

# Photonic Games: Hands-on challenges to spark teenagers' interest in light

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## ABSTRACT

It often takes one single event to interest teenagers in a topic that will become a passion or a career. It is in this spirit that the SPIE and OSA Student Chapters at Université Laval created the Photonic Games three years ago, to kindle an interest in teenagers towards studies and careers in optics. The activity, offered each year to more than a hundred grade 11 students, is divided in two parts. First, we offer a hands-on workshop in their classrooms about reflection, refraction, dispersion, birefringence and polarization. A few days later, all the students come to the *Centre d'optique, photonique et laser* (COPL) at Université Laval for a day of competition where a volunteer physics student accompanies each team of four students. Challenges are various to promote the qualities that make great scientists: creativity, teamwork, knowledge, inquisitiveness, self-confidence and perseverance. The first two editions of the Photonic Games have proven to be beneficial for the students, teachers and volunteers, and we endeavor to improve it as we construct on our experience with the past editions to fine-tune and improve the Photonic Games concept.

**Keywords:** outreach, education, games, challenges, high school

## 1. INTRODUCTION

With the current decrease in the number of students in applied science programs, the optics and photonics industry will soon be facing a lack of qualified labor. The SPIE and OSA Student Chapters at the *Centre d'optique, photonique et laser* (COPL) decided to create an activity for grade 11 students that would spark an interest for technology-oriented careers, particularly in optics and photonics. The event we created is called the Photonic Games, and it consists in a workshop about basic optical principles, followed by a day of challenges and games based on these principles. The participants must use their resourcefulness, their creativity and their teamwork abilities. Last year, 50 university-level students from three different colleges volunteered to accompany the participating teams and lead the challenges. For the 2010 edition of this yearly event, we will introduce the science of light and lasers to more than 140 students from 4 high schools in the Quebec City area.

This paper is divided in three sections. Section 2 details the workshops and the challenges included in the Photonic Games, and describes which skills are developed in each. Section 3 delineates the many benefits this event provides to all parties involved: participants, organizers, volunteers, host center and sponsors. To conclude, Section 4 lists our advice for any group who would be interested in planning a similar event.

## 2. GAMES AND CHALLENGES TO DEVELOP NUMEROUS SKILLS

The main goal of the Photonic Games is to interest high school students in optics and photonics. To achieve this, we decided to give the students a hands-on experience of impressive optical principles and made sure every participant found something they were good at by offering challenges that require a wide set of skills, from knowledge about optics to artistic creativity and physical prowess. We also wanted to show them that they already have the skills that make great scientists, for instance creativity, teamwork, inquisitiveness, self-confidence and perseverance. All these factors guided our choices for what would be included in the workshops and challenges.

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## 2.1 Classroom workshops

During the week prior to the day of the competition, four college-level students visit the participating groups in their classrooms. The volunteers bring a large variety of optical components and divide the class in small groups. The students examine the various components (Figure 1) and the volunteers guide them to observe their effects and understand their use and purpose. For each principle, applications in the industry and in day-to-day life are explained. We cover principles such as reflection, refraction, dispersion, birefringence and polarization (Table 1). The material we use for the workshops comes from various sources: the Hands-On Optics “Terrific Telescopes” kit<sup>1</sup>, the OSA Optics Discovery kit<sup>2</sup>, the NEMO Diffractive Optics EduKit<sup>3</sup> and various components from educational resources companies<sup>4</sup>. We also show them a video<sup>5</sup> about our research center and present a short history of lasers and how they work.



Figure 1. During the workshop, a hands-on approach is used to introduce various principles of optics. Here, students are viewing the three-dimensional images formed by a hologram and discovering the wavelength-separation effect of diffraction gratings.

Table 1. List of optical phenomena explored during the workshop, how these effects are presented and examples of their applications in the industry and in day-to-day life.

