

# TRANSPORTATION CHANNELS CALCULATION METHOD IN MATLAB

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Output devices and charged particles transport channels are necessary components of any modern particle accelerator. They differ both in sizes and in terms of focusing elements depending on particle accelerator type and its destination. A package of transport line designing codes for magnet optical channels in MATLAB environment is presented in this report. Charged particles dynamics in a focusing channel can be studied easily by means of the matrix technique. MATLAB usage is convenient because its information objects are matrixes. MATLAB allows the use the modular principle to build the software package. Program blocks are small in size and easy to use. They can be executed separately or commonly. A set of codes has a user-friendly interface. Transport channel construction consists of focusing lenses (doublets and triplets). The main of the magneto-optical channel parameters are total length and lens position and parameters of the output beam in the phase space (channel acceptance, beam emittance – beam transverse dimensions, particles divergence and image stigmaticity). Choice of the channel operation parameters is based on the conditions for satisfying mutually competing demands. And therefore the channel parameters calculation is carried out by using the search engine optimization techniques.

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## INTRODUCTION

Depending on the type of accelerator and its purpose transport channels differ both on the length and on a set of focusing elements whose parameters depend on the type of accelerated particles and their energy. For particles with a momentum in the range from tens of MeV/c to hundreds GeV/c basic channel elements are magnetic quadrupole lenses and dipole bending magnets [1 - 9]. The main characteristics of the magneto-optical channels are full length of the channel, the location of the lenses along the channel and magnitude of the magnetic field in the lenses, as well as the acceptance of the channel and the emittance of the beam at the output plane of the channel (the transverse dimensions of the beam and the angular divergence of a beam of particles) and the stigmatic image [7]. Achievement of the required parameters is associated with the choice of a compromise of mutually competing conditions imposed on the parameters of the channel and thus final calculation of focusing system is made with search methods for the minimum of function of many variables. The objective function, which determines the quality of the projected channel (ie, the degree of achievement of the set of parameter values), is a multiextreme function, which creates additional difficulties in the calculation of the focusing system.

Existing software packages for magneto-optical channels calculation (see for example [4, 6]), developed and intended for the design of unique accelerator complex are rather difficult to apply to the majority of mass-produced accelerators for industrial and medical applications, as they require a lot of experience and sufficient skills for their users. The proposed method is intended to relatively simple designing of transport channels of charged particles and allows a convenient and understandable form study the focusing process of focusing charged particles by different systems and to assess the degree of influence of each channel parameter on required sizes beam formation.

Since the dynamic of charged particles in the focusing channel are conveniently written in matrix form, the use of MATLAB, where information processing object is a matrix, is quite justified. Program code is easy to write and understand. Resources of the system allow use the modular principle of the program creation. Software modules of basic elements of magneto-optical systems are small in size and easy to use. IFR «Katran» having an opened modular structure can be adapted to the specific technical requirements of the accelerator installation. The developed method can also be used for training students in the course of CAD electric torch.

## 1. TRANSPORTATION CHANNELS CALCULATION METHOD

### 1.1. MATHEMATICAL PROBLEM

As it is known the motion of a particle with charge  $e$  in an electric field with a strength of  $\vec{E}$  and a magnetic field with the induction of  $\vec{B}$  is described by the equation

$$\frac{d}{dt}(m\vec{v}) = e(\vec{E} + [\vec{v} * \vec{B}]) \quad (1)$$

in which the right side is the Lorentz force, where  $m$  is the total relativistic mass and  $\vec{r} = z\vec{z}_0 + x\vec{x}_0 + s\vec{s}_0$  – radius vector of the particle,  $\vec{v} = \dot{\vec{r}}$  is particle speed.

Fig. 1 shows a coordinate system where 1 and 2 - 3 - 4 -  $x$  and  $z$  are transverse coordinates, and  $s$  is longitudinal coordinate along which particle motion performs,  $\vec{x}_0, \vec{z}_0, \vec{s}_0$  is orths.

