

Interferometry training through a virtual learning environment

Carla Rodríguez^{1*}, Angel Lizana¹, Juan Carlos Escalera¹, Josep Vidal¹, Maria J. Yzuel¹, Juan Campos¹

¹ Grup d'Òptica, Physics Department, Universitat Autònoma de Barcelona, Bellaterra 08193, Spain

*carla.rodriguez@uab.cat

Abstract: We propose the use of an interferometry virtual learning environment as a versatile, interactive and supportive tool for theoretical concepts deep-learning, to complement experimental sessions. © 2021 The Author(s)

1. Introduction

During the last decades, the number of classroom lectures that are being complemented with a virtual learning environment is significantly increasing. Rather than completely substituting experimental (laboratory) sessions, interactive applets (programmed in MATLAB, LabView, etc.) define a supporting tool. What is more, note that not all educational institutions can afford experimental set-ups: in this way, interactive applets bring virtual experimental sessions to students even if they do not dispose from lab facilities and corresponding instrumentation. In addition, current COVID-19 pandemic (and its associated lockdown periods) has deprived universities and other educational institutions from having experimental sessions necessary to deep learning the theoretical concepts and under this scenario, applets become important educational tools, they allowing to virtually mimicking experimental experiences. The advantages of using an educational applet are not limited to the above but are broad. For instance, applets can be included in gamification educational approaches, or be used to test students' knowledge and propose some exercises to be solved through the applet usage. Consequently, we have developed an interactive software programmed in MATLAB devoted to students of Optics courses at different educational levels, and in particular, to teach basic interferometry concepts. This is done by simulating two well-known physical experiments: The Young interferometry (double slit) and the Fresnel's biprism experiments. The proposed applet provides a virtual didactic and interactive way to assimilate the theoretical background discussed at lectures. What is more, focusing on interferometry field, even if we have access to labs, those are usually restricted to specific experimental set-up configurations but the applet arises as an excellent complement, providing multiple simulated scenarios. For instance, the applet allows performing those experiments by using different light sources, while most lab implementations are limited to one particular light source.

2. The interferometry virtual environment

The interferometry-based applet simulates two situations: Young's double-slit (Fig. 1a) and Fresnel's bi-prism (Fig. 1b) interferometry [1,2]. For the Young's double-slit interferometry (Fig. 1a), we suppose a monochromatic (wavelength λ) and time-coherent light wave (emerging from an entrance slit, named S, of width b) going through two narrow slits (separated a distance d) named S₁ and S₂, and projected to a screen placed at a distance D from double slit plane. In the paraxial-approximation and without considering the width of S, the intensity profile observed on the output reads $I(x, y) = 2I_0[1 + \cos \delta(x, y)]$, being δ the phase difference between the two arms [1]. In counterpart, by considering the width b of the entrance slit S, the visibility of the fringes depends of the angular size of S seen from double slit plane [2]. Additionally, special cases are also considered, such as when placing a plate of thickness e_L and refractive index n_L , in front of one of the slits or using a partially coherent light source [2]. Finally, considering a Fresnel biprism [1] of main angle α and refractive index n placed a distance a from entrance slit S (Fig. 1b), the fringe separation is given by $d = 2\alpha(n-1)a$.

The applet (main window interface shown in Fig. 1c) includes different tools and educational utilities devoted to train and understand the interferometry concepts above defined. Particularly, the user can simulate four main different interferometry configurations (which can be modified by adding an extra plate of a given thickness and refractive index in front of one of the slits, changing the light source or switching on/off the paraxial approximation): (1) Young's double slit with infinitesimal aperture, (2) Young's double slit with finite aperture, (3) Fresnel's biprism and (4) Young's double slit illuminated with different polarization conditions.

In consonance with the previously defined concepts, the applet main entrance parameters for the double-slit set-up (Fig. 1a) are labeled as d , D and a . If a plate is placed in front of one of the slits, the thickness and the refractive

index of the extra plate are given by eL and nL , respectively. For the Fresnel's biprism set-up (Fig. 1b), parameters are given by the main angle of the prism, its refractive index and the distance to the entrance slit S (set by α , n and a , respectively).

