OPTICS AND PHOTONICS FOR CHILDREN IN TIMES OF COVID-19 CRISIS

Dana Seyringer

Research Centre for Microtechnology, Vorarlberg University of Applied Sciences, Hochschulstr. 1, 6850 Dornbirn, Austria

Abstract

Today, optics and photonics is widely regarded as one of the most important key technologies for this century. Many experts even anticipate that the 21st century will be century of photon much as the 20th century was the century of electron. Optics and photonics technologies affect almost all areas of our life and cover a wide range of applications in science and industry, e.g. in information and communication technology, in medicine, life science engineering as well as in energy and environmental technology.

However even so attractive, the photonics is not well known by most people. To motivate especially young generation for optics and photonics we worked out a lecture related to the "light" for children aged eight to twelve years. We have prepared many experiments to explain the nature of light and its applications in our everyday life. Finally, we focused on the optical data transmission, i.e. how modern communication over optical networks works.

To reach many children at home we recorded this lecture and offered it as a video online in the frame of children's university at Vorarlberg University of Applied Sciences. By combining the hands-on teaching with having a fun while learning about the basic optics concepts we aroused interest of many children with a very positive feedback.

Keywords: *Children University, optical data transmission, hands-on teaching, basic optics concepts, online teaching, photonics explorer*

1. INTRODUCTION

The children's university at Vorarlberg University of Applied Sciences (Fachhochschule Vorarlberg, FHV) has a long tradition [1]. It is dedicated to the children of age between 8 and 12 years. The lecture topics are taken from different fields, like business, engineering, design, or social studies, etc. Some examples are "How can I organize my birthday?", "Crazy Machines", "When children need a help", "My house from the future" but also "Laser: how it works?", "Are computers really so clever?" or "Which language use computers to communicate?". There are 12 courses per academic year, which are held at FHV or at Vorarlberg State Conservatory (Vorarlberger Landeskonservatorium, VLK) [2]. The dates are always on Wednesday from 14 pm to 15 pm. Usually, the courses take place in a lecture room where about 150 children can participate. FHV also offers the technical support for video broadcasting in the next room, where parents, waiting for the children, can watch the lectures. The visit is free and each participating child together with the accompanying person will get a free ticket for the local transportation. After each course, the children get a small snack or present. The children, who participated at least in half of the courses obtain a certificate or a diploma from the university chancellor at the end of the academic year.

For each upcoming lecture the children must register at the university homepage a week before the lecture starts. The university also offers the possibility to register the whole school classes. Especially, the topics like "Laser", "Optical data transmission" or "How computers work?", the topics which are only partially included in the curricula, are in a great demand because of the high interest from the secondary schools.

It is important to mention that in the last years the FHV has been offering also the "Youth University" for the adolescents of age 13 to 15 years.

The lectures are usually organized by FHV together with VLK and Vorarlberg Teaching University (Pädagogische Hochschule Vorarlberg, PHV) [3]. Additionally, from 2014 a new form of cooperation

between FHV and regional industrial companies like Alpla, Bachmann Electronic, Doppelmayr, Hirschmann Automotive, illwerke vkw, Julius Blum, Liebherr, meusburger, thyssenkrupp Presta and Zumtobel Group was established. Together they promote interest in technology and technical study opportunities, starting with the Children's and Youth University, workshops with schools, and networking meetings with graduates of FHV. The aim is to strengthen interest in technology and technical fields of study.

2. CHILDREN'S UNIVERSITY ONLINE

Since more than one year (Corona time) the Children's University at FHV moved to a new format. Under the title "#kinderuni4you", the lectures are pre-recorded on video and the children can then watch them at home on their laptop, tablet, or cell phone. The duration of each video is usually about 15 minutes. Videos are available online at the FHV homepage for 7 days and each child can decide when and where to watch the virtual lecture.

As always, children must register for each lecture to be able to get diploma at the end of academic year. In each "online" semester, six lecture videos (different topics) are available for children. In April 2021 the lecture "Light's got it!", dedicated to light was prepared in cooperation between Zumtobel Group [4] and FHV (Fig. 1). In this lecture, the light, its properties and applications were explained a simple way:

"Imagine a world without light! Without light we would see nothing. With certain light we not only see well, but also feel better. Other light is good for plants. Light in yet another form is used to allow information to be sent between computers. We'll show how different light can be and how we can use it to communicate. Fix is, in this lecture you will see a light!"



