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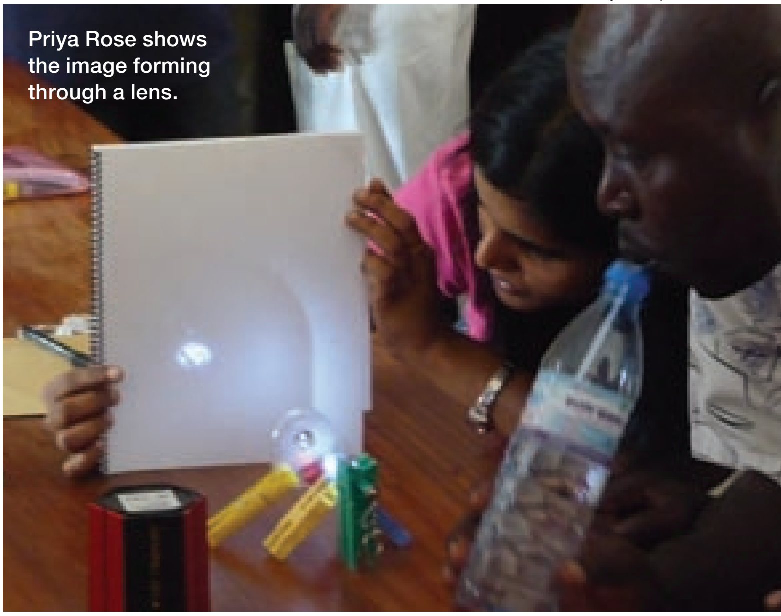
A spectroscope made with a CD-ROM and a cookie box.


Priya Rose shows the image forming through a lens.

Teaching Optics in North Uganda

The Experience of the Naples Student Chapter

Lucio Rossi, Priya Rose and Antigone Marino

One fine summer day, a group of Italian students were struck with a simple idea—but one that would not be quite so effortless to execute. Learn how OSA's Napoli Student Chapter got a crash course in conducting international educational outreach.

The idea came to us easily, following the conclusion of the IONS-4 conference held in Napoli in June 2008. Everybody in the OSA Napoli Chapter was feeling a mixture of pride, exhaustion and excitement after having just hosted a successful meeting. One evening, as we sat over the lovely seafront of via Caracciolo, we began talking about what our next challenging project should be. Annalisa Bruno and Antigone Marino proposed helping to strengthen education in developing countries by carrying out an outreach education project in Africa.

At that time, we had no idea how difficult this project would be; we were just pleased with ourselves that we had come up with another great project to propose to OSA. (Our first reaction was something along the lines of "Oh hell yes!") Our chapter had already conducted several education outreach activities, mainly directed to high-school and junior-high students, but this would be entirely different. We didn't know much about the African school system. We were not even sure if the students were the right people to target in order have the maximum impact.

> The challenge is that many African teachers are using an instructional method that was inherited from colonialism. They often do not engage students through discussion and experiment.

Refining the idea

Professors Luigi Smaldone and Elena Sassi, who teach at the University of Napoli Federico II, gave us some much-needed guidance. We called a meeting with them since we knew that they were in charge of a project at our university called "GuluNap," which is intended to train basic science teachers in Uganda. "African students are enormously interested in learning new things and improving their knowledge," Smaldone said. The challenge, the professors told us, is that many African teachers are using an instructional method that was inherited from colonialism. They often do not engage students through discussion and experiment; rather, they simply read a lesson from a book and write formulas to be memorized. Thus, students are not

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Step-by-Step: How to Make a CD Spectroscope

Theory

A *diffraction grating* is an optical material with a very regular pattern inscribed on it that allows light to be split into separate components (wavelengths) and to travel in different directions. In this way, the grating acts as a *dispersive element*.

Diffraction gratings are very useful in *spectrometry*—which is a spectroscopic technique to assess the amount of a given chemical species inside a material. The wavelengths of light that are reflected or emitted by a material depend on its chemical characteristics. The mathematical equation that relates the angle at which a normal incident beam of wavelength λ is reflected (or transmitted for transparent gratins) with the diffraction grating pattern spacing is called the *grating equation*:

$$d\sin(\theta_m)=m\lambda,$$

where d is the grating spacing, m is an integer number, λ is the wavelength and θ_m is the diffraction angle.

