CONTENTS

No.2 Civil Engineering

M. Amdur (Israel)
Modular Hydro-Power Farm ..... 1

A. Berkovitch, L. Eppelbaum
From Seismic Inversion to Applied Optics: A Novel Approach to Design of Complex Systems ..... 12

A. M. Boldyrev, A. A. Sventikov
Optimization of Integration Parameters of Suspension Shell Structures ..... 27

S. Y. Gridnev
Using of the Kantorovich Method for Modeling of Bending Vibration of the Floating Bridge Systems ..... 32

V. N. Melkumov, S. A. Kolodyazhnyj
Ecological Influence of Fires on Environment ..... 38

V. N. Melkumov, S. N. Kuznetsov
Dynamics of Formation of Air Streams and Temperatures Fields in Premise ..... 48

G. Muravin, I. Mizrahi, N. Frage, B. Muravin
Revealing Flaws by Quantitative Acoustic Emission Non-destructive and Photo-Elastic Methods ..... 55

M. Y. Panov, V. N. Semyonov
Urban Systems of Low Gas Pressure: Models of Operational Control ..... 75

V. P. Podolskiy
Simulating of a Heat Transfer Process in Road Structure, Equipped with a Snow Melting System ..... 82

V. S. Safronov, V. N. Goryachev
Risk of Beginning of Limit States in Ferro-Concrete Road Bridges at Earthquakes ..... 88

T. V. Samodurova
Physico-statistical Forecast of Short-Term Road Ice Formation ..... 95

V. N. Semyonov
Organization of Energy Saving in Housing and Communal Complex of Municipality ..... 100

D. M. Shapiro, A. V. Agarkov
Deformation Non-linear Calculation of Reinforced Concrete T-section Beams ..... 113

A. N. Tkachenko
Pneumatic Shuttering Systems: Researches and Use ..... 121

V. Voichek, V. Babaev, E. Melamed, D. Beilin
Modern Problems of the Computer-Aided Design of Building Structures ..... 129

CONGRATULATIONS ..... 139

O. Michailov
Parametric Identification of Vessel Volume ..... 140

V. Y. Mischenko, B. B. Hrustalyov
Calculation of Innovative Potential of Regional Building Complex Enterprises ..... 145

T. Tamarin, O. Figovsky
Investment and Innovation ..... 149
FROM SEISMIC INVERSION TO APPLIED OPTICS: A NOVEL APPROACH TO DESIGN OF COMPLEX SYSTEMS

A. Berkovitch* and L. Eppelbaum**

*Geomage Ltd, Modiin, Israel, alex@geomage.com
**Tel Aviv University, Tel Aviv, Israel, levap@post.tau.ac.il

ABSTRACT
Propagation of seismic waves studied in geophysical prospecting and propagation of optic waves through defined media are based on the same physical-mathematical principals. It makes possible transferring modern procedures developed in the first field to the second one and back. In this paper we suggest to transfer novel procedures developed in seismic prospecting, to applied optics. For such a conversion we selected two developed approaches:

1. Homeomorphic Imaging, and

The first approach is based on the employment of revealed local theoretical relationship between the geometrical characteristics of two fundamental beams and geometrical properties of geological layers (bodies) of the studied media. Geometrical characteristics of the fundamental beams are spreading functions and curvatures of the special wave fronts. The second approach – new description of boundary conditions permits to determine a perfect seismic (optical) system having necessary focusing and imaging properties, which is free from any aberrations. An optimal optical system is determined as an arrangement corresponding to some perfect system with the admissible accuracy. Application of the developed procedures in the optic design will permit to apply a description of optical surface using:

a. Parametric functions,
b. Differential equations, and
c. Mixed (parametric-differential).

On this base the optical systems consisting of minimal number of optical elements with complicated shape might be promptly computed. Other important application field of the suggested methods is design of optical systems with diffractive elements.