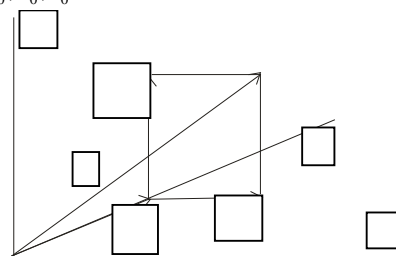


Fig. 1. Stationary Cartesian coordinate system  $\{z, x, s\}$

Taking into account that the energy of the relativistic particles in a magnetic field does not change, and no electric field, the equations of motion take the form

$$\begin{aligned} \dot{z} &= \frac{e}{m} (\dot{x}B_x - sB_x) \\ \dot{x} &= \frac{e}{m} (sB_z - \dot{z}B_x) \\ \ddot{s} &= \frac{e}{m} (\dot{z}B_x - \dot{x}B_z) \end{aligned} \quad (2)$$

Going from time differentiation to differentiation with respect to the longitudinal coordinate ( $s$ ), making the substitution variables and the corresponding transformations, we obtain the equations of the particle trajectory in the transverse planes [2].

$$z'' = \frac{e}{p} \sqrt{1+z'^2+x'^2} [x'B_s - (1+z'^2)B_x + x'z'B_z] \quad (3)$$

$$x'' = -\frac{e}{p} \sqrt{1+z'^2+x'^2} [z'B_s - (1+x'^2)B_z + x'z'B_x]$$

where  $p = mv$  is momentum of the particle.

Transport channel is composed of quadrupole lenses and drift spaces. In the most practically interesting cases the transverse components of the magnetic field within the lens can be considered as linear functions of the coordinates, and the longitudinal component of the magnetic field is absent

$$\begin{aligned} B_x &= gz, \\ B_z &= gx, \\ B_s &= 0, \end{aligned} \quad (4)$$

$g$  is the magnetic field gradient.

Then the equations of motion (3) of the charged particles in the quadrupole take the form

$$\begin{aligned} z'' &= -k\sqrt{1+z'^2+x'^2} [(1+z'^2)z - x'z'x], \\ x'' &= k\sqrt{1+z'^2+x'^2} [(1+x'^2)x - x'z'z], \end{aligned} \quad (5)$$

where  $k$  characterizes the focusing magnetic field strength ( $k = e^*g/p$ ).

The solutions of these equations  $x(s)$  and  $z(s)$  in the region near the axis (axis  $s$ ) can be expanded in powers of the initial parameters

$$z_0 = z(0), z'_0 = z'(0), x_0 = x(0), x'_0 = x'(0).$$

In the practice in the majority cases it is enough only to keep the linear terms of the expansion. Then  $x(s)$  and  $z(s)$  are solutions of linear equations of the trajectory (6) in the quadrupole

$$\begin{aligned} x'' - k^*x &= 0, \\ z'' + k^*z &= 0. \end{aligned} \quad (6)$$

Solutions of the equations (6) in the matrix form on the output of the lens with length  $l$  can be written as

$$\begin{aligned} \begin{vmatrix} z \\ z' \end{vmatrix} &= \begin{vmatrix} ch(\theta) & l/\theta * sh(\theta) \\ \theta/l * sh(\theta) & ch(\theta) \end{vmatrix} \begin{vmatrix} z_0 \\ z'_0 \end{vmatrix}, \\ \begin{vmatrix} x \\ x' \end{vmatrix} &= \begin{vmatrix} \cos(\theta) & l/\theta * \sin(\theta) \\ -\theta/l * \sin(\theta) & \cos(\theta) \end{vmatrix} \begin{vmatrix} x_0 \\ x'_0 \end{vmatrix}, \end{aligned} \quad (7)$$

where  $\theta$  is transit angle. ( $\theta = \sqrt{3^*g/p} * l$ ),  $x_0, x'_0, z_0, z'_0$  are the coordinates of the particle input,

$x, x', z, z'$  – coordinates of the particles at the output of the channel section – linear and angular coordinates of the particles relative to the optical axis of the channel.