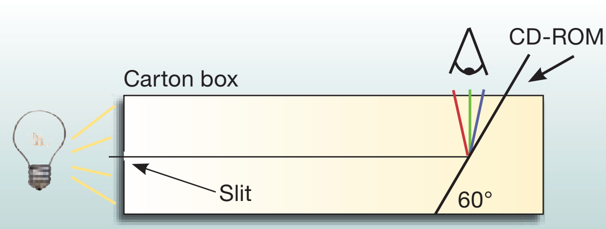
Why does a compact disk (CD) behave like a diffraction grating? On CDs, data are stored in "pits" or as localized modulations of the material's refractive index. Usually on a CD, each pit is 100 nm deep and 500 nm wide, while the distance between the tracks is 1.6 μm. The CD tracks are the pattern that creates the grating effect. This experiment shows you how to create your own CD spectrometer.

Materials

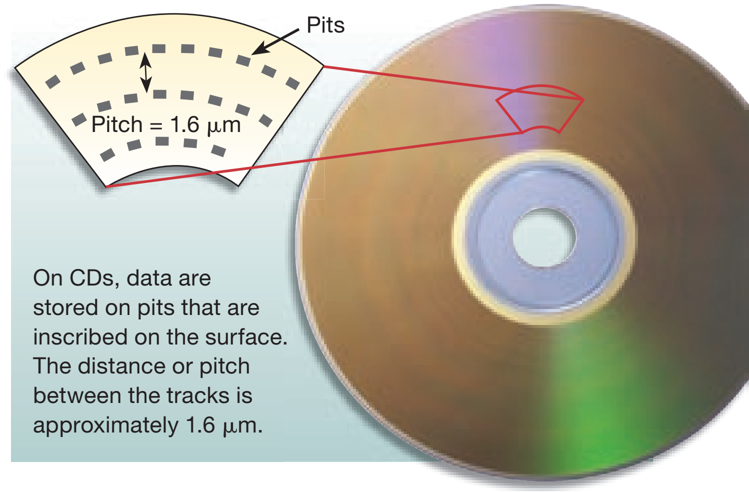
- ✓ An empty cereal box or laundry detergent box
- ✓ A broken CD
- ✓ Duct tape
- ✓ Cutter

Instructions

- Cut a slit on one side of the box. It must be a couple of centimeters long and very narrow.
- On the other side, make another cut to insert the CD (see the figure below) and an opening to view the CD surface. This cut should be 60° because that is the angle at which the center wavelength of the visible spectrum (green light) is reflected.
- Put the CD in place and fix it firmly with duct tape.



The CD spectroscope.



On CDs, data are stored on pits that are inscribed on the surface. The distance or pitch between the tracks is approximately 1.6 μm.

- Point the slit toward a light source and look inside the opening; you should see a nice light spectrum reflected on the CD top surface.
- If the spectrum is too dim, you should make the slit a little wider. On the other hand, if the spectrum is too blurry, the slit should be narrower.

Conclusions

Light reflected or emitted by different materials has a different spectrum. By means of a spectroscope, one can see the wavelength components of this light, in this case just in the visible spectrum. In general, a spectrometer is capable of discriminating the various wavelength components of the light received and also of evaluating their relative intensity.

It is very interesting to compare different sources of light in terms of their spectrum. The light coming from the sun or from an incandescent bulb has a uniform spectrum, while that emitted from a neon bulb or a laptop PC screen shows many lines.

Sub-experiment

Try using a fixed-wavelength light source like that of a red laser (approximately 600 nm) to evaluate the pitch of the CD-ROM tracks, making use of the grating equation.

Suggestion: It is better to show the effect in transmission, so take off the CD reflective coating with the help of some scotch tape. Shine the laser from one side of the grating and look at the pattern created on a screen at a fixed distance. You should notice some spots that are regularly separated from a central one. The ratio of the distance between the central and first-side spot and the distance between the screen and the grating is the tangent of the diffraction angle θ_m.

ONLINE EXTRA: Visit www.osa-opn.org for another ready-to-do experiment—how to make water lenses.

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The water waveguide.

