New Optical Museum at Saint-Petersburg for education and training

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ABSTRACT

Nowadays the educational problem of teaching optics and photonics is to attract the young generation to the wonderful and magic world of light, optical science, technology and systems. The main issue is to explain that in the course of last several hundred years optics has been representing the most clear world view for humanity. In fact, the optics itself is a multidisciplinary complex of independent scientific directions, and, moreover, it has always been a generator of new fields of knowledge. Besides, optics and photonics are the fields within which the most fundamental problems of today's reality are to be resolved.

It is absolutely necessary to encourage our scholars in getting optics and photonics education as an alternative physical basis to gaining solely computer knowledge. The main obstacle is the poor connection between program of optical education and the real optical researches, disintegration of different branches of the optical science, the demographic situation, some problems with teaching mathematics and physics at schools, and the collision between traditional educational methods and the mentality of the new generation. In Russia the Saint-Petersburg State University of Information Technologies, Mechanics and Optics offers partial solution to these problems: the organization of a real place for interactive optical science in a form of a new museum of optics, intended for education and training, seems to be the most effective way. This was the main reason for establishing such a museum in Saint-Petersburg at the end of 2008.

Keywords: optical and photonics education, optical museum, nature of light, theories of vision, physical optics, applied optics, ophtolmology, optical illusions and puzzles.

1. INTRODUCTION

The main tasks of the museum are to introduce the brilliant world of optics; to realize different educational strategies for several young generations of different ages, from kids to university students; to use the capabilities of Saint-Petersburg high cultural level to attract not only the citizens but also people from the country to optical community; to demonstrate classical optical phenomena in an interactive way using modern devises, equipment and systems.

The Optical Museum is situated in a picturesque Vasil'evsky Island, which used to be a historical and scientific center of old Saint-Petersburg. The museum occupies the ground floor of a XIX century building on the Birzhevaya line. Long before it was an apartment where the famous merchants' Eliseev'i family lived, and later it was occupied by the department of S.I. Vavilov State Optical institute. The organization of the Optical Museum was supported by the city administration, the Russian Optical Society and several optical and IT companies.

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The main museum halls include basic exponents on light and sight, holography, optical artifacts and a collection of historic books on optics; glass and optical materials, elements and light sources; microscopes and interferometers; projection and photo techniques; detectors of UV and IR spectra; various kinds of mirrors, laser diffraction systems and etc. Several halls are devoted to astronomical optics with mini-planetarium, precise equipment; laser games, such as laser weapon and chess, kaleidoscopes, mirror systems, light music. For training the on-line experiments in interference, polarization, diffraction (including fractal diffraction), 16 types of microscopes and 10 types of lasers are demonstrated. Special posters introduce the materials of life and deeds of outstanding and famous foreign and Russian scientists: academicians D.S. Rozdestvensky, S.I. Vavilov, G.T. Petrovsky, Yu.N. Denisyuk and others. The most interesting sights for children are the computer holography, Chinese magic and Greek burning mirrors, modern adaptive mirror, solar cells, laser security systems, polarizing control based on photo elasticity and night vision systems.

Lectures, seminars and conferences on optics and photonics are held at the conference hall. For example, lectures on the history of optics for students and post-graduates, based on two volumes of the book “Five Millennium of Optics” are given at the Museum. The video presentation of the Museum will be soon available in the Internet. The museum is a unique example of an educating State Optical Museum in Russia. The specialists from Saint-Petersburg State University of Informational Technologies, Mechanics and Optics and from the Russian Optical Society would be glad to invite foreign colleges and specialists in optics and photonics to visit our museum.

2. THE CONCEPTS OF MUSEUM

The main goals of the museum, which have already been realized, are:

- To combine certain historical facts, classical experiments with most modern optical stage.
- To mix illusions, optical tricks and paradoxes with serious scientific problems and explanations of optical phenomena.
- To provide a wide range of conducted activities: from surveys and educational excursions to a series of lectures with demonstrations and thematic workshops.
- To arise deep interest in many different groups of visitors by the diversity of content. The collections can attract school children of 7 to 10 grades, students of the first and second courses, master’s degree and post–graduate students, adults with technical and humanitarian education.
- To offer two different ways of functioning: for scholars and student groups, who appoint the visit in advance, and for family visits. The first case is more preferred.
- To organize a group of young guides from among the students and masters of university. The most effective way to attract new generations to science is when young people introduce science to those who are younger. Older guides are to be left mostly as a reserve or for status excursions.