The motion of a charged particle in free space in the matrix form can be written as

$$\begin{vmatrix} z \\ z' \end{vmatrix} = \begin{vmatrix} 1 & s \\ 0 & 1 \end{vmatrix} \begin{vmatrix} z_0 \\ z'_0 \end{vmatrix}, \quad \begin{vmatrix} x \\ x' \end{vmatrix} = \begin{vmatrix} 1 & s \\ 0 & 1 \end{vmatrix} \begin{vmatrix} x_0 \\ x'_0 \end{vmatrix}, \quad (8)$$

where  $s$  is the length of the drift space.

## 1.2. THE STRUCTURE OF THE RFP «KATRAN». DESIGN STAGES TRANSPORTATION CHANNEL

The basic flowchart of the software package and interrelation of modules are given in Fig. 2. In the head program key parameters of a beam of charged particles and structurally set parameters of lenses and the channel as a whole, and also values of target parameters necessary for calculations, normalizing and weight coefficients are established.

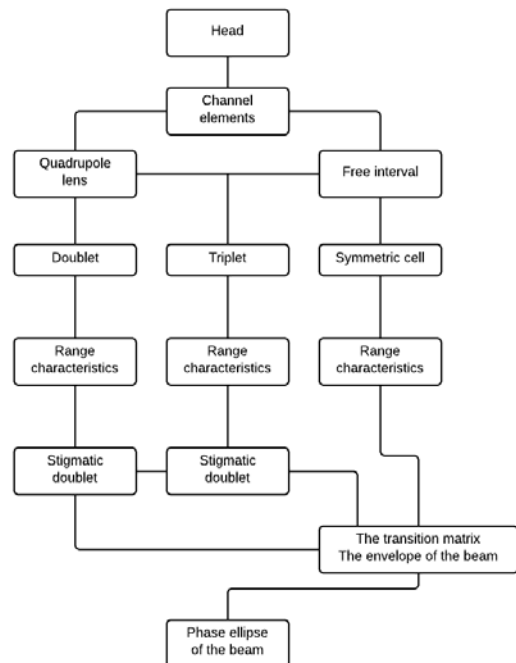


Fig. 2. Block scheme of the modular structure of the package

Design of the channel of transportation consists of several stages. At the first stage the choice of "reference" option of a quadrupole lens, i.e. the lenses which parameters allow to carry out in principle the necessary focusing of a beam without claims for a system optimality as a whole is carried out. The subsequent construction and specification of focusing system can lead to correction of parameters of a lens. At the second stage, based on a "reference" version of the lens focusing system formed in accordance with the requirements imposed on the transportation channel and conducted research of their focusing properties based on a range of characteristics. At the last stage, the selection of optimal parameters focusing system and visualization of the results – the construction of phase ellipses and the beam envelope. Calculation of dynamics of particles is carried

out for a nominal momentum of charged particles  $p = p_0$ .

First step: Modules – «Elements channel» → «The quadrupole lens» + «free period». The matrix of transition of quadrupole in focusing and defocusing planes and the transition matrix of space are written down in the modules. A pre-selection "reference" version of quadrupole parameters – the magnetic field ( $B$ ), the length of the lens is carried out. The transition matrix structure - the "free span - a lens" has the form

$$\begin{pmatrix} x \\ x' \end{pmatrix} = \begin{pmatrix} m_{11} & m_{12} \\ m_{21} & m_{22} \end{pmatrix} * \begin{pmatrix} 1 & F \\ 0 & 1 \end{pmatrix} * \begin{pmatrix} x_0 \\ x'_0 \end{pmatrix},$$

$$\begin{pmatrix} x \\ x' \end{pmatrix} = \begin{pmatrix} M_{11} & M_{12} \\ M_{21} & M_{22} \end{pmatrix} * \begin{pmatrix} x_0 \\ x'_0 \end{pmatrix}, \quad (9)$$

$\begin{pmatrix} x_0 \\ x'_0 \end{pmatrix}$  is parameters of the beam at the entrance to the

structure,  $\begin{pmatrix} x \\ x' \end{pmatrix}$  is parameters of the beam at the output

of the structure,  $\begin{pmatrix} m_{11} & m_{12} \\ m_{21} & m_{22} \end{pmatrix}$  is transition matrix of lenses

$\begin{pmatrix} 1 & F \\ 0 & 1 \end{pmatrix}$  – is transition matrix of free interval,  $\begin{pmatrix} M_{11} & M_{12} \\ M_{21} & M_{22} \end{pmatrix}$  –

transition matrix structure of the "free period – lens".

