EDW - edge diffraction wave, edge dislocation wave, or whether *tertio est datur*? (On the bicentenary of the Thomas Young's wave diffraction theory)

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ABSTRACT

A dramatic bicentenary history of the Thomas Young's wave interpretation of diffraction phenomena is briefly outlined. Both theoretical and experimental milestones substantiating the Young's diffraction paradigm are discussed. Vitality and topicality of the Young's views on the nature of diffraction are argued. Relation of the Young's concept of diffraction phenomena with the novel decomposition of the solution of the diffraction problem in the spirit of 'singular optics' is considered.

Keywords: diffraction, holography, optical phase conjugation, edge diffraction wave, edge dislocation wave, singular optics, polarization, quasi-optics

1. INTRODUCTION

This paper is devoted to the bicentenary jubilee of the Thomas Young's interpretation of diffraction phenomena (1801/1802) substantiating the wave nature of propagating light. This presentation is especially pleasurable for us, while the main contribution in the development and assertion of the Young's model of diffraction had been made by Adalbert (Wojciech) Rubinowicz, the great Polish scientist, one of the greatest physicians-theorists for Optics in the 20th century, and, before, the great native of Chernivtsi (the city where this conference is held), and the prominent graduate of Chernivtsi University. Once more ground to remind now the essence of the Young-Rubinowicz model of diffraction phenomena consists in the fact that this model, at the threshold of its bicentenary birthday and at the spike of the 'Young's boom' (using the Prof Kakichashvily's expression), meets the objections from the point of view of such influential division of modern optics as a *singular optics*.

Evolution of the Young's views on diffraction, reviving again and again as Phoenics of Optics (and not only of Optics) despite of incessant assaults, is too known to be reproduced here in details. In Section 2 we remind only the milestones of this evolution, with emphasize on the criterion experiments those put in evidence physical adequacy of the Young-Rubinowicz model of diffraction phenomena. Further, in Section 3 we analyze the alternative decomposition of the diffraction field in the spirit of singular optics. *Pro* and *contra* of both approaches to description and understanding of diffraction phenomena are discussed. At last, in Section 4 we summarize topicality of these approaches in solving of diverse problems of modern pure and applied optics.

2. MILESTONES OF EVOLUTION OF THE YOUNG'S CONCEPT OF DIFFRACTION PHENOMENA

The Young's heuristic explanation of an aperture diffraction is reduced to the following. Diffraction fringes at the directly illuminated area behind an opaque obstacle result from interference of the geometric-optical wave (GOW) from a quasi-point primary source, and the edge diffraction wave (EDW), which 'may be though of as arising from scattering of the incident radiation by the boundary of the aperture'[1]. At the same time, a diffraction field at the geometrical shadow region is

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equal to (coincides with) the EDW 're-scattered' by the boundary of the aperture. Let us at once to do three important remarks:

(i) The term 'boundary diffraction wave' is often used instead of 'edge diffraction wave' for the considerations of terminological tradition, though the last term is more adequate[2]. Moreover, after developing statistical radio-physics and statistical optics, the terms 'boundary field' or 'boundary wave' are applied to the diffracting or scattering device as a whole rather than to the rim of the field-of-view stop. To avoid terminological ambiguity, we say: 'EDW'.
(ii) Young assumed that the EDW 'is continuous everywhere, even across the boundary of the shadow'[3].
(iii) As it is shown in rigorous diffraction theories[4,5], 'the edge does not radiate'. Actually, the *real* edge radiation source is forbidden electrodynamically[4]. It means that the edge retransmitters must to be considered only as virtual rather than physically existing ones.

The last remark is supported by the well-known fact that the Young's model of diffraction phenomena cannot be directly formalized proceeding from the wave equation, i.e. the second-order differential equation in partial derivatives of hyperbolic type[3]. Nevertheless, it is remarkable that the observed diffraction pattern occurs, in all studied up to now cases, just the same as it follows from the Young's predictions. To say that the stroke of genius Young's diffraction paradigm is physically appealing is to say nothing. The same idea literally 'enters into the brain' to anyone who meets the diffraction problem. This affirmation has more than valued historical confirmation. Namely, just the same explanation of a knife-edge diffraction had been given by A.Fresnel (independently of Th.Young) in his first memoir on diffraction[6] (1815). Fresnel, in contrast to Young, uses the results of his carefully performed and in details described measurements of the dependence of intensity maxima and minima positions at the knife-edge diffraction pattern versus the distance of observation. The outstanding experiments performed by Fresnel are described in his first paper in such details, which provide reproduction of them now using the modern source (laser) and metrological techniques. And these results are explained by Fresnel just from the Young's point of view!

Fig.1 reproduces the main graph from the Fresnel memoir by 1815. This graph is accompanied with the highly interesting comments, which are reformulated here in terms of modern coherent optics. At first, spatial frequency (or, equivalently, spatial period) of interference fringes observed at the geometrical shadow region and its evolution with changing of the distance of an observation plane from an opaque strip is independent on the distance between the primary quasi-point (and quasi-monochromatic) radiation source and the strip. The explanation, in the spirit of the Young's paradigm, is suggested itself: the diffraction fringes behind a strip result from interference of the waves emanating from the strip's edges. At second, the diffraction fringes at the directly illuminated area are spreading along hyperbolas rather than along straight lines*. This behavior of diffraction fringes at the directly illuminated area can be explained *only as follows*: the diffraction fringes at the directly illuminated area result from interference of two waves: one produced by the primary source and another originating from the edge of an obstacle**. It may be of interest from the historical point of view that the classical interference experiment of Young reproduced in all textbooks in Optics along two centuries and widely used now for measuring of spatial coherence of light had been initially performed just in the arrangement shown in Fig.1 (with the Young's own hair) rather than into two-slit arrangement. Thus, Young accounted the *virtual* edge retransmitters rather than *fictitious* Huygens' secondary sources.

But why did Fresnel disavow his own initial explanation of diffraction phenomena, which had the mighty convincing force?! The answer is simple being, unfortunately, related to any field of creative work. The matter of the fact, any conceptual progress in any sphere of knowledge entails with the creator's ambitions. Being publicly (of course, groundlessly) accused in plagiarism, Fresnel declares a war to Young and (!) to himself. He performs several glorious experiments (including well-known interference experiment with 'Fresnel bi-mirror'), the only purpose of which was to disprove the Young's model of diffraction phenomena. Being steadfastly sure, due to his experimental experience, in the wave nature of propagating light, Fresnel turns to the old Huygens principle. The detailed analysis of Fresnel argumentation against the Young's diffraction paradigm is the subject of special paper. Here we note only: all Fresnel arguments are seemed to be naive from the point of view of modern optics.

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* It is worthwhile to be emphasized that only this simple result, disproving much less accurate measurements performed by Newton, was the criterion one led to the triumph of the wave interpretation of propagating light's phenomena.

** One can refer to any comprehensive monograph in holography to take understanding that *any* plane hologram of a point source is the photographic recording of spatial cross-section of the set of hyperboloids of rotation resulting from interference of two spherical waves.

The main success of Fresnel was in the remarkable mathematical description of a knife-edge diffraction pattern (Fresnel integrals) that gave correct positions and magnitudes of maxima and minima of the spatial light intensity distribution behind an opaque half-plane. All predictions of the Huygens-Fresnel principle were reliably proved, including important experiments[7,8] in the sixties of the 20th century. It has been experimentally shown that the configuration (spatial frequency), intensity and phase distributions of a knife-edge diffraction pattern in the nearest vicinity of the geometrical shadow boundary are governed by the Fresnel integrals and correctly imaged using the Cornu's spiral. However, it deserves to remind the limitations of the Fresnel considerations. First of all, Fresnel, similarly to Young, never wrote the wave equation; it had been made only by Kirhhoff in 1882. Fresnel constructed his description of diffraction by formalizing the heuristic Huygens principle rather than deriving it from the rigorous wave notions. Further, Fresnel integrals had been constructed under the paraxial approximation. Both Fresnel and later researchers established that the knife-edge diffraction pattern was not dependent on polarization of the radiation, on conductivity of the screen, and on the curvature of the diffracting edge[7]. This fact is often used in criticism of the Young's model[9,10]. However, one has to take in mind that

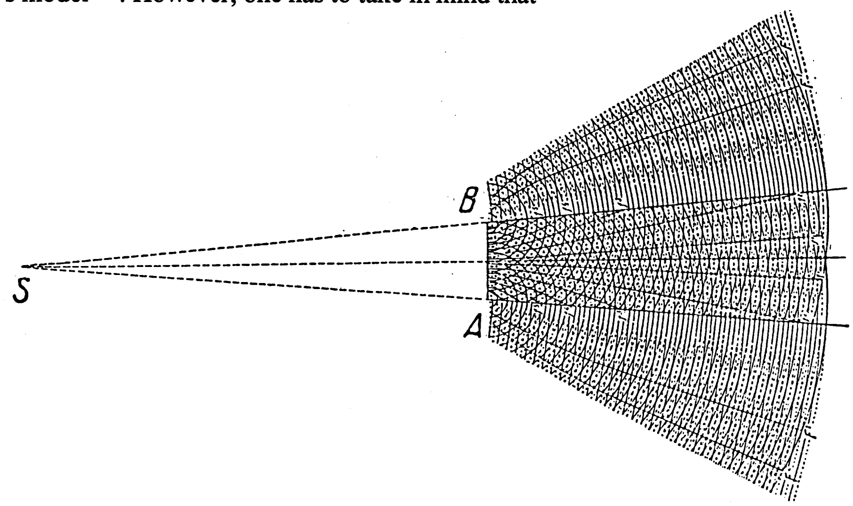

Figure 1 [6]. To the initial explanation of diffraction phenomena by Fresnel: *S* - quasi-point (and quasi-monochromatic) primary source, *A* and *B* - the edges of the strip (a wire in the Fresnel experiment and a hair in the Young's prior experiment). Fresnel draws the circles cente-red at the strip edges and shows the measured by him isophotes of diffraction (interference) pattern: *straight* interference fringes within the geometrical shadow region and *hyperbolas* at the directly illuminated area.

