

The photoelectric effect and study of the diffraction of light: Two new experiments in UNILabs virtual and remote laboratories network

JUAN PEDRO SÁNCHEZ⁽¹⁾(*), JACOBO SÁENZ⁽²⁾, LUIS DE LA TORRE⁽²⁾,
CARMEN CARRERAS⁽¹⁾, MANUEL YUSTE⁽¹⁾, RUBÉN HERADIO⁽²⁾
and SEBASTIÁN DORMIDO⁽¹⁾

⁽¹⁾ *Department of Material Physics, UNED - Madrid, Spain*

⁽²⁾ *Department of Computer Science and Automatic Control, UNED - Madrid, Spain*

received 26 October 2015

Summary. — This work describes two experiments: “study of the diffraction of light: Fraunhofer approximation” and “the photoelectric effect”. Both of them count with a virtual, simulated, version of the experiment as well as with a real one which can be operated remotely. The two previous virtual and remote labs (built using Easy Java(script) Simulations) are integrated in UNILabs, a network of online interactive laboratories based on the free Learning Management System Moodle. In this web environment, students can find not only the virtual and remote labs but also manuals with related theory, the user interface description for each application, and so on.

1. – Introduction

Traditional face-to-face lectures and experimental laboratory sessions can be complemented with new online experimental frameworks. While there already are lots of Internet resources (many of them accessible for free) to fulfil many theoretical aspects on education, engineering and scientific studies also need more specific Internet based tools to cover the practical part of their teaching. Examples of this can be found in works (Chang G. W., Yeh Z. M., Chang H. M. and Pan S. Y. (2005), de la Torre L., Sánchez J., Dormido S., Sánchez J. P., Yuste M., Carreras C. (2011) and Wannous M. and Nakano H. (2010)).

Tools such as Learning Management Systems (LMSs) and web-based labs have become widespread in distance education in the last decade. LMSs support the administration,

(*) E-mail: jpsanchez@ccia.uned.es

documentation, tracking, and reporting of training programs, classroom and online events (Ellis R. K. (2009)). Web-based labs make possible to illustrate scientific phenomena that require costly or difficult-to-assemble equipment, and should ideally consist of two different and complementary parts:

- *Virtual Labs* provide computer based simulations which offer similar views and ways of work to their traditional counterparts. Nowadays, simulations have evolved into interactive graphical user interfaces where students can manipulate the experiment parameters and explore its evolution.
- *Remote Labs* use real plants and physical devices which are teleoperated in real time. Remote experimentation through the Internet has been available for more than a decade and its interest has never diminished over the years.

Even though constructivist web learning environments and Virtual/Remote Labs (VRLs) already exist, there is still a lack of convergence and interoperability between both tools (Gravier C., Fayolle J., Bayard B., Ates M. and Lardon J. (2008), Guimaraes E. G., Cardozo E., Moraes D. H. and Coelho P. R. (2010) and Salzmann C. and Gillet D. (2007)). This work applies a solution that solves this gap (de la Torre L., Sánchez J. P., Heradio R., Carreras C., Yuste M., Sánchez J. and Dormido S. (2012) and Heradio R., de la Torre L., Sánchez J., Dormido S. and Vargas H. (2011)), to two newly developed virtual and remote laboratories on Physics (the photoelectric effect and the study of diffraction of light).

In terms of hardware, each remote practice uses a different set of tools and devices. In terms of software, they are both built using the same computer program (Easy Java(script) Simulations or EjsS). Virtual laboratories are also developed using this same program. Since all the applications (either for virtual or remote labs) are based on the same technology, their integration into a LMS (Moodle, in this case) is simplified. Moodle is a widespread used LMS (more than 60 million registered users, according to its official webpage) that supports constructivist learning, offering its users communication and interaction facilities. EjsS (Christian W. and Esquembre F. (2007) and Christian W., Esquembre F. and Barbato L. (2011)) is a tool designed for the creation of discrete computer simulations. During the last few years, EjsS has grown for helping to create web-accessible labs in control engineering education. With this objective in mind, recent releases of EjsS support connections with external applications, such as LabView and Matlab/Simulink. Hence, EjsS is useful not only to create virtual labs, but also the graphical user interfaces (GUIs) of their remote counterparts.