Therefore, to determine the focal length of the lens  $F$  necessary condition is  $x' = x_0 * M_{21} + x'_0 * M_{22} = 0$ , which is equal to

$$M_{22} = 0, \text{ because } x'_0 = 0. \quad (10)$$

Performing matrix multiplication in (9) we obtain

$$M_{22} = m_{21} * F + m_{22} = -\theta/l * \sin \theta * F + \cos \theta = 0, \quad (11)$$

$$N_{22} = n_{21} * F + n_{22} = \theta/l * \sin \theta * F + \cos \theta = 0. \quad (12)$$

The focal lengths of the quadrupole lens in the focusing ( $Ff$ ) and defocusing ( $Fd$ ) planes.

$$Ff = l/\theta * \cot \theta, \quad (13)$$

$$Fd = -l/\theta * \cot \theta.$$

These relations allow for construction and analysis of the range of characteristics of the quadrupole lenses.

Second stage: Modules – «Doublet» → «range of characteristics.» In modules are written procedures for search focal length doublet and procedures for the formation of the objective functions for different variants of calculation. Based on the results of the first stage and advancing relevant requirements of the numerical values of the transition matrix elements in the transverse planes can be formed by a beam of charged particles of the desired configuration, and adjust the overall length of the transport channel. As an example, consider the construction of a system of two quadrupole lenses (doublet), which provides stigmatic image of the output of the system and tries to save the initial shape of the beam.

Link between the output and the input parameters of the beam is determined by the full transition matrix in the area "source – the output of the second lens."

$MF^{FOD}$  and  $MF^{DOF}$  is the transition matrix of the free period "source – the first lens",

$D$  – the transition matrix of the free space between the lens,

$$\begin{pmatrix} x \\ x' \end{pmatrix} = |L2| * |D| * |L1| * |MF^{FOD}| * \begin{pmatrix} x_0 \\ x'_0 \end{pmatrix},$$

$$\begin{pmatrix} x \\ x' \end{pmatrix} = \begin{vmatrix} H_{11} & H_{12} \\ H_{21} & H_{22} \end{vmatrix} \begin{pmatrix} x_0 \\ x'_0 \end{pmatrix}, \quad (14)$$

$$\begin{pmatrix} z \\ z' \end{pmatrix} = |L2| * |D| * |L1| * |MF^{DOF}| * \begin{pmatrix} z_0 \\ z'_0 \end{pmatrix},$$

$$\begin{pmatrix} z \\ z' \end{pmatrix} = \begin{vmatrix} V_{11} & V_{12} \\ V_{21} & V_{22} \end{vmatrix} \begin{pmatrix} z_0 \\ z'_0 \end{pmatrix}.$$

$L1$  and  $L2$  are transition matrixes of the first and second elements in the appropriate orientation;  $H$  and  $V$  are the transition matrixes in the area "source – the output of the second lens" in the horizontal (FOD) and vertical (DOF) planes.

If a point source is located on the optical axis by a distance equal to the focal length of the doublet then after doublet passing particles will travel on parallel axis. Mathematical notation of this condition

$$H_{22} = 0 \quad \text{and} \quad V_{22} = 0. \quad (15)$$

Knowledge of focal lengths of the doublet  $F^{FOD}$

and  $F^{DOF}$  determines the geometry of the focusing system. Fig. 3. Shows the dependence of focal length

doublet  $F^{FOD}$  and  $F^{DOF}$  on the values of the transit angle of the second lens at selected above "reference"

parameters of the first lens and a given distance between the lenses. As seen from the graphs, there is a range of

values of the transit angle of the second lens, wherein the focal length of doublet  $F^{FOD}$  and  $F^{DOF}$  are positive.

This is the "work area" suitable for further searches. To solve this problem we use extreme methods of

search and in this case, in objective function is setted only one target parameter –  $H_{22} \rightarrow 0$  (for  $F^{FOD}$ ) and

$V_{22} \rightarrow 0$  (for  $F^{DOF}$ ) by varying the values of the transit angle of the second lens.

