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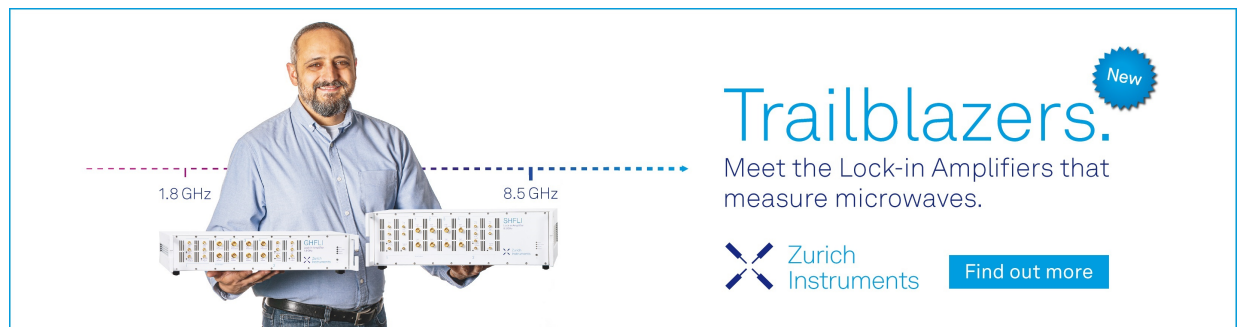
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The Possibilities of Using Virtual Reality When Introducing Students to Scientific Activities in Physics

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Abstract. The article is devoted to the prospects of using virtual and mixed reality systems as a tool for introducing students into scientific activity. Attention is paid to the development of content for such systems in condensed matter physics based on the method of molecular dynamics. In this study we suggested one of the possible ways to simplify the making of 3D models for a course in solid state physics. A survey was conducted among students about the complexity of developing such models. The results obtained testify in favor of the use of such methods both in teaching physics itself and in forming a base of models. In addition, the use of these technologies increases the interest of students in the subject of study. The results of this study indicate the feasibility of using this technology as an educational tool when introduced to scientific activity.

INTRODUCTION

The most important task of higher education is training highly qualified specialists. Nowadays, it is impossible to imagine the educational process at all stages of student preparation without conducting research work. In its turn, the current level of technology, used in the workplace, requires more thorough familiarization and the practice of working with these technologies. The increased social demand for new scientific developments and, accordingly, specialists in this field, requires new ways of involving students in scientific work.

One of these tools is virtual and mixed reality systems. They have a significant number of quality advantages over traditional audio-visual media, for example, conducting dangerous or expensive experiments.

The application of such systems in education is well studied and has its positive and negative aspects [1-9]. Although most studies on quality equipment indicates a positive effect from the use of these technologies. The main area of application lies in the field of natural sciences [10-19]. In this direction, we have carried out a number of studies [20-23], concerning the application of these technologies in teacher training.

Also, there are works where immersive technologies are used to obtain new scientific knowledge. In [24], this technology is used to analyze the diffraction data of a full-scale experiment. In [25], virtual reality technology is used to visualize protein structures. In this paper, we will consider the possibility of using virtual and mixed reality technologies to attract condensed matter to scientific research. The theme of physical research lies in the field of studying soliton-type waves [26, 27].

METHODS AND APPROACHES

During this study we used classvr hardware and software as the environment of VR (virtual reality), AR (augmented reality) and MR (mixed reality), so we could control the operation of each headset and simultaneously, took into account the individual characteristics of each student. The portal system let us download the developed content, which is extremely important when considering non-standard tasks (Fig. 1 a). Moreover, this website has ready developments that can be used in classes in a wide range of disciplines, both at school and at university.

A simple communication mechanism between three-dimensional models of objects and a cube of mixed reality will allow you to make the operational work with models (Fig. 1 b). In addition, control over the focusing of the learner's gaze allows you to more closely track the activity and, if necessary, make adjustments to the learning process.



FIGURE 1. Content and virtual reality headsets: a) VR content management system; b) photo of working with a three-dimensional crystal model through a cube of mixed reality.

We also used the method of polling students participating in the experiment, conducted in the form of a free interview on a given topic.

RESULTS AND DISCUSSION

Involving students in scientific research is always fraught with a number of difficulties. First of all, this is insufficient knowledge and low motivation. The solution of these problems is possible by different methods, in particular, due to material incentives and additional training courses. However, this approach does not solve the main problem associated with saving time. Students need to spend considerable time in order to understand the essence of the research task, to understand the ultimate goal of the study.

The research problems considered in this work are theoretical in nature and cause even more difficulties in solving them. The impossibility of conducting full-scale experiments and the uncertainty of the results of theoretical research leads to the reluctance of students to participate in scientific research. Faced with these problems, it was decided to maximally visualize the investigated processes. For these purposes, we used three-dimensional models constructed using the molecular dynamics method, which greatly simplified the entry of senior students into the process of building models for research. Such an approach, as noted earlier in [14], can already be interpreted as the application of VR. In fact, the construction of computer models provides the basic properties of VR consisting in simulating the impact and reaction to this effect. Virtual laboratories are widespread, both in the learning process and in research. Students did not have any difficulties with the transition from the training models used in the study of special courses in solid state physics to research models.

We noted some features of the interaction with models constructed by the molecular dynamics method. Initially, models were used without visualizing intermediate results and without constructing a three-dimensional view of crystal models. The user entered the initial data in the appropriate fields in the program and started the calculations, which could last several hours. This was not very convenient and reduced the motivation to conduct research. Adding

visualization of the calculation process itself allowed us to solve most of the difficulties associated with a decrease in interest in the work process itself. For visualization, third-party applications were also used.