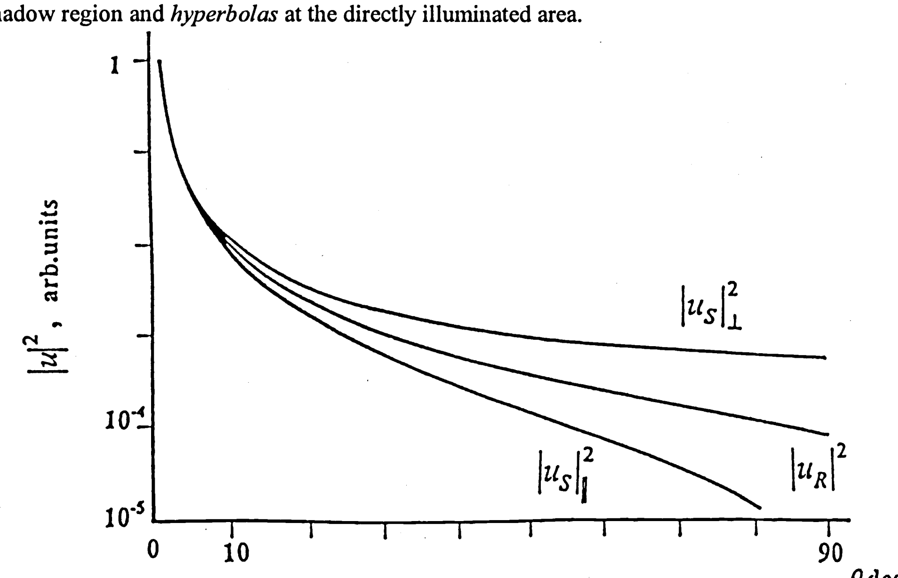

Figure 2. Behavior of diffraction field at large diffraction angles predicted by the rigorous (vector) Sommerfeld's solution of diffraction problem, $|u_S|_\perp^2$ and $|u_S|_\parallel^2$, and by scalar diffraction theory, $|u_R|^2$.

the experimental results represented in Ref.7 are obtained within the nearest vicinity of the geometrical shadow boundary, namely, for the diffraction angles non exceeding 0.5^0. As it follows from the vector diffraction theories[1,4,5,11,12], all solutions of the diffraction problem are equal to each other for obstacles of any conductivity and for the probing beams of any state of polarization within this range of the diffraction angles alone. At the same time, these theories predict considerable dependencies of a diffraction field behavior on the state of polarization of the incident wave for large diffraction angles. Such dependencies are observed not only at the radio-wave range of spectrum, but also in optical experiments[13]. Of course, the Fresnel scalar solution is incorrect at the diffraction angles far from paraxial region. The well-known consequence of this fact is that the diffraction field's amplitude vanishes only at 180^0 rather that at 90^0, as Fresnel believed. The Fresnel solution gives only a part of even a scalar solution, as it is seen from Fig.2, where $|u_S|^2_\perp$ and $|u_S|^2_\parallel$ show the angular de-pendencies of the diffraction field intensity predicted by Sommerfeld's theory for the cases, respectively, when the electrical vector of the incident wave is perpendicular to the diffracting rim of the perfectly conducting half-plane (H-polarization) and parallel to this rim (E-polarization), and $|u_R|^2$ corresponds to the scalar solution derived from the Kirhhoff's diffraction integral or, equivalently, from the Rubinowicz's representation of this integral[1-3].

Formal equivalency of the Young's and Huygens-Fresnel interpretations of diffraction phenomena was understood shortly after developing of the Kirhhoff's scalar theory of diffraction*. In 1888, Maggi[14], applying the well-known Stokes theorem, reduced the double Kirhhoff's diffraction integral over an aperture at an opaque screen to the single (curvilinear) integral over the rim of an aperture. This result had been consigned to oblivion up to 1917, when it had been anew substantiated by Rubinowicz[15], who had a possibility to compare his solution with the rigorous Sommerfeld's solution of the problem of diffraction at the edge of perfectly conducting half-plane. Moreover, Rubinowicz could lean for support on the entrancing Kalashnikov experiment (1911) dealing with observation of the EDW at the geometrical shadow region. The Kalashnikov experiment is sketched in Fig.3. A light from the quasi-point primary source, *PS*, is incident at the knife-edge, *KE*. At the geometrical shadow region Kalashnikov places several pins shown in Fig.3 by black circles. Beyond the pins, he places a photographic film that undergoes long-time exposure by the diffraction field. If the Huygens-Fresnel secondary sources at

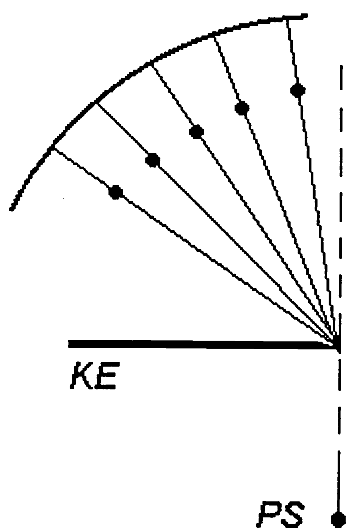

Figure 3. Sketch of the Kalashnikov experiment: *PS* - primary quasi-point source, *KE* - knife-edge; black circles are the pins followed by a photographic film.

* Saying 'formal equivalency' we mean that the Young's and Fresnel approaches are *alternative* to each other (being derived from different initial ideas), but that these approaches are not *mutually exclusive* (being reduced one to other by the direct mathematical transformation).

a half-infinite aperture are real, then the processed film's darkening must to be uniform. But the Kalashnikov experiment leads to the opposite result. The film's darkening occurs to be non-uniform, and the positions of the areas of the film's maximal amplitude transmittance correspond to the situation, when the film is exposed by the wave *as if* propagating from the knife edge, i.e. by the EDW. This simple experiment excludes an ambiguous interpretation. It shows that, though the edge retransmitter is forbidden, the wave motion at the geometrical shadow region is nevertheless the same as it has been predicted by Young. Namely, the part of a knife-edge diffraction field propagating into the geometrical shadow of a half-plane is the cylindrical wave with the origin at the diffracting edge.

The glorious theoretical result obtained by Rubinowicz is reproduced here in the extremely simplified form proper to our consideration. The contribution of the EDW into diffraction field is described by the contour integral with the integrand consisting of three factors. First of them is a (spherical or plane) wave coming to the running point of the rim of an aperture from the primary source, the second is the spherical wave diverging from this point into half-space behind the aperture, and the third is the inclination factor determining anisotropic structure of the EDW. Fig.4 shows schematically the actual genesis of a knife-edge diffraction for the case of normally incident plane wave. The GOW, u_g, undergoes disrupt at the geometrical shadow boundary, being equal to unity at the directly illuminated area, and being equal to zero at the geometrical shadow region, while the EDW, u_d, is governed by the angular dependence $u_d(\theta) \sim \cot(\theta/2)$, where θ is the diffraction angle. One can see that, in contrast to the initial Young's idea, both components of the diffraction field supposed by the Young's paradigm undergo discontinuities at the geometrical shadow boundary. It means that both components, being taken separately, do not obey the wave equation. Real wave motion behind the screen is provided only by the combination of these components, as the discontinuity in one component is compensated by the discontinuity into another component. The nature of the discussed discontinuity is quite clear: it is the direct consequence of the discontinuous Kirhhoff's boundary conditions[1]. It is clear that the formal representation of a diffraction field as a sum of the GOW and the EDW loses validity at the nearest vicinity of the geometrical shadow boundary. This circumstance is sometimes used as the impact argument in objections against the Young's (-Maggi-Sommerfeld-Rubinowicz-Miyamoto-Wolf- *etc.*) approach[9,10]. However, this inconsistency with the paradigm of *everywhere continuous wave motion* takes place within really very narrow area in the vicinity of the shadow boundary, whose cross-section is of the order of magnitude of the central Fresnel zone constructed at the observation plane from the real primary and the virtual edge sources. Under typical conditions of