Fig. 1. Children University at FHV ("Kinderuni Vorarlberg") [5]

2.1. Light, its properties and applications

The first part of the lecture was dedicated to the light, its properties and applications. There are different types of light, like natural light from the sun or artificial light using various lighting elements. Each of them has a different influence on the humans and also different applications in our daily life. Important properties of the light are: the light is fast, it travels straight and is colored. Therefore, it can be used for communication, as well. Some examples are ambulance cars, fire trucks, police cars but also traffic lights using three different colures to communicate with us on the road or light towers which are of high importance in ship navigation. Computers also use light to talk to each other. This is known as optical data transmission.

2.2. Introduction into optical data transmission

Nowadays we can't imagine our life without computers. Writing messages to friends, surfing the Internet, downloading music and videos, or simply playing games - it's all part of our daily lives. But do we know what's behind it all?

2.2.1. The internet connects people like roads

The internet is a huge network that connects millions of people. You can think of it like our road network (Fig. 2). Houses, where we live, are the computers in the network and the roads connect the houses just like the cables connect all the computers. Cars driving on the roads are information that we send or download.



Fig. 2. Road network is like a computer network

The simplest network consists of two computers connected to each other with an electrical cable (Fig. 3). All information (data) is then transferred between the computers in the form of electrical signals. No matter if it is an e-mail, a song or a photo, all of them are first encoded (translated into computer language) in the computer into so-called bits, i.e. consist of many 0's and 1's (so called binary code). Each bit is then assigned an electrical signal (logical 1) or no signal (logical 0) and sent over the cable. The first computer is called "transmitter" because it sends the data. The second computer, "receiver", then decodes the received data back into a text, song, or photo.

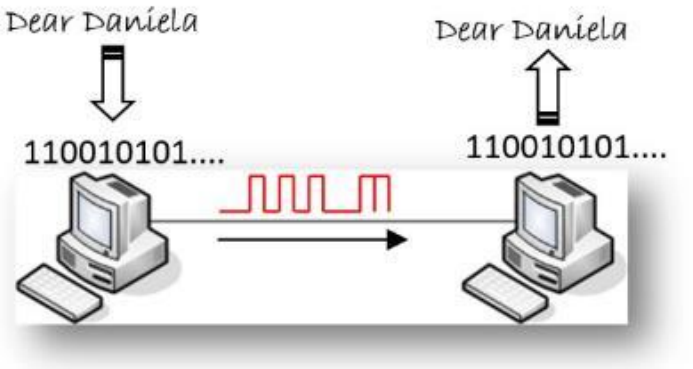


Fig. 3. Two computers connected via cable

As long as only two computers "hang" on one cable, data transmission is very fast. But when several computers have to share a communication cable, transmission becomes slower and slower. The greatest challenge, however, lies in the communication cables that connect cities, countries and even continents. For such communication, a simple "road" - an electric cable - is not enough; a highway with many lanes must be built to serve so many cars (huge amount of data). But how does it work?

2.2.2. Light signals bring the solution

The solution to this problem lies in the application of a new technology that uses optical signals for transmission instead of electrical signals. To do this, our communication system, which consists of only two computers (Fig. 3), must be extended (Fig. 4). First, electrical signals (coming from the electrical part of the network) have to be converted into optical signals. For this purpose, light sources such as a light-emitting diode (LED) or a laser (transmitter) are used. This source is modulated, that is, switched on or off, to represent the binary digits (1 and 0) from the electrical part of the network. An optical fiber in an optical cable then transmits the optical signals (light pulses) over long distances. And because computers can only work with electrical signals, received optical signals are converted back into electrical signals. This requires photodetectors (receivers). Light-sensitive diodes - photodiodes - are used as photodetectors. The output is again electrical pulses for passing information in the form of bits.

