Invited Paper

Computers in Optics Education: Principles and Basic Models

Michael A. Vorontsov

International Laser Center, Moscow State University,
119899 Moscow, USSR

Modern optics looks like a quickly growing tree with its numerous branches rushed upwards and its branched top (Fig.1). According to this analogy the problems of the optics education are to interest young talented people in a ripe fruit of that tree, to help them reach the low branches of the tree and to show them the way to the top. There are plenty of ways leading to the fruit-bearing top, and every teacher who works hard in this or that field of optics has his optimal algorithm of reaching the top.

Fortunately, conservatism protecting the young generation from the revolutionary changes the unfortunate consequences of which are as a rule very difficult to predict is inherent to education. We use a blackboard, a piece of chalk, deliver lectures, have individual talks, solve problems just in the same way as it was three hundred years ago. These traditional forms of teaching are preferable because of peculiarities of perception.

On the other hand, quick and uncontrolled growth of our optical tree stimulates the search of new forms of teaching (most effective ways of climbing up the top).

Changes in science and technology haven't made a great influence on the forms of teaching. There were no particular problems: cinema, video-techniques, slides that have not changed anything in teaching, are usually used at the lectures and seldom at the seminars. And it is here that we see the triumph of sensible conservatism because most of students and teachers prefer not slides and films but a piece of chalk, a blackboard and a duster that will do to perform a fascinating drama of appearing a new piece of knowledge in sight of the students.

And at last modern personal computers have appeared. How to use this up-to-date equipment in the process of teaching? As a rule revolutionary ideas are first to appear. They are to rase to the ground all the old forms of teaching (the heritage of the "dark" past) and on their debris to build a new dazzling world of complete computer teaching.

Whatever perfect the program of teaching could be the substitution of the teacher by a computer inevitably violates the personal emotion environment where the process of teaching takes place. Effective teaching is impossible without mutual emotions, lively humor, competition, delicate human interrelations. It is probably the reason of this very complicated teaching programs based on a developed dialogue with a computer on the principle of "question-answer" that serious objections both from students and teachers are raised. Instead of answering numerous questions of the program, students are more interested in "breaking it up", and receiving all correct answers (the winner takes all) * .

As for the objections of teachers they are considered as the protest against dictatorship in education that inevitably appears after the revolutionary changes. The methods of teaching are dictated by the authors of the program, that causes general dissatisfaction and it is justly classified as an encroachment on the rights and freedom to bring up a young generation after one's pattern and likeness.

At the same time in some countries more essential and advanced teaching programs on general physics were compiled, and subjects in optics take a significant place among them. The program module PLATO (Control Data Corporation), program products of California and Stanford Universities, teaching programs developed in Sophia, Moscow and Novosibirsk Universities in the laboratory of computer technology education of the USA led by A. Bork and others should be especially distinguished among them [1-3]. Nevertheless it is not still early to speak of a large scale of computer application in teaching **.

Modern computer education in physics represents a mixture of ideas and program products, different in subjects, methods, level of complexity and technical implementation. (In case of this strong statement we refer to [4]).

* *Here the ideology of WTA type (Winner Takes All) set to the neurons of our brain seems to function.*

** *In this respect, short courses of lectures delivered by a number of leading scientists in the field of modern optics in the International Laser Center of Moscow University are extremely significant. Not one of the lecturers who have came from different countries applied any teaching programs. The brilliant lectures on non-linear optics delivered by Prof. Alan Newell, who used standard technical facilities - a piece of chalk, a blackboard and 2 or 3 slides with the views of beautiful Arizona at the end of the lecture made a very deep impression.*