Phenomenon	Experience in the workshop	Applications
Reflection	Concave mirrors Convex mirrors	Rear-view mirrors Surveillance/security mirrors
Refraction	Converging lenses Diverging lenses	Everything that contains lenses: glasses, cameras, microscopes, telescopes, etc.
Dispersion	Prism	Rainbow
Polarization	Stress lines in plastic object between polarizers	3D movies Sunglasses
Birefringence	Calcite crystal that doubles printed letters	Liquid crystal screens (flat screens, cell phone displays, calculators)
Diffraction	Diffraction grating “Rainbow” glasses Shapes with laser pointer and diffraction slide	Spectrometer: instrument that analyses light emitted, transmitted or reflected by an object
Laser	Laser pointer	DVD/Blu-Ray player Bar-code reader Laser eye surgery

## 2.2 Jell-Optics

For the Jell-Optics challenge, each team is provided with a block of lemon Jell-O, a cutting instrument and a playing board on which targets are drawn and a laser pointer is fixed. To make the Jell-O easier to work with, we use half the water mentioned in the recipe and added gelatin. In 25 minutes, the teenagers must use refraction and total internal reflection in the Jell-O pieces that they cut to tilt the path of the laser beam and make it hit as many targets as possible. This challenge requires precision in the manipulation of the Jell-O pieces, and the students rapidly develop an intuitive sense of how light can be bent by transparent materials. Many teams discover total internal reflection (Figure 2) and use it to reach targets that are far from the original light path.

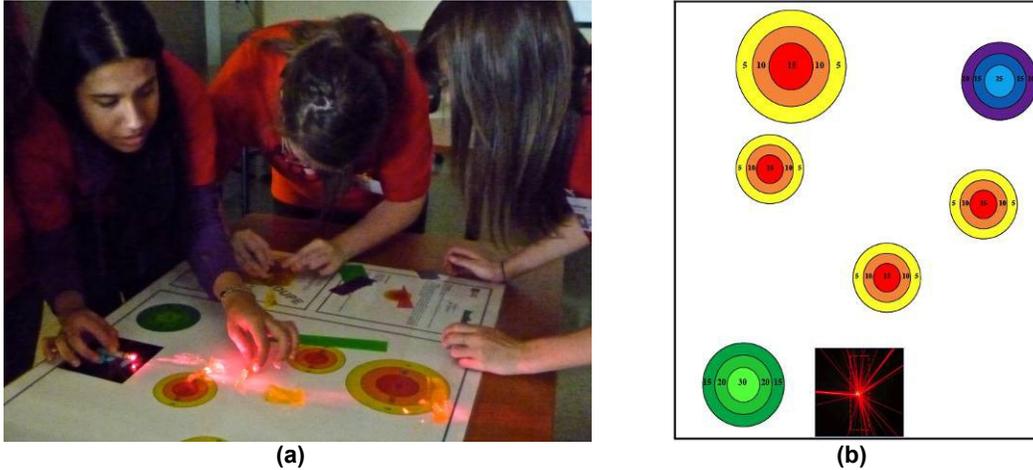


Figure 2. The Jell-Optics challenge consists of using refraction and total internal reflection in blocks of Jell-O to (a) change the direction of a laser beam and (b) hit various targets.

## 2.3 Optical mini-golf

In this challenge, students must apply the rules of reflection that they have learned in class. Knowing that the incident angle is equal to the reflected angle with respect to the normal of the mirror, they must place as few mirrors as possible to get a laser beam to hit a target that is blocked by various obstacles on a mini-golf course.



Figure 3. In the optical mini-golf challenge, students must choose the position and angle of mirrors so that a laser beam avoids the obstacles and hits the target with the fewest mirrors possible.

We encourage laser safety by enforcing the rule that the mirrors cannot be moved while the laser pointer is turned on. We also encourage the participants to think before they act by adding points for each trial (every time they turn the laser pointer on) and for each mirror used. As in golf, the team with fewest points wins.

## 2.4 Quiz

The quiz challenge was developed to stimulate participants who are mostly theoretical, and who have good deduction skills. Two teams confront each other and try to gain points by rapidly giving the correct answer to questions, by guessing the optical component that is drawn by a participant and by solving words related to optics with scrambled letters. The questions and words that must be guessed all related to principles of optics and photonics that were explored in the workshop or in the other challenges. The 2010 version of this challenge will be focused on lasers to commemorate the fiftieth anniversary of their invention.