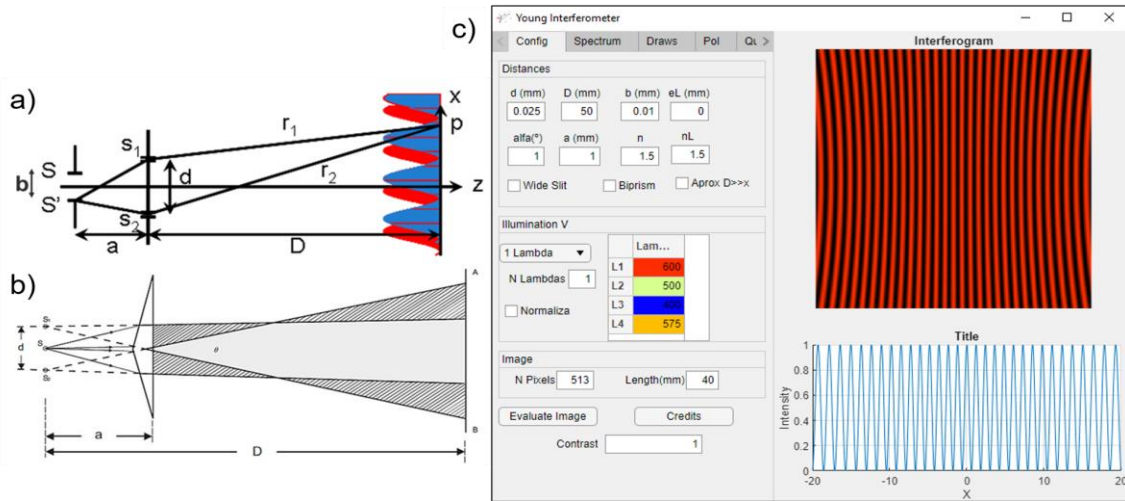


Fig. 1. a) Double-slit set-up, b) Fresnel's biprism set-up and c) Applet main window interface.

Also, the light source characteristics can be modified: the user can select single, two, or four combined wavelengths or spectral distribution source. When pressing "Evaluate Spectrum", the applet computes the Power Spectral Density versus the frequency range and the coherence degree (g) as a function of the time difference between the two slit arms. Regarding the (4) set-up conditions, "Pol." window is devoted to the change of incident polarization states (user sets the azimuth and ellipticity of the S_1 state of polarization, SoP, and the applet sets the orthogonal one to S_2) and detector characteristics (*Linear*, *Constant contrast* or *Variable Contrast*). Detected SoPs are drawn in Poincaré sphere as well as their corresponding polarization ellipses. Finally, the "Questions" window allows to perform exam or tailored questions/exercises to be solved by students with the help of applet simulations. The initial numerical parameters are randomly generated, so the applet resolves the exercise by the time the student fills the white boxes with its own answer and presses "Check...": both files, the student and the applet resolutions are saved and can be sent for their evaluation.

4. Conclusions

In this work we have presented an interferometry-based applet as a complementary tool for experimental sessions and support theoretical lectures at different educational levels. Particularly, the developed applet starts by simulating basic Young's and Fresnel's biprism interferometry. By adding extra optical elements, changing the illumination conditions, including polarization or checking the real (or approximated) solution, the initial basic experiment can turn into a wide range of different physical situations leading to even more complex output fringe patterns. The applet also has the advantage that the student can calculate different numerical parameters that are difficult to measure on the lab (for instance fringe visibility), and they can also compare the simulated and real (computer-acquired) images if they are available. It is also interesting to remark that not all the possible set-ups can be done on the lab on a limited time, thus, the applet is an excellent way to study new situations at home. Moreover, a collection of dynamic questions or exercises are proposed to be solved by the student with the help of applet simulation. This can be a very useful teacher's tool to assess the comprehension of the topic by the students and to evaluate them. In summary, this applet can be useful to reinforce the theoretical concepts in many different situations, such as interactive homework, in classroom lectures, self-training and also as a parallel and complementary experiments in lab sessions. It can also be an excellent way to assess the learning of the students. In this way, this applet constitutes a complete virtual training tool capable to simulate even complex situations, for a reliable interferometry deep learning.

3. References

- [1] E. Hecht, *Optics*, 4th ed. (Addison Wesley, 2002), Chap. 9.
- [2] M. Born and E. Wolf, *Principles of Optics: Electromagnetic Theory of Propagation, Interference and Diffraction of Light*, 7th (expanded) ed. (Cambridge University, 1999), Chap. 7.