 0-8194-0732-1/92/$4.00

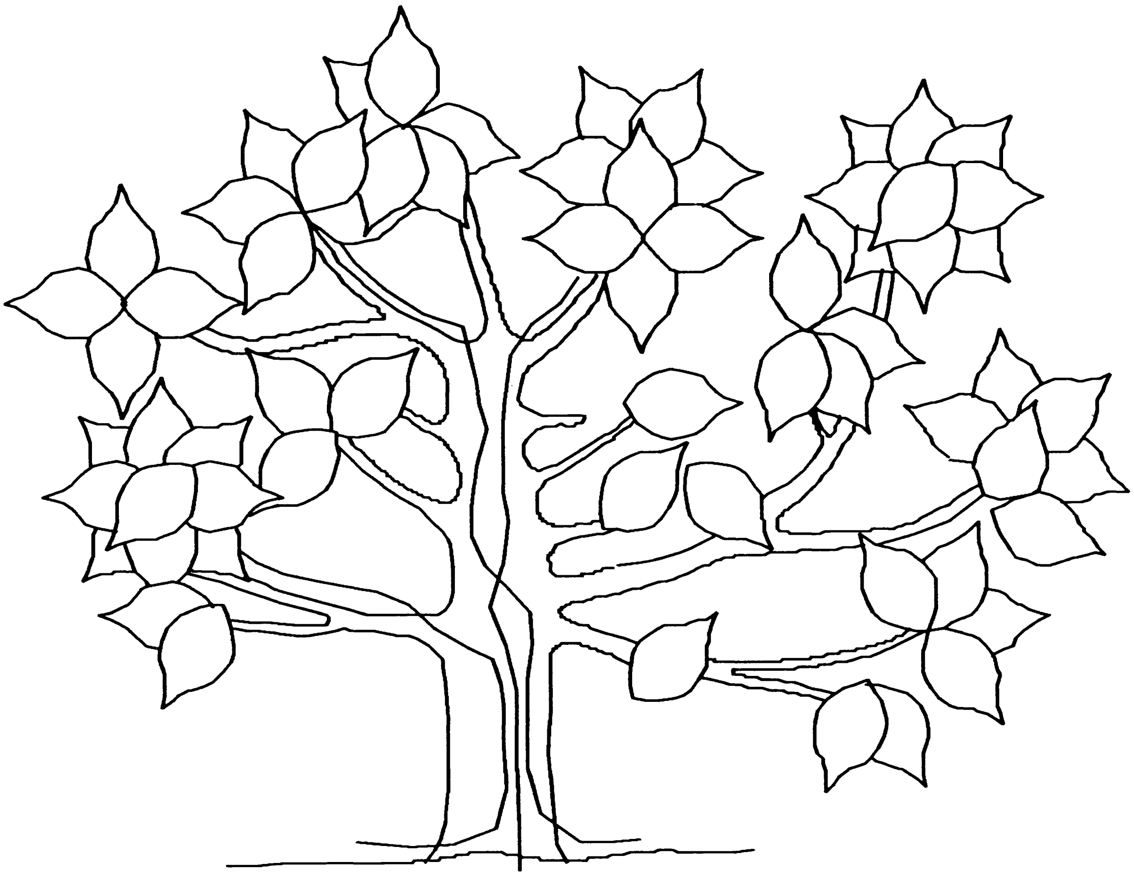

Fig.1. Which way to the top of the optical tree is the best one ?

Without claiming to generalization let's consider some ideas underlying computer optics education today. The situation is not so hopeless as it seems on the face of it. The ice has been broken - the lectures accompaned by computer demonstration have been getting accustomed [5]. As for the ideology, probably, there are no special problems in the development of such a type of program product, although, of course, we should like to have well-prepared libraries for computer application at the lectures. But is it really time to collect the demonstration programs scattered all over the world, and how to do it?

Besides the computer lecture demonstrations there are program modules to accompany the seminar studies . They are closely connected with the topics discussed at the seminars and, as a rule, they are related as their expansion and generalization. Choosing the examples for discussion, the teacher concerns to a considerable extent about analytical solutions. As a result there a restricted class of idealized,"classical" examples (modules) that are very far from our real optical life is formed . Any step aside (the integral not taken in quadratures, the differential equation having no analytical solution, etc.) make students protest and they consider it as the rudest violation of the fundamental "rule of the game" which they know very well - the answer for the problem may be only expressed by an analytical formula.

From this point of view, the computer problems accompanying the seminars are very important. They allow to break the "chains of analytics to some extent and to show the students the wonderful world of real optical problems. In the way of freedom for computer choice there appears another danger, and as our experience shows it is real enough.

Love goes away, love of "a wonderful Formula" for the sake of which it is worth spending time and efforts. A peculiar computer reflex is being developed: having learnt the task set, students try to compile the program immediately without any attempt to find the analytical form.

