# NUMERICAL MODEL OF ATMOSPHERIC ADAPTIVE OPTICAL SYSTEM. III. A COMPUTER VERSION OF THE MODEL

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*The program package developed on the basis of the numerical model of an adaptive optical system, discussed in the first two parts of the paper, is described. Particular attention is paid to the package interface, which provides graphical input and output of information and allows users to deal with the package without special training in programming.*

## 1. CHARACTERISTICS AND STRUCTURE OF THE PROGRAM PACKAGE

Based on the numerical algorithms considered in Parts 1 and 2 of the present paper, we have developed the program package for simulating the operation of an atmospheric adaptive optical system. When conducting numerical experiments the software package provides the following possibilities:

—setting of conditions of beam propagation (propagation in linear medium, under conditions of thermal blooming, in the turbulent atmosphere, under joint action of both latter factors);

— setting of the experimental geometry (vertical, slant, and horizontal paths);

— setting of the components of the adaptive system (the type of an adaptive mirror and a wave—front sensor);

— selection of the algorithm for beam control (phase conjugation, inversion of wave front);

— use of the set of service functions (solution of the problem and recording of amplitude and phase distributions at each step as well as with the subsequent plotting of dynamics, graphic representation of the results on a display screen and/or on a printer).

As a separate program unit with a built—in interface, the package includes the model of a flexible static mirror constructed on the basis of the finite—element method. (Part 2, Section 6 of the present paper). The mirror parameters are set before running the basic program. When forming the adaptive system element base the mirror is included into the full model.

The developed program package is adapted to WINDOWS what makes it possible to use the VISUAL BASIC language[2] supported by this system. VISUAL BASIC enables one to implement the program control and parameter input/output operations of the form convenient for an user. At the same time, the basic computational procedures are written in FORTRAN language, what provides higher speed of operation as compared with VISUAL BASIC and has a wider set of built—in functions. The interaction is performed using the dynamic DLL library[2] in which some subroutines written in FORTRAN are stored.

## 2. SETTING OF PROPAGATION CONDITIONS AND FORMATION OF ELEMENT BASE OF AN ADAPTIVE SYSTEM

The parameters of an adaptive system are set by means of a specially developed graphic interface. In this case the program can be controlled using a computer keyboard or a mouse. Figure 1 shows the principal window of interface appearing on the display screen when making reference to the program. The column with the keys of the parameters setting occurs in the right—hand part of the window. They serve for initiating the following functions.
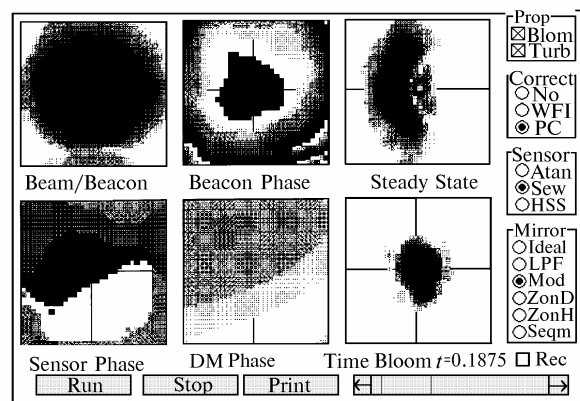


*FIG. 1.*

Key group **Prop** is intended for the selection of the beam propagation conditions (propagation under conditions of thermal blooming, in the turbulent atmosphere, vacuum, or with simultaneous consideration of turbulence and nonlinearity).

Key group **Correct** is intended for the selection of the algorithm of compensation for distortions. It is possible to consider the beam propagation in the absence of correction as well as to realize the control based on the algorithm of wave front inversion or phase conjugation.

Key group **Sensor** is intended for selection of the wave—front sensor (an ideal sensor, a possibility to supplement an ideal device with the algorithm of joining of phase surface, and introduction of a Hartmann sensor into the system).

Group **Mirror** is intended for selection of an adaptive mirror.

Six half—tone figures occur in the central part of the interface main window. These figures show:

1) intensity of the basic or reference beam (according to the user's choice) in the plane of the emitter aperture;

2) phase distribution of the reference beam;

3) beam intensity distribution in the observation plane at thermal blooming;

4) phase distribution recorded by the wave—front sensor;

5) phase surface reproduced by an adaptive mirror;

6) running distribution of beam intensity in the observation plane.