Keywords: Seismic inversion, Applied optics, Homeomorphic Imaging

INTRODUCTION

The broad and diverse application of the applied optics has been required a creating of the optical system (array) theory design consisting of lenses and mirrors and elements of arbitrary shapes having homogeneous and inhomogeneous optical properties. Different versions of this theory were developed by recasting of certain methods existing before in the classic optics and the laser theory.
The most often used methods of optics design for diffractive, aspherical and spherical surfaces are based on optimization using merit function, design using differential equations and point-by-point computation for construction of ray without differential equations [e.g., 1-5].

The known procedures of optical design [6-9] are characterized by the following limitations:

1. Ambiguity of the best find solution of optical design,
2. Immobility of calculated systems (the systems are non-turning and axis-symmetrical ones),
3. Impossibility of calculation of systems with diffractive elements. These standard procedures are realized in the well-known optimization programs such as BEAM4, ZEMAX and in some others. However, abovementioned limitations in sufficient degree are restricted the technical feasibility of optical system design.

The most general improvement of the classic optic methodology is a matrix method. This method is some generalization of the classic-matrix method and the ABCD matrix introduced by Kogelnik [10] to describe the Gaussian beam propagation and optical reasonable properties. In other approaches are employed differential equation technique and ray tracing. All these methods were widely applied in many areas of integrated optics. However, all these procedures have an essential shortcoming caused by their origin: the classic optical theory was created for a system having the unit optical axis in the Gaussian or paraxial approximation. Efforts to recast the methods proposed for special cases, in the general situation are always accomplished with the certain artificial steps. At the same time, a more natural approach consists of creating a theory intended for design of general optical systems and arrays having inhomogeneous lenses and mirrors, and elements of arbitrary shape with large apertures. Such a general theory has been developed in a seismic prospecting and seismology.

CERTAIN PECULIARITIES OF DATA PROCESSING IN SEISMIC INVESTIGATIONS

The ray theory for calculation of wave field propagation in the elastic media, consisting of many surfaces of arbitrary shapes with inhomogeneous layers, was proposed in fiftieth [11,12]. This theory was developed and widely used by computing the seismic waves in 2-D and 3-D elastic media involving complicated and diverse structures [13,14]. During the last decade has been developed a novel approach called “Homeomorphic Imaging” (HI) to interpret seismic data and solve asymptotic inverse problem [15-20]. A basis idea of the HI approach is a consideration (calculation) of the so-called Homeomorphic Images of the target (for example, reflector or refractor), constructed by application of geometrical characteristics of a wave directly associated with the investigated object. Each homeomorphic image is a topological equivalent of the studied object, i.e. there is one-to-one correspondence between a point (or element) of the object and a point of the image. It means that propagation of wavefront could be considered as topological mapping of object coupled with the wave in a caustic of the front.

In the HI theory was shown [16,19] that calculation of wave fronts and fields propagating through complicated structure could base on a consideration of the fundamental ray tubes, surrounding a set of grid central rays, connecting pairs of points on the input and output of the system. Geometry of the ray tube cross-section at the start and end points is described through the use of spreading function and radii of wave front curvatures. It is also proved that geometrical characteristic of any other ray tubes surrounding the same central ray could be determined using parameters of the fundamental ray tubes. These results made feasible geometry of fronts corresponding to arbitrary distribution of sources (objects and images).

SEISMIC INVERSION AND OPTICAL DESIGN: COMMON ASPECTS AND DISTINCTIONS

Both in seismic inversion and optical design are considered laws of waves propagation based on the concept of rays as lines along them energy is propagated.
The seismic method of geophysical prospecting utilizes the fact that elastic waves travel with different velocities in different rocks (layers). The principle is to initiate such waves at some point and determine at a number of other points the time of arrival of the energy that is refracted or reflected on the discontinuities between rock formations [14,21]. For construction of velocity model of the studied medium are used a method of seismic inversion. Seismic inversion is based on using time arrivals of seismic waves registered at the earth surface. The new approach to seismic processing called HI (see Section 2) allows to obtain from the total observed seismic field not only time arrival but also new types of parameters: angles curvature of arrival and spreading function of observed wave fronts. These parameters may be also calculated using dynamic ray tracing by solving the direct problem. Thus, HI parameters employment allows to construct more accurate and simple a model of studied medium.