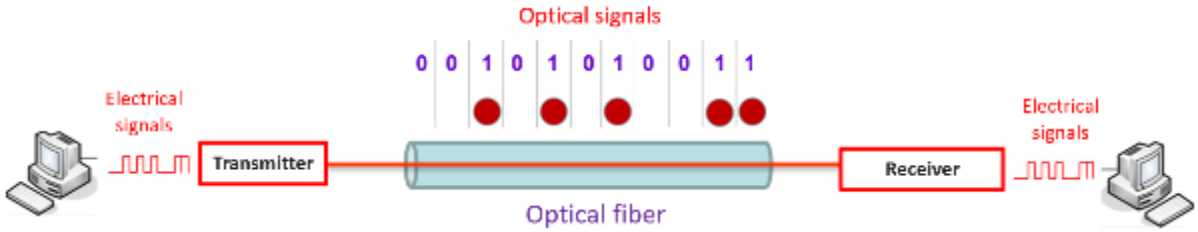


Fig. 4. Optical transmitting system

2.2.3. Fiber Optics: a new technology revolution on the Internet

This new technology is called "Fiber Optics": "Optics" - because light signals are used as the information medium and "Fiber" because glass fibers in the optical cables serve as the transmission medium. In the model picture of our roads, light signals are moving cars and the glass fibers are like a "virtual highway" in which one can increase the number of lanes without having to build new ones (Fig. 5), thereby taking advantage of the fact that the light is coloured. Each colour is like a lane on the highway (a separate transmission channel). The more colours are used, the more data can be sent simultaneously through a single fiber without interfering with each other. Even with two different coloured light signals, we double the transmission capacity. That is one of many advantages of this new technology.

In order to be able to transmit different optical signals simultaneously in one optical fiber, so-called optical multiplexers (MUX) are used. At the receiving end, all optical signals are split back into individual signals, using optical demultiplexers (DeMUX). This technique is known as Wavelength Division Multiplexing (WDM).

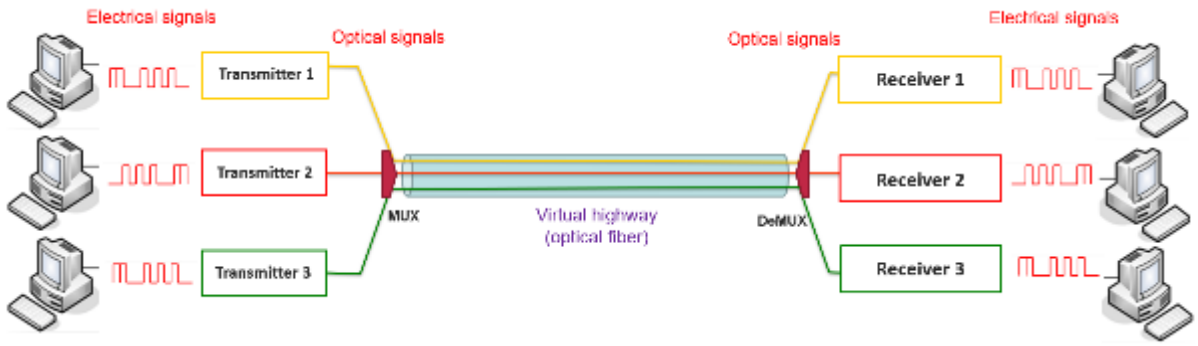


Fig. 5. WDM optical system

The other important advantage of this technology is that the optical signals can be sent over hundreds of kilometres. Nevertheless, how is it possible that the light remains trapped in the fiber and get not lost?

2.2.4. How does a glass fiber work?

The fact that light can be guided over hundreds of kilometers in a fiber almost without loss is based on two physical phenomena: reflection and refraction of light at the boundary between two optically different media. If we consider these two phenomena, under certain conditions so-called total internal reflection takes place. In other words, the light does not enter the other optical medium, but remains within the fiber (Fig. 6).

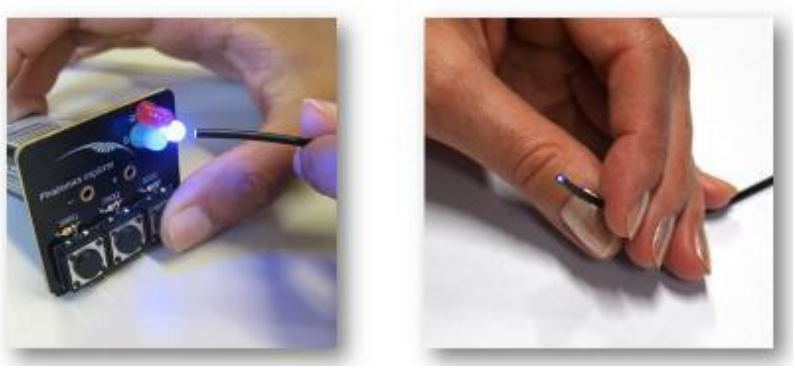


Fig. 6. Light propagation in an optical fiber: coupling light into the optical fiber (left) and out (right)

2.2.5. Around the world at the speed of light!

Today, an optical fiber can transmit up to 80 different light signals (wavelengths) simultaneously. If you pack several optical fibers together in a glass cable, you can send enormous amounts of data around the globe incredibly fast. It is thanks to Jean-Daniel Colladon, a Swiss professor at University of Geneva, who first demonstrated total internal reflection in 1842 (Fig. 7).