When the visitors enter the museum, the first thing they notice is the cloak-room with dozens of distorting mirrors. By exploring them, one first gets interested in optical illusions, and through this in the optics itself.

3. THE FIRST HALL

We’ve decided to start our tour not with the historical chronology, but with holography, which is the most interesting from a cognitive point of view, spectacular and attractive, which helps to gradually involve the students into the magic world of optics. Today each one of us meets with hologram or holographic effects in his everyday life. Thus ordinary exhibitions of holograms, which used to be very popular 10-15 years ago, are of no particular surprise now. But nowadays the feeling of a “miracle” appears in the majority of those who are not yet very profound in science. And the main educational task of the first hall of the museum is to open the secret, to try to explain the conditions of formation and features of three-dimensional holographic images.

The explanation begins with demonstration of the simplest stereoscope (Fig.1). These toys belonging to the end of XIX century allow to “feel the difference” between the plane and 3D images. It is appropriate now to recall the method of parallax, by using which such illusions were created; the binocular vision, and even the way we define the direction of the sound source by ears. Depending on the age of the audience, we talk on the everyone two optical and two acoustic receivers to the right and to the left of the computer, which processes their signals - the brain. It is the brain that has the ability to compare the moments of impact of both acoustic waves on the eardrum (temporal phase) or to compare the moments of impact of both light waves of slightly different direction (spatial phase), entering the pupils.

Gradually, we bring the students to the idea that the possibility of registering 3D images is a matter of the registration of the phase of an optical signal. But before we turn to the explanation of holography creation schemes themselves, we offer our visitors to solve another well-known 3D illusion formed by a system of two parabolic mirrors (Fig.2). The projection of the real image on the surface is something trivial, but the view of an actual three-dimensional image “hanging in the air” arouses constant surprise and sincere interest: «And how does this work»? It is now the very time to talk about a full circumferential illumination of the object, about the scattering of light, the structure of the wave front and especially about peculiarities of its visual perception.

So now we can proceed to the principles of registration of the phase component of a wave front. We explain that none of the light receivers does not respond to the phase, we talk about the idea of “freezing” the phase from the object using the second so-called reference wave, very similar to the first.

We might remind the advanced students that such light beams are known as coherent, and their interaction with the strengthening or weakening of the total intensity is described in the terms of the light interference. We also remind them the ideas of Dennis Gabor on how to obtain 3D images by “photographing interference pattern”, expressed in 1948, long before the creation of lasers. Using two reticulated lids of frying pans, we demonstrate the dependence of the forms of interference lines on the phase difference of both waves (Fig.3).

The spacing between the wires constitutes about 0.5 mm, and thus, on a scale of a 1:1000, the nets become a rather successful model for the two interfering light beams. We change the “optical path difference” (or the difference between the phases) by rotating the nets against one another, and adding both narrow and broad *moire* stripes, which are a good analogue of *interference stripes*.

Now it is the time to explore the real maquette of the holographic installation (Fig.4). We show that the laser source radiation is divided into two beams from the very start – the reference and the object beam, and that the expanded reference beam illuminates the position of a usual *photographic layer* - the future hologram. After lighting up the object, the second beam scatters in all directions, partly falling on the same *recording layer*. And this is were the *interference stripes* pattern, which carries the information of the wave phase features, scattered by object, is registered. We finish the explanation of hologram recording with a few words about the photo-chemical process. We surely give all those who wish an opportunity to examine a piece of a hologram under a microscope to make sure that there is no images on it, but only a miniature and extremely complex ornament of dark and light curved lines. At this point, considering a prepared audience, one can discuss the characteristics of holographic recording methods, the reliability of information storage and its degree of redundancy; discuss the “associative” nature of the holographic memory of the multi-view holograms with multiple images, recorded on one layer. We might also discuss more subtle issues: the conditions of angular illumination according to Leytz, the best intensities ratio between the object and reference waves, the requirements for grain size of the photographic *plates*, etc.