The distinct peculiarity of the optics design is that we have here a model with known time arrivals. For such a model we should find respective optical surface and compute their velocities. As a rule, time arrival of waves through optical systems is sufficiently simple one. Besides this, in the description of optical system we can employ information of the homeocentric points of sources and their imaging. Here all rays emitted from the homeocentric point are focused in one image point and these rays have the same time arrivals. In seismic inversion the rays usually are not focused in the one point and have different time arrivals.

Therefore, we must underline that a seismic inversion is developed for a more general physical-mathematical model. This gives us a basement for transferring modern approaches developed in the seismic inversion to optics design. We suggest employing the HI parameters in the optics design for description of boundary conditions as well as a new system of differential equations for description of optical surfaces.

FEASIBILITY OF TRANSFERRING DEVELOPED PROCEDURES TO OPTIC DESIGN

It should be noted that transferring of modern developments from the one to other geophysical methods is a widely distributed procedure in applied geophysics (for instance, [22,23]). Such a transferring enables to adapt rapidly and effectively new ideas developed in the non-adjoining fields of science.

The optical modification of the HI theory permits to calculate systems and arrays having surfaces and elements of arbitrary shapes with the large apertures and arbitrary angles of incidence. A preliminary analysis of the optical problematic indicates that design of optical systems and arrays can be based on a consideration of a so called perfect optic system having needed focusing and imaging properties and free from any kind of aberrations. The formal description of the perfect optical system is similar to the HI presentation by wave fields processing in a seismic prospecting. An optic system is determined as a result of optimization process of finding a set of optical surfaces and elements fitting the perfect system with admissible errors, which can be estimated quantitatively. The procedure of searching the optimal optic system directly corresponds to a procedure of “true seismic model” construction using HI approach.

The suggested approach is based on:

1. dynamic ray tracing,
2. asymptotic approximation of wave front curvature [13,19,20,24,25],
3. calculation of aberration using the wave front form,
4. optimization using a new kind of boundary conditions,
5. usage of differential equations for description of the optical surfaces.
The suggested approach has all preferences of the abovementioned methods and is an improved hybrid of theirs. This method is based on a calculation of differential equations (including optimization) and as well as construction of surfaces using point-by-point rays computation.

The suggested approach has several main benefits:

(a) rapid calculation of various optical systems by global optimization,
(b) construction of optical systems with the least required number of lenses,
(c) flexible optical systems with the turning (moving) non-axis symmetrical elements,
(d) construction of optical systems with a huge angle vision and imaging as well as a small ratio of a focal length/system aperture.

On the basis of the suggested approach it is supposed to eliminate the various aberrations: spherical, coma, chromatic and astigmatic. For a case when the surfaces of the conventional optical system are represented by known functions, it is possible to calculate the necessary compensation and construct an ideal optical system (on the basis of adding diffractive and aspheric elements).

This procedure may be also used for design of the various optical systems with diffractive, spherical and aspheric surfaces and their arbitrary combination. We believe that the method may be effectively used for fabrication of aspheric and diffractive surfaces.

**DYNAMIC RAY TRACING**

The conventional technique of optical system design is based on the ray tracing inside of optical system. The ray tracing consists of a successive calculation of a grid ray passes (coordinates of angles of rays). Dynamic ray tracing also includes a computation so called functions $P$ and $Q$ describing spreading function and radii of curvature of wavefront orthogonal to rays. In fact, it means that a ray tube, surrounding the fixed ray, is considered as a dynamic ray tracing. This procedure was developed and programmed in detail in seismic prospecting for recognition of complicated structures having curvilinear surfaces and inhomogeneous layers [19,26]. In the $HI$ theory, this dynamic ray tracing is supplemented by the special boundary conditions for functions $Q$ and $P$ at the initial and end points.

Two fundamental solutions are introduced on the basis of boundary conditions. This is an equivalent to consideration of the two fundamental ray tubes for each traced ray. It was shown in the $HI$ theory [19,26] that parameters of any arbitrary ray tube could be determined using the fundamental ray tubes. It means that any arbitrary configuration of ray fronts, passing through the media, could be calculated with a help of a set of two fundamental solutions. Here we present only a short sketch of the theory where for simplification the medium is considered as homogeneous one.