Let us pay attention to one more type of the program product of the optics education. That is a computer or a so-called electronic textbook [4-6]. Such program module may include the text of the textbook proper with the examples of computer demonstrations of the basic statements and models, the system of problems and the reference information. Lecture computer demonstrations and program modules accompaning the seminars may be included into an electronic textbook. This work demands great efforts from teachers and the programmers. At the same time it is difficult to say a'priori whether the result will be productive.

The classical "paper" text-book is good because it can be read in the way you like, and anywhere you like in the tube or at the beach, it is always at hand. In short teachers and students like it so much that they will be hardly delighted to accept an electronic text-book. There are plenty of "paper" text-books, every teacher who worked N-number of years (N>1) has already written or, at least, hopes to write a text-book that will be considered to be the best one. The electronic text-book is inevitably a collective work (for one person it is a very excessive toil *) .

And how to keep individualism in the teaching literature, on the one hand and to use the possibilities of a computer on the other hand? The solution has appeared to be rather simple. The standard "paper" text-book is provided with a diskette of computer examples, problems, some demonstrations[6]. Such careful introduction of computers into the teaching process is effective by all means, if an electronic text-book is not turned into a tedious accompanying description of programs. It should be noted that in this case a computer is also only an effective accompaniment (orchestration) of the traditional forms of education, but not a new element of the teaching process.

So, is it possible to bring up something fundamentally new into education with the help of a computer? Lately a very good term "computer medium" has appeared[7]. This term like an unknown flying object appears in different aspects in the articles on computer technology education, in the speeches at conferences and discussions.

First of all it is necessary to find out what has caused the appearance of seditious ideas of creating the computer medium for optics education. For this purpose let us consider in general the structure of optics education at Moscow University. At the first stage (1 and 2 academic years) optics is presented by one of the sections of the general physics course. (During the 4 term there are 2 lectures and a seminar per week and laboratory works and 2 oral examinations.) According to our analogy at this stage a student who has climbed up along the tree trunk can see numerous branches leading to the top (basic directions of physical optics). Then the students are allotted to the departments where their further specialization is determined. After that the student chooses a narrower specialization, comes to the laboratory, to this or that teacher who in this case is granted an "honorary title" - a scientific supervisor.

Let us consider the problems arising in a scientific lab because of the students having the "initial optics training". The newcomers who peep timidly through the laboratory door provoke contradicting feelings. On the one hand we are always short of hands and brains. There are always more problems than opportunities for their solution and in this case the student's coming is always welcome. On the other hand .... What a great deal of time, efforts and nerves you must spend to make a newcomer feel at ease in the lab and give real help to the common cause.

Moreover, active and fruitful scientific research and bringing up a young generation are the things which are difficult to combine. One, two students of the 3d, 4th and 5th years and two or three post-graduates and modus vivendi is changed. You take integrals seldom, your soldering iron is used more seldom and you prefer BASIC to other programming languages. It is like a drug. You complain of students and say that without them you could "advance, prove, show and do something". And if they disappeared ... ? Apparently, the only medicine is - to make a point of writing equations (but not hare-brained schemes) more than the most active student or post-graduate does.

The method for developing of optics thinking (student's bringing up in the lab) is usually rather strict. Having immediately received a "piece" of a current problem, the scientific supervisor is working at, and the references to the latest journal publications, the student goes to the library in being slightly shocked. He spends one or two weeks to understand at last that he will have to work hard and much. He appears in the lab with dimmed eyes and after his first words it becomes clear to his scientific supervisor that education is an iteration process. As a result the initial task is reduced up to almost a trivial one, then there follows a number of heart-to-heart talks about general principles, text-books, etc. The frontal attack is changed for systematic, hard "climbing"; the training task is gradually complicated, talks become longer and more interesting; something is kept in the student's head as a result of numerous special courses that the student takes at the department. All this said lasts 3,5 years and only at the very end, during the diploma period the laboratory gains the colleague who is utterly devoted to optics. It would be good to work together but very often they have to part. (After graduating from the university only about 1/5-1/7 of students take the post-graduation course).

The laboratory has to part not only with the student or the post-graduate but it leaves a fresh sprout of the optics

**As is known the worst text-books are those which have been written by group of authors and the more of them take part in this work, the worse the text-book will be.*

branch to the mercy of fate . The student together with his teacher have carefully grown it for the three years. But a young gardener has gone away and very often there is not energy enough to keep the young sprout alive. (A sad famous statement comes to the mind " ... there is no man, there is no problem").