Then we explain of the recovery phase of holographic images. We draw special attention to the principle difference between the illumination of ordinary paintings or photographs, hanging on the walls, and the special illumination of holograms, which results in the apparent 3D images. It is necessary to indicate the direction of restoring light beams and their coherence with the orientation of a reference wave during the hologram recording. All these considerations must be immediately followed by concrete examples of artistic or technical holograms in the same room (Fig.5). The main task is to make the audience realize, that the viewed images are the result of spatial diffraction of light from the illuminating lamp with the same system of stripes, which we created while recording the hologram. And as it preserve all the phase information, the virtual images in front if replicated the 3D effect. In this sense a holography is the culmination of the wave properties of light: during the recording wee use the interference phenomena while during the reconstruction we use the diffraction.

It is obvious that this story could be greatly expanded and deepened for students with good physical and mathematical basis. Some particular exhibits of the holography collection illustrate perfectly *the zero beam* with violation of the Leytz conditions; the emergence of a real image, the peculiarities of diffraction on the sinusoidal gratings; the multiplication of the images, formed by the sinusoidal diffraction lattices; emergence of multiplicity of images in the form of nonlinear distortions of the lines forms, etc.

At this point you can make a short break and give the audience 5-7 minutes to take a good look of the holograms. Each visitor is offered a pocket flashlight to examine the content of a number of multi-view holograms, and even determine the right lighting conditions for the elements of a creative mosaic sculpture, composed of many small pieces of holograms. After the “entertaining” brake we may proceed with serious but highly absorbing work in the first hall. We still have to deal with the principles of obtaining color holograms and to get acquainted with the work of its inventor - Yuri Denisyuk, who worked and taught in the same building where the Museum of Optics is situated. The pages of his diary concerning his working plans, and especially the timing for them, always make a deep impression on today masters and post-graduate students, who are not that much used to work so intensely and selflessly as the older generation of scientists. This is followed by a story about the principles and visual demonstrations of the most impressive among recent achievements in the field of volume vision: the creation of computer, including *iridescent*, holographs of 3D objects; the dynamic holography using liquid crystal layers; holographic interferometry of *ultra fast* processes. The limited size of paper does not allow to give more details on the content and methodology of these sections study. Meanwhile, the total time spent by the student group in this first, holographic hall, ranges from 20 to 30 minutes.

4. THE SECOND HALL

In contrast to the first hi-tech exposition, the second hall represents the historical collections in traditional style (Fig.6). Here the exponents on the history of optics are displayed: models of ancient lamps, the first samples of transparent artifacts of crystal and glass, collection of bronze mirrors, models of various gnomon sundials, antique viewfinders. In the center of the room there are two vertical glass cases with installations dedicated to the two principal optical instruments: the telescope and the microscope. There are glass cases with exponents concerning the structure of the eye, the principles of color vision, and, of course, spectral composition of white light. The story here focuses on very basic issues – the retrospective of theories on the nature of light and color, the hypotheses on the vision mechanisms and the technology of optical measurements. The story is accompanied by demonstrations of different light sources from oil lamps to laser, light receivers from an eye to a solar battery, and some classical experiments on refraction, diffraction and interference. But let us be consecutive.

The introduction to the collections of the second hall starts with examination of a relief model of the eye in a scale of 20:1. One can disassemble and assemble two 3D models of eyeballs, as well as to examine their own eye-sight keenness (Fig.7). After brief training on a special eye-simulator, visitors may practice in examining their friend's eyeballs using an ophthalmoscope. Finally, the constant interest is arise by the standard color table, which give each examinee an objective estimation of his own color sensitivity by four grades – from a low, which means nearly color blindness, to a high grade, that of a professional artist. The experiments on the visual color transmission logically bring the audience to the general problem of color diversity. It is no accident, that the question of light and color correlation has been one of the most difficult in the history of optics: the color palettes are based on too many varied physical effects. Students are shown the refractive nature of a rainbow, the interference colors of *pellicle*, absorbing coloration of natural minerals and colored glass filters. The spectrum of white light, acquired by using high power diffraction gratings, appeared to be the most striking and instructive to the audience. Projected on a piece of opal glass, it has not only allowed the visitors to see a consistent rotation of the spectral colors of visible spectra band, but also to remind them of the *adjacent areas* of the optical spectrum - the ultraviolet and infrared. At the end of our tour we return to a detailed study of the features of UV and infrared radiation we return route, while in the central hall it recommended to conduct another simple, yet always successful demonstration of the possibility of visualization of an infrared radiation right at home – using a cell phone with CCD-camera and a remote control of any audio or video device.