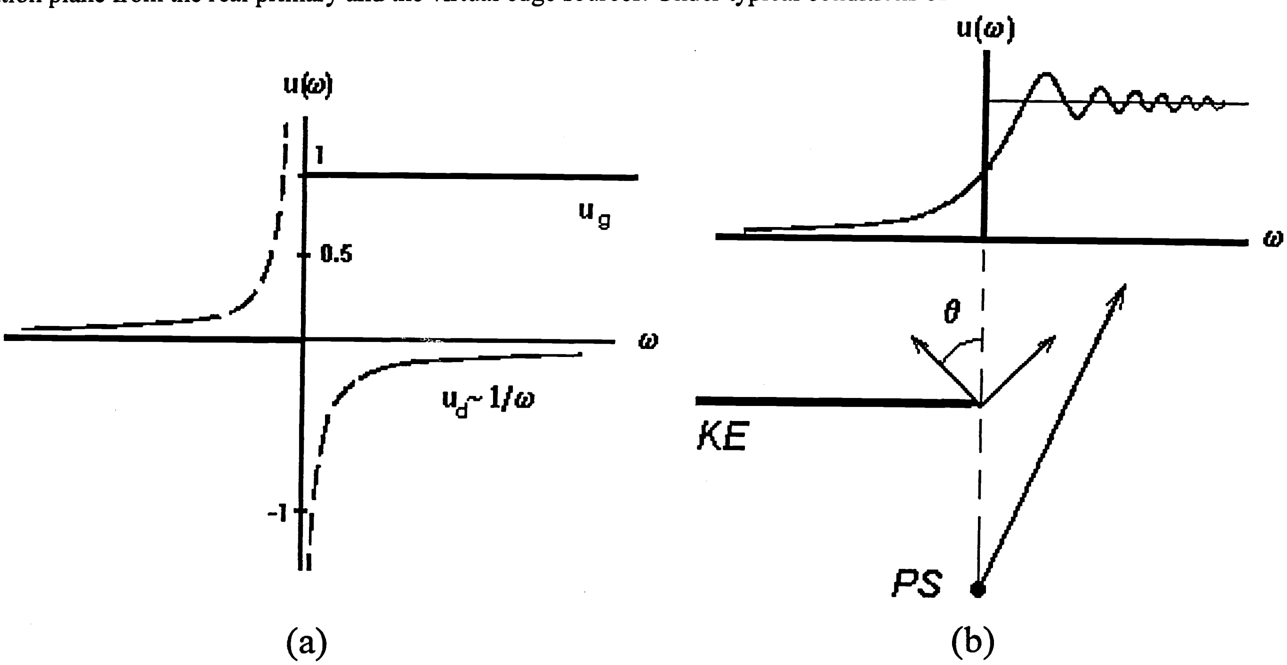

Figure 4. Components of a knife-edge diffraction field following to the Rubinowicz representation of the Kirhhoff's diffraction integral (a): u_g is the GOW, u_d is the EDW, and formation of a knife-edge diffraction pattern (b): *PS* - primary source, *KE* - knife edge, θ is the diffraction angle.

an optical experiment angular extension of this zone is always much less than 10^{-2} rad. Outside this narrow area, the asymptotic Young-Rubinowicz model provides high-accurate description of a diffraction field. Scalar approximation gives practically reasonable results up to 30-40 degrees, i.e. everywhere within the Fourier-optics domain. Moreover, a direct vectorial generalization of this model using an electromagnetic theory of diffraction is possible to describe a diffraction field at larger diffraction angles. To perform such a generalization, one must simply to identify a whole diffraction field at wave zone (at the distances from the edge $z >> \lambda$) within the geometrical shadow region with the EDW[13], and to apply to this field an electro-magnetic diffraction theory[11]. In contrast, in the vicinity of the shadow boundary one must to use the Fresnel integrals or compute a whole (undivided into components) field on the base of the Leontovich's parabolic equation, which gives highly accurate solution*.

An independence of diffraction on the matter (conductivity) and on the structure of the diffraction device (curvature radius of the diffracting edge) at small diffraction angles finds its exhaustive explanation within the framework of so-called *'quasi-optics'* based on Leontovich's parabolic equation. Let's remind that the transition from the exact hyperbolic (*wave*) equation to the asymptotic parabolic (*diffuse*) equation is performed under paraxial approximation, when one can neglect the second derivative of the propagating field on z-coordinate ($+z$ is the propagation direction of the incident wave). Within the framework of quasi-optics approach, the true origin of diffraction is recognized. Namely, *non-zero gradient of the field behind a sharp edge of an opaque obstacle is only the actual source of diffraction phenomena; the diffracting edge is only the precondition to provide the gradient of an amplitude along the wave front.* In its turn, the amplitude gradient provides peculiar effect of an «amplitude diffusion» (*diffusion without mass-transfer*) of the wave through the geometrical shadow boundary. Being «diffusing» (tunneling) through the shadow boundary, the complex amplitude of a wave field 'goes out' from the directly illuminated area *with its own phase*. It explains, why the EDW within the geometrical shadow region is 'in-phase' with the incident wave (see Fig.4). Further, the lack of complex amplitude at the directly illuminated area due to diffusion may be interpreted as the resultant effect of complementary edge source (re-)transmitting into this area in opposite phase in respect to the incident wave, in agreement with the structure of the inclination factor supposed by the Rubinowicz's representation of the Kirhhoff's diffraction integral (see Fig.4). If the diffraction field propagates in a free-space beyond the obstacle, than the origin of amplitude gradient (material obstacle's sharp edge) is neglected, and only amplitude gradient itself is important. Of course, the situation changes, when one considers large diffraction angles, especially diffraction angles approaching 90^0. This situation is seldom in optics, but it is typical for propagation of (electromagnetic) radio-waves along the Earth surface. In this case, one observes considerable polarization dependence of diffraction field, and one must to use the Leontovch's approximate boundary conditions and the Fock's «principle of a local field» at the diffracting edge[16]. The last concept lying in the basis of *'the shortened equations' method'* introduced by Leontovich and Fock in 1944-1946.

Once more intriguing historical collision occurs in this context. When the diffusion mechanism of diffraction had been substantiated by the Leontovich's parabolic equation, Malyuzhinyets[17] tried to prescribe the priority in recognizing of such mechanism to Th.Young, exploiting the Young's heuristic considerations. But our own survey of the historical framework of the problem shows that the Malyuzhinyets' attempt is not adequate. It has been noted above, that Young did not write the wave equation (written yet by L.Euler in the 18th century). Young, moreover, would not use the diffusion equation, while this equation had been written for the first time by A.Fick only in 1855, a half century later as the Young's diffraction paradigm was put forward! And even the equation of heat-conductivity (also of a parabolic type) has been written by Fourier in 1822, when the wave interpretation of diffraction in Fresnel version had been completed and world-recognized. In our opinion, when Young writes on dif-fusion of radiation, he applies the term 'diffusion' only in generalized (figural) sense, which may be understood now as 'scat-tering' or 'dispersion' of radiation.

Many years after the classical Rubinowicz's contribution, the Young's interpretation of diffraction revives again simultaneously in several world-class research centers[18,19,2,20-23]. Keller[19] derives the quite original approach of *geometrical* theory of *wave* diffraction, which occurs to be in conceptual agreement with the Young's ideas[5]. Miyamoto and Wolf[2] show that the concept of the EDW may be generalized on the case of the incident waves of arbitrary spatial structure. Marchand and Wolf[20] show that the same result is obtained proceeding from the Rayleigh-Sommerfeld diffraction integral rather than from the Kirhhoff's one. It is remarkable that the next paper by Wolf and Marchand[21] explains, why the Kirhhoff's boundary conditions, being inconsistent mathematically and violated in practice, lead nevertheless to the true and experimentally verified results concerning to the diffraction field in a wave zone. Namely, Wolf and Marchand decompose the EDW into the angular spectrum of plane-wave components and show that the component of this spectrum *propagating along the aperture* is just

* Asymptotic (rather than rigorous) nature of this solution follows from the fact that it cannot be extended with impunity to arbitrary diffraction angles.

the evanescent (exponentially decaying) wave, non affecting the diffraction field at a wave zone. After the cited papers by E.Wolf *et al.*, it is impossible to say that the Young's diffraction paradigm was to be consigned to oblivion. Due to these papers, the Young's diffraction paradigm had been completely legalized in optical science. Note here the following essential generalizations of the Young-Rubinowicz-Wolf concept of diffraction phenomena. Lit and Tremblay[24] applied successfully the EDW theory to the cascaded apertures that was of importance for the theory of laser resonators[25,26]. Suzuki[27] extended the EDW theory to the systems with arbitrary aperture transmittance function. He shows that when the gradient of an amplitude transmittance is like to the Dirac's delta-function, the exact solution of the diffraction problem is reduced to .the one given by Rubinowicz. Otis[28], and Smirnov and Strokovsky[29] applied this concept to the practically important case of Gaussian incident beams.

