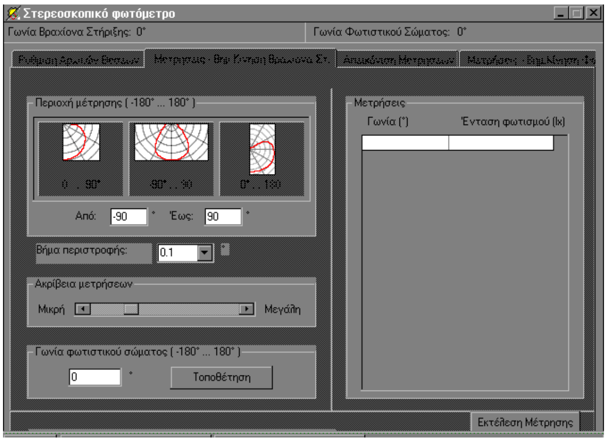


Fig. 6: Parameter definition of a complete set of measurements in a plane.

At each angle-step the rotation stops, a large number of measurements (500 - 3000) are taken and their mean value is calculated. This value is considered to be the luminous intensity of the luminaire at that angle of rotation. The rotation stops in order to avoid errors due to the stabilisation time (if any) of the photometer head and of the light source. The user can define the time delay and the number of measurements at every position, which finally affect the accuracy of the measurement. The higher is the accuracy, the longer is the time duration of the measurement. The required time for the measurement of the luminous intensity in the range $\alpha$=0° … 180°, with angle step 2,5° and 1500 measurements at each step (medium accuracy) is 15 minutes.

The third display of the software (Fig. 7) is used for drawing of the polar diagrams. The user defines the distance from the photometer head to the light source and the software calculates the luminous intensity from the measured illuminances, using the photometric law. He can also define the luminous flux of the light source in order to get the polar diagram cd/1000lm. The simultaneous drawing of the polar diagrams in two planes is another option of the software.

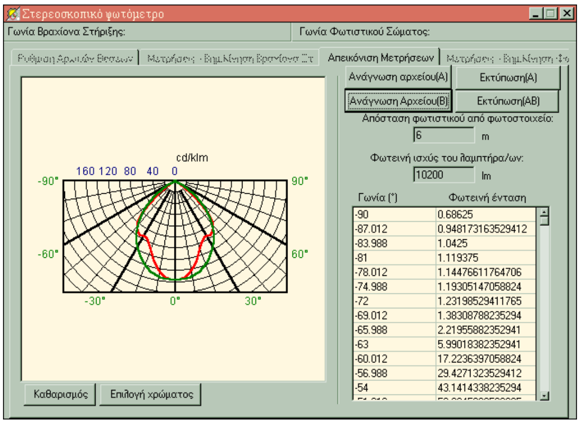


Fig. 7: Drawing of polar diagrams.

## 5. Conclusions

The development of the described goniophotometer was based on an old mechanical construction with limited possibilities of rotation. Its major disadvantage was the old electronic controller that was impossible to co-operate with the modern electronics and to connect with a personal computer. Under-graduate and post-graduate students made the modification of the system under the supervision of the staff of the laboratory and with their co-operation. The final product is a goniophotometer with high accuracy and satisfactory abilities of rotation. The cost of the modification was low enough comparing with the cost of a brand new goniophotometer. Perhaps its technology cannot be compared with the one of the modern goniophotometers. Nevertheless, its performance after two years in operation is quite satisfactory. The tests that were performed showed that the system was suitable for quality assurance measurements and scientific research.

## 6. References


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