The historical part of the excursion begins near the cases displaying samples of oil lamps, the light of which was used by the mankind for nearly two millennia. There are primitive clay lampions, as well as Greek terracotta samples with one or several wick spouts. The collection also contains several types of Roman lucides and early Christian bronze lucernes. And finally, several imitations of Muslim oil lamps are displayed, perhaps those by rubbing which you can call a genie. Further progress in the manufacture of light sources is represented by series of candles and candelabras, kerosene lamps, incandescent lamps, spectral lamps, plasma and gas-filled lamps. LED panels, and laser systems complete this section.

The next historical plot is dedicated to the first proto-optical elements of a transparent material. Magic crystal balls possessed by the Egyptian pharaohs, crystal eye fibulas of ancient statues, healing crystal spheres of Tibetan monks are united in a coherent conversation. The transparent "Alhazen hemispheres" that rather popular in the Islamic world, are also represented. Later those evolved into medieval prototypes of magnifiers – the "reading stones", which were an obligatory tool of any Latin monk-scribes before the first magnifier appeared. The further improvement of glass manufacturing allowed to create the first convex glass lenses "for the elderly" in the XIII century (Fig.8), and after a hundred years a concave lenses to correct nearsightedness appeared. And only after two centuries, by combining the long-focus positive lens with the short-focus negative lens the first visual pipe was invented. And with this the era of instrumental optics has begun…

As the practice has shown, the following historical demonstration of the magic mirrors of ancient China appears to be the most impressive. Generally, all historical stories relating to the bronze mirrors always enjoy success. Here are the stories of the pharaohs' mirrors, which were buried in the tombs aside to their masters; the riddles of the Etruscan bilingual mirrors, and the imitation of inflaming effect of the Archimedean mirrors. The last experiment, of course, can not be conducted to the point of getting an open flame inside the museum hall. However, even the measurement of temperature in the focal point of the mirror parabola arouses great interest and curiosity among young students.

The most representative is the museum collection of copies of the Chinese mirrors dating back to the Han period (II-VII centuries). Two of them, created with special technology were reconstituted in the Shanghai University. They display the magical effect when the light beam, reflected from the polished front surface, reproduces the ornament from the back surface. Although the audience can see the metal casting of 5-6 millimeter width, is still gets an impression of a magic “transparent bronze”. The explanation of this ancient effect, which is based on the visualization of the invisible relief on the polished side of the mirror, combines perfectly with the further story about the distortions of reflected wave fronts, obtained by using the most advanced adaptive mirrors. In the center of the room a film mirror with a pneumatic control system is installed, which allows to show the principles of compensation of the distortions. This model of a segmented adaptive mirror changes to a convex, then flat, then concave form, creating the whole range of geometrically distorted images: from the enlarged direct virtual images to reduced real inverted ones.

Here, in the center of the room, three series of training and educational demonstrations can be carried out. The first one imitates the experiments of the great astronomer Claudius Ptolemy on the study of refraction of the partition edges of glass and water, which he conducted as early as in the I century, trying to get the data for recoding the atmosphere refraction. Here it is appropriate to say about the related issues, for example, the ancient theories of vision, based on a model of an eye emitting direct lines of visual rays. The demonstration of inversion of the light beam coming out of water into the air is perceived with great interest, when many visitors, along with Ptolemy, for the first time discovered the effect of total internal reflection. At this point it is necessarily to return to the modern times and say about the features of light propagation in dielectric transparent fibers, which are often believed to be simply hollow tubes with internal specular walls. We can finish the talk on the refraction and the refractive index with a curious trick, always admired not only by the kids, but by the adult visitors as well. During this trick a hundred and a half of small transparent balls disappear in the vessel filled with water. The most appropriate and affordable tools to be used for such an entertainment are the water gel balls, that are being sold in flower and interior design shops.