There are the main experiments verifying the Young-Rubinowicz's model of diffraction phenomena. Two basic techniques of dark-field observation are sketched in Fig.5, namely, the Toepler's schlieren technique and the Faucault knife one. A knife edge, *KE*, is placed in front of an objective, *Ob*, at distance exceeding its focal length. Regular image, *I*, is the real and inverted image of a knife edge. When, following to Toepler, one blocks the image of quasi-point primary source, P_0, with a small opaque scre-en, *BS*, then regular image is changed to the double-contour image of the diffracting edge. True image of the edge is the middle line of zero amplitude resulting from destructive interference of two out-of-phase by π components of the EDW of equal intensity. Two bright fringes decorating this *dark* image result from prevalence in amplitude of any of two components of the EDW at non-zero diffraction angles. In contrast, if the Faucault knife technique is applied, excluding both the primary source image and one of two components of the EDW, than one observes non-compensated interferentionally *single bright* image of the diffracting edge. This image (bright fringe) is positioned just the same as the dark (zero-amplitude) line in the Toepler experiment. Of course, resolution in both cases is dependent on the aperture conditions of the experiment. Under identical aperture conditions, a half-width of the single bright fringe (by Faucault) is equal to the distance between the intensity maxima at the double-contour image (by Toepler). To all appearance[3,30], such experiments were for the first time performed by Banerji in 1919. In our knowledge, the best demonstration experiment had been performed in laser era by S.Ganci[30]. In[31], it has been shown interferentionally (see Fig.5) that two bright fringes neighboring the dark image of a knife edge in Toepler experiment are out-of-phase by π, in agreement with the Rubinowicz's representation of the Kirhhoff's diffraction integral.

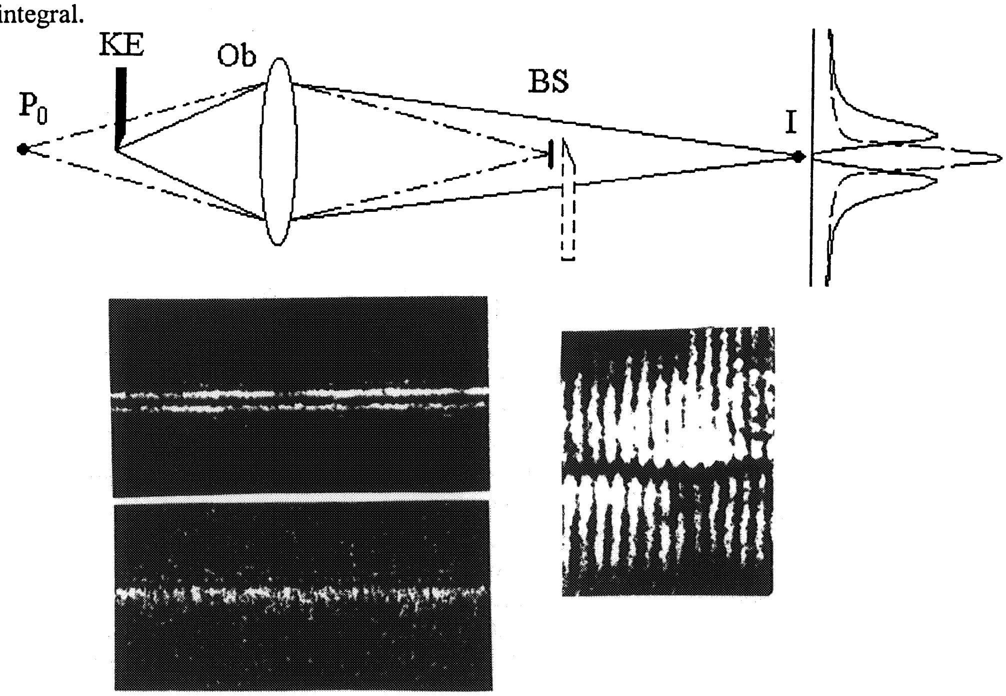

Figure 5. Sketch of dark-field observation experiments following by Toepler and Faucault: P_0 - primary source, *KE* - knife edge, *Ob* - objective, *BS* - blocking screen, *I* - image; double-contour image (following Toepler), single-contour image (following Faucault), and interference testing of a phase structure of the doubly contoured dark-field image.

It is worthwhile to understand now: why the Young-Rubinowicz model of diffraction phenomena did not attract attention of re-searchers working in holography along many years? In our knowledge, the only reference to the 'edge effects' in holography up to the middle of nineties of the 20th century had been made by Gabor in Ref.32 (Section 7). It is really strange, as a holography is the method essentially based on diffraction phenomena, and as such, it is the unique tool for verification of alternative concepts of diffraction[33]. Our answer is the following. Both Gabor and Leith and Upatnieks in their pioneering studies in holography proceeded from the Kirhhoff's diffraction theory, manifestly referencing to this theory. The milestone papers by Leith and Upatnieks arose in *Journal of the Optical Society of America* in 1962, some months after outstanding publications on diffraction by E.Wolf *et al.* Explosive success of holography in sixties formed universal impression that holography *per se* was the final proof of the principles from which it had been developed. In our opinion, however, this impression is not incontrovertible. Initial motive led us to the developing of so-called 'Young holography', i.e. holography of the EDW[13,31,33-41], was of pure didactic nature. We tried to find out: who did record the first hologram? Some of the great forerunners of Gabor are well-known[42]: they are Wolfke and Bragg. But we looked for the simplest conditions of photographic recording those providing a holographic effect. The result of our consideration is as the following. *The simplest case of a photographic recording of spatially non-uniform intensity distribution providing the holographic effect is a common photographic recording of a knife-edge diffraction pattern.* Thus, the anonymous pioneer of holography lived in the middle of the 19th century, when both Young and Fresnel died, but photography as the method of recording of light radiation had been discovered.

It has been shown[33] that the photographic recording of a knife-edge diffraction pattern may be considered as (*and it is*) a hologram of the rim of the diffracting device. Holography provides the unique possibility to divide the diffraction field at the directly illuminated area into two components, namely, the GOW and the EDW's component propagating to the directly illuminated area. Our initial idea is concisely reproduced below. If, following to Young, one interprets the part of a knife-edge diffraction pattern within the directly illuminated area as resulted from interference of the GOW and the EDW, then one may consider the GOW as the reference wave in respect to the EDW. Consequently, one must to expect that the GOW illuminating a photographic recording of such a diffraction pattern (in the absence of a knife edge) will reconstruct the main and the conjugate *contour* images of the obstacle. Such a hologram, if it is possible, will image just the virtual source of the EDW. For that, the main (virtual) contour image will be observed at the strong background due to the read out wave. But one can choose the geometrical conditions for hologram recording and reconstruction, when the conjugate image will be real, i.e. it will be reconstructed behind a hologram[33]. In this case, one can use a complementary opaque screen at the hologram plane to provide dark-field (in Faucault sense) observation of the conjugate image of the 're-transmitting' edge. This prediction is obviously supported by an important feature of a knife-edge diffraction pattern at the directly illuminated area: the coordinate dependence of spatial frequency of diffraction (interference) fringes is $\mu \sim X/\lambda f$, where X is the distance of the running point of the field from the geometrical shadow boundary, λ is the wave length of the incident wave, and f is the focal length of Fresnel zone pattern, which in the case of a plane incident wave is equal to the distance from the knife edge to the observation plane. It means that a photographic recording of a knife-edge diffraction pattern is none other than the one-dimensional (and one-sided) Fresnel zone plate, whose imaging ($\equiv$holographic) properties are well-known.

Our attempt to verify experimentally this consequence of the Young-Rubinowicz model of diffraction phenomena in holography led to prompt success[33-35]. The sense of this result is that the virtual Young's edge retransmitters may be 'portraited' (imaged), while the Huygens-Fresnel secondary sources are fictitious radiators, which can not be observed in principle[33,43]. Detailed description of diverse results obtained in Young holography may be found in Refs.13,31,33-41. Here we want to emphasize only one of these results. Applying the original technique for optical phase conjugation using a static nonlinear hologram recorded with a standing reference wave[44-47], *we self-reversed the EDW to its origin* and, in such a manner, formed the image of the diffracting rim just at the place where the rim is located[40,41]. Note that in the regime of EDW self-conjugation using a static nonlinearly recorded hologram, one can realize holographic analogs of both classical (by Toepler and by Faucault) dark-field observation techniques. All observed by ours results are in excellent qualitative and quantitative agreement with the predictions derived from the Young-Rubinowicz model of diffraction phenomena. At the same time, holographic implementations of the conditions of dark-field observation based on balancing of diffraction efficiency of a hologram at different areas of the recorded diffraction pattern possesses important advantages in comparison with a 'hard' blocking of *dc*-term by the use of opaque screens. Namely, holographic techniques naturally provide 'soft' blocking of low-frequency components of the object wave that leads to suppressing of undesirable diffraction side-lobes into reconstructed images.

