MPTL14 2009
Udine 23-27 September 2009

LUCEGRAFO. A SIMPLE USB DATA ACQUISITION SYSTEM FOR DIFFRACTION EXPERIMENTS

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1. *Abstract*

New technologies give us new opportunities for physics teaching/learning. Phenomena can be studied in real time with simple computer on-line equipments based on sensors. A USB system for diffraction measurements is constituted by a photodiode inserted in a housing made an alluminium block solid with the cursor of a linear potentiometer, so that the optic signal is correlated with the position by means of the resistance of the potentiometer. A small rectangular screen (12 cm x 2 cm), solid with to the optic sensor support, has the function of allowing overall qualitative observation of the distribution of light intensity. At the centre of the screen there is a slit (0,4 mm X 10 mm) functioning as a diaphragm for the optic sensor. A screw guide for fine movements of the cursor is available. The calibration of the system is made measuring the light intensity as a function of the distance from a point-like source.
Educational activities proposed in previous contributions (Mascellani 1989; Frisina et al 1996) are implemented with better results.

2. The computer on-line system: LUCEGRAFO

Here are presented the hardware and the software of our prototype apparatus that allows easy but precise measurements of light intensity patterns produced by edges, single or multiple slits. The present apparatus is an improved version of one described by other authors (Madcellani 1989; Frisina 1993). Our goal is to create a low-cost device that allows accurate experimental investigations of single slit or multiple slit diffraction patterns to offer the opportunity to individuate the phenomenon laws by data analisys. Here we present the system and some typical data obtained with measurements in the case of single slit in Fraunhofer conditions to compare results with those of other systems available. Measurements in Frenel conditions or with multiple slits can be carried out with the same system. Educational proposal is described in other contributions (Mascellani, 1989; Corni 1993)

2.1 Hardware

The equipment is elementary: a commercial linear cursor potentiometer, an optical sensor realized with a photodiode, an interface card for data acquisition and analogical-digital conversion, USB cable.
The interface card, implemented with a microcontroller PIC 18F252 by Microchip Technology, is used to read in the same time the two independent sensors. The digital signals are sent to the computer via USB connection, realized using a decoding module FT245BM.

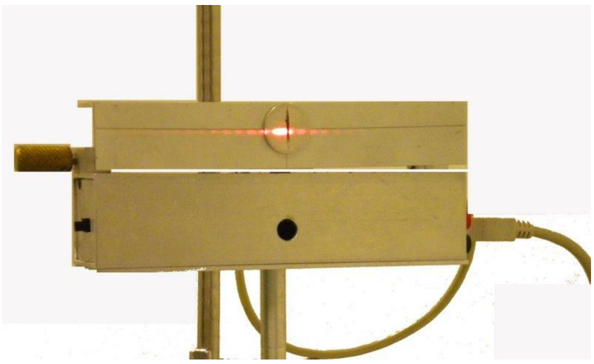

Fig. 1 – The LUCEGRAFO system

Fig 1 shows that the photodiode is inserted in a housing made an aluminium block solid with the cursor of the potentiometer.
The experimental dependence of the light intensity on the square of distance is both a confirm of the current transfer function assumed and the way to find the unknown parameters.
There are 3 ranges of sensibility, to acquire the 12th maximum and the central maximum, at a distance of 2 m, with a single slit of 0,12 mm and a laser with λ~650A.

2.2 Software:

During the measure the system acquires and represents on the screen, both in graphical and numerical way, couples (intensity, position), one per second, so that, moving the cursor by manual adjustment of the screw, the space distribution of light intensity for a length of 100 cm is acquired.
The measure is represented in linear response: the intensity, in the graph, is represented in arbitrary units, proportional to the light intensity incident the sensor.

2.3 Apparatus for measurements

Besides having the LUCEGRAFO system, it is sufficient to have available:

- a low-power laser
- a personal computer
- slits
- vertical-rod supports.

An optical bank is not required: it is enough to take care over the alignment of the measurement system.
In the following we present the data obtained using a He-Ne laser for education use (1 mW, λ=650 nm), and commercial slits.

3. Examples of measurements

Here some examples of activities are presented, those impossible to carry out with traditional systems without sensors in didactic laboratories.

3.1 Exploration of light intensity distribution of a diffraction pattern.

Qualitative inspection of the diffraction pattern obtained on a white screen, changing the distance D between slit and screen. This places in evidence that the screen intercepts angular constant distribution of light intensity: in fact, the distances of minima and maxima from the centre of the central maximum increase proportionally to the distance D.

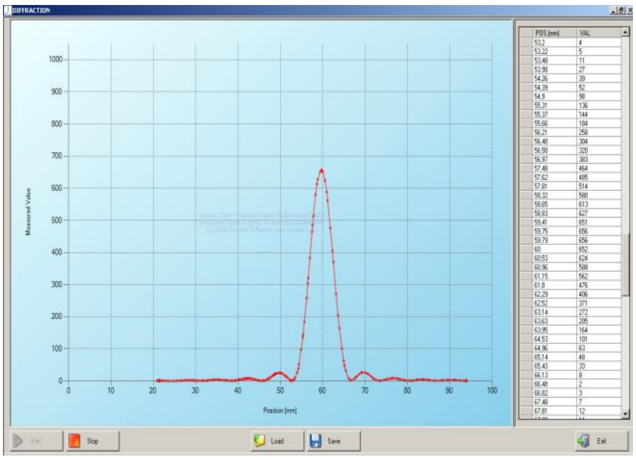

Fig. 2 - Diffraction pattern with the system in the low range of sensibility: calibrating the relative intensity in the order of magnitude of the central maximum