Figure 4. In the quiz game, participants must find the right answers to questions about basic optical principles.

## 2.5 Solar car race

In the solar car race challenge, a racetrack is set up with two bright halogen lamps; the first one is fixed close to the starting line, and the second one, in the second half of the track, can be moved parallel to the track (Figure 5). Equipped with large mirrors, metallic tubes and Fresnel lenses, the participants must focus light on a mini-car's solar panel to activate the car's motor and make it move as fast as possible. By trial and error, the students discover that there is an optimal distance between the Fresnel lens and the solar panel (the focal length of the lens). At this distance, light is best concentrated on the solar panel and the car moves fast. They also learn to use mirrors and reflecting surfaces to collect more light than by using just the lens. After a few trials, many teams coordinate their efforts and each member has a specific light-guiding task along the racetrack, in a collective effort to achieve the fastest travel times.

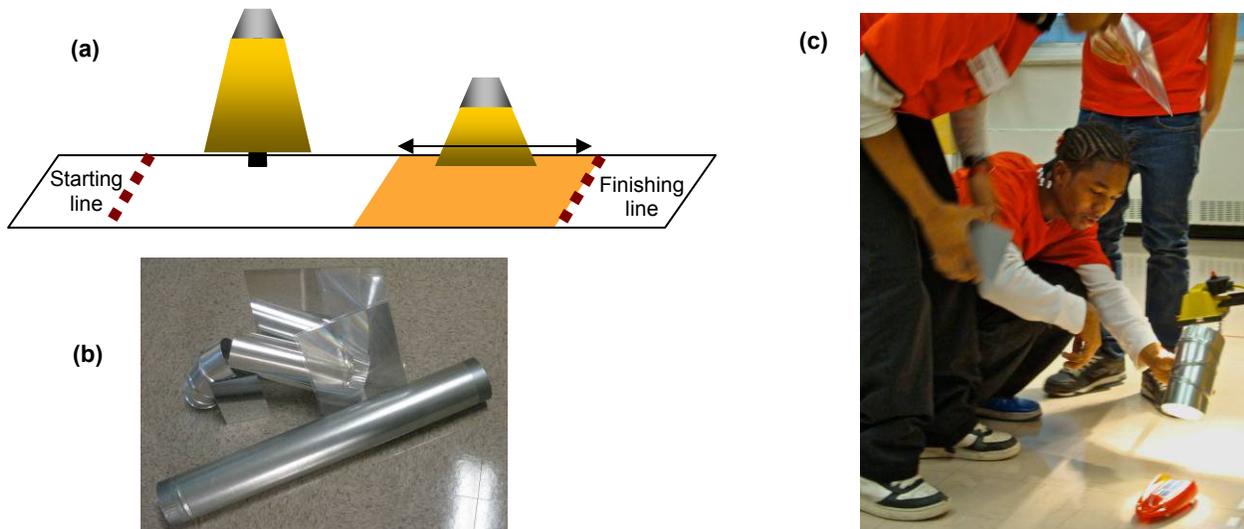


Figure 5. (a) The racetrack is composed of two halogen lamps where students should use (b) Fresnel lenses, large mirrors and metallic tubes (c) to focus light on the solar panel of a small solar car. The highlighted zone in (a) defines the area where the second lamp can be moved.

## 2.6 Laser maze

The laser maze challenge requires physical skills and an understanding of reflection. In the first part of the challenge, each team member must try to steal a piece of treasure that is protected by a laser security system. Many laser beams cross the path leading to the treasure, and if one of the beams is blocked, an alarm rings. The path and the treasure are set up in a dark room, and infrared cameras allow the rest of the team to monitor their teammate's progress from another room and guide him/her with a walkie-talkie (Figure 6).

For the second, more theoretical, part of the challenge, the students are asked to plan a second "robbery". They are given a map of a path leading to a treasure, similar to the maze. The mirrors and starting laser beam are drawn, and they must complete the map by tracing the laser beam's path using a ruler and protractor.



Figure 6. Infrared cameras show the dark room in which a maze of laser beams blocks a path. One of the students is guided through this maze by his teammates, who must find out where the beams are to tell him where to step.