It will be good if someone who is following the young specialist picks up the idea or after graduating the university the student will continue the common work. But the latter can be related as a rare case.

Fresh air flow together with new students and post-graduates filling the university laboratories blowing away the dust from the top of the optics tree sweep away only having time to inhale fragrance aroma of its fruit. It is nobleness to keep it because it is a wind. It is possible, however, to keep anything ?

Here it is the basic on which computer product for education (computer medium) must be produced.
It is possible to try and solve two main problems with the help of the computer medium: to make a teacher free from the routine work in education for creative work and to keep new sprouts of knowledge in optics. (Besides the financial problem that can be determined as the most important one. " Of all arts for us the most important is ..." extorting money to continue our research.)

How to create the computer medium? The simplest thing (that does not demand special efforts) is to formulate general instructions by drawing the most beautiful building out of general arguments, diagrams and schemes on a sheet of paper.

But we shall take another way because as K.Marx said "There is no wide high way in science ..." but " ... only rocky paths". (As for the wide high ways in Russia there were always difficulties with them, and the classic writers pointed to this fact.)

Giving the certain example let us try to find possible ways of the computer medium creating in a "sovereign" laboratory of controlled laser systems of the Physical Department and International Laser Center at the Moscow University [8]. The sphere of scientific interests of the laboratory (Fig.2) - is a small part of the optics tree top. You can see strangely mixed branches, sticking out twigs, broken sprouts. In short - it looks like jungle. Where are the former plans and schemes, well-composed "projects" for the development of the laboratory? And how much paper has been covered with writing on this point? Our part of the optics tree as well as all others grows as it can and let it be so.

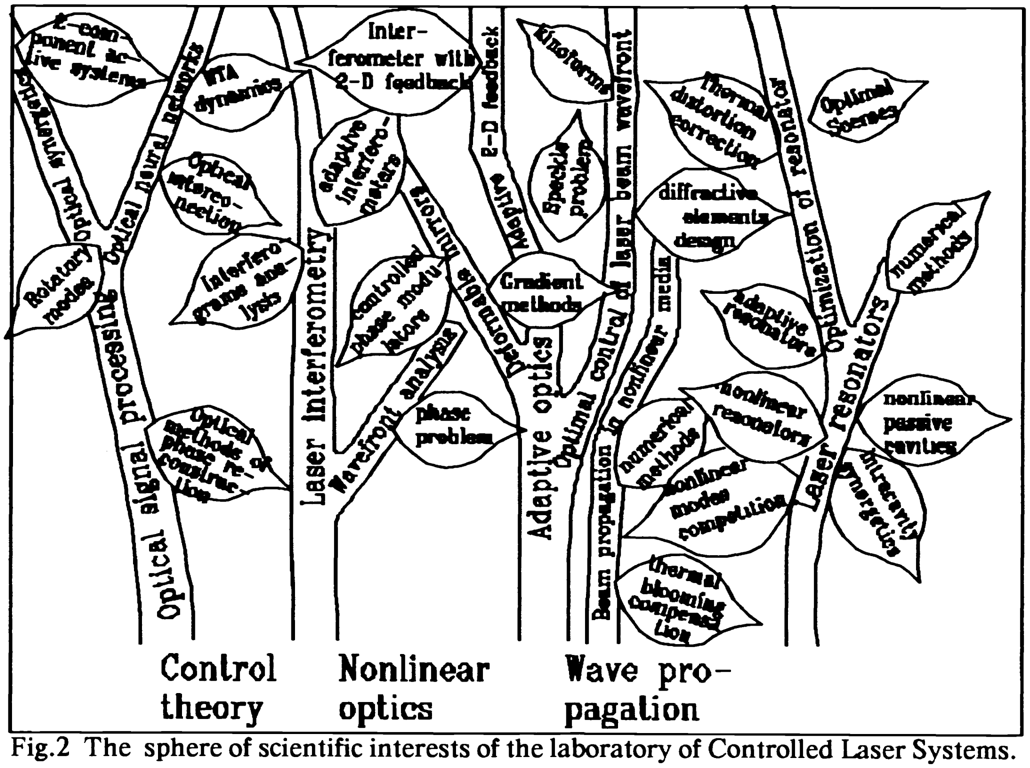

Fig.2 The sphere of scientific interests of the laboratory of Controlled Laser Systems.