The second demonstration reconstructs a much younger scientific achievement: the famous “Poisson’s spots” – a phenomenon of diffraction, connected with the concentration of light energy in the center of the shadow of a round object. Depending on the time limit we can retell more or less detailed famous dialogue, which took place in the French Academy of Sciences during Fresnel’s report on the first theory of diffraction. The highlight of the demonstration is the construction of laser device, energy of which allows us to get the macroscopic picture of the Poisson’s spot within a distance of 4-5 meters and with exterior lighting, with the picture being clearly visible to all the visitors. It is worth noting that with the help of this laser installation we can hold special thematic lesson on diffraction for the advanced groups, because the total number of experiments that can be demonstrated on this *setup* is more than three dozens. Among those are the Fresnel’s diffraction at the apertures of different shapes, and Fraunhofer diffraction in the far zone, and experiments with diffraction gratings, with irregular structures and even the diffraction on fractal objects. After a small upgrade the installation can be also used for demonstrating the principles of Fourier optics.

The final demonstration in the center of the second hall is devoted to the practical use of interference measurements. Using the model of Mach-Zehnder dual beam interferometer we can show very clearly the possibility of precise measurement of the refractive index for gas mixtures. Then the students can examine a real device that works on this principle – the so-called pit interferometer, which has saved many lives, because it showed dangerous concentrations of methane in mines. We can also add another example to the practical value of interferometry – the detection of glaciers with high snow slide possibility by using the scheme of the Michelson. Built on the mountain tops, the laser version of the interferometer, with one its mirrors being enhanced on the glacier, can detect its motion just in a few tens of minutes. The parameters of this movement are very impressive: the glacier is considered an avalanching when its speed is 3 centimeters per year!

Near the exit from the second hall we have a thematic retrospective section – these are stands and glass cases with exponents on the history of photography. Apart from the collection of antique cameras and magic projector-lamps there is a bust of Louis Daguerre and numerous examples of daguerreotypes and photographs dating back to the end of XIX - beginning of the XX centuries. However the focus is on the "great-grandfather" of all the optical devices - the famous camera obscure, in fact a simple box with a small pinhole. A short story is finished with a demonstration of magical features of the camera: the creation of real reduced inverted images of external objects without using any lenses. As the students can work on their own with high power lanterns during these experiments, here, over the Daguerre's bust, there is also an element of a professional solar battery. After directing the light beams on its surface, visitors will immediately notice how the frame, connected to the battery, starts rotating. A few words about the solar energy seem to be a logical conclusion to the study of second hall.

5. THE THIRD HALL

The exposition in this hall is devoted to optical materials and elements. Some particular glass-cases contain different samples, concerning modern optics. The first one contains a collection of fiber-optic components, including those representing regular lightguides, different kinds of endoscopes, active components for fiber-optical lasers, constructive options of axicons, micro lens arrays for photolithography. The second glass case has samples of some of the first laser-activated glasses - neodymium, sapphire, IAG etc. Right in front of them there is a real neodymium laser with an amplifying unit and an external resonator. Its sectional design allows to show to trained visitor not only the solid-state laser device, but to clarify the mechanism of optical pumping and the role of confocal resonator mirrors. The third case displays elements of ancient and modern ophthalmologic instruments. The visitors can see sets of glass lenses of different time of manufacture, apparatus for determining optical properties of the eye, special laser stimulators of visual activity.