You can assess the nature of the influence of the distance between the lenses on the value of the "work area" (see Fig. 3) – with increasing distance between the lenses, "workspace" increases.

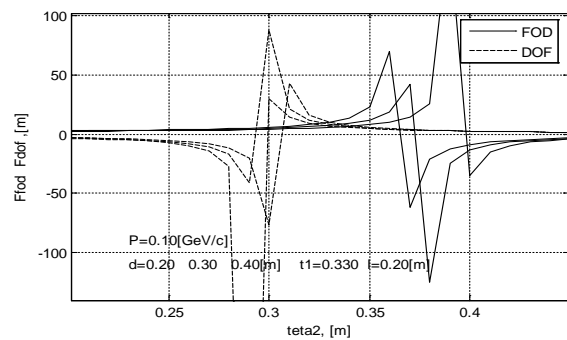


Fig. 3. Dependence of the local lengths of the doublet transit angle of the second lens

The third stage: Modules – «stigmatic doublet» → «transition matrixes. The envelope of the beam» → «The phase ellipse of the beam. The procedures for finding

optimal parameters of the doublet and procedures of the objective function for the stigmatic image doublet, as well as the procedure for constructing the phase ellipses at the output of each element of the transport channel and the construction of the beam envelope are written down in the modules. For the quadrupole doublet lenses are searched optimal values of the following parameters – span angles of the two lenses, the distance from the source to the first lens, the distance between the lenses and the distance from the second lens to the image plane. All these doublet parameters are included in the formation of the elements objective function of the transition matrices channel.

## 2. EXAMPLE OF CALCULATING OF TRANSPORT CHANNEL ELEMENTS

The mathematical formulation of the synthesis problem – to determine the optimal solution, which, for whatever characteristics preferred over others solutions. The problem is multiextremal because in the solutions search area there are a number of local minima of the objective function, which can be represented as

$$Ft = \sqrt{\sum_{i=1}^5 \left( a_i \frac{(\varphi_i(\vec{x}) - \varphi_i^*)^2}{\varphi_i^{norm}} \right)^2}, \quad (16)$$

where  $\varphi_i(\vec{x})$  – function depending on the vector (system settings);  $\varphi_i^*$  – setting goals;  $\varphi_i^{norm}$  – normalization factor;  $a_i$  – weighting factor.

One of the features of the problem is bad scaling – length of transport channel free gaps vary in the range from tens of centimeters to hundreds of meters, while the values of angles spans the lens lie in the range 0.2...0.5 rad. Scaling – transformation of the variables with the appropriate normalization coefficients  $\varphi_i^{norm}$  to this form when the value of the variables are comparable in magnitude, and the objective function value is measured in terms of dimensionless quantities are close to unity.

As a method for finding the optimal solution uses the internal functions of MATLAB realize the direct search method (the simplex method) – the algorithm Nelder-Milda and gradient methods.

In the context of solving the above problems as a function  $\varphi_i(\vec{x})$  are the transition matrices elements  $H_{22} = 0$  and  $V_{22} = 0$  to determine the focal length doublet,  $HD_{12} = 0$  and  $VD_{12} = 0$  (full matrix elements of doublet transmission) to obtain a stigmatic image, and the total length of the focusing system. The weighting factors take numerical values indicating the degree of importance of the achievement of this component of the objective function the parameter setting goals. Target data  $\varphi_i^*$  – values set by the user.

In Table, the first column contains the parameters of the starting vector, i.e. the value of the channel, which begins the process of finding their optimum values. Parameters of starting vector are set based on analysis of the first two stages of the calculation. These parameters are described in the order of elements along the channel.

