**UDC 535.015**

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# THE ROLE OF COHERENCE IN IMAGE FORMATION

***Abstract.*** The article presents the key stages of the history of the development of the wave theory of the formation of a diffraction grating image in a microscope system of coherent, non-coherent and partly coherent illumination.

***Key words***: experiment, primary image, spectrum, secondary image, Abbe theory, diffraction grating, microscopic objective, minimal resolvable distance.

## INTRODUCTION

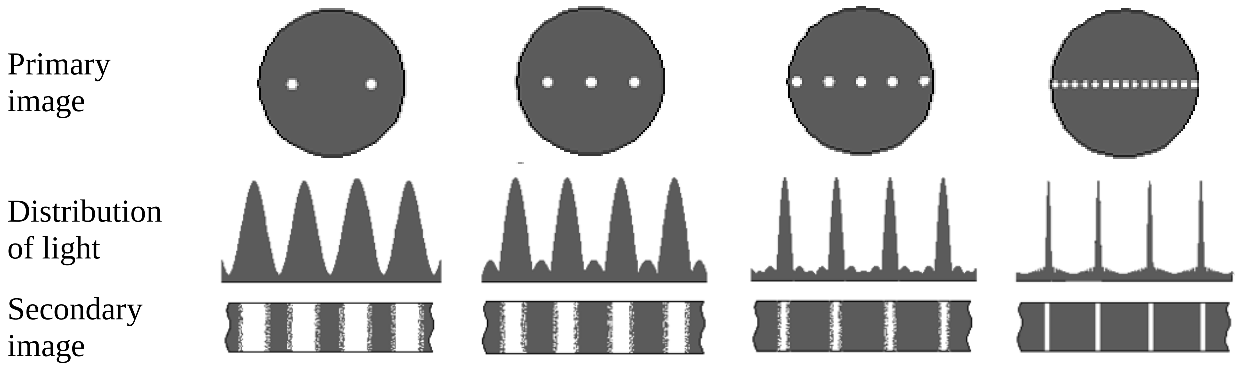
Ernst Abbe, Hermann Helmholtz, Albert Porter and others have widely studied the theory of image formation in an optical microscope under coherent light. After that many followers developed the theory for different cases and expanded it.

## COHERENT ILLUMINATION

Following Abbe's theory, the image of the object in a microscope is formed in two stages: the formation of its spatial spectrum in the back focal plane of the microscopic objective (the primary image), and then - an enlarged image of the object in the plane of the image (secondary image).

The diffraction pattern in the plane of the primary image is formed from a number of identical high-altitude maxima at the same distance from each other. One of them is corresponded to the zero diffraction angle and is in the place where the image of the source of illumination is formed without diffraction, taken as "zero maximum"; all other maxima are symmetrically relative to it.

Table 1. Image formation stages




As a result, of diffraction on the object, some deflected rays pass through the lens, the other part is cut off by an aperture. Thus, harmonics with very high spatial frequencies do not pass through a numerical aperture. As a result, the image of small objects can not be obtained. The minimal condition for the image formation is the presence in the plane of the primary image of at least two maxima (table 1.1).

It was also discovered that when installing in the plane of the primary image of a mask that passes only part of the spectrum, it may affect the secondary image. Abbe, for example, showed that when applying a one-dimensional grating spectrum to a mask that transmits only zero and paired maximums, the secondary image looks identical to

the case of a grating with a double frequency of strokes. And when overlaying on a spectrum of a two-dimensional lattice of a mask in the form of a slit it is possible to obtain a secondary image identical to one-dimensional grating, which was demonstrated by A. Porter (Fig. 1).

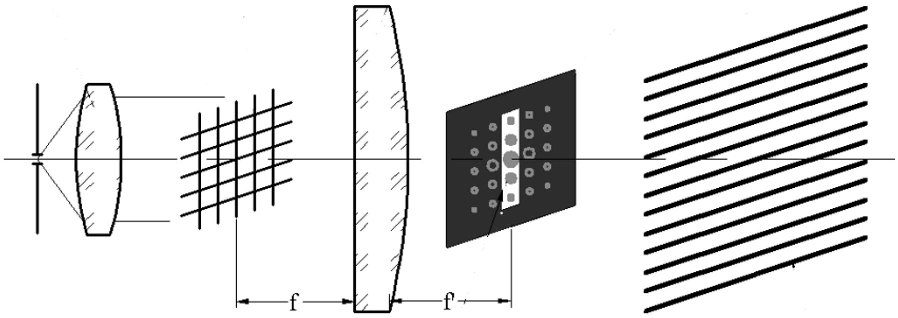



Figure 1. Optical scheme of the Abbe-Porter experiment

**NON-COHERENT ILLUMINATION**

Prof. L. Mandelstam has investigated that the image of a self-illuminated object, as well as incoherently illuminated, essentially has the same properties as the coherently illuminated image.