Looking at the scheme (Fig.2) it is not difficult to notice a few "strategic" directions according to which the movement takes place: interferometry, adaptive optics, optical processing of information, resonators. Of course, this division is conventional, the directions are closely intertwined and continuously interacted. The deviations from the "general" lines occur all the time, side-line connections appear (often arbitrary), however it is not so important for students. At the first stage of the work in the laboratory his main task is to reach one of the "hot" problems as soon as possible and proceed to the real scientific research.

Suppose the student has taken an interest in the problems connected with the study of the optical resonators; new schemes, resonators with aspherical optics, adaptive resonators, nonlinear resonators, dynamic spatial modes, interaction and competition of nonlinear modes, introcavity synergetics, a nonlinear resonator as an optical computer and etc. All these words that we say at the first meeting look like peculiar invocations, hypnosis, the main purpose of which is to tempt an unexperienced soul. At last you have gained your object. And what is left of that brilliant monologue (of the first talk)? If sobebody asks what it was about? The answer will be of the kind: "... something about resonators, I don't remember strictly, but it sounds fantastically beautiful indeed". After the course of general physics there was summer. It is not surprising that all the information that has been kept in the student's mind about resonators is the imperishable image of two mirrors put against each ather.

This is our starting point. It's just the time to "palm off" the program on the student and place him into the computer resonator active medium. Perhaps, generation will start. At last the program is loaded - into the computer. On the screen there appear words: "Work level": "Freshman", "Know something", "Expert", "In case of difficulties in any place call *help*". Having takln any level out of three work levels (of cause, "*specialist*") the student is in "pure resonator field", with two plane mirrors being along the edges of the field. At the bottom of the field there are building blocks: a piece of active medium, a thin lense and a thick one.

After a short excursion around the main menu operations the student finds the content of the embedded:
electronic text-book, the instruction on the work with the program, the library of classical resonator schemes, the library of optical schemes of modern lasers, personal libraries of resonators of his senior mates, numerous tables and reference data, bibliography of resonators, etc. (The detailed descriptions of the program module structures and functions are given in the supplement).

Now not the program module pooper is so important for us, but the character of "interrelations" of the student, the teacher and the computer medium in the process of teaching.

It is quite evident that the student does not read the textbook, instructions, etc. - the most important thing for him is to act. In 5-10 minutes on the clean resonator field between the mirrors there will just appear the first element, for example, an active medium. It has been picked up by the "mouse", but ... by attempting to make a "soft landing" for the element of the resonator field there also appear first difficulties.

Without filling in the table of the input parameters of the element the landing does not take place *. Of course, a set of arbitrary data will follow as an answer, however, such attempts as a rule fail. Remembering about the helping hand, the student marks the word which is not clear for him and presses "*Help*".

The program extracts from the memory a short explanation what a word is and points out the corresponding place in the electronic text book where this term is described is detail. Having marked this place by the mouse, the students immediately receives the necessary part of the text book.

The first rule of the computer medium. The information is given only when it is necessary.

Suppose, everything is clear with "*words*", but what figures should be selected? Having pointed to the figure and called *Help* the student receives the table of physical values characteristic of the parameter chosen - one of the electronic tables has operated. If is in this way that adaptation to the resonator "*words*" and resonator "*figures*" begins.

However, the probable outcome of the first attempt is a failure. The meaning of a number of terms is not properly understood even in reading certain pieces of the textbook (the reason is the lack of general training in physics). The way out of such a situation is very simple - to load the program module once more and to confess that unfortunately the real resonator training now corresponds only to the level "*freshman*". While working at this level conditions remain formally the same regime, however, some possibilities prove

* *For the active element the input parameters are: the index of refraction, the surfaces curvature, the parameters of the thermal lens or lenslike medium, the angles of the element inclination to the optical axis.*

to be blocked. The list of the input parameters and the output characteristics are essentially restricted and only the most intelligible "*words*" are presented. And the problem of making the first optical resonator scheme in the students life is simplified. At last, arranging the elements of the resonator field queerly and moving them left to right, the student thinks that it is time to assure what a wonderful resonator he has constructed.