The velocities between the optical surfaces are constant and only several interfaces have a spherical form. The rays propagate along the straight line, and the directions are changing only by refraction or reflection from surfaces of optical elements (mirrors of lenses).

An equation of ray may be written in the following general form:

$$
\beta = \beta_i \quad \text{and} \quad t = \Delta l \cdot n_j + \sum_{k=1}^{i-1} n_j \left[ x_i - x_{j-1} \right]^2 + \left( y_i - y_{j-1} \right)^2 \right]^{1/2},
$$

(1a)

$$
x = \cos \beta_j \Delta l + x_j,
$$

(1b)

$$
y = \sin \beta_j \Delta l + y_j,
$$

(1c)

where $x_j$, $y_j$ and $\beta_j$ are the coordinates and the angle of the ray, respectively, at the point of refraction or reflection from the optical surface $S_j$ (Figure 1), $\Delta l$ is the length of the ray, $n_j$ is the index of refraction, and $j$ is the optical element.
The refraction or reflection angles of the ray could be calculated using the Snell’s law. After introducing \( \beta_j \) as the angle of normal to the surface \( S_j \) we can write:

(a) for refraction:
\[
\sin \gamma_j = \frac{n_j \sin \gamma_j - \beta_j}{n_j \sin \gamma_j - \beta_j - 1}
\]

(b) for reflection:
\[
\beta_j = 2\beta_j - \frac{\pi}{2} - \gamma_j
\]

The constant velocity of optical elements makes it possible to simplify the equation of dynamic ray tracing:
\[
\frac{dQ}{dl} = vP, \quad \frac{dP}{dl} = \frac{1}{v} \frac{\partial^2 Q}{\partial q^2}
\]

where \( Q \) is the spreading function, \( P \) is the derivative of the slowness in a direction tangent to the wave fronts, \( L \) is the length of the ray, and \( q \) is the distance on the normal to the ray.

**Figure 1.** Graphic definition of rays and surfaces parameters

For a case of conventional optical model an equation of dynamic ray tracing [13] may be presented in the following form:
\[
Q_{j+1} = vP_j \Delta l, \quad P_j = \text{const.}
\]

Examining the behavior of paraxial ray we can see that the angle between two rays will stay constant during the propagation in the model with constant velocity and will change only after the reflection or refraction. For a case of linear approximation we have:
\[
\Delta \beta = nP \Delta \Theta, \quad \Delta q = Q \Delta \Theta,
\]

where the elements \( \Delta \beta \) and \( \Delta q \) are the angle and the distance between the central and paraxial rays, respectively, when the ray ridge is the same wave front (see Figure 1). For numerical calculation the following expressions can be used:
(a) case of refraction

\[ \tau_i Q_j \cos^i \theta_j = -i Q_j \cos^i \theta_j, \]  
\[ \tau_j P_j \cos^i \theta_j = -i P_j \cos^i \theta_j - n_{j-1} \cos \left( \alpha_j^r - n_j \cos \alpha_j^i \right) \frac{Q_j}{R_j}, \]  
where \( \tau \) is the changing of the value after refraction; \( i \) is the index of incident wave, \( j \) is the number of layer, \( \alpha_j^r = \beta_{j-1} - \gamma_j \) is the angle between incident and normal rays to the surface \( S_j \), \( \alpha_j^i = \beta_j - \gamma_j \) is the angle between the refracted ray and the normal to the same surface, and \( R_j \) is the radius of curvature to the surface in the point of refraction (the value is positive one, if the incident ray met the surface).

(b) case of reflection

Let’s assume: \( \alpha_j^r = \alpha_j^i \). Then

\[ k Q_j = + Q_j, \]  
\[ k P_j = - P_j - \left( n_{j-1} - n_j \right) \frac{Q_j}{R_j}, \]  
where \( k \) is the index of reflected wave.

Equation (4a) is a linear differential equation having two independent solutions. Any other solution can be founded as a linear combination of the revealed solutions.