Group photo.

given the chance to develop their own critical thinking skills.

Based on their advice—and the realization that we could reach more students by training teachers than students—we decided to target our program to high-school teachers. We provided them with more stimulating teaching tools, including didactic laboratory experiments that would be cheap and easy to carry out in the African context.

The talk with Profs. Sassi and Smaldone marked the beginning of a collaboration among us, GuluNap and the University of Gulu. We proposed two projects to the OSA Foundation—one about building up no-cost and low-cost laboratory experiments for Africa and the other for holding a workshop of optics in Gulu, which we called "Light in North Uganda." We could not describe our excitement when the OSA Foundation approved both projects, providing us with $2,000 in U.S. dollars.

We saw in their eyes the pleasure they took in discovering again what they had learned from books in a more visible and practical way. We were sure that they would communicate this enthusiasm to their pupils.

Conducting Foreign Outreach: How to Get Started

- Get in touch with a foreign university. Tip: Ask student friends abroad to help you make connections.
- Check if your department or university has a similar project or is willing to fund yours.
- Be patient. It takes a long time to organize an outreach project, especially from a long distance.
- If you don't have a foreign contact established before you go, add a few extra weeks into your on-site planning in order to get everything organized.
- If you have problems organizing or fundraising, get in touch with a non-governmental organization or a religious or lay organization. Here are some websites you can start from:

UNESCO:	www.unesco.org/en/education
CCIVS:	http://ccivs.org
Education International:	www.ei-ie.org/en/index.php
Save the Children:	www.savethechildren.org
Terres de Hommes:	www.terredeshommes.org
Comboni Missionaries:	www.combonimissionaries.org

Preparing and gathering materials

It all began to take form. We started by preparing experiments. We soon realized that we didn't need to invent experiments from scratch; we just had to make some of the classic demonstrations that we already knew more affordable and doable for Ugandans. Where we needed real lenses to show focusing and image forming, a plastic bottle could do the job of behaving like a perfectly cylindrical or even plano-convex lens. We also found a way to use a hair to show diffraction.

Of course, many experiments need a laser—the double-slit interference experiment, for example, or a demonstration of how light can be guided in a trickle of water in the Tyndall experiment. We were initially concerned about the fact that, in Africa, a laser pointer could be difficult to find. To address this, we provided each attendant with a cheap laser pointer that we bought over the Internet for 80 euro-cents each.

We didn't know then that toy laser pointers are commonly sold in the markets in the city of Kampala. The only thing that was impossible to find in Uganda was polarizers. We wound up buying those elsewhere, but again they were not expensive.

After preparing the experiments, we publicized the event in high schools, gathering 40 science teachers from all the districts of North Uganda. They agreed to dedicate part of their Christmas break to this activity.

Getting there

On January 10, 2010, we traveled with our guide Luigi Smaldone to one of the most beautiful places on earth, flying south to Entebbe and crossing the dusty Kampala road up to the small town of Gulu. The first week was spent preparing for the workshop and the second week was dedicated entirely to the workshop itself. We scheduled six hours a day of classes in the morning and our low-cost and no-cost experiments in the afternoon. Of the many demonstrations that we did, the teachers most appreciated the Tyndall experiment showing how light can be guided in water and our presentation on how to make a spectroscope with a CD-ROM and a cereal box (see experiment on p. 15).

When we evaluated the questionnaires that the teachers took before and after our workshop, we were stunned by the results. The improvement was substantial for many topics. For example, the percentage of correct answers on polarization jumped from 16 to 51 percent, and those on imaging from 31 to 60 percent. What we found even more satisfactory was seeing in their eyes the pleasure they took in discovering again what they had learned from books in a more visible and practical way. We were sure that they would communicate this enthusiasm to their pupils.

So what will be the next challenge for the Student Chapter of Napoli? Who knows, but if you happen to meet a bunch of crazy students chatting near the seafront of via Caracciolo, be prepared. Good ideas are on the way! ◭

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[References and Resources]

- >> **GuluNap**: www.gulunap.unina.it
- >> **Gulu University**: www.gu.ac.ug
- >> **University of Naples Federico II**: www.unina.it
- >> **University of Naples Student Chapter**: www.fisica.unina.it/osa