Generally speaking, the program module allows to research the behavior of any (in the list) output parameter of the resonator from the change of any of the characteristics of the arbitrarily chosen element. (For the simplest resonator made of three elements it is about 200 functions).

The second rule. The maximum freedom in selecting the object for research and its characteristics.

And what is freedom for those who are not prepared for it? It is natural, that the optical scheme constructed inproficiently is capable to answer any inquiry only by means of endlessly tedious diagrams (a straight line along the axis, something in infinity, etc) and by boring instructions of the kind "You have obtained an absurd result from the physical point of view - go on reading the text-book".

Having played in the resonator field for two hours, the student addresses the teacher for the further instructions. The student is sent to the library as it is always done in the best computer traditions. In this case it is the library of "*classical resonator schemes*" built-in into the computer medium , and it is desirable that teaching should begin with investigating these schemes.

The program module is loaded again and the library file is activated. One of the familar schemes there appears in the resonator field (a resonator with a plane mirror or a confocal resonator, or a semiconfocal resonator or, etc.) What is to do with it?

"What is to do?" - this is the most popular question nowadays and it appears on the screen together with the chosen "classical resonator scheme". Pointing to the scheme with the mouse the student receives the note: "Analyze ..., make clear ..., try ... this or that". It is "the collection of problems and exercises" built-in into the medium and written in a free manner. Here one can come across some notes, commentaries, emotional statements on certain problems and resonator schemes. All this fortune has been made by the teachers, undergraduates and the post-graduates as well. Thus, step by step the "resonator teaching medium" is being consistently created.

Everybody has the right to make his own contribution but for this purpose it is necessary to work at the level of "*Expert*". Only at this level everything is permitted: if you don't like how the text-book is written - write your own one and replace, correct tables, enrich bibliography, compile your library of classical and other resonators. If you prepare for the lecture and a new idea comes to your mind (why not) - put it quickly into the computer medium, into the text-book, the library. The main idea is not to lose it (to bring to the computer). If a student has found a new piece information, then input it quickly into the tables. If a post-graduate has made a new interesting resonator scheme - input it into the library too, and with the commentary, please. And it is desirable that new publications should be referred to.

The third rule. Simplicity and ease of the teaching material correction.

The computer medium is quickly filled up, exceed the limits of those original opportunities. But you needn't worry about it - it's possible to widen it. For example, somebody has noticed that the resonator schemes with a broken axis are in fashion. Well, than we shall "break" the axis (to break - is not to build). We shall add a new option ("the resonators with the optical axis break"); we shall "land" it on one of the menu branches. "You'd better take a notice of a thermal lens" - the post-graduate notices - "... there is a program", and we shall include it into the medium.

The computer medium growstogether with the local part of our optical tree. It is the copy, the trace of our efforts. Traveling along the latter the student learns much not only about optics; he also learns something from the history of the laboratory. It should be noted that the same program module can't be loaded non-stop everything has its limits. Having achieved critical mass, a computer medium generates the other one.

The fourth rule - succession, indivisible structure of the program envelope, the possibilities of add-in.

Students and post-graduates leave the laboratory, but their work does not disappear, it is accumulated in the computer medium; new possibilities, problems, libraries appear and bibliography is widened.

We have described only one example of the computer medium for optics education. Besides the resonator field the interferometric one will appear soon (the research in this field is under way). Taking account of the scientific interests of the laboratory "the interferometric field" will certainly give rise to the branches (menu options) of the problems for retrieval of the phase, the solution of the reverse problems of the phase diagnostics and etc.

Starting with the classical problems of diffraction on the periodical structures one can construct one more computer medium filling it up with amplitude and phase lattices (possibility to vary the bar profile, the lattice size, the light conditions) by the thermal lenses, by the simplest types of holograms. Here there are its own libraries of "classical diffraction lattices", its own text-book, reference-material, problems. From this basic branch to holography, to the problems of syntheses of diffraction optics elements, to the selection of modes, to the schemes of wave front conjugation and etc.

Matrix optics is an excellent object for the computer medium work. The optics information processing has its own "field", its own scripts of the program module formation and lots of possibilities.

Optical physics from the education view point is an unique subject. "The deposition depth" of the most fascinating problems is relatively small. Once you scratch the surface, make a step and you will find yourself in a surprizingly beautiful and dynamic world of modern optics. And it is the computer medium that can help a student to make this step.