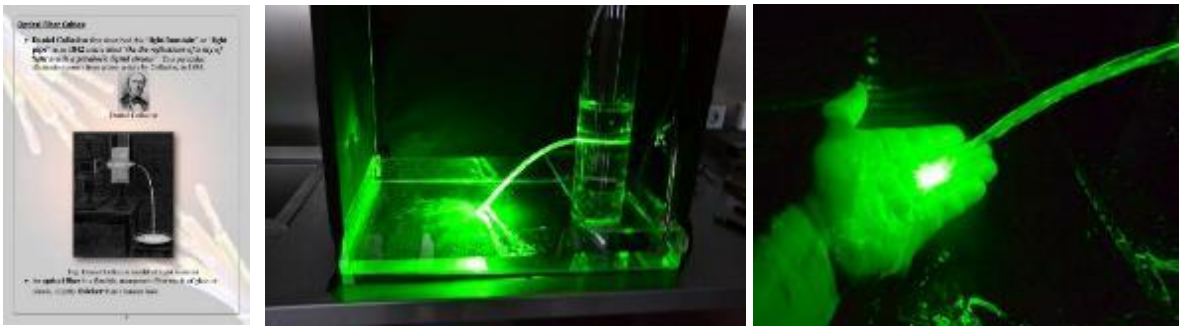


Fig. 7. Demonstration of total internal reflexion: Daniel Colladon's light pipe (left), light experiment at FHV (middle) and total reflexion (right) [6]

2.3. Making of

As a first step we have worked out different scenes and prepared a script with dialogs and experiments. The lecture was recorded in a lecture room at FHV. Two IT colleagues from FHV took over this task. Recording the video took approximately four hours (Fig. 8).



Fig. 8. Making of: Children University lecture "Light's got it!"

The lecture was split into following topics:

1. Light and its properties
2. Light as a communication
3. Light in modern optical networks

2.3.1. Light and its properties

We have begun our lecture with a short introduction to the light and why do we need it: "we need light to wake up in the morning, we need light at school for learning, we need light at work but also in the free time (Fig. 9 left column). We have discussed the different kinds of light (daylight & artificial light) and its impact on or life (Fig. 9 middle column). The children have learnt that the light is fast, it travels straight and is coloured (Fig. 9 right column).

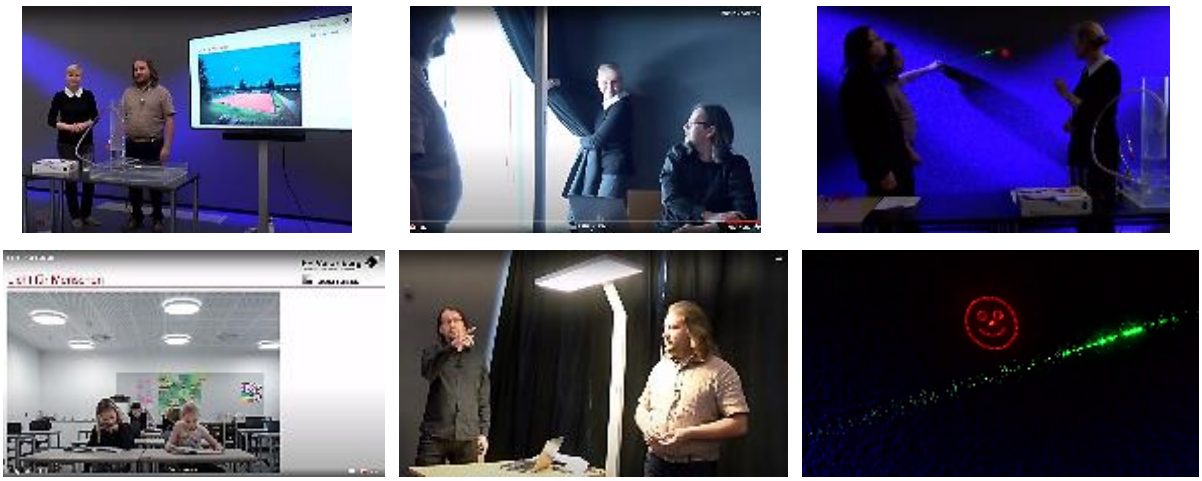


Fig. 9. Light and its properties

2.3.2. Light as a communication

In the second part of the lecture, we moved to the application of light in the communication (Fig. 10 left). Some examples are ambulance cars, fire trucks, police cars or light towers which are of high importance in ship navigation. In our daily life the most important are the traffic lights using three different colors to communicate with us on the road (Fig. 10 middle & right).