If we present such a non-coherent source as a set of coherent points, in a self-illuminating object, the phenomenon of diffraction on the periodic structure of the mask is preserved. Even in the absence of a visible spectrum in the plane of the original image, the installation of the mask leads to a change in the secondary image. Each small area on the object's surface emits as an elementary coherent source, this radiation passes through an optical system and it diffracts on an aperture with a mask in the back focal plane. The result it appears spatial filtration of numerous small plots. If these small areas are not coherent, then the back focal plane simply does not appear the primary image (Fig. 2).

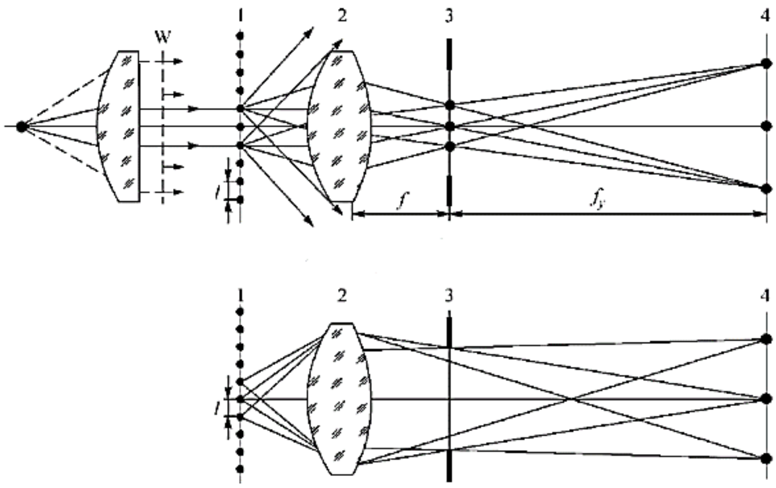



Figure 2. Mandelshtam’s experiments

**PARTLY COHERENT ILLUMINATION**

The common case is a partially coherent illumination. Properties of point source image are characterized by condenser parameters. Essential role is played by its aperture. Its value determines the diffraction pattern of Airy in the plane of the object.

Prof. D. Rozhdestvensky introduced the concept of the degree of non-coherence, as the ratio of the numerical aperture of the condenser to the numerical aperture of the

optical system (Fig. 3). If this value is equal to zero - the point image of the condenser in the plane of the object is very large and covers the whole field of view, and therefore the entire object is illuminated. This is a case of pure coherent lighting. When this degree goes to infinity - the lighting is not enough, so the object is illuminated by a large set of small incoherent areas. This is a case of pure incoherent lighting (absolute incoherence is impossible, since the numerical aperture is always greater than zero). If the coefficient is much less than one, this means a greater effect of coherent lighting, much more than one means a more significant role of incoherent illumination. The ratio is best when the coherent areas of the condenser and objects are almost equal.

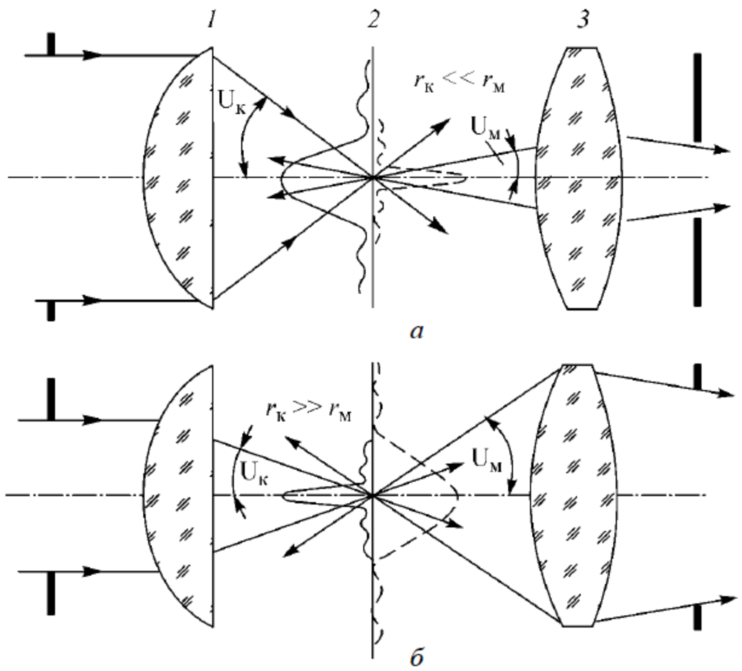



Figure 3. Optical scheme for explanation of the degree of non-coherence.

According to the Prof. A. Mareshall condition of the two points coherence, if the change in the optical path between them is sufficiently small (much smaller than the wavelength), we have approximation to absolute coherence. It is also a fair statement: if two points of the object are close enough to each other, there is also coherence. When the object takes waves from two points with significant angles between them, that is, when the change in the optical path of waves, much larger than the wavelength, we have an approximation to absolute incoherence.

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