Thus, we can write

\[ \begin{align*}
Q &= aQ_1 + bQ_2 \\
P &= aP_1 + bP_2
\end{align*} \]  
where \( a \) and \( b \) are the coefficients (the coefficients are introduced from the initial data of entered wave front), and \( Q_1, P_1 \) and \( Q_2, P_2 \) are two independent solutions, respectively.

A radius of the wave front curvature could be calculated as

\[ R = \frac{Q}{vP} = \frac{aQ_1 + bQ_2}{v(aP_1 + bP_2)}. \]  

Therefore, two independent solutions permit to find any wave front curvature using these two fundamental solutions.

Taking into account that the equation (11) (or (4a)) is a linear system of differential equations where only two equations are independent ones and considering that Wronskian (determinant) is invariant, we have only three independent solutions (for example, \( Q_1, Q_2 \) and \( P_2 \)).

THE BOUNDARY CONDITIONS

The correct description of boundary conditions is very important for exact calculation of optical systems. These conditions are usually formulated as incident and output wave fronts. The boundary conditions could be presented in the two following ways:

(a) boundary conditions are given for coordinates and angles of arrival and incidence rays. These conditions together with the time of arrival are necessary for solution of a design optical system. Such methods are broadly used in the majority of known optical design programs [for instance, 3,7,9,27].
(b) The second method is suggested in this paper. The necessary boundary conditions are the curvature of wave front and distribution of spreading function of incident and arrival wave fronts [28,29].

For example, in Figure 2 is presented an optical system creating the plane wave front with the constant distribution of the brightness as an output from undirected point of source $S_o$.

For each ray emitting from the point $S_o$, we have the following initial conditions:

$$P(S_o) = 1, \quad Q(S_o) = 0, \quad R(S_o) = \frac{Q(S_o) n_{S_o}}{P(S_o)} = 0.$$  \hspace{1cm} (13)

Respectively, output conditions for a plane front and constant brightness are follows:

$$P(A_j) = 0, \quad Q(A_j) = \text{const}, \quad R(A_j) = \frac{Q(A_j) n_{A_j}}{P(A_j)} = \infty.$$  \hspace{1cm} (14)

![Figure 2. Propagation of wavefield through imaging optical system](image)

Figure 2: Propagation of wavefield through imaging optical system

Taking into account that $Q(A_j) = \frac{\partial^2}{\partial \beta_i(S_0)^2} = \text{const}$, the distribution of brightness of the outside wave also is a constant value.

Example of such an optical system (for the described boundary conditions) is a telescopic objective with a focal length defined according to the definition [1]:

$$F = \frac{Q(A_0)}{P(S_0)} = \text{const}.$$  \hspace{1cm} (15)

Another application of these boundary conditions is an example of optical system calculation where the Gaussian plane beam of a laser is reconstructed to the plane wave with the constant distribution of brightness along the wavefront (Figure 3).

We can assume that the function $f(y)$ represents the brightness of the laser source. The boundary conditions can write by such a way:

for incident plane

$$P(S_j) = 0, \quad Q(S_j) = f(y_i).$$  \hspace{1cm} (16)

for arrival plane

$$P(A_j) = 0, \quad Q(A_j) = 1.$$  \hspace{1cm} (17)

The boundary conditions may include two or more numbers of wave fronts (geometrical modes).
THE SYSTEM OF DIFFERENTIAL EQUATIONS FOR COMPUTING THE OPTICAL SYSTEM

On the basis of the boundary conditions and employing the non-linear optimization (by such a way that modes with initial conditions will arrive with chosen conditions), it is possible to find the radius of curvature of the surface at the point of the ray intersection (refraction or reflection) with the surfaces. Number of the boundary conditions (number of the geometrical modes) gives the number of necessary unknown surface curvatures. In the case when number of surfaces is larger that the number of boundary conditions of the calculated system, part of the curvatures in the system should be given earlier.

The selected ray satisfying to the necessary conditions, gives knowledge of the values $Q_j$ and $P_j$ at the points of intersection. These values make it possible to write the differential equations for coordinates of the points of paraxial ray intersection with the same surfaces (Figure 4).