Fig. 10. Application of light in the communication

2.3.3. Light in modern optical networks

In the last part of the lecture, we focused on the application of light in modern optical networks. We explained how the information is presented in the computers (in the form of bits, i.e. in the form of electrical signals) and how it is sent through the optical network (in the form of optical signals) as shown in Fig. 4. We also discussed how optical fibers work. We have explained total internal reflexion and shown a simple but impressive experiment with a glass of water mixed with a few drops of milk (Fig. 11 upper row). This optical phenomena is also used in the fibers to transfer the information. As already mentioned in subsection 2.2.5, Daniel Colladon was one of the first, who observed total reflexion in a jet of water, so called “Daniel Colladon's Light fountain” or “Light pipe” (Fig. 7 left). We have built a copy of this “Light pipe” at our university (shown in Fig. 7 middle & right and in Fig. 11 lower row). Finaly, we sent optical signals over a real optical fiber (Fig. 11 right, upper row).

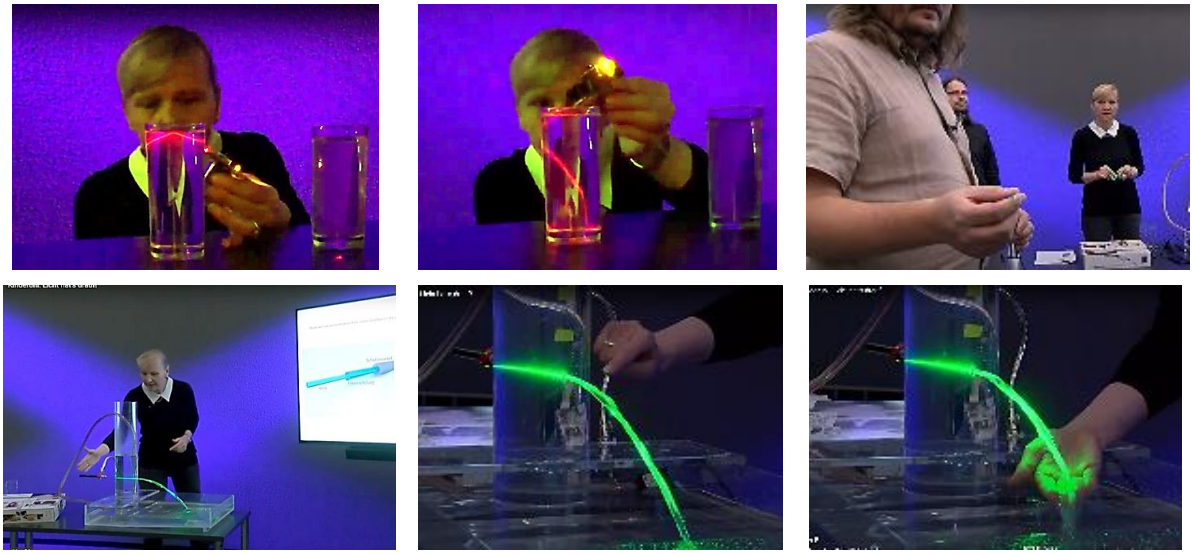


Fig. 11. Demonstration of total internal reflexion; Sending optical signals in a fiber; “Daniel Colladon's Light pipe”

Today, total reflexion in an optical fiber can be also found in various decorative applications as shown in Fig. 12.



Fig. 12. Fiber optics in various decorative applications

2.4. Feedback from children

At the end of lecture children got a homework with two tasks:

1. Describe what kind of light you need to wake up in the morning.
2. Try to repeat the experiment with total internal reflexion in a glass of water.

We have got a couple of answers with very impressive pictures (Fig. 13).