The output to supplementary windows of the interface, by means of which the beam parameters (power, radius, wavelength) are set as well as the atmospheric parameters (wind velocity, turbulence intensity, absorption coefficient, and so on) is done via the menu of the main window.

## 3. SETTING PARAMETERS OF A FLEXIBLE STATIC MIRROR

As was noted above the setting of parameters of the flexible static mirror in the above considered program package is formulated as a separate block. The basic interface windows are described in the present section.
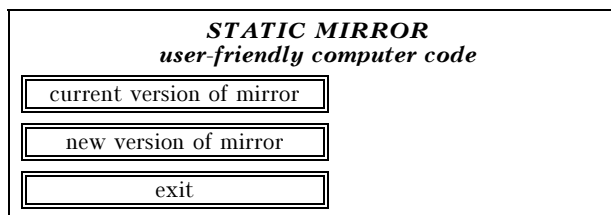
*FIG. 2.*

With the call to the program, the first window appears in the display screen (Fig. 2), which provides for
— output of parameters of the mirror model recorded beforehand (the key "Current version of the mirror");
— calculation and recording of the rigidity matrix of a new model of the mirror (the key "New version of the mirror");
— completion of the program operation (the key "Exit").

As a result of the call to the block for reading the rigidity matrix parameters, the panel DEMO appears in the screen (Fig. 3). In the left upper corner of this panel the diagram of the mirror is given. The points of actuator fastening are denoted by circles, the points of mirror fastening to the base are denoted by squares. Besides, the panel shows such parameters as the material of the plate, the number of actuators and points of fastening as well as the dimension of the computation grid. This block makes it possible to assess the quality of reproducting the lowest Zernike polynomials with the mirror (the keys "defocusing," "astigmatism," "coma," "sph. aberration"). When pressing these keys the image of the reproduced polynomial and the mirror surface appears at the lower left, the screen shows the value of the rms error of reproduction.

If the other rigidity matrix should be given, the program block is controlled by means of the interface panel "Main Panel" (Fig. 4). Here the user can select material of the plate and set the dimension of the computation grid (maximum size is 21×21). The number of mirror actuators, which cannot exceed the number of nodes, also depends on the latter parameter. The program operation is facilitated by the instructions at the screen.