2. – UNILabs: the network of virtual and remote laboratories

UNILabs (<http://unilabs.dia.uned.es>) is a University Network of Interactive Labs, born on September 2013. One year later, it already offers ten courses from eight different universities with around 20 virtual and/or remote laboratories and covering topics such as physics, automatic control or mathematics. The secret of the fast growing of UNILabs is its web 2.0 features, extended to the addition of simulations, virtual and/or remote laboratories: in UNILabs, each teacher has editing rights over their own courses and therefore, any of them can add, in an easy and an autonomous way, the experimentation resources they need for their courses and subjects. Figure 1 shows UNILabs homepage.

UNILabs web portal is based on Moodle, a LMS that provides a social context for students collaboration. Moodle enriches virtual and remote labs by facilitating and

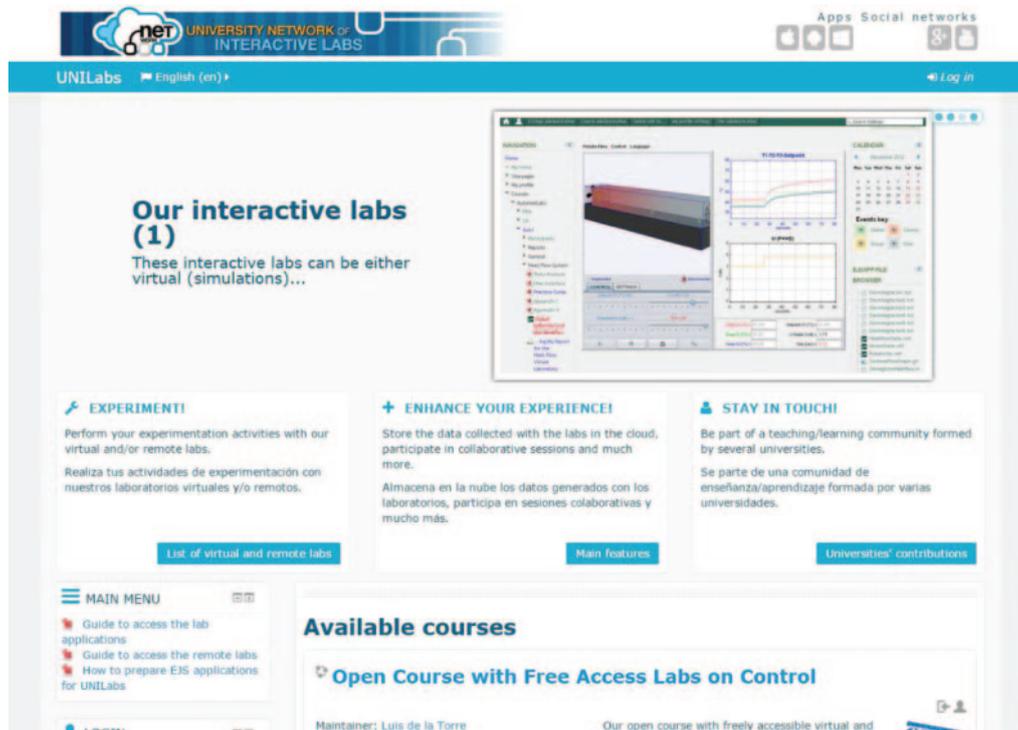


Fig. 1. – UNILabs homepage.

promoting the tools for students to discuss the experiments between them and teachers, exchange their lab reports, etc. In addition, Moodle helps to distribute all the convenient resources for a complete online experiment. For instance, attached to the web-lab, a course in Moodle may include a description of the phenomena under study, videos, the task protocol that students must follow, a questionnaire, etc. Finally, Moodle allows creating open courses that are accessible and available for anyone, making our labs, both the virtual and remote ones, usable for any person who might be interested: for example, students who want to learn more on their own. While the VRLs on Physics are only accessible for students of those universities that participate in the UNILabs project, it is planned to make them freely accessible for anyone in a new open course focused on Physics topics.