This challenge is very technical and we still need to improve it. For the first edition, the mirrors were mounted on large paper clips and the detection was visual. For the second edition, we mounted the mirrors on a wooden frame and set up a computer-controlled alarm system, but the mirror supports were not stable enough to keep the beam aligned on the detectors, so we went back to visual detection. For the upcoming edition, we plan on using metal supports and frames with larger detectors. Even with these technical setbacks, 36% of the participants rated this challenge as their favorite.

## 2.7 Photography contest

For the photography contest, each team has to use various optical phenomena to create a digital photography on the theme of light. Each team has access to a digital camera on a tripod, a visible light source with interchangeable filters, a near-UV light to excite fluorescent objects and a wide variety of objects with interesting visual effects. This challenge stimulates artistic creativity and encourages the students to investigate various optical phenomena in order to make them stand out in the photographs. They must also choose their best photo and give it a title. The photos are evaluated by a jury of university students and professors, according to the criteria listed in Table 2.

Table 2. Evaluation criteria used by the jury of the photography contest.

Criterion	Description	Weighting
Title	The chosen title is pertinent and original	20 points
Esthetics and originality	The photo is attractive (from an artistic point of view) and is distinguished from the others	40 points
Image quality	The subject is well framed, at focus, etc.	40 points

The winning photo of the 2009 Photonic Games (Figure 7) has been used for the banner of the Photonic Games website<sup>6</sup> and on the cover of the promotional DVD for the COPL.

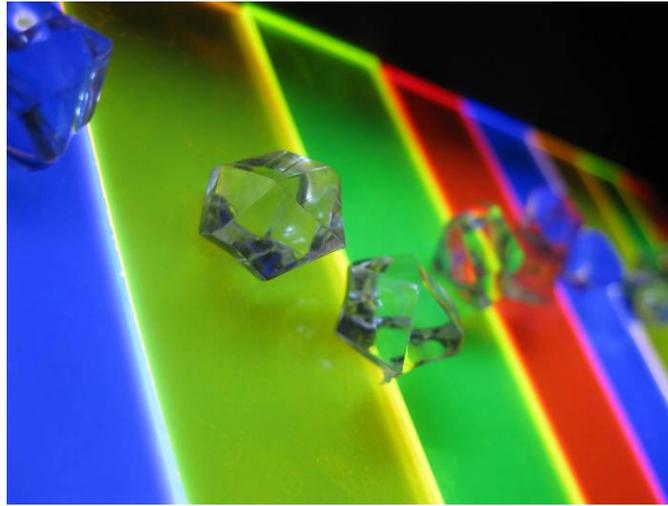


Figure 7. The winning photo of the 2009 photography contest uses fluorescent microscope slides (graciously provided by Chroma) and small glass beads. The title of this picture is “Cristal musical”: musical crystal.

## 2.8 Laboratory tours

The last part of the Photonic Games is a tour of the COPL laboratories. Guided by graduate students from the COPL, the participants enter clean room facilities and visit various laboratory rooms with experimental set-ups for experiences covering different aspects of photonic research. They see laser amplification chains, thin film deposition facilities, phase mask and holographic grating set-ups, and much more. The graduate students who present their laboratories share their passion for research with the high school students and give them a sense of what working in optics could be like.



Figure 8. In the laboratory tours, the students visit clean rooms, learn about various applications of lasers and get a feeling of what experimental research in optics and photonics can be like.

### **3. BENEFITS FOR THOSE INVOLVED**

Outreach events such as the Photonic Games are highly beneficial to all parties involved, especially the participating high school students, the university-level students who organized the event and the volunteers. The host center and the sponsors also profit from the event.

#### **3.1 Participants**

Benefits for the participants are the most obvious: they gain a constructive and hands-on learning experience and a sense of accomplishment from completing the challenges. The students in the winning teams, who often are not those who have the best grades in school, gain self-esteem and confidence in their skills. Finally and most importantly, the participants learn about possibilities of studies and careers that they had not been in contact with before.

#### **3.2 Organizers**

For the organizers, planning and carrying out such a large-scale event develops their management skills and leadership. They also gain a sense of duty as they realize to what degree the global outcome of the event is affected by how each person carries out his/her responsibilities.