There is the reason to allocate *Young holograms* into special hologram type. Following the tradition, the fundamental hologram types (Fresnel hologram, Fraunhofer hologram, Fourier hologram, and, sometimes, focused-image hologram) are introduced by taking into account the approximation adopted for asymptotic computation of a diffraction integral for the object wave and reference one at the plane of registration[48,49]. All mentioned hologram types are introduced on the base of the Kirhhoff's diffraction integral. In the case of the focused-image hologram, one computes the exposing object field by taking two sequential integral transforms. Further, proceeding from the alternative approach to description of diffraction phenomena introduced by Rayleigh, when the elementary waves into the set of which the boundary object field is expanded are infinite-aperture plane waves rather than spherical ones (as in Huygens-Fresnel-Kirhhoff theory), one can recognize once more fundamental hologram type, namely, 'Rayleigh hologram' or hologram of evanescent waves. At last, introducing the Young-type hologram is justified by exploiting of the alternative decomposition of the object wave, namely into the GOW and the EDW.

Shoucri's interpretation of contour (diffraction) integral[50,51]. Let us consider here one interesting interpretation of diffraction phenomena related to the Young-Rubinowicz model, which had been introduced by Shoucri[50] in 1969 and reproduced by him along thirty years[51]. The consideration performed by Shoucri is as follows.

Shoucri divides the plane where a diffraction aperture at an opaque screen is placed into infinite series of Fresnel zones and adds together the contributions from all zones at the point of observation of a diffraction field. The contributions from the beginning m zones located within the aperture are added in a common way, and the contributions from the zones from $m+1$ to infinity blocked by the screen are subtracted from a whole (undisrupted by the screen) field. The key peculiarity of this consideration is elimination *by assumption* the 'shining edge'[1,3-5] and its influence on the diffracting field from the analysis. It is obvious, the result obtained is equivalent to the Kirhhoff's one as well as to one derived proceeding from the Maggi-Rubinowicz contour integral. On this ground, Shoucri asserts that the contour integral does not represent physically existing wave motion, but it rather provides only a formal description of the resultant effect of 'subtracting' of the contributions from the blocked Fresnel zones from a whole field. It is remarkable that interpretation of a contour integral in diffraction theory is advanced by Shoucri along the third of century. Nevertheless, has no any experiment been proposed for its proof up to now. Let us discuss here such experiment and show that it may be only the 'brain experiment' rather than the real one. In this respect, the discussed below experiment is similar to the famous 'twins paradox' in the special relativity theory. So, being formally irreproachable, it nevertheless cannot be directly verified.

The Shoucri's interpretation would be verified in the following way. Let an undisrupted wave of unite amplitude from the primary source, hereinafter Wave I, to be co-axially superimposed (for example, interferometrically) with the copy of a part of this wave, hereinafter Wave II. Let the Wave II to be of the same wave front and amplitude as the Wave I, being at the same time out-of-phase by π with this wave and having sharp discontinuity at its boundary with the jump of amplitude from unity to zero. It is clear, perfect interference compensation of a part of Wave I will take place, amplitude gradient will occur at the boundary 'light-darkness', and amplitude diffusion of the 'cut' Wave I into dark region will begin. Following to Shoucri's argumentation, one can assume that two identical (in wave front and amplitude) but out-of-phase by π sets of Fresnel zones (integer or partial[50,51]) associated with Wave I and Wave II correspond in this hypothetical experiment to the region of darkness. In accordance with Shoucri's conclusion, an additional field (Wave II) associated with Fresnel zones of the 'extinguished' region is the source of diffraction. The result could be equivalent to one realized with blocking of the corresponding part of Wave I by a material sharp-edged opaque screen.

Of course, the described 'brain experiment' cannot be performed. To do this, one must, at least, to have a possibility to construct the sharply-edged Wave II with the amplitude gradient like to the Dirac's delta-function. But it is the same as to suppose a possibility of *diffractionless propagation of sharply cut wave*. One just reveals the 'vicious circle' in this point: such a possibility is excluded by diffraction phenomena. The best practical approximation to the desirable conditions of the discussed experiment consists in the use of material opaque screen at the reference leg of an interferometer to provide the boundary 'light-darkness'. However, this boundary always turns out to be blurred to a certain extent due to diffraction! Besides, inevitability of the usage of (as though auxiliary) material screen occurs in obvious contradiction with the Shoucri's interpretation, for which proof this experiment is destined. Namely, inevitability of introducing in the wave (or in its part) of a material screen disturbing homogeneity of the space of wave propagation to obtain the diffraction effect just manifests physical existence, *physical reality* of the component of a wave motion with the center of divergence at the edge of a material blocking screen.

It is quite clear now that the Shoucri's interpretation, providing accurate formal description of diffraction phenomena in the nearest vicinity of the geometrical shadow boundary, does not reveal the true source of diffraction phenomena (amplitude gradient of the field, and the screen edge as the precondition of this gradient). Besides, the Shoucri's interpretation suffers from the lack of any definition of an opaque screen. An opaque screen is equal to the superposition of two out-of-phase by π waves of equal amplitudes only formally[43]. If only the described 'brain experiment' would be performed, it would be standing for a classical (non-quantum) effect of light-by-light diffraction without interaction of radiation with a matter. Of course, such a possibility is quite fantastic. At last, virtual Fresnel zones associated with the blocking screen and considered by Shoucri as the 'supplier' of the energy for developing of diffraction can not be visualized (imaged) and, as such, they are fictitious secondary sources similarly to the Huygens-Fresnes ones.

Insolvency of the Shoucri's interpretation may be also shown by taking into account the well-known fact that the diffraction field within the geometrical shadow region depends only on the field's magnitude at the diffracting edge, rather than on the field distribution within an aperture. This fact has been demonstrated for a far-field aperture diffraction of converging spherical wave[31,36] everywhere outside the central diffraction maximum of Fraunhofer pattern, as well as for the case of a knife-edge diffraction of Gaussian beams[29]. Namely, if a knife edge is located at the amplitude maximum of a Gaussian beam, then the diffraction field at the geometrical shadow region turns out to be strictly the same as in the case, when a knife edge is illuminated by a plane or spherical wave of constant amplitude equal to the amplitude maximum of a Gaussian beam. Of course, the Cornu's spiral is deformed in the case of Gaussian incident beam, and the Shoucri's computation is modified. But independence of a diffraction field within the geometrical shadow region on the specified structure of the incident wave far from the nearest vicinity of the diffracting edge is once more valued argument against physical adequacy of the Shoucri's interpretation.

3. KHIZHNYAK'S DECOMPOSITION OF THE DIFFRACTION FIELD

When our study[13,31,33-41] on holography of an ED(*diffraction*)W had been completed, we quite unexpectedly clashed with another decomposition of a diffraction field arising, in particular, in a knife-edge diffraction. This approach had been inspired by Khizh-nyak *et al.*[9,10,52-57] using the same acronym as being introduced earlier by us, 'EDW', but whose sense became quite different from one in the Young-Rubinowicz model of diffraction. The authors of the mentioned approach flatly deny legitimacy of the diffraction field decomposition following to the Young-Rubinowicz model of diffraction (in which we are sure owing to our own experimental experience as well as to our knowledge of the conceptual and historical framework of the problem) ignoring all the mentioned in Section 2 (and many other) evidences in favor of this model, and assert that only their decomposition provides 'exceptionally fruitful approach'[54], which gives 'attractive and elegant explanation of Sommerfeld's solution'[10], 'new look at the wave composition of a diffraction field'[10], 'a gracious union of numerical precise rigorous mathematical solution and possibility of deeper circumstantiation of the wave process'[52], and 'explanation of true nature of diffracting wave field'[55]. Here we explain the essence of this approach and discuss its advantages and disadvantages.

The discussed decomposition of a knife-edge diffraction field is performed as follows. The part of Sommerfeld's rigorous solution of the diffraction problem, associated with the component of the incident wave whose electrical vector is parallel to sharp straight edge of a half-infinite perfectly conducting screen (*E*-polarization, see curve $|u_S|^2_{\|}$ in Fig.2), is *formally* decomposed in-to two components[9,10] shown in Fig.6: (*1*) an infinitely-extended plane wave bearing a half amplitude of the plane incident wave, being out-of-phase by π with this wave; (*2*) an infinitely-extended quasi-plane ED(*dislocation*)W. The term 'dislocation' is applied here to the wave with infinitely extended line of zero amplitude, in the spirit of singular optics[58]. A mean direction of propagation of this wave is the same as one of the incident wave, its amplitude at the geometrical shadow boundary is zero, and its amplitude oscillations decay at 'wings', so that the ED(*dislocation*)W at its 'wings' approaches a plane wave. Two parts of the ED(*dislocation*)W symmetrical in respect to the shadow boundary are out-of-phase by π to each other. Both the plane-wave component of the diffraction field and the ED(*dislocation*)W are assumed to be 'occupying a whole space and insensitive to the presence of the screen'[10]. Khizhnyak *et al.* declare that the mentioned decomposition determines 'real physically existing waves'[10] those are the natural eigenmodes of the diffraction field[52].