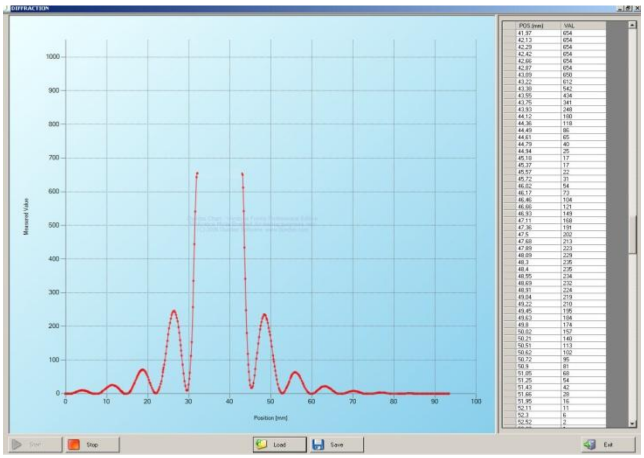

Fig. 3 - Diffraction pattern with the system in the medium range of sensibility: calibrating the relative intensity in the order of magnitude of the first order maximum

Fig 2 and Fig 3 shows the on-line acquisition of light intensity distribution on the screen in the areas of the central peak with the system in different range of relative intensity: calibrating the relative intensity (filtering) with those of the central maximum (Fig. 2) or those of the first order maximum (Fig.3) to underline the two order of magnitude between the intensity of the central maximum and those of the others.
It is immediately evident that the system cannot reveal in the same scale both the intensity of the central maximum and those of the nearby ones, unless the incident intensity is reduced. This gives the opportunity for a discussion both of the characteristics of the diffraction pattern and those of optical sensors.

3.2 Fitting of a light intensity distribution

It is possible, with a separate software program, perform a fitting of experimental data by overlaying the Fraunhofer light intensity distribution to that obtained experimentally.
Modeling is done using the following relationship:

$$I(\theta) = I_0 \left(\frac{\sin(z)}{z} \right)^2 \qquad \text{where} \qquad z = \frac{\pi \cdot a \cdot \sin(\theta)}{\lambda}$$

The program requires input data for fitting. The input parameters, for comparison between experimental data and calculated points in the case of Fig. 4, are the following:

slit **a** (mm)	distance **D** (mm)	laser **λ** (nm)	maximum intensity $\mathbf{I_M}$ (a.u.)	maximum position $\mathbf{X_M}$ (mm)	maximum order number
0,12	1390	650	235	48,4	1

The result obtained is shown in Fig. 4, where appears in red the figure obtained according to Fraunhofer theory.

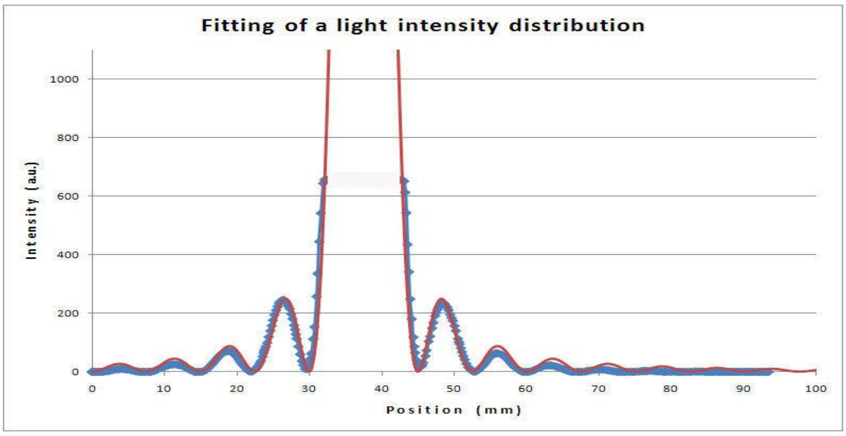

Fig. 4 – Light intensity as a function of distance from de first maximum of a diffraction pattern obtained with a slit 0,12 mm wide at a distance of 1390 mm from the screen.

4. Address reference

For information about the availability of the system described in this paper (hardware and software) contact:
Univesity of Udine – mario.gervasio@uniud.it or marisa.michelini@uniud.it.
The system (hardware and software) can be obtained at the reproduction costs (about 500,00€) by Next srl – Udine.

5. References

Mascellani V,.E.Mazzega. M.Michelini. Nuove opportunità di apprendimento in ottica mediante l'uso dell'elaboratore, La Fisica nella Scuola, XXII, suppl.4, 4, 1989 p.4S

Mascellani V, E.Mazzega, M.Miche!ini, Un sistema per esperienze di ottica on-line e indicazioni per attività didattiche nello studio della diffrazione ottica, La Fisica nella Scuola, XXV, Speciale congiunto AIF-SIF), 1992 p.l32

Corni F, V Mascellani, E Mazzega, M Michelini, G Ottaviani, A simple on-line system employed in action experiments, in Light and Information, Girep Book, L C Pereira, J A Ferreira, H A Lopes Editors, Univ. do Minho, Braga 1993

Frisina A, M Michelini, Physical optics with on-line measurements of light intensity, in Teaching the Science of Condensed Matter and New Materials, GIREP-ICPE Book, Forum 1996, p.I62

Gervasio M, M.Michelini, R. Viola, Sensors as extension of senses via USB: three case studies on thermal, optical and electrical phenomena.