And what is the computer medium of the optics education as we see it? First of all this is a virgin land for the activity in the chosen direction of optics.

One of its main aims is the creation of special conditions for progressive movement from the fundamentals of optics to its modern problems within the unique program module.

The other purpose is to establish a direct dialog between the freshman who begins to open the world of optics for himself and the expert (scientist) who has perceived its beauty and complexity.

Working in the common computer medium the student must have a possibility to peep behind that border to which he has just come, and see what occurs there, to know what problems his senior colleagues are busy with.

On the other hand the expert, the specialist in the field of modern optics who has passed a thorny path often has no time and necessary conditions to warn and direct the freshman, and to give him "a piece" of his important experience.

The computer medium must give him such an opportunity. The organization and creation of the computer medium of optics education requires mutual efforts of many laboratories, programmers, financial and practical support. "The game is worth the candle" and the stake in this game is a really new quality of optics education.

References

1. D.Kane, B.Sherwood, in "*Computer Assisted Learning in Physics Education*", Oxford, Pergamon, 1980.
2.. A.Bork, "Education and computers: the situation today and some possible futures", T.I.E. Journal, **12** (3), pp. 92-97, 1984.
3. B.Cabrera, J.I.Terman, She Xin Wei, "Physics Simulations", Phys. Dep. Stanford Univ.,1986.
4. J.W.Wilson, E.F.Redish,"Using computers in teaching physics", Phys. Today., **42**, No. 1, pp. 34-41, 1989.
5. H.Gould, J.Tobochnik, "An Introduction to Computer Simulation Methods", Addision-Wesley, Reading, MA, 1988.
6. D.W.Heerman, "Computer Simulation Methods in Theoretical Physics", Springer-Verlag, 1986.
7. W.M.Mac Donald, E.F.Redish, J.W.Wilson, "The MUPPET Manifesto. The Maryland University Project on Physics and Educational Technology uses microcomputers in the classroom to teach physics", Computer in Physics, No.4,pp.23-30,1988.
8. V.E.Kunitsyn, A.N.Matveev, M.A.Vorontsov, "Technology of Teaching Physics in a Computer Environment", Proceedings International Conference on Advanced Research on Computers in Education, Tokyo, Japan, pp.71-79, 1990.

Supplement

Computer medium: Optical resonators; design and analysis

Borodina I.A., Iroshnikov N.G., Vorontsov M.A.

International Laser Center, Physical Department, Moscow State University,
119899 Moscow, USSR

The Purpose Of Program Module; Operation Levels

Program module "Optical resonators" is an example of computer media aimed for optical education; this module was designed for preliminary acquaintance, further comprehensive study and professional work in modern branch of physical and applied optics called "Laser optical resonators".

The module contains:
-software for designing and analysis of various types of resonators;
-special already installed "electronic" textbook for preliminary acquaintance with optics of resonators;
-the library of optical schemes of "classical" resonators extended by comments and problems for their study;
-vast bibliography concerning the optics of resonators from textbooks and classical works up to surveys and original scientific papers;
-the library of schemes of modern lasers;
-references about basic elements of laser's resonators;
-sophisticated helper accessible at the stage of designing and analysis of resonator schemes;
-opportunities to create personal libraries about resonators and of archiving analysis data.
Program module includes 3 basic operation levels.

Level 1. "newcomer"

This level is to be used for preliminary acquaintance with the theme "Optical resonators". Apparently it corresponds to the level of juniors of universities and technical colleges.This level requires both active use of "electronic" textbook and ordinary educational books of general physics. Besides this, the library of "classical" resonators (CRES.LIB) with comments and problems is available for the user of the first level. One can choose particular scheme of resonator and study its main features. It should be add that user can vary values of some parameters of optical elements of "classical" schemes and investigate their influence on resonator characteristics. The rotection of the library from intentional or random failures is established.

Electronic textbook, libraries of resonators, references, comments and problems can be modified, extended or even completely replaced by another ones without any failure of main program module. All these changes can be accomplished from the third (professional) level. Therefore, in the frame of program module one or another way of study of the subject by the user of the first level can be implemented. Thus, teacher (expert, scientist) shares experience, methodical recommendations, tasks and comments with newcomer. So program module is an open system with advanced feedback.