The main exponent here is the famous Abbe catalog, made in the Soviet Union in the second half of the last century. It is a collection of almost all then-existing optical glasses of different chemical compositions and brands from the lightest crones to super heavy flints. A considerable part of the collection is composed of special radiation-proof glass, designed by the orders of the military. The uniqueness of the collection is first of all the in the sizes of homogeneous glass blocks, for manufacturing which a research group under the guidance of academician G.T. Petrovsky has settled more than one dozen of the most difficult technological problems. The background of the catalog is a fresco, depicting the motives of medieval engravings and representing the main stages of glass manufacturing. Developed by legendary artists from the island of Murano, these techniques had been the main secret of the Republic of Venetian for several centuries. The catalog is mounted on a special three-tier basis, with each glass installed in a special frame and highlighted by a multi colored LED lines (Fig.9). For those who wish to explore the issues of optical materials science there is a computer kiosk with touch screen and plasma panel to visualize Abbe diagram classification right next to the collection. In classification each glass is marked by a single spot, and is accompanied by information on its refractive and dispersive properties, chemical composition and physical-mechanical parameters. As an illustration to the processes of glass manufacturing, the visitors can also see the examples of real technological equipment – ceramic crucibles and mixers. The story of the diversity of optical glasses, created by mankind, flows smoothly into a discussion of such serious problems of refractive imaging optics, as a correction of nonlinear distortions (geometric aberrations), the need to compensate the varying dispersion of rays of different wavelengths (chromatic aberration), etc. The level and duration of the discussion varies widely from a brief reference for the youngest children to mini-seminars held for specialists.

Right after the hall of glass, there are two rooms which are at the moment only being prepared to receive some relevant museum equipment. One of them will be store a collection of 16 microscopes, different by working principles and magnifying capabilities, each of which will be available for the trainees (within reasonable limits). Reviewing the most popular micro objects in detail may be accompanied by their sketching or photographing. In the second of the rooms, that are stile being designed, a kind of master class will be conducted, a visit of which is planned to be organized as a separate program. Here the fiber-optical equipment for laser engraving, a special stand for a quick hologram recording, designed by specialist from our University and possibly a computerized system for creating transparent 3D-models in the glass will be located.

6. THE FINAL PART – INTERACTIVE & GAMES ZONE

The tour described above takes about ¾ of the time spent by visitors in the Museum. The remain part of the exhibition is places in much smaller rooms and is devoted to entertainment and cognitive rest, of course, within the frame of optical thematic.

First, the visitors enter a dim room with lasers. Here one should move carefully – otherwise the laser security system, placed at the bottom, will detect you. An acousto-optic deflector draws its laser designs on the ceiling; it can be controlled by voice or music. On the walls lines of verticals and horizontals are marked – thus the work of laser levels, laser horizons and theodolites is shown. Those who wish may shoot a laser gun or use professional laser glasses that completely block all light colors except red. In the room there are also placed lasers, emitting beams of all primary colors – red, green and even blue – and an infrared laser with a built-in nonlinear optical crystal for second harmonic generation.

The next small windowless room is an astronomy optics room with a mini-planetarium. The rotation of the stars sky is accompanied by a small video on the history of telescopes of different schemes, two of which are also represented here – a reflector and a refractor. It worth noticing that some interior design items appeared to be a good supplementary material for this section, for example four plasma light-balls, located in each corner of the room. The story about the glow of a plasma discharge is accompanied by a fascinating and totally useless attempt “to catch lightning”. In this very room visitors also have an opportunity to use night vision devices. And it is not only the visualization of passive infrared radiation which is available, but also a work in active mode with backlighting by special infrared searchlights.

Next, passing along the narrow corridor, we enter some “strange place”. There is an empty frame hanging on the wall, with a canvas which has no image on it. Next to it there is a cupboard, containing miniatures of picturesque landscapes but totally empty skies. In the dark depths of the cupboard one can see druses of crystals, some small items of matted plastics, and finally blank sheets of paper. But in a second, everything changes in a wonderful way: the normal light is turned off while the magic ultraviolet is being turned on. In the frame there appears a beautiful waterfront view of St. Petersburg; fairy-tale characters on flying carpets or Chagall’s violinists appear in the skies on the miniatures; the plastics shine with bright colors and crystals start to glow. Some secret signs, seals and even color photographs appear on the seemingly blank sheets of paper. When the first surprise passes, we start to talk about the luminescence, an effect of no equilibrium luminosity of certain substances under the action of UV radiation. Some visitors listen to the explanation with interest, others prefer to approach a special UV-emitters and search for some glowing part on themselves or to check the authenticity of their banknotes. Those who wish to draw their own pictures, glowing in the dark, are given some professional advice. We also teach how to distinguish harmless luminescent paint from the phosphorescent which is not very good for health.

