MESO-OPTICS

Foundations and Applications

Cover:

Design of the meso-optical mirror with ring response (a half) which was fabricated in 1986 with diffraction limited resolution.

MESO-OPTICS

Foundations and Applications

L M Soroko

Joint Institute for Nuclear Research, Russia

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In memory
of my wife,
Valentina M. Soroko

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Abstract

“ALMOST EVERYTHING ABOUT CONICAL WAVEFRONTS” is the motto of this book, which can be conceived as an up-to-date encyclopedic review of the theoretical and experimental investigations, performed by many researchers in the field of meso-optics. With many examples it is illustrated that meso-optics is indeed a rapidly developing branch of modern optics, in which the conical wavefronts are used, though sometimes implicitly, to transfer in space the information about the objects or the electromagnetic energy.

By starting from axicons, various meso-optical elements and new scopes of meso-optics is described. Diffraction free light beams and the localized electromagnetic wavefields is discussed. It is shown that gravitational lens can be accepted as a beamsplitter in the interferometer of the cosmic scale. Of particular interest will be inverse meso-optics, which can be used in electron accelerators for transportation of synchrotron radiation and in micromechanics. Some meso-optical microscopes and meso-optical metrological devices will be suggested. The history of meso-optics is followed from the first gravitational lenses in our universe up to the localized electromagnetic fields developed recently. Some integral transforms, useful in meso-optics, is presented in the Appendix.

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PREFACE

The aim of this book is to acquaint the reader with up-to-date theoretical, experimental and instrumental contributions of many researchers to the new branch of modern optics which is referred to as “meso-optics”.

The **theoretical** contribution follows from the new insight into the traditional optical imaging systems, such as lens, which focuses the light along two orthogonal directions. It has been discovered that imaging systems with axial symmetry, which focus the light only along one coordinate and not along another, orthogonal coordinate, can be used effectively for solving some awkward or even deadlock problems. In the course of more than ten years we have been using the term “meso-optics” to say that conical wavefronts do contribute principally into the systems for transferring in space the information about the object and also for transmitting the electromagnetic energy at long distances.

The **experimental** contribution covers the observations of various new phenomena with conical wavefronts, such as longitudinal interference of the diffraction free wavefronts, the decisive demonstration that information about the position of the microscopic straight-like objects in 3D space can be converted into two point-like spots with high data compression by means of sophisticated meso-optical imaging system, and the evident description of the exotic phenomenon, “darkness” in optics and meso-optics.

The **instrumental** contribution covers traditional and nontraditional techniques in optics, holography and tomography, which seems to be the most adequate to meso-optics. We have now diamond turning technique, computer generated hologram, precise plotter for manufacturing kinoform with prescribed phase relief and the technique for making “focusators”. The first kinoform for visible light with diffraction limited resolution was fabricated in 1984. The first precise meso-optical mirror with ring response was made in 1986. Therefore any proposals presented in this book in the field of meso-optics, for visible light and X-ray radiation, are provided with adequate technology basis.

In addition to meso-optics, by means of which the object point is transformed into the line segment or circle, “inverse meso-optics”, which enables one to convert into the point of coherent radiation generated by the source in the form of a straight line segment was also discovered. The direct application of inverse meso-optics for transportation of the X-ray synchrotron radiation and for manufacture of micromechanical parts of the devices is well evident.

What else can we benefit from meso-optics? First of all it must be stated, that the problem of the depth of focus in microscopy was solved by means of the meso-optical Fourier transform microscope, in which the information about position of the straight-like microscopic object has been compressed up to two point-like spots of the diffraction limited dimensions. The new device, confocal meso-optical scanning microscope is to be noticed. All meso-optical microscopes and tomographs, suggested in this book, have no counterparts in the conventional optical microscopy and tomography. These systems offer high productivity and can be applied adequately in microscopic robotics vision, for material testing in industry and in high energy particle physics.

This book is organized as follows. After introduction to meso-optics, the properties of conical wavefronts are explained in detail, and some applications of axicons are described. Meso-optical elements with ring response and their adequate application in the meso-optical Fourier transform microscope is also explained. The theory of this device and its features are presented along with description of some other designs of this device and application of the meso-optical Fourier transform microscope in high energy physics.

The diffraction free wavefields, Bessel–Gauss beams and various devices for generation of the diffraction free fields are described further. Following explanation of the exotic phenomenon “darkness” in optics and meso-optics, the longitudinal interference of the diffraction free wavefronts and its application in ophthalmology are presented. The problem of the localized electromagnetic waves is treated along with theoretical and experimental investigations in this rapidly developing part of meso-optics.

Gravitational lens, which is also a meso-optical element, accomplishes nonlinear transformation of the space coordinates and velocity components of the celestial objects. Typical examples of the gravitational lenses discovered recently and the property of gravitational lens as a beam-splitter is described. The fundamental properties of the critical curve (caustics) which separates the space into areas with different number of meso-optical images are considered with emphasis on the parallax gravitational effect in binary and planetary systems. The main topics of gravitational lens applications are presented.

Two chapters of this book are devoted to confocal meso-optical microscope–microtomographs, new stereo-microscope with high depth resolution and to some meso-optical metrological devices. Some potential new applications of meso-optics in science, industry and medicine is suggested throughout this book.

The history of meso-optics, presented in this book, starts from the early stage of our universe, to first gravitational lenses, followed by publications

in the last century and finally up-to-date innovations, many of which were proposed and performed with active participation of the author. The Appendix contains some integral transforms, which are useful in meso-optics.

The author believes that after publication of this book the frontiers of meso-optics will be expanded and its development will be accelerated.

L. M. Soroko
Dubna, Russia

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General view of the Meso-Optical Fourier Transform Microscope (JINR, Dubna).

Meso-optical image of the open rectangular with symmetry axes oriented along x and y coordinate axes.

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Symbol of Meso-Optics.

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