Rigorously speaking, the discussed decomposition of a knife-edge diffraction field does not belong to Khizhnyak *et al.* The same formal decomposition had been introduced (of course, without singular phraseology) fifty years before by Gabor[32] (see Eqs. (22) to (24) and Figs.12 and 13). Moreover, similar representation was used for more general case of Gaussian incident beam diffracted by a circular aperture[59]. It is unlikely that Khizhnyak *et al.* did not know the papers[32,59]. It is moreover staggering that Khizhnyak *et al.* attribute this decomposition to themselves[52-57]!

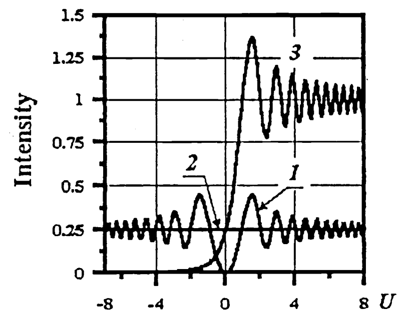

Figure 6 [10]. Khizhnyak's decomposition of the diffraction field behind a half-infinite opaque screen: *1* - the ED(*dislocation*)W, *2* - the plane wave, *3* - the resulting diffraction wave.

The authors[9,10,52-57] do not proceed from the Maxwell's equations, as Sommerfeld does to obtain his rigorous solution[1,4,5]. They, also, do not write the wave equation, and do not specify the boundary conditions to solve this equation (or, at best[53], specify these conditions following to Kirhhoff[*]). Instead, they use the ready solution of a diffraction problem in terms of the Fresnel in tegrals. It is quite obvious from Fig.2 that any transformations of this solution might give only a part of even the scalar solution. It means that the Khizhnyak's solution of the diffraction problem must to be specified only as the asymptotic rather than as the rigorous one, as asserted[9,10,52-57], despite at extremely small diffraction angles such a representation, really, may provide high numerical accuracy in description of a diffraction field, irrespectively of the assumptions concerning to the screen's conductivity, radius of curvature of the diffracting rim, and the state of polarization of the incident wave. In our opinion, even extension of the approach[10] on the case of *H*-polarized incident wave, as it is performed in Ref.56, will not lead to the experimentally verified results. In this context, it is non superfluous to remind the van de Hulst's utterance[60] that Sommerfeld's solution is *rigorous* (being derived proceeding from the rigorous, though idealized, boundary conditions), but it is not *exact* (being no undergoing literal experimental verification due to impossibility to implement *perfectly* conducting screen). Actually, various vectorial diffraction theories for real opaque screens give considerably different results, some of which are in glaring contradiction with Sommerfeld's solution[11]. One experimental example of this circumstance may be found in Ref.13.

Nevertheless, the Khizhnyak's decomposition of a diffraction field possesses undoubted aesthetic advantages. Namely:

(i) both wave components shown in Fig.6 are continuous in amplitude, and only the ED(*dislocation*)W has a phase discontinuity at the edge-dislocation plane (coinciding with the shadow boundary). It is important that a phase discontinuity is not forbidden by the wave considerations: it means simply that a wave phase is changed by π at zero-crossing. As so, both mentioned components obey the wave equation and 'can exist and propagate in free space separately'[10];

(ii) besides, the Khizhnyak's decomposition of a diffraction field arising from a plane-wave diffraction at an opaque half-plane undergoes an obvious generalization on arbitrarily shaped wave fronts of the incident field. So, an *incident beam* (instead of the above mentioned infinitely-extended incident plane wave) is expanded into angular spectrum of plane waves, and the Khizhnyak's decomposition of the *diffraction field* is applied to the each of these waves that results in a simple convolution integral. It has been shown, in part, for the case of a half-plane diffraction of Gaussian beams[52];

(iii) at last, the wave components figuring in the Khizhnyak's decomposition have convenient formal representation, which provides reducing of computation time in solving various diffraction problems under paraxial approximation[57].

[*] It is well known that the Kirhhoff's boundary conditions are inconsistent being in contradiction with the wave concept. So, if the wave field and its derivative vanish simultaneously at any point, then the wave field vanishes at a whole space. Such conditions provide only asymptotic solution of the diffraction problem. That's why, the authors[10,53] are compelled to introduce an additional (to shown in Fig.6 plane wave and the ED(*dislocation*)W) so-called a 'pressed' wave at the geometrical shadow region just behind an opaque screen. Of course, existence and the predicted structure of the 'pressed' wave have never been proved experimentally.

The last advantage is obvious only in comparison with computation of two-dimensional (area) diffraction integrals, but it is unsupported being compared with the computation following the Rubinowicz's representation that also leads to one-dimensional (contour) diffraction integral[1,3]. Moreover, one can make the next step within the framework of the Young-Rubinowicz model by applying the stationary phase principle[2], and reduce solving of the diffraction problem to summation over finite set (often extremely limited) of the contributions from so-called critical points within the plane of diffraction device. The Khizhnyak's decomposition of the diffraction field certainly cedes to this approach. Thus, the last of three mentioned advantages of the Khizhnyak's decomposition is ephemeral.

Now consider the experimental arguments in favor to the Khizhnyak's decomposition of diffraction field. First of all, the discussed decomposition cannot be directly realized neither by subtraction of a part of a whole diffraction field using any dark-field technique nor by phase shift of a part of a whole diffraction field using a phase-contrast technique. The only possibility proposed to 'isolate' the ED(*dislocation*)W from a whole diffraction field consists in interference superposition of a knife-edge diffraction field with an additional reference background, for example, in the arrangement of Mach-Zehnder interferometer[9,10,52-57]. For that, the reference wave must to be specially matched with the knife-edge diffraction field: (a) in wave front, (b) in direction of propagation, (c) in amplitude, (d) in phase. If the reference wave and the wave incident on a knife edge are of the same wave front and propagation direction at the interferometer output, and the reference wave is of half amplitude of the incident wave, and both waves are out-of-phase by π to each other, then one can observe a dislocation wave at the interferometer output, see top fragments in Fig.7. The authors[9,10] interpret this result as 'destructive-interference subtraction' of the plane-wave component figuring in the Khizhnyak's decomposition from a whole knife-edge diffraction field. Superimposing an *additional* titled reference wave with the combined field originated from a superposition of the knife-edge diffraction field with the interferometrically matched reference wave results in revealing of a phase structure of the ED(*dislocation*)W. Namely, it proves that the parts of this wave symmetrical in respect to the line of zero amplitude ('edge-dislocation line' coinciding with the geometrical shadow boundary) are out-of-phase by π . Further, if the reference leg of an interferometer is blocked, then one can observe conventional knife-edge diffraction pattern, and the use of an additional titled reference wave reveals the cylindrical wave front of the diffraction field at the geometrical shadow region, see bottom fragments in Fig.7.

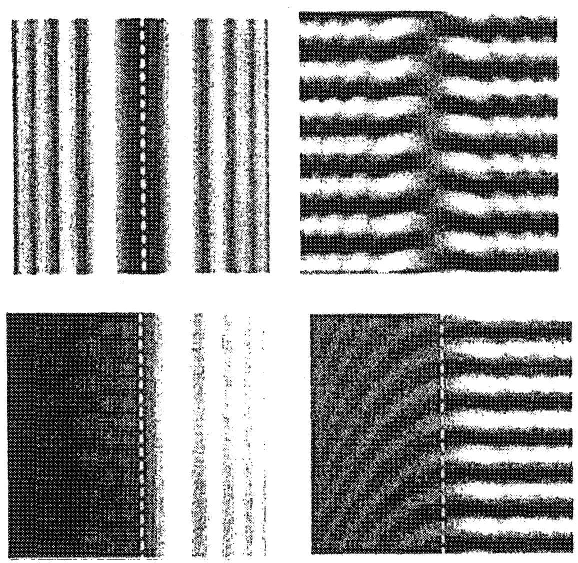

Figure 7 [10]. Top: a pattern appearing at the interferometer output and its interferogram with additional titled reference wave; bottom: a pattern appearing at the interferometer output with blocked reference wave and its interferogram with additional titled reference wave.