More information about the UNILabs portal and the tools it is based on can be found in video format at our youtube channel: <http://www.youtube.com/user/UNEDLabs>.

3. – New Physics experiments

The new Physics real and remote experiments in UNILabs count with a virtual (simulated) counterpart so students can familiarize with both the phenomena under study and the user interface before they access the actual, remote lab. The virtual labs offer a way of obtaining theoretical results students can use for contrasting and comparing with the real ones obtained from the remote experiments.

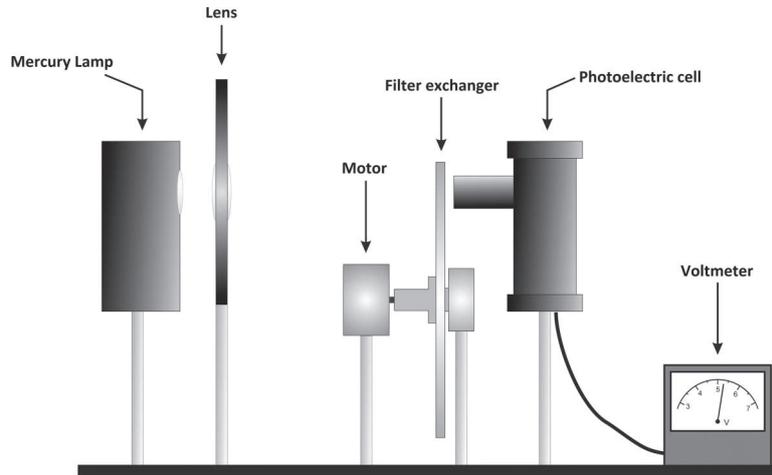


Fig. 2. – Diagram of the photoelectric effect experiment.

3.1. The photoelectric effect. – In this practice, fundamentals of the photoelectric effect are studied and an experimental determination of Planck’s constant, h , is carried out. A commercial experimental setup from Leybold Didactic was used to allow students performing this experiment in a remote way. This setup consists of an optical bench with a mercury lamp, a collimator lens, a disc with a collection of interferential filters of different wavelengths and a photoelectric cell. A power supply for the mercury lamp, an amplifier circuit used to take measurements, a second small power supply for this amplifier circuit and a voltmeter are also part of this commercial setup.

The tweaks made over this commercial setup in order to support a remote use were: 1) replacing the original disc with the collection of filters by a larger and motorized disc (which allows a larger number of filters) thanks to the use of a stepper motor, 2) connecting an Arduino board for data acquisition (to complement the original voltmeter) and controlling the motor, 3) placing a webcam to provide visual feedback, and 4) programming the control of the instrumentation and the GUI (created using EjsS). The experimental procedure consists in registering the charge voltage in the capacitor (saturation value) when radiations of different wavelength act over the photoelectric cell. The selection of the different wavelengths is achieved by means of the corresponding filters. An analysis of the data registered in this experiment allows determining Planck’s constant. Figure 2 depicts the assembly used for this experiment while fig. 3 shows a couple of pictures.

The VRL applications for this experiment allow selecting the wavelength of the light that gets to the photoelectric cell, taking measures of the registered stopping voltages (see left image in fig. 4) and plotting both values (voltages against wavelengths) in order to make a linear regression and obtain h with good precision (see right image in fig. 4).

3.2. Study of the diffraction of light. – The aim of the experiment is to study the diffraction patterns produced by different diffracting objects. First, students must observe the diffraction patterns projected over the translucent screen, thanks to the use of a webcam. From the visual analysis of these figures, they can check the validity of the light diffraction theory and, by determining the position of the intensity minima and maxima, estimate the size of those objects that produce such figures. As a second task,

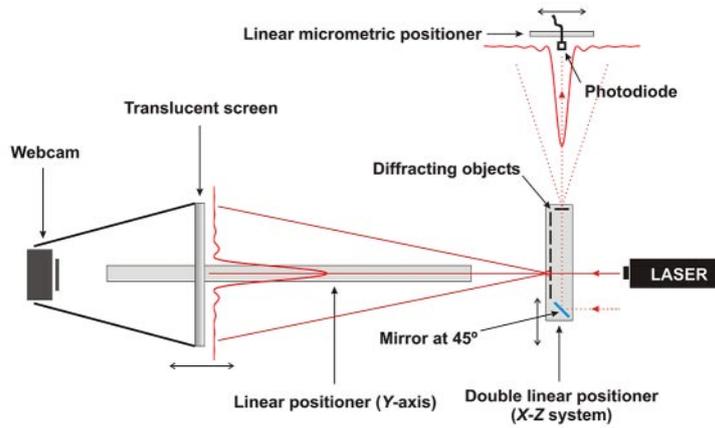


Fig. 5. – Diagram of the diffraction of light experiment.

