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### **Teaching (and learning) optics using interactive simulations: the JavaOptics Course**

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#### **Abstract**

We present an educational resource based in an optical software package for undergraduate students. It consists in a web based textbook with several applets for illustrating the theory and simplify the teaching tasks in the classroom. These programs are also used as a method for self-learning in an on-line environment. Applets are written in Java language using the Java Network Launching Protocol (JNLP) for avoiding problems related with the use of specific browsers or java interpreter's versions.

#### **Summary**

##### **1. Introduction**

Optics, as a part of physics disciplines, is a formal subject with concepts that can be difficult to understand for undergraduate students. Since 2000, the members of the UB optical research group, have been developing materials in electronic format for teaching theoretical, technological and experimental concepts related with optics and photonics 1, 2. The objective was to generate enough resources to allow students to manipulate and investigate concepts, equations and images, before study based on the exclusive use of a textbook. The main difficulty of our students in their learning is the understanding of theoretical concepts related with experimental situations. As a consequence, the goal of this project is to generate a small number of sophisticated programs that allows a student to interact with all the significant concepts studied in an undergraduate optics course

The Java Optics Course (JOC) is an ensemble of teaching resources for Physical Optics at university level as part of Physics studies. Some of the resources can also be used by high-school teachers or students to illustrate and broaden knowledge on certain aspects of physics at this teaching level. The resources may be used either in an ordinary course as support material or as the main working tool in an on-line Internet course. The kernel of the resources developed is a software package, designed to simulate the physics of several optical phenomena. All the programs are freely available in the JOC website, <http://www.ub.edu/javaoptics>. The applets have been programmed in java using JNLP 3 technology to assure a correct behavior of the programs with independence of the software or operating system installed in the computer.

We have recently started to investigate the connections between the learning progress of our students and the use of simulation programs. Information is collected by enquiring regularly of the students' opinion and by analyzing their answers in exams (particularly the wrong answers). Preliminary results of the research show that concepts that are difficult to understand (for instance: virtual image formation, reflection of waves in dielectric media, resolution in interferometers or diffraction of light in Fresnel conditions) are more easily acquired if the students can experiment and manipulate the concepts using these applets.

## 2. The software package

Some of the programs available in the course are:

1. Optical systems. This applet shows the behavior of optical systems, such as lenses, projectors, telescopes, etc. It includes the calculation of their characteristics (cardinal points) and image formation, either by using paraxial optics approximation or by exact calculation. In the latter case you can see and analyze the systems' optical aberrations.

2. Light polarization and Fresnel laws. This applet lets you study light polarization and its reflection and refraction in isotropic media. It shows how to obtain the different polarization states of light from the superposition of two plane waves and it studies Fresnel coefficients for an incident wave on a surface separating two media, the first being a dielectric and the second either a dielectric or a conductor.

3. Young's experiment. This simulation shows Young interferences resulting from the interaction of a number of waves. When using a single extended source or two point sources, spatial coherence can be studied as well.

4. Multiple beam interference. This applet shows multiple beam interferences from a parallel dielectric thin film. The applet lets you study the evolution of reflection and refraction factors when the index of refraction and the absorption of the film and the substrate are modified. These can be constant or have a wavelength dependency.

5. Fabry-Perot interferometer. This program allows you to study the factors involved in an experiment with a Fabry-Perot interferometer. It lets you visualize the result of the multiple-wave interferences produced in the interferometer cavity when an extended source emitting two extremely close wavelengths is used. In this way, the resolving power of the instrument can be observed under different conditions. The influence of the reflection coefficient of the interferometer inner-faces on the visibility and the resolving power can be investigated as well.

6. Michelson interferometer. This applet lets you study the Michelson interferometer and see the evolution of light rings as the parameters of the system are changed. The case of a point source, which corresponds to the Twyman interferometer, is also analyzed.

7. Fresnel and Fraunhofer diffraction. This program shows the Fresnel and Fraunhofer diffraction patterns. The applet includes some default objects such as the slit, the rectangle and the circle, whose geometrical characteristics can be modified.

8. Fourier Optics. This simulation incorporates some image processing techniques in the Fourier optics domain. You can compute and see the Fourier transform of an object and the convolution between two images. You can also simulate the VanderLugt correlator (matched filter, phase-only filter and inverse filter) and the joint transform correlator (linear or binary joint power spectrum).

9. Colorimetry. This applet lets you study colors and their characteristic parameters, such as dominant wavelength, purity and coordinates in the XYZ or CIE system representations. You can obtain different colors by additive or subtractive mixing and you can also study the changes of a filter color depending on the illuminant.

We are currently developing more simulations and several programs are in beta testing stage. We expect that new programs, including dispersion of light in prisms, vision models, fiber optics, propagation in anisotropic media and photometry, will be available in fall of 2005.

### **References**

A. Carnicer et al. An on-line applet-based course for undergraduate students, 19th Congress of the International Commission for Optics (ICO XIX), Firenze (2002).

A. Carnicer et al., The Java Optics Course <http://www.ub.edu/javaoptics>, Physics on stage 3, Noordwijk (2003).

See, for instance, <http://java.sun.com/products/javawebstart/index.jsp>

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