Of course, the Khizhnyak's interpretation of the experimental results represented in Fig.7 is deprived of any convincing force. These results have a simple interpretation in terms of classical (non-singular) wave optics. First of all, it is seen from this figure that spatial frequency of the ED(*dislocation*)W's amplitude linearly increases as the distance from the geometrical shadow boundary (shown by a dashed line) increases. From the point of view of the Young-Rubinowicz model, such spatial structure of the ED(*dislocation*)W is naturally explained as the result of interference of the cylindrical ED(*diffraction*)W with the center of divergence at the knife edge, and the reference wave specified as described above. This clear interpretation is supported by observation of spatial evolution of the ED(*dislocation*)W with increasing of the distance of observation. So, if one uses a plane reference wave, then the isophotes spread following to the parabolic law; and if one uses a cylindrical reference wave, then the isophotes spread following to the hyperbolic law (see discussion of Fig.1). That's why, we believe that Fig.7 (top fragments) shows really something quite different from those asserted by the authors of this experiment. Namely, *the formal (Gabor-) Khizhnyak's decomposition of a knife-edge diffraction field suggests the diffraction-interference means to produce the wave with the edge dislocation, rather than shows the means to 'isolate' such a wave from the knife-edge diffraction field, and all the following*[52-57] *concerns only with the study of this actual subject of singular optics, rather than with the diffraction problem per se*. Let us argue the last conclusion.

First of all, to show that the Khizhnyak's decomposition does not determine the natural eigenmodes of a diffraction field, it is sufficient to modify the reference wave in any way (with unchanged wave incident on a knife edge): in wave front, in direction of propagation, in amplitude, or in phase. For the each of denumerable infinity of such modifications, one can interpret the 'interferentional rest' at the interferometer output as the result of interference subtraction of the whole diffraction field's wave component, bearing the same amplitude as the specified reference wave being out-of-phase by π with this wave. Of course, all these situations are physically equal to each other, but, obviously, the ED(*dislocation*)W does not appear in most cases. Besides, this circumstance raises to the problem of spatial stability of the ED(*dislocation*)W. The statement that the results represented in Fig.7 (top fragments) show 'physically stable field with edge dislocation propagating along the geometrical shadow boundary'[53] is not substantiated neither conceptually nor metrologically.

Further, there are another means to produce the wave with the edge dislocation[9,10,13]. One of them consists in the use of a plate with the π - phase step, and another consists in the use of 'bi-grating' with a half-period shift of the maxima of an amplitude transmittance at the adjacent areas of the grating. These means for producing of a dislocation wave are much more practicable than the one following from the Khizhnyak's decomposition, as they do not pre-assume a fine interferometrical adjustment. All results represented in Refs.52-57 would be obtained applying these much more simple techniques.

At last, Khizhnyak *et al.*, unfortunately, did not avoid once more borrowing on the results of their forerunners (see comments of Fig.6). The result shown in the right bottom fragment of Fig.7 had been obtained many years ago by the same (interferometrical) technique and found a firm metrological confirmation[8]. This important paper is not cited by Khizhnyak *et al.* In Fig.8 we reproduce the result[8]. It is remarkable that this result occurs to be in obvious contradiction with the objections of the authors[10] against the Young's diffraction paradigm. Really, both the interferogram at the right bottom fragment of Fig.7 and Fig.8 evidence that the knife-edge diffraction field within the geometrical shadow region is the cylindrical wave, as predicted by Young. The question arises: in what way may the plane-wave component and the ED(*dislocation*)W approaching a plane wave at wings to form a cylindrical wave front of the resulting diffraction field? This question is not answered by Khizhnyak *et al.*

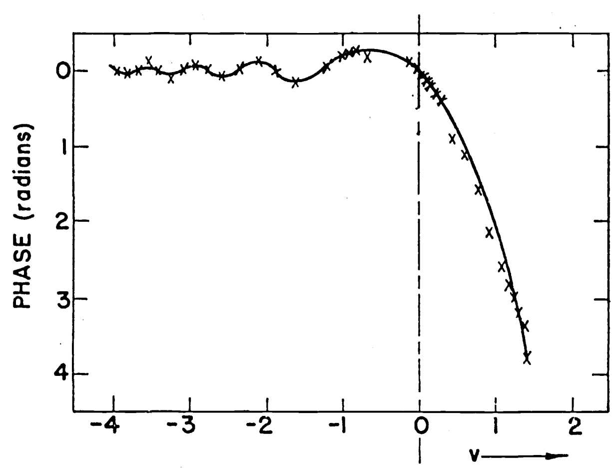

Figure 8 [8]. Phase in the knife-edge diffraction pattern calculated using Fresnel integral and the Cornu's spiral (a curve) and determined interferometrically (crosses).

Another inconsistency between the conclusions made by the authors[9,10,52-57] proceeding from the Khizhnyak's decomposition and physical reality concerns to explanation of the 'shining edge effect'. One can see from Fig.6 that only *amplitude oscillations* of the ED(*dislocation*)W decay as the distance from the geometrical shadow boundary increases, while the ED(*dislocation*)W's *amplitude* reaches its absolute minimum (zero) just at the geometrical shadow boundary. That's why, explanation[55] of the 'shi-ning edge' as the resultant effect of combined action of the plane-wave component of a knife-edge diffraction field and the ED(*dislocation*)W is quite groundless.

4. CONCLUSIONS

The set of evidences in favor of the Young-Rubinowicz model of diffraction phenomena, some of which we discussed in Section 2, leads to the conclusion that this model has been firmly grounded both theoretically and experimentally. Theory of the ED(*diffraction*)W is conceptually and formally connected with other models of diffraction. The parameters of the ED(*diffraction*)W (amplitude, phase and polarization angular distributions) predicted by the theory are verified experimentally. Being of asymptotic nature and possessing, as any asymptotic theory, some inconsistencies (in part, discontinuity at the geometrical shadow boundary), the ED(*diffraction*)W theory nevertheless leads to the experimentally proved conclusions. The Young's diffraction paradigm, being refined mainly by Sommerfeld, Rubinowicz and Wolf, gives a clear explanation of the diffraction field behavior everywhere outside the nearest vicinity of the geometrical shadow boundary, where the diffusion model of diffraction must to be applied. The initial Young-Sommerfeld-Rubinowicz-Wolf concept dealing with diffraction at a sharp edge has been successfully generalized for the case diffraction apertures with arbitrary amplitude transmittance. In many cases, the use of the Young-Rubinowicz model resulted in a more deep insight into nature and peculiarities of diffraction phenomena than those provided by the alternative models, as well as in developing of new techniques of information processing by means of coherent optics.

The objections against the Young-Rubinowicz model of diffraction, beginning from Fresnel and up to Shoucri and Khizhnyak *et al.*, are not persuasive. In some cases these objections are reduced to simple reformulating of the Young's results in other terms (Shoucri). In other cases (Khizhnyak *et al.*) one wish *to deliver over the desirable as for the true*. Saying this, we do not wish to deny legitimacy of alternative approaches in explanation of diffraction phenomena. Moreover, there are no any reasons to give preference to the Young's diffraction paradigm against other ones. So, the Khizhnyak's decomposition of a diffraction field results in original means for constructing the ED(*dislocation*)W and provides new feasibilities for investigation of this subject of singular optics.

Thus, let us conclude by the A.France's words: «There is something divine in any God»!

REFERENCES

1. Born M., Wolf E., *Principles of Optics*, Pergamon, New York, 1964.
2. Miyamoto K., Wolf E., 'Generalization of the Maggy-Rubinowicz theory of the boundary diffraction wave', Parts I, II, *Journ. of Opt. Soc. of Amer.*, **52** No.6, pp. 615-637, 1962.
3. Rubinowicz A., 'Thomas Young and theory of diffraction', *Nature*, **180**, pp. 160-162, 1957.
4. Sommerfeld A., *Optics*, Academic Press, New York, 1954.
5. Hoenl H., Maue A., Westpfahl K., *Theorie der Beugung* / Handbuch der Physik Herausgegeben von S.Flugge, Band 25/1, Springer, Berlin, 1961.
6. *Oeuvres completes d'Augustin Fresnel*, publiees par M.M.Henr ide Senarmont, Emile Verdet et Leonor Fresnel, Paris, **1**, No.2, p.9, 1866.
7. Barnett J.D., Harris F.S., 'Test of the effect of edge parameters on small-angle diffraction of light at a straight edge', *Journ. of Opt. Soc. of Amer.*, **52** No.6, pp. 637-643, 1962.
8. Harris J.S., Givens M.P., 'Determination of phase in the knife-edge diffraction pattern', *Journ. of Opt. Soc. of Amer.*, **56** No.7, pp. 862-865, 1966.
9. Khizhnyak A.I., Anokhov S.P., Lymarenko R.A., Soskin M.S., Vasnetsov M.V., 'Manifestation of a hidden dislocation wave originated in a plane wave diffraction on a half-plane screen', *SPIE Proc.,* **3904**, pp. 19-26, 1999.
10. Khizhnyak A.I., Anokhov S.P., Lymarenko R.A., Soskin M.S., Vasnetsov M.V., 'Structure of an edge-dislocation wave originating in plane-wave diffraction by a half-plane', *Journ. of Opt. Soc. of Amer. A,* **17** No.12, pp. 2199-2207, 2000.
11. Karczewski B., Wolf E., 'Comparison of three theories of electromagnetic diffraction at an aperture', Parts I, II, *Journ. of Opt. Soc. of Amer.*, **56** No.9, pp. 1207-1219, 1966.