Further, in more detail from a methodological point of view, we consider scientific problems that students were involved in solving. As already noted, the main attention was paid to soliton-type waves in crystals, the conditions for their existence and propagation. In particular, these are solitary waves, discrete breathers, and crowdions of various dimensions.

Visualization of waves in the continuum approximation usually does not cause difficulties, for example, on the surface of a liquid. At the same time, waves in discrete systems with a short wavelength or localized vibrations of individual particles of a system are more difficult to visualize. Let us consider soliton-type waves — structurally stable waves propagating in a nonlinear medium. Most often, such waves are described by some solution of various differential equations. For example, an equation that describes one of these solitary wave solutions has the form:

$$U(q,t) = 2\alpha^2 \cosh \varepsilon^2 / (1 + \alpha^2 \cosh \varepsilon^2) \quad (1)$$

where $\varepsilon = q - Vt$, α — the amplitude factor, q — the coordinate, V — the soliton speed, t — the time. There is a simpler version in the form of a bell-shaped function that describes the initial profile of a discrete breather with a rigid type of nonlinearity:

$$f(x) = A_0 \exp(-x^2 / 2C^2) \quad (2)$$

where A_0 sets the initial amplitude of the central atoms of the discrete breather, x is the relative coordinate of the pair of atoms in the row, parameter C determines the degree of spatial localization of the discrete breather.

The given examples of a formalized description of physical processes and the formulation of the problem of their modelling in real physical systems caused serious difficulties. The classical description of the given functions in the form of graphs did not provide a proper understanding of the physical essence of the processes in crystals. The situation improved with the demonstration of three-dimensional models on the screen constructed by the method of molecular dynamics. But when solving scientific problems, it is not always possible to demonstrate ready-made models based on a formalized description. Therefore, we developed content for virtual reality headsets in the form of three-dimensional crystal models.

The construction of such simple models does not require much effort and can be carried out in the appropriate graphic editor. When working with them, students can understand the basic issues of constructing crystal models, study crystallographic planes without significant time and reading literature. For more complex models, export to the appropriate format from molecular dynamics model data files was used. For example, Fig. 2 (a) shows the wave front described by (1). In Fig. 2 (b) we showed a nickel crystal with nanopores.

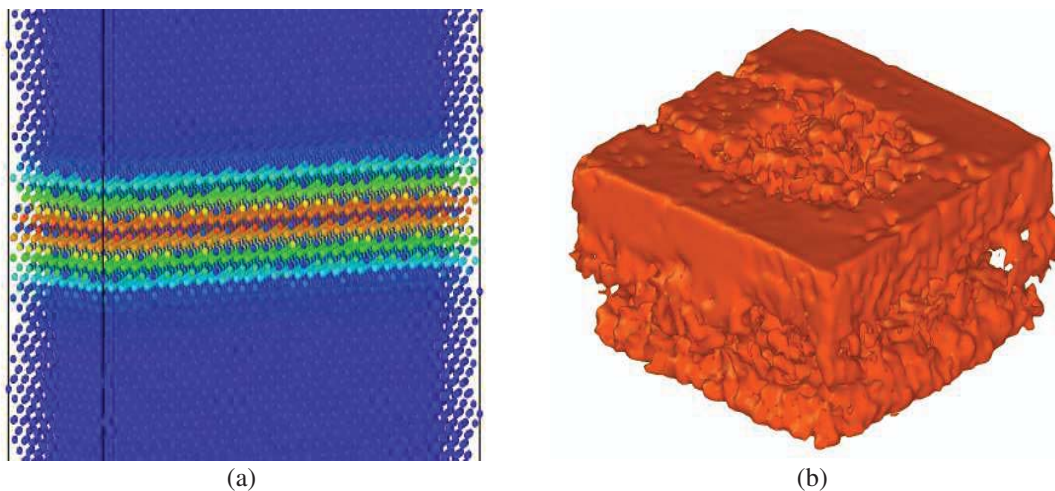


FIGURE 2. Three-dimensional models: a) propagation of a solitary wave; b) nanopores in a crystal.

The above illustrations of three-dimensional objects (Fig. 2 a and b) allowed students to clearly understand complex concepts and increased interest in further work.

Two-dimensional models were also demonstrated using virtual reality headsets. Most students noted that two-dimensional models are better perceived on a computer screen. The total number of students participating in the

experiment was 12 people, who are the best senior students motivated by scientific activity. Everyone noted that working with three-dimensional objects through VR headsets and a cube of mixed reality is convenient and allows you to understand in detail the features of the objects under study.

When introducing condensed matter into scientific activity in the field of physics, students face complex tasks related to the visualization of complex objects of the microworld. The use of VR technology allows us to simplify this process in the initial stages. Like many other technical means of teaching, VR headset can increase the interest and motivation of students, and facilitate the assimilation of complex scientific concepts and a description of physical processes. One of the active factors is the novelty of this technology and complete immersion in the environment, which reduces the effect of distractions. It should be noted that the further successful activity of students in carrying out scientific research depends on their determination and basic knowledge in this area.

CONCLUSION

Application of these technologies is increasing students' interest in the subject of studies. Obviously, this is primarily due to the novelty and unusual equipment. At the same time, it has increased the interest in scientific activity on the part of students. The application of these methods uses more clearly complex objects on the example of nanopores and other objects of the microworld in crystals.

Summarizing, we can say that the use of VR as a means to enhance students' interest in research in physics seems promising. Determination of the scope of use of VR content and its concretization requires a longer and more detailed study in a specific area of research in physics. The results of this study indicate the appropriateness of applying this technology in the considered direction of student learning.

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