Finally, program capabilities of the first level can be employed for computer lecture demonstrations, in composing home tasks, control works, in choosing subjects of colloquiums.

Level 2. "student"

This level is proposed for more comprehensive study of optical resonators. This is the level of those students who have taken optics as their subject.

Comparing with the first level a number of new options are available:
-designing of various schemes of optical resonators;
-composing personal library about resonators;
-enhanced number of opportunities for analysis of resonators is provided (here the notions of parameter of stability, Gauss mode, thermal lens etc. are introduced);
-more extensive educational and reference information is included;
-installation of the libraries of optical schemes of modern resonators been practically implemented (MRC.LIB). User can investigate these schemes; also following chosen type of resonator taken from the library one can try to optimize its geometry and basic features.

Program options of the second level can be used in the courses of laser physics, in composing home tasks, term papers and diplomas.

level 3 "expert"

This is professional operation level for post graduates specializing in laser physics, engineers, designers of laser systems, scientists investigating new types of resonators.

Module software of this level provides the following options:

-design and analysis of various types of stable optical resonators in the frame of the ray approximation, taking into account radially symmetric thermal distortions of active element; also investigation of resonators with breaks of optical axis and angular depositioning of optical elements;

-composing the libraries of optical schemes of resonators;

-comparison of various resonator schemes.

Functions Of Program Module.

files creation analysis parameters

-reading (loading) the file , which contains optical scheme of resonator, from hard disk or external media;

-saving (storing and writing) an optical scheme of resonator to file;

-renewing information displayed at the screen;

-choosing certain scheme of resonator to be modified and analyzed;

-printing the scheme of resonator;

-viewing arbitrary text file;

-reading the description of given program;

-exiting the program;

-choosing and fixing of optical elements;

-correction of values of parameters of optical elements;

-displacing elements along optical axis of resonator;

-removing optical elements;

-restoring of the element just removed;

-viewing the information about parameters of any element of optical system;

-viewing the list of main parameters of resonator;

-investigating dependencies of resonator characteristics on parameters of particular optical element;

-printing graphical information;

-displaying acoustics of main Gauss mode;

-calculation of radius of the beam of main mode in any cross section of resonator, including optical elements;

-fixing basic parameters of optical elements of resonator;

-creating configuration files;

-reading configuration files from hard disk or external media.

Main Options Of The Program

In the frame of the ray approximation program module allows to design and analyze optical schemes of both stable and unstable resonators that contain the following elements:

-mirrors with arbitrary radius of curvature of surface;

-thin lenses with various focal lengths;

-thick lenses with different radii of curvature of surfaces (user assigns thickness and refractive index of substance);

-active elements with arbitrary refractive indexes and lengths.

One can account the influence of radially symmetric thermal lens of active element, and also choose the active element with non-plane front and back sides (spherical sides or plane sides fixed at given angle to optical axis of resonator are implied). Each optical element can be fixed at arbitrary angle to optical axis, and in the frame of geometrical optics this allows to treat the influence of depositioning of optical elements, the presence of plane-parallel plates in resonator, also this provides the opportunity to calculate complicated resonators with breaks of optical axis.

Optical elements can be fixed close to each other, therefore this ensures the possibility to analyze the resonators with combined optical elements.

Program module allows to calculate the most important characteristics of optical resonators:

-parameter of stability; -coefficient of magnification;

-coefficient of geometrical losses;

-beam path inside resonator;

-radius of beam constriction of main Gauss mode;

-position of constriction;
-beam radii at mirror surfaces;
-confocal parameter of Gauss beam;
-radius of wave front at the plane of output mirror;
-Fresnel number of resonator;
-value of radius of main mode beam at any plane inside resonator, including optical elements.
All calculations are performed by the methods of matrix optics.

Computer Textbook "Optical resonators; design and analysis"

1. The structure and operation options of program module.
2. General information about resonators (main elements and their parameters).
3. Ideal resonators; analysis by means of geometrical optics.
4. "Gauss" mode.
5. Active element; thermal deformations.
6. Resonators with breaks of optical axis.
7. Libraries of resonators (physical and historical characteristics of library files; references).
8. Reference data (lists of specific values of parameters).
9. Bibliography.