Going back a little bit, we turn to the right after the guide and get to the hall of polarization. This characteristic of light has not yet been discussed, and here you need to spend some time to effectively explain the transverse of the electromagnetic waves, the operating principle of linear Polaroid films and show the blocking of light in a system with crossed polarizers. The easiest way to demonstrate the polarization effects is to use a white light beam from overhead, with rotary frames of polarizers being fixed right on its working surface. Now anyone can place a transparent object between crossed polarizers and achieves the enlightenment of the path where the object has changed the direction of light oscillations. Among the available samples there are Iceland spar crystals, peaces of solidified resin, pressed peaces of the photoelastic plastics.

The visitors can offer their own objects for polarization examining – from the *pellicle wrappers* of cigarette packs to plastic glasses with deformed lenses. Not very proficient visitors are impressed by the way the objects with internal stresses look in polarized light: this visualization is the main "focus" of the polarizing room. Other experiments include the models of optical systems with special scattering prism. With their rotation one can see clearly the change in the trajectory of laser beam internal reflection, and, moreover, they can easily explain the polarization of light in the scattering from the normal (so-called Raleigh butterfly). These demonstrations, as well as the definition the full polarization angle (Brewster's angle) or observation of the conoscopic pictures with the polarized beams interference, of course, are not included in the program of round excursions, but are offered to specially educated groups of students.

The last two rooms, on the contrary, are completely comprehensible to all visitors from small children to adults and even elderly people. They are focused on game booths basing on optics. Here are the main ones: a mirror illusion called "compound face" (two volunteers look at each other through a narrow banded system of mirrors with separating empty spaces); octagonal mirror room, in which the image of any object place inside is multiplicated; a set of kaleidoscopes of different structures, forming ornamental patterns; a laser harp (fig.10), with which it is possible to play familiar melodies; a strobe balalaika with a neck and illuminated from beneath by a rapidly flashing LED lines; laser chess and laser shooting range with a "beam weapon" and much more. The kids spend some time in these gaming rooms on their own, and then the main part of the excursion is finished. Anyone may spend extra time in any of the halls of the museum if wishes. The visitors are not only but encouraged to take photos of themselves and the exhibits.

As a conclusion, it is necessary to mention that the Museum of Optics has a small kiosk with optical souvenirs and toys, as well as a holographic studio, which works with already existing designs and also offers a service of making a holography by an individual design.

This entire educational complex based on a combination of education, research activities and games, and having a clear business plan, should become, in our view, the prototype of the centers attracting young people to science and technology, whether to optics, aerodynamics or acoustics.

Fig.1. Examples of simplest stereoscopes

Fig.2. 3D illusion formed by two parabolic mirrors

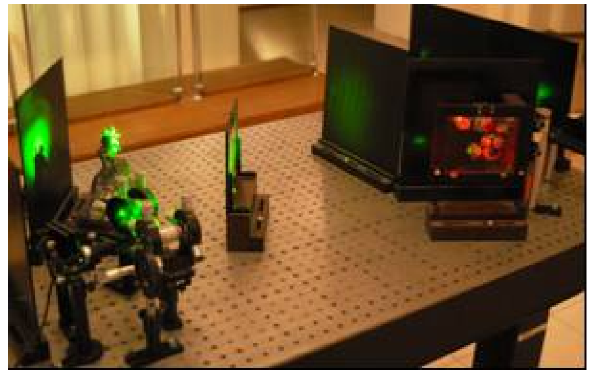

Fig.3. Simple demonstration of interference

Fig.4. Model of the holographic installation

Fig.5. Part of the first hall holographic collection

Fig.6. Centre view of the second hall

Fig.7. Case with eye-models

Fig.8. Ancient crystal balls, reading stones & glasses

Fig.9. View of famous Abbe-catalog

Fig.10. Laser harp as a harmony of Light & Music