12. Zardecki A., 'Partial polarization in three theories of electromagnetic diffraction at an aperture', *Journ. of Opt. Soc. of Amer.*, **56** No.12, pp. 1722-1726, 1966.
13. Bogatiryova G.V., Polyanskii P.V., 'On the structure of the edge diffraction wave over a wide angular range', *Proc. SPIE*, **3904**, pp. 240-255, 1999.
14. Maggi G.A., 'Sulla propagazione libera e perturbata dellae onde luminose in un mezzo isotropo', *Ann. Mat.*, **16** No.2, pp.21-48, 1888.
15. Rubinowicz A., 'Die beugungswelle in der Kirchhoffschen theorie der beugungserscheinunger', *Ann. der Physik*, **53** No.2, pp. 257-278, 1917.
16. Fock V.A., *Problems of diffraction and propagation of electromagnetic waves*, Sovetskoye Radio, Moscow 1970 (*In Russian*).
17. Malyuzhinyets G.D., 'Development of notions on diffraction (to the 130th anniversary of Th.Young's death)', *Uspekhy Fizicheskich Nauk (Successes of Physics)*, **69** No.2, pp. 321-334, 1959 (*in Russian*).
18. Osterberg H., Smith L.W., 'Closed solution of Rayleigh's integral for axial points', *Journ. of Opt. Soc. of Amer.*, **51** No.10, pp. 1050-1054, 1961.
19. Keller J.B., 'Geometrical theory of diffraction', *Journ. of Opt. Soc. of Amer.*, **52** No.2, pp. 116-130, 1962.
20. Marchand E.W., Wolf E., 'Boundary diffraction wave in the domain of the Rayleigh-Kirhhoff diffraction theory', *Journ. of Opt. Soc. of Amer.*, **52** No.7, pp. 761-767, 1962.
21. Wolf E., Marchand E.W., 'Comparison of the Kirhhoff and the Rayleigh-Sommerfeld theories of diffraction at an aperture', *Journ. of Opt. Soc. of Amer.*, **54** No.5, pp. 587-94, 1964.
22. Rubinowicz A., 'The Miyamoto-Wolf diffraction wave': in *Progress in Optics*, [E.Wolf, Ed.], **4**, pp. 199-240, 1965.
23. Marchand E.W., Wolf E., 'Consistent formulation of Kirhhoff's diffraction theory', *Journ. of Opt. Soc. of Amer.*, **56** No.12, pp. 1712-1722, 1966.
24. Lit J.W.Y., Tremblay R., 'Boundary-diffraction-wave theory of cascaded-apertures diffraction', *Journ. of Opt. Soc. of Amer.*, **59** No.5, pp. 559-567, 1969.
25. Anan'yev Yu.A., *Optical resonators and problem of laser beam divergence*, Nauka, Moscow 1979 (*In Russian*).
26. Anan'yev Yu.A., *Optical resonators and laser beams*, Nauka, Moscow 1990 (*In Russian*).
27. Suzuki T., 'Extension of the theory of the boundary diffraction wave to systems with arbitrary aperture-transmittance function', *Journ. of Opt. Soc. of Amer.*, **61** No.4, pp. 439-445, 1971.
28. Otis G., 'Application of the boundary-diffraction-wave theory to Gaussian beams', *Journ. of Opt. Soc. of Amer.*, **64** No.11, pp. 1545-1550, 1974.
29. Smirnov A.N., Strokovskii S.A., 'On diffraction of optical Hermite-Gaussian beams from a diaphragm', *Optics & Spectroscopy*, **76** No.6, pp. 1019-1026, 1994.
30. Ganci S., 'An experiment of the physical reality of the edge-diffracted waves', *Am. J. Phys.*, **57** No.4, pp.370-373, 1989.
31. Polyanskii P.V., Polyanskaya G.V., 'Young hologram is the fifth hologram type', *Journ. of Opt. Technol.*, **64** No.4, pp. 52-63, 1997.
32. Gabor D., 'Microscopy by reconstructed wavefronts: II', *Proc.Phys.Soc.,* **B64**, pp. 449-469, 1951.
33. Polyanskii P.V., Polyanskaya G.V., 'On a consequence of the Young-Rubinowicz model of diffraction phenomena in holography', *Optica Applicata*, **25** No.3, pp. 171-183, 1995.
34. Polyanskii P.V., 'New version of a diffraction microscope based on Young hologram', *Proc. SPIE*, **2647**, pp. 357-364, 1995.
35. Polyanskii P.V., Polyanskaya G.V., 'Imaging properties of Young hologram', *Proc. SPIE*, **2647**, pp. 503-507, 1995.
36. Polyanskaya G.V., 'Imaging by off-axis fractalogram', *Proc. SPIE*, **3317**, pp. 251-260, 1997.
37. Polyanskii P.V., 'On the contouring effect at the complex conjugate associative response of a quadric hologram', *Optics & Spectroscopy*, **85** No.5, pp. 854-858, 1998.
38. Angelsky O.V., Konovchuk A.V., Polyanskii P.V., 'Reproduction properties of referenceless fractalograms', *Pure and Appl. Optics*, **7** No.3, pp. 421-433, 1998.
39. Angelsky O.V., Konovchuk A.V., Polyanskii P.V., 'Off-axis quadric fractalogram', *Journ. of Optics A: Pure and Appl. Optics*, **1** No.1, pp. 15-24, 1999.
40. Bogatiryova G.V., Polyanskii P.V., 'Self-conjugation of the edge diffraction wave using a quadric hologram', *Optica Applicata*, **29** No.4, pp. 583-600, 1999.
41. Bogatiryova G.V., *Properties of Young holograms*, PhD Thesis, Chernivtsy (Ukraine), 207 p., 2000.
42. Piekara A.H., *Nowe Oblicze Optiky (New Look of Optics)*, PWN, Warsaw, 1968 (In Polish).
43. *The Feynman Lectures on Physics*, Vol.I, Addison-Wesley Publishing Company, London, 1963.

44. Polyanskii P.V., 'Permanent associative memory using quadric hologram-based static phase conjugate mirror', *Proc. SPIE*, **2778**, pp. 945-946, 1996.
45. Polyanskii P.V., 'Associative properties of second-order holograms', *Journ. of Opt. Technol.*, **64** No.4, pp. 28-37, 1997.
46. Polyanskii P.V., 'Reproduction properties of a quadric hologram with a standing reference wave', *Proc. SPIE*, **3317**, pp. 166-177, 1997.
47. Polyanskii P.V., 'Associative memory using static phase-conjugate mirror on the base of second-order hologram', *Optics & Spectroscopy*, **84** No.2, pp. 346-351, 1998.
48. Collier R.J., Burckhardt C.B., Lin L.H., *Optical Holography*, Academic Press, New York, 1971.
49. *Handbook of Optical Holography* [Caulfield H.J., Ed.], Academic Press, New York, 1979.
50. Shoucri R.M., 'Exact calculation of the field due to a single Fresnel zone by the use of the Maggi-Rubinowicz contour integral', *Journ. of Opt. Soc. of Amer.*, **59** No.9, pp. 1158-1162, 1969.
51. Shoucri R.M., 'The physical meaning of the contour wave in diffraction theory', *Canad. Journ. of Phys.*, 2000.
52. Anokhov S.P., Khizhnyak A.I., Lymarenko R.A., 'Diffraction of optical beams by a half-plane', *Semiconductor Physics, Quantum Electronics & Optoelectronics*, **3** No.1, pp. 94-101, 2000.
53. Anokhov S.P., Lymarenko R.A., Khizhnyak A.I., 'Arbitrarily titled plane wave diffraction by slit', *Ukr. Phys. Journ.*, **46** No.1, pp. 62-64, 2001.
54. Anokhov S.P., Lymarenko R.A., Soskin M.S., Khizhnyak A.I., 'Common technique of shadow boundary contouring', *Ukr. Phys. Journ.*, **46** No.2, pp.158-160, 2001.
55. Anokhov S.P., Lymarenko R.A., Khizhnyak A.I., 'The fictitious character of Young boundary wave', *Ukr. Phys. Journ.*, **46** No.3, pp. 298-302, 2001.
56. Lymarenko R.A., *Properties of singular component of diffraction field and its application for apertured electromagnetic field modeling*, PhD Thesis, Kyiv (Ukraine), 117 p., 2001.
57. Lymarenko R.A., Soskin M.S., Khizhnyak A.I., Anokhov S.P., 'Singular trajectory transformation in apertured electromagnetic field and vortices generation by plane wave diffraction on wireframe elliptical aperture', *Proc. SPIE*, 2001 (*in this issue*).
58. Nye J.F., *Natural Focusing and Fine Structure of Light: Caustics and Wave Dislocations*, Inst. Phys. Publ., Bristol, 1999.
59. Otis G., Lachambre J.-L., Lit J.W.Y., Lavigne P., 'Diffracted waves in the shadow boundary region', *Journ. of Opt. Soc. of Amer.*, **67** No.4, pp. 551-553, 1977.
60. Van de Hulst H.C., *Light Scattering by Small Particles*, Wiley, New York, 1961.