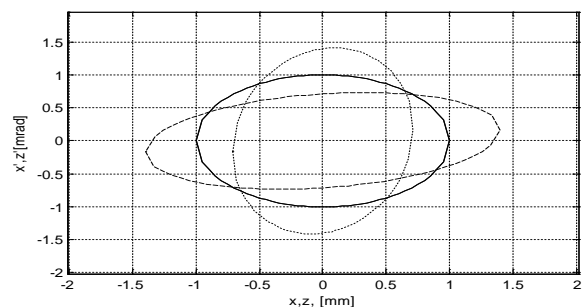
Symbols  $U, D, V$  – corresponding to free intervals (measured in meters),  $\theta$  – the transit angle lens (measured in radians).

From the analysis of wide-band characteristics of the lens was chosen reference variant lens length  $L = 0.2$  m, with the induction of the magnetic field  $B = 1.6$  kgs and the transit angle  $\theta = 0.42$  when the momentum of the particles  $P = 100$  MeV/c. A result of optimization of parameters (see Table) the total length of the canal will 14.5...20.5 m. These characteristics are consistent with existing channels FIAN synchrotron [11].

*Optimized parameters of the doublet a transition matrix*

Starting vector	Optimized parameters	HD Horizontal plane	VD Vertical plane
$U=10.0000$ $\theta_1=0.4300$ $D=0.3000$ $\theta_2=0.4500$ $V=10.0000$	$U=9.9935$ $\theta_1=0.4361$ $D=0.0911$ $\theta_2=0.4361$ $V=9.9919$	-1.3137 0.0014 -0.2027 -0.7610	-0.7615 -0.0062 -0.2028 -1.3149
$U=10.0000$ $\theta_1=0.4300$ $D=0.3000$ $\theta_2=0.4500$ $V=10.0000$	$U=9.4120$ $\theta_1=0.4363$ $D=0.1068$ $\theta_2=0.4365$ $V=9.2326$	-1.3087 0.0024 -0.2171 -0.7637	-0.7362 -0.0028 -0.2183 -1.3592
$U=7.0000$ $\theta_1=0.4300$ $D=0.3000$ $\theta_2=0.4500$ $V=7.0000$	$U=6.9441$ $\theta_1=0.4104$ $D=0.2856$ $\theta_2=0.4104$ $V=6.9399$	-1.4883 -0.0014 -0.2970 -0.6722	-0.6714 -0.0016 -0.2971 -1.4901

The first two solutions differ in the normalization factor for the lengths of the input and output gaps. A third option in the starting vector has a smaller dimension values of input and output space than the first embodiment. The presented data show that the achievement of the optimal variant is mainly due to the selection of the values of the span angle and distance between the lenses. The third embodiment shows the phase channel ellipses particle beam entering and leaving the doublet (Fig. 4).



*Fig. 4. Phase portrait of the beam: entrance plane – a solid ellipse, output plane (horizontal) – dotted ellipse; output plane (vertical) – pointed ellipse*

In Fig. 5 the envelopes of the beam in the horizontal (solid line) and vertical (dashed line) planes are shown for symmetrical beam. Therefore at the initial part of the channel from output of the accelerator to the first lens envelopes on both planes coincide. If the maximum angular particles divergence at the exit of the accelerator

is about 1 mrad then the maximum beam size at the channel is  $\approx 17$  mm.

From these results one can conclude that for a given channel geometry beam with a larger angular divergence can be transported (up to 5 mrad with an aperture of 10 cm), or it is possible to use a lens with a smaller aperture (e.g., aperture 4 cm) or it is necessary to repeat the search of focusing doublet parameters for satisfying formulation problem. In such a sequence the design of the quadrupole lenses triplet and symmetric cell is performed.

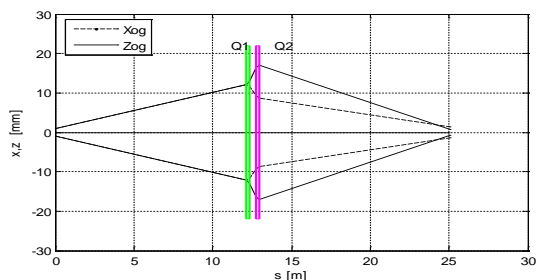


Fig. 5. Beam envelopes in horizontal (solid line) and vertical (dotted line) plane