Surface $S_j$

$$
\begin{align*}
\frac{dx_j}{dx} &= x_j' - x_j \\
\frac{dy_j}{dy} &= y_j' - y_j \\
\end{align*}
$$

Figure 4. Determination of differentials for rays and surfaces

$$
\Delta q = Q_j \Delta \theta, \quad \Delta S = \frac{\Delta q}{\cos \alpha_j} = \frac{Q_j \Delta \theta_0}{\cos \alpha_j}.
$$

Taking into account that $\partial x = \partial S \cos \gamma_j, \partial y = \partial S \sin \gamma_j$, we can write the differential equation of the surfaces

Figure 3. Propagation of wave field through afocal optical system

\[f(y) - \text{distribution of brightness}\] constant brightness
System (19) is the linear homogeneous equation system where each term can be calculated numerically in the process of satisfaction to the boundary conditions. Each surface is represented by two differential equations. Thus, system of 2(m-1) equations could be used for construction of whole optical instrument.

For the optical systems with diffractive elements, equations (17) describe the piecewise smooth surfaces, when on the singular points should be simultaneously introduced the changing of coordinates which are moved on a length of wave.

**BOUNDARY CONDITIONS FOR AN IDEAL IMAGING SYSTEM**

An ideal microscope is an imaging system applying for close examination of various small targets. In the ideal microscopic imaging system the rays propagating from one point of object should coincide at one point on the focal plane (Figure 5). However, in reality the geometric rays in any optic systems are distributed in some area around this point. This phenomenon is well known as an aberration. For the axisymmetrical systems the problem of coma aberration reducing is the most difficult problem. At the same time, rays from different points of the object are not coincided and will be distributed according to the angles of its entry.

![Figure 5. Model of an ideal microscope system](image)

**Boundary conditions for a microscope system without spherical aberration**

For a system without spherical aberration the rays emitted from the point \( x_A \) will be gathered at the point \( x_F \). It means that each ray \( j \) of a fan emitted from point \( x_A \) in a direction \( \beta_j^- \) enters to the point \( x_F \) with the angle \( \beta_j^+ \). Index \( \beta_j \) will designate propagation along the ray \( j \). For a perfect optical imaging system on the each ray are two fundamental wave fronts, which must correspond to the definite boundary conditions. A first boundary condition corresponds to removing spherical aberrations and second – removing coma aberration. The boundary conditions for a microscope system without spherical aberration can be written as:

(a) emitted from point \( x_A \) on the plane \( A \) (Figure 6) before the system:
where \( C^j(x_F) \) is an unknown function.

**Boundary conditions for a microscope system without coma aberration**

The boundary conditions for the case when rays emitting from the point \( X_A \) are gathering together at the point \( x_F \), are more complex ones.

The conditions for the microscope optic system without coma aberration are following: the plane wave front propagated from the point \( x_A^j \) along the ray \( j \) will be focused on the bold part of the sphere (Figure 7) and the second (thin) part of the sphere will be a focal surface of the system.

Two angles that are at the same segment of the arc \( S \) (see Figure 7) taking into account well-known geometric theorems have the same values:

\[
\angle x_F G_j x_F = \Delta \psi_j = \Delta \psi_0. \tag{22}
\]

Let’s assume a radius \( R_F \) of the sphere. The rays emitted from point source \( x_A^j \) at the plane \( A \) with any \( j \), and paraxial rays emitted with any angle \( \theta \) from this point, are gathering together at the one point \( x_F^j \) only at the focal surface. It is obvious that wave front of the point source emitted from the

![Figure 6. Model of a microscope system without spherical aberration](image-url)
plane A will focus on the dash part of the sphere (point $G_j$). Then all rays, entering to the system with the same angle, will be gathering together at the one point $x^F_j$ (on the right part of considered sphere in Figure 7).

![Figure 7. Homeomorphic Imaging of an ideal microscope system](image)

The boundary conditions for the rays emitted from the point $x_A$ and arrived to the point $x_F$ (responsible for absence of coma aberration) could be written using the following manner. Let’s assume a fictitious point source $G_j$ that emits two rays in the different directions along the rays $j$: first one – to the focal surface, second one – to the object.