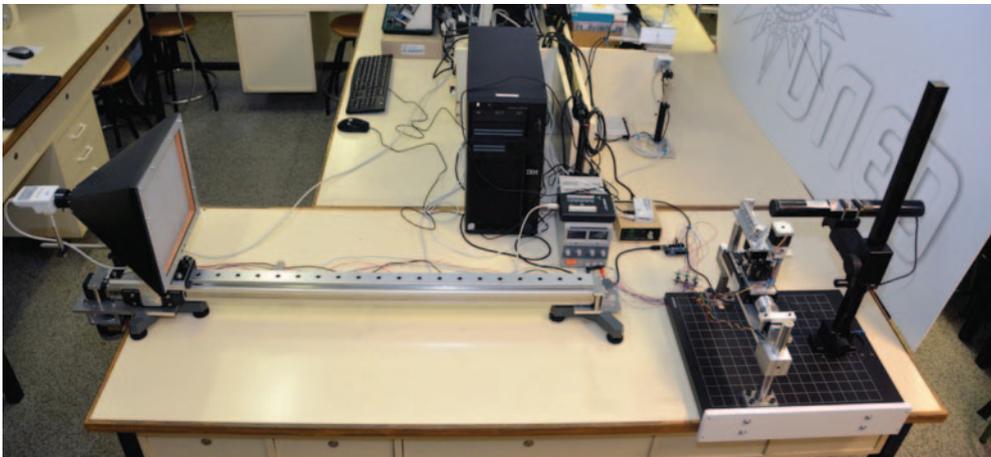


Fig. 6. – Picture of the didactical setup for the diffraction of light experiment.

ray can be diverted to a perpendicular direction (X -axis) in order to project the figure of a different diffracting object over the photodiode, also mounted over a horizontal motorized positioner with micrometric precision. By placing or not the mirror in the incident ray trajectory, students can change between the measurement of intensities with the photodiode and the mere visual observation of the rest of figures. Figure 5 depicts the assembly used for this experiment while fig. 6 shows a picture of it.

The virtual laboratory application interface allows determining the size of the diffracting object using both a qualitative method (left image in fig. 7) and a quantitative method (right image in fig. 7). The remote laboratory application interface is very similar in terms of graphical design and usability (an example is given in fig. 8) and it also offers the previous two methods for determining the size of the diffracting objects. However, due to physical limitations, while in the virtual lab the second (quantitative) method can be used with all the objects, in the remote lab it can be used just with one.

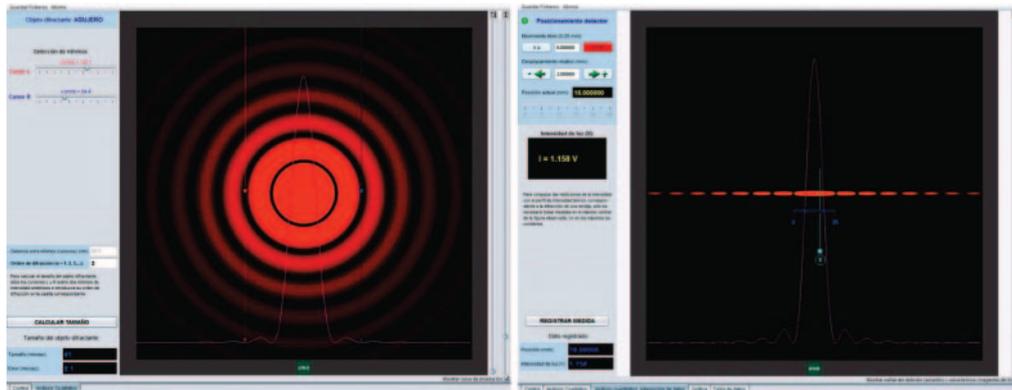


Fig. 7. – Virtual lab application for the diffraction of light experiment.