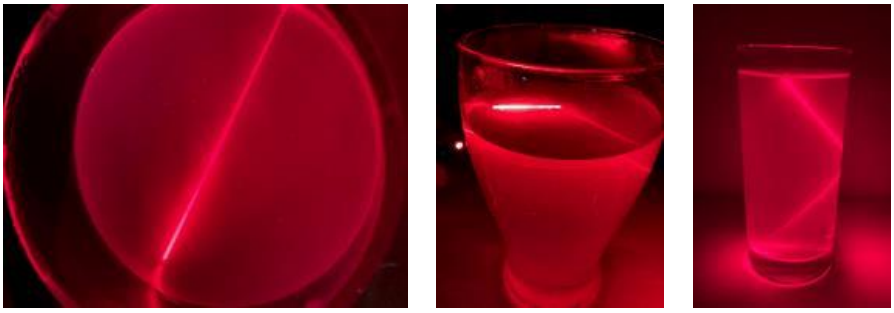


Fig. 13. Pictures of total reflexion in a glass of water received from children

3. PHOTONICS EXPLORER

The experiments used in video were taken from Photonics Explorer, an educational kit (Fig. 14 middle) developed by the photonics research team B - PHOT at VUB (Vrije Universiteit Brussel) for students of secondary schools (Fig. 14 left). The concept is a 'lab-in-a-box' that enables students of the 2nd and 3rd grade to do photonics experiments themselves at school with lasers, LEDs, lenses, optical fibers, and other high-tech components.

The kit fits the learning objectives for sciences and pursues two main objectives of STEM (Science Technology Engineering Mathematics). In the first instance Photonics Explorer links technology applications to real-world situations and to the life of young people. They discover for example how the polarization of light is crucial for LCD screens of smartphones and tablets, or how light can speed up the download of movies from the Internet. Furthermore, the kit is also built entirely around inquiry-based learning in which all students are involved, observing and reasoning actively. This hands-on approach gives students more confidence and stimulates their curiosity and problem-solving skills.

Since November 2011, EYESTvzw is responsible for the assembly and mass distribution, and for supporting teachers in our endeavour to convey the fascination of science and engineering to pupils. To organise the distribution all over Europe, EYESTvzw works together with very motivated partners in

several European countries. Local Associated Partners are responsible for the teacher trainings (Fig. 14 right) and the distribution of the Photonics Explorer in a particular country or region. For more information visit www.eyest.eu.



Fig. 14. Photonics Explorer: students of secondary schools experimenting with the different properties of light (left), an educational kit (middle), workshops for teachers (right) [7]

4. CONCLUSIONS

In this paper we have shown that science can be made attractive for children even in such a difficult time like COVID19 when "home schooling" is a primary education form. In the frame of "Children's University" we have prepared a video related to "Light and its applications". Together with colleagues from Zumtobel Group we have prepared many experiments to rise the interest of children in the field of optics and photonics. The feedback from the children and teachers of secondary schools confirms a high interest in this topic.

ACKNOWLEDGEMENTS

I would like to thank Stefan Lorenz and Lukas Osl from Zumtobel Group for a great collaboration in creating the lecture, to Gerold Vögel and Hansjörg Kappeler from FHV for a video production and to Annerose Löw and Claudia Franceschini from FHV for the organization. Finally, I would like to thank Thomas Auer, Bernadette Egle, Sibille Dallapiccola, Michael Mayer and Simon Weirather for the development of the "Light Pipe" experimental set-up in the frame of student project at FHV. This work was carried out in the framework of the project PHORSCH!, no. 878789, funded by the Austrian Research Promotion Agency (FFG).

REFERENCES

1. Vorarlberg University of Applied Sciences (Fachhochschule Vorarlberg), <https://www.fhv.at/>.
2. Vorarlberg State Conservatory (Vorarlberger Landeskonservatorium), <https://vlk.ac.at/>.
3. Vorarlberg Teaching University (Pädagogische Hochschule Vorarlberg), <https://www.ph-vorarlberg.ac.at/>.
4. Zumtobel Group, <https://z.lighting/de/>.
5. Childern's university, <https://www.fhv.at/ueber-die-fh/ueber-uns/kinder-und-jugend/kinderuni-vorarlberg/>.
6. Wikipedia, <https://en.wikipedia.org/wiki/Jean-Daniel_Colladon>.
7. D. Seyringer, C. Burtscher, G. Piredda, A. Prasad and J. Zehetner: „The Night of Science: Optics and Photonics for All", The European Conference on Technology in the Classroom 2016 (ECTC2016), iafor (The International Academic Forum), Brighton, UK, June 29 - July 3, 2016.