For a direction to the focal surface the length of the arc is

$$S = Q(x_F)\Delta \psi.$$  

(23)

This length will be a constant value for all rays $j$. Therefore,

$$Q(x_F) = Q(x_F)\cos \beta_j = 2R_j \cos \beta_j^+,$$  

(24)

$$P(x_F) = P(x_F) = 1,$$  

(25)

where $R_j$ is the radius of the local surface.

We introduce that the wave fronts propagate in the media with a constant velocity. The conditions for the wave front, propagating from the point source $G_j$ to the plane of the object, are following [29]: a length of the object:

$$\Delta x^- = Q(x_A)\Delta \psi = Q(x_A)\frac{Q(x_A)\Delta \psi}{\cos \beta_j^-},$$  

(26)

where $Q(x_A) = f$ (a local length of the optical system) and $\Delta x^-$ should be equal for all rays and wave fronts arriving as the plane wave fronts.

As a result

$$Q(x_F) = f \cos \beta_j^-,$$  

(27)

and
After combining all conditions together we can write the following equations for the ideal imaging microscope system:

\[ P_j^1(x_A^1) = \frac{f \cos \beta_j^-}{2R_F \cos \beta_j^+} \]

at the point \( x_F \) on the local surface

\[ P_1^1(x_F) = 1, \quad Q_1^1(x_F) = 0, \]

\[ P_2^1(x_F) = 0, \quad Q_2^1(x_F) = f \cos \beta_j^- \]

and at the point \( x_F \) on the local surface

\[ P_1^1(x_F) = C^1(x_F), \quad Q_1^1(x_F) = 0, \]

\[ P_2^1(x_F) = 1, \quad Q_2^1(x_F) = 2R \cos \beta_j^+ \]

Here function \( C(x_F) \) could be easy estimated taking into account the Wronskian invariance:

\[ C^1(x_F) = \frac{f \cos \beta_j^-}{2R_F \cos \beta_j^+}. \]

Then the considered conditions may be written in the form:

\[ P_1^1(x_A) = 1, \quad Q_1^1(x_A) = 0, \]

\[ P_2^1(x_A) = 0, \quad Q_2^1(x_A) = 1, \]

at the point \( x_F \) on the local surface

\[ P_1^1(x_F) = \frac{f \cos \beta_j^-}{2R \cos \beta_j^+}, \quad Q_1^1(x_F) = 0, \]

\[ P_2^1(x_F) = 1, \quad Q_2^1(x_F) = \frac{2R \cos \beta_j^+}{f \cos \beta_j^-}. \]

FIELD OF APPLICATION

The presented investigation is a basis for development of new theory of design and calculation of diffracted and integrated optics systems and arrays. The authors suggest that the theory will be effective for computation of optical systems consisting of a many (demanding) numbers of optical elements of complicated (arbitrary) shape. The essential benefit of the developed procedure comparing with other known methods is the possibility for simultaneous calculation of unlimited number of the optical surfaces with different shape (spheric, aspheric, diffractive and the mixing complex combinations of these surfaces) with complicated contours and required accuracy.

The suggested method could be generally used in the following directions of the non-conventional optics: analysis, design and application of optical systems and arrays consisting of diffractive microlenses, elements of spherical and aspherical surfaces and hybrid elements.

CONCLUSION

It was shown that there is an analogy between inversion of registered wave fields in seismic prospecting and development of optical systems design. Procedure “Homeomorphic Imaging” developed in seismic prospecting could be effectively applied to calculation of complex optical systems with arbitrary shapes, large apertures and arbitrary angles of incidence. For description of
complex optical systems was suggested to use new boundary conditions based on employment of dynamic ray tracing developed in seismic prospecting. These boundary conditions and respective differential equations make possible to create a more simple description of complex optical systems and compute more accurate their optical surfaces. Feasibility of suggested approach application was shown on examples of microscope imaging and afocal systems. For various optical systems (telescope, microscope, etc.), the specific boundary conditions should be developed (it was illustrated on example of microscope system).

ACKNOWLEDGEMENT

The authors are grateful to Prof. Emeritus Boris Gelchinsky (Dept. of Geophysics, Tel Aviv University) for his useful comments and suggestions.
REFERENCES