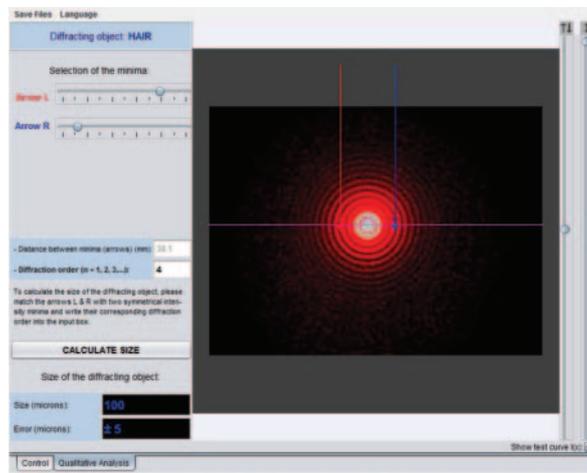


Fig. 8. – Remote lab application for the diffraction of light experiment.

4. – Conclusion

The development of new virtual and remote laboratories is important to increase the subjects covered by the University Network of Interactive Laboratories web portal. Two new virtual and remote laboratories to carry out physics practices in the photoelectric effect and the diffraction of light are now available in UNILabs. At the moment of writing these lines, the virtual and the remote labs are only accessible for our students but we plan on making them freely accessible for anyone in a new open course focused on Physics topics.

With respect to the architecture used to develop the two new virtual labs, EjsS was selected due to its easy and power of use. Regarding the remote labs, their GUI were also built using EjsS while low-cost hardware boards (Arduino) were used for data acquisition, controlling motors and turning on and off the light sources.

REFERENCES

- [1] CHANG G. W., YEH Z. M., CHANG H. M. and PAN S. Y., *IEEE Trans. Educ.*, **48** (2005) 642.
- [2] CHRISTIAN W. and ESQUEMBRE F., *Phys. Teach.*, **45** (2007) 475.
- [3] CHRISTIAN W., ESQUEMBRE F. and BARBATO L., *Science*, **334** (2011) 1077.
- [4] ELLIS R. K., Field guide to learning management systems, *ASTD Learning Circuits*, Technical Report, 2009.
- [5] GRAVIER C., FAYOLLE J., BAYARD B., ATEs M. and LARDON J., *Int. J. Online Eng.*, **4** (2008) 19.
- [6] GUIMARAES E. G., CARDOZO E., MORAES D. H. and COELHO P. R., *IEEE Trans. Learn. Technol.*, **4** (2010) 149.
- [7] HERADIO R., DE LA TORRE L., SANCHEZ J., DORMIDO S. and VARGAS H., *An architecture for virtual and remote laboratories to support distance learning*, in *Proceedings of the Research in Engineering Education Symposium* (Universidad Politécnica de Madrid) 2011, pp. 579–587, ISBN 978-84-695-2615-6.
- [8] SALZMANN C. and GILLET D., *Challenges in remote laboratory sustainability*, in *International Conference on Engineering Education* (University of Coimbra, Portugal, 2007).
- [9] DE LA TORRE L., SANCHEZ J. P., HERADIO R., CARRERAS C., YUSTE M., SANCHEZ J. and DORMIDO S., *UNEDlabs - an example of EJS labs integration into Moodle*, in *Proceedings of the World Conference on Physics Education 2012, Istanbul, Turkey* (Pagem Akademi, Istanbul) 2014, pp. 537–546, ISBN 978-605-364-658-7.
- [10] DE LA TORRE L., SÁNCHEZ J. P., HERADIO R., CARRERAS C., YUSTE M., SÁNCHEZ J., and DORMIDO S., *Eur. J. Phys.*, **32** (2011) 571.
- [11] WANNOUS M. and NAKANO H., *IEEE Trans. Learn. Technol.*, **3** (2010) 129.