#### **3.3 Volunteers**

Some university-level students who volunteer for the day of the event accompany the team of high school students, while others lead the various challenges and conduct the laboratory visits. They all develop teaching skills and gain experience in popularization – teenagers will tell you right away if they do not understand what you are talking about. Last year, we had 50 volunteers from 3 different universities. There were students in physics, physics engineering, electrical engineering and chemistry, studying at the bachelor, master and doctorate level. Volunteering for the Photonic Games allowed these students to mingle and widen their network, creating links between the different research groups and universities.

#### **3.4 Host center**

This event provides great publicity and visibility for the host center. It is also an activity that helps recruit future students. Furthermore, the network that is developed between volunteers from different research groups encourages multidisciplinary.

#### **3.5 Sponsors**

Sponsors are offered visibility on the event's website, and their contribution is advertised during the event. They therefore get direct advertisement with a large number of students in optics and photonics (future employees or buyers), and they help create an interest for their field of activity in the next generation of students.

### **4. ADVICE FOR PLANNING SIMILAR EVENTS**

As mentioned above, the organizers of the Photonic Games have learned a great deal in how to plan and carry out a large-scale outreach event. We believe that the following advice, derived from our personal experience, could be useful to any group that is interested in planning their own version of the Photonic Games, or any other outreach event involving many students.

#### **4.1 Start early**

Do not underestimate the time it takes to carry out an event of this scale. Start planning months ahead and make a timeline. As soon as you have a general idea of the event, you can make a sponsorship plan and start looking for sponsors. Schools can be hard to reach when you don't have personal connections, and they are most cooperative when the teachers are planning for the upcoming year (a few weeks before school starts). Rent rooms for the day of the event many months before, and keep in mind that technical challenges like the laser maze can be quite complex to set up and should be tested extensively.

## 4.2 Gather a great team of organizers

When building the organizing committee, try to include students with different profiles (practical, theoretical, communicative, scientific, educators, etc.). This will ensure that your team has a wide set of skills and tools. Look for students who are dynamic, responsible and have a lot of initiative.

## 4.3 Divide tasks and delegate

It is easier to find volunteers for many quick and simple tasks than for few large and complex tasks. Once a person has accomplished a few tasks for an event, he/she often starts to feel attached to the event and wishes to get more involved.

## 4.4 Keep things simple for the schools

Schools are sometimes apprehensive towards unknown activities; to make them understand that they should encourage this event, we insist that it is free for the students and the school, and that we provide transportation as well as food for the students. We try to make this as easy as possible for the teacher by going to the schools to drop off and pick up the paperwork, and we check for allergies and photo authorizations.

## 4.5 Choose the date wisely

To gather many volunteers, it is ideal to plan on a day when there are no classes, not too close to final exams. We use the fall break since it is a break for the university but not for high schools.

## 4.6 Aim for fun and learning experiences

When a school participates in the Photonic Games, all the students in grade 11 physics come to the event, they do not choose to participate individually. To keep their motivation high, we make sure that each participant will find at least one aspect that they enjoy and learn from by diversifying the challenges and keeping equations and calculations to a minimum.

## 4.7 Tie up loose ends

The event does not end as soon as the participants leave. Store your material properly so that it does not get lost or damaged until the next time it will be used. If you wish to repeat the event in the future, or think of planning other similar events that will require funding, it is important to give feedback to the sponsors in a thank you note. Do not forget to thank the schools and volunteers. We like to have feedback from the students and teachers a few days after the event (it could be by calling the teacher, visiting the classrooms or asking the participants to answer a set of questions) – this feedback is useful for future funding and grant applications. Finally, get feedback from your team of organizers and take note of improvements to be made while the event is still fresh in everyone's minds.

## ACKNOWLEDGEMENTS

The Photonic Games were made possible by the devotion of our student volunteers, by the enthusiastic participation of the high schools and by the financial and material support from our many sponsors. Special thanks to SPIE, which has been our main sponsor for the last three years through the SPIE Outreach Grant, and has provided the organizers with networking opportunities that helped make the Photonic Games a success.

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