## REFERENCES

1. E.D. Courant, M.S. Livingston, H.S. Snyder. The strong-focusing synchrotron – a new high energy accelerator // *Phys. Rev.* 1952, v. 88, №5, p. 1190.
2. K. Steffen. *High-energy beams optics*. M.: «Mir», 1969.
3. V.A. Budkin, A.A. Glazkov. *On the choice of optimal optical channel of a separator by cybernetic method. Accelerators*. Iss. XII, M.: «Atomizdat», 1970.
4. TRANSPORT. *A computer program designing charged particle beam transport system*. CERN 80-04.
5. K. Steffen. *Basic course accelerator optics*. CERN 85-19.
6. *The MAD Program*. CERN/LEP-TH/88-38.
7. P.W. Hawkes, E. Kasper, et al. *Principles of electron optics*. Elsevier, 1996.
8. V.I. Kotov, V.V. Miller. *Focusing and separation on the masses of the high-energy particles*. M.: «Atomizdat», 1969.
9. V.A. Baskov, Yu.A. Bashmakov, A.V. Verdi, et al. *Diagnostics system of transport of an electron beam on the basis of scintillation counters*: Preprint FIAN, 1997, №13, p. 22.
10. F.P. Vasil'ev. *Numerical methods for solving extreme problems*. M.: «Nauka», 1988.
11. G. Rekleytis, A. Reyvindarn, K. Regsdel. *Optimization in Engineering*. Russian translation. In 2 books. M.: «Mir», 1986.
12. E. Polak. *Numerical optimization*. Wiley, 1974.
13. G.P. Averianov, V.A. Budkin, V.V. Dmitrieva. *Computer-aided design*. M.: «MEPhI», 2010.
14. G.P. Averianov, V.A. Budkin, V.A. Vorontsov, V.V. Dmitrieva. *CAD electrophysics*. M.: «MEPhI», 2011.

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## МЕТОДИКА РАСЧЕТА КАНАЛОВ ТРАНСПОРТИРОВКИ ПУЧКОВ ЗАРЯЖЕННЫХ ЧАСТИЦ В СРЕДЕ МАТЛАБ

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Представлен пакет прикладных программ по проектированию каналов транспортировки, предназначенный для разработки магнитооптических каналов в среде широко распространённой системы MATLAB. Поскольку динамику заряженных частиц в фокусирующих каналах удобно записывать в матричной форме, то использование системы MATLAB, в которой объектом обработки информации является матрица, вполне обосновано. Комплекс программ обладает наглядным и удобным интерфейсом. Канал транспортировки строится из фокусирующих систем – дублеты и триплеты. Основными характеристиками магнитооптических каналов являются их полная длина и места расположения линз, а также параметры пучка в выходной плоскости канала (аксептанс канала, эмиттанс пучка – поперечные размеры пучка, расходимость частиц и стигматичность изображения). Выбор рабочего варианта параметров канала производится из условия удовлетворения взаимно конкурирующих требований, и поэтому расчёт параметров канала осуществляется с использованием методов поисковой оптимизации.

## МЕТОДИКА РОЗРАХУНКУ КАНАЛІВ ТРАНСПОРТУВАННЯ ПУЧКІВ ЗАРЯДЖЕНИХ ЧАСТОК У СЕРЕДОВИЩІ МАТЛАБ

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Представлено пакет програм з проектування каналів транспортування, призначений для розробки магнітооптичних каналів у середовищі широко поширеної системи MATLAB. Оскільки динаміку заряджених часток у фокусуючих каналах зручно записувати в матричній формі, то використання системи MATLAB, в якій об'єктом обробки інформації є матриця, цілком обґрунтоване. Комплекс програм має наочний і зручний інтерфейс. Канал транспортування будується з фокусуючих систем – дублети і триплеті. Основними характеристиками магнітооптичних каналів є їх повна довжина і місця розташування лінз, а також параметри пучка у вихідній площині каналу (аксептанс каналу, емітанс пучка – поперечні розміри пучка, розбіжність часток і стигматичність зображення). Вибір робочого варіанта параметрів каналу робиться з умови задоволення взаємно конкуруючих вимог, і тому розрахунок параметрів каналу здійснюється з використанням методів пошукової оптимізації.