Setting of the geometry of actuators location is done with the panel given in Fig. 5. In the left–hand part of Fig. 5, the calculating grid is presented where the points of possible location of actuators are denoted by the squares. To set the point, the mouse cursor is positioned on the chosen square. The position of actuators is set by single press and cancelled by double press. The geometry of points of mirror fastening to the support is set analogously.
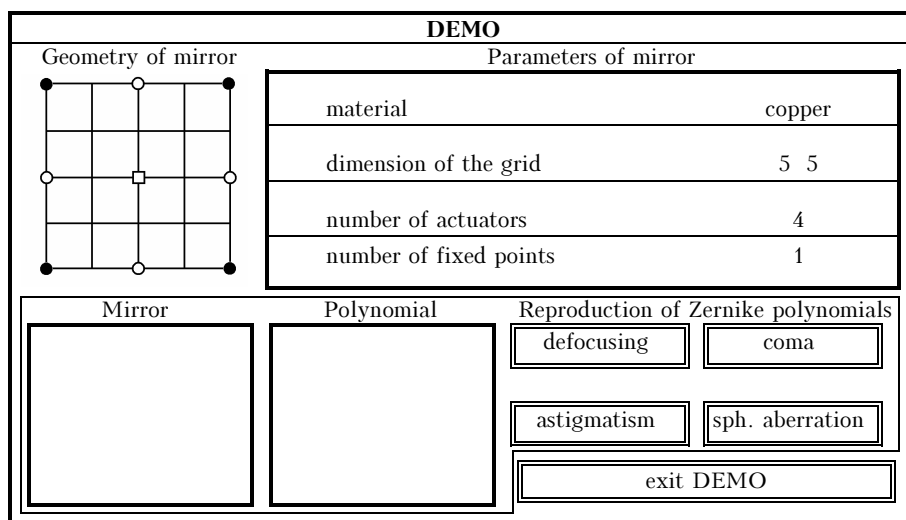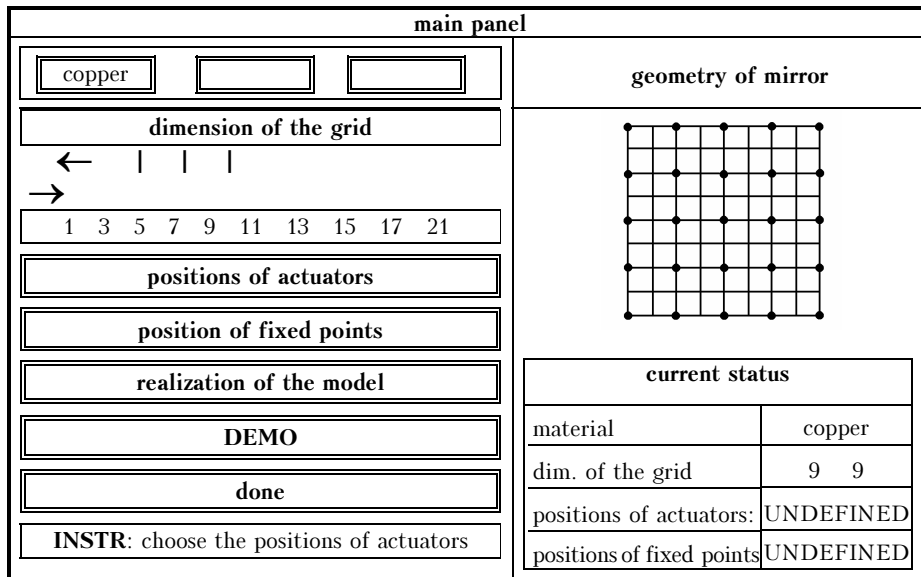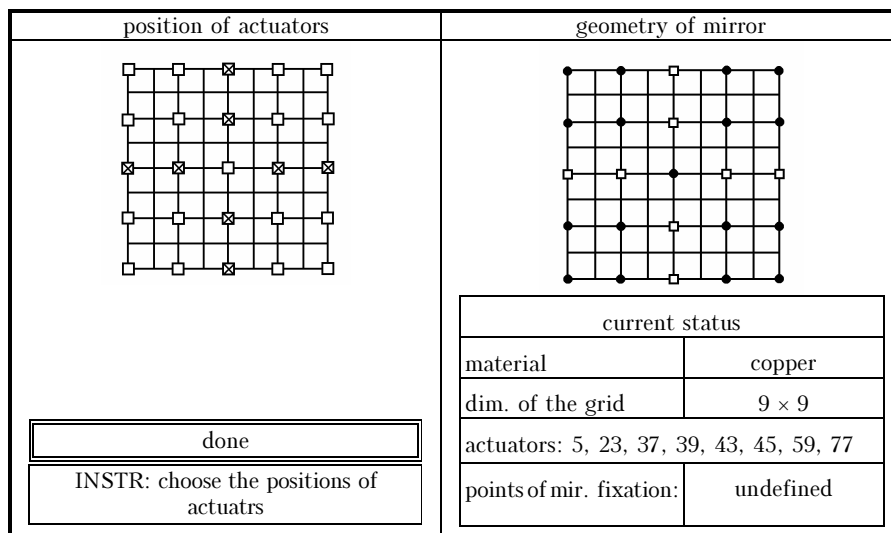
*FIG. 3.*

*FIG. 4.*



*FIG. 5.*

Once the parameters are set the reference is made to the FORTRAN program for calculating and recording the rigidity matrix. The results of calculations can be seen upon calling to the panel DEMO.

In addition to the programs described above the work is in progress on the block for calculating the deformations of dynamic mirror and its graphic interface.

## CONCLUSION

This paper describes the mathematical model of the adaptive optical system; the numerical methods for the model implementation are considered; the principles of operation of the application package are described. The presented schemes have been tested and compared with the available experimental data (unfortunately, the corresponding results are outside this issue). The above schemes can be used in development of numerical experiments in the field of adaptive optics, when predicting the results of the field and laboratory experiments and estimating the efficiency of optical systems designed. It should also be noted that the graphic interface enables one to demonstrate a series of physical phenomena to the students of institutes and technical schools.

In conclusion we would like to emphasize that for operation with the program package a detailed knowledge of programming languages is not necessary. We believe that this considerably extends the number of potential users and enables one to pay more attention and time to physical aspects of the phenomena studied.

## REFERENCES

1. *Microsoft  Windows  User's  Guide,*  Microsoft Corporation (1990), 640 pp.
2. *Microsoft  Visual  Basic  User's  Guide,*  Microsoft Corporation (1993), 482 pp.