Diffraction: An Experimental Search for the Physical Mechanisms of Pattern Formation

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Abstract

Diffraction is traditionally regarded as a consequence of the disruption of wavefront continuity by an obstacle, whereas experiments usually provide access only to the final intensity distribution observed on a distant screen. In the present work, an approach for the instrumental observation of the spatial evolution of the diffraction process was implemented through successive modifications of classical interference and diffraction arrangements adapted to new experimental objectives.

It was experimentally established that, after interaction with a single half-plane obstacle, a finite layered structure is formed within the light beam. This structure remains confined to the beam cross-section and consists of alternating bright and dark regions oriented parallel to the obstacle edge. In the absence of spatial overlap with other disturbances, these layers gradually smooth out and the intensity distribution returns to a nearly uniform state.

It is shown that, in more complex configurations, each half-plane generates its own system of spatial beam stratification. Signatures of these structures are observed at distances of approximately 15 cm before the geometrical edge of the obstacle and persist over a comparable distance after it. When spatial overlap occurs, mutual deflecting interactions between the layer systems arise, suppressing relaxation and leading to the formation of a stable wide-angle diffraction pattern.

Experiments employing beams marked by a regular geometric light pattern revealed that dark-layer regions suppress the transmission of light from other sources in a manner similar to opaque objects.

By varying the degree of spatial overlap between layer systems, a continuous transition was achieved from the classical distribution dominated by the central maximum to regimes exhibiting enhancement of higher-order maxima. Additional experiments revealed a spatially selective character of layer interactions and a weak dependence of the observed effects on the surface quality of macroscopic obstacles.

The obtained results provide a basis for further investigation of the causal mechanisms responsible for the formation of diffraction structures and suggest potential practical applications of the observed regularities under controlled boundary conditions.

Introduction

Diffraction is one of the oldest and most fundamental manifestations of wave phenomena [1–3]. Since the time of Fresnel and Sommerfeld, it has been treated as a consequence of the disruption of the continuity of a wavefront by an obstacle, while in classical studies and textbook schemes the primary observable quantity is the resulting intensity distribution on a distant screen. As a result, the process of forming a diffraction pattern from an incident light beam is largely reconstructed from the final outcome.

Theoretical approaches—from the Kirchhoff integral to modern numerical propagation methods—allow the structure of the observed diffraction pattern to be calculated with high accuracy [3–5]. However, experimentally, only the final intensity distribution is typically observed, whereas the intermediate stages of the spatial evolution of the beam have been studied in considerably less detail. Meanwhile, direct observation of such stages can reveal spatial structures and regularities that are not evident when analyzing only the final result.

A number of studies have pointed to the existence of intensity and phase variations near the edge of an obstacle; however, such effects are usually interpreted as local features of already established diffraction processes. Historically, the main focus has been placed on the agreement between observed patterns and existing wave models, while the spatial dynamics of the process between the region of light–obstacle interaction and the detection plane has been much less thoroughly investigated.

In the present work, an experimental approach is implemented for direct instrumental observation of the spatial evolution of the diffraction process. For this purpose, modified configurations with single half-planes spatially separated at their edges ("diffraction step") are used, as well as a macroscopic method for revealing the internal structure of the light beam, enabling its direct near-field visualization.

A distinctive feature of this study is the sequential development of the experimental methodology based on the results of preceding observations. The work preserves the original logic of experimental inquiry: after identifying regions of greatest interest for observing the process, methods were developed for its spatial separation, direct investigation of the internal beam structure, and subsequent study of the properties of the detected structural elements.

Methods and Equipment

The following components were used in the study:

- A 606-type laser pointer with a green laser diode and an integrated focusing lens;
- Razor blade fragments (used as half-planes);
- A pin and a school ruler;
- Plasticine for precise fixation of elements;
- An observation screen placed at a distance of approximately 3 m (made of two sheets of A4 white paper).

Observations and Experimental Results

Observation 1. Experimental determination of the dominant mechanism of two-beam interference in regions of its conventional observation

Problem statement. In classical wave descriptions, the interference pattern is treated as a dynamic result of continuous phase superposition of waves at every point within the region of overlap of coherent beams [3, 5]. However, since the spatial trajectories of intensity maxima and minima in a homogeneous medium are linear, and direct instrumental observation of the phase-superposition process itself is not accessible, it is experimentally extremely difficult to distinguish a continuously evolving interference process in space from free rectilinear propagation of an already formed localized layered structure of the light field.

This distinction does not affect the final intensity distribution; however, in classical interpretations the diffraction pattern is considered to arise from interference of secondary waves generated at an obstacle. Therefore, to clarify the physical mechanism of diffraction, determining the spatial region of formation of the interference structure itself is methodologically important. This determines both the choice of experimental instrumentation and the spatial localization of observation regions.

Objective of the observation. To experimentally distinguish the region in which wave phase superposition occurs from the region in which the interference pattern propagates without further phase interaction — as a projection of a previously formed spatial structure.

Experimental methodology. To investigate the spatial evolution of the light field, a two-beam interference setup based on a Fresnel biprism was implemented. A spatially limited source aperture (green laser) was used as the test excitation. The beam geometry was chosen such that the region of interference overlap between real and virtual sources naturally transitioned into a region of their mutual divergence without the use of additional optical elements.

The behavior of interference fringes was recorded on a detection screen positioned at varying distances from the biprism: from the region of direct beam overlap to the region of complete longitudinal separation of the interfering beams. As a control experiment, an analogous configuration using a Lloyd's mirror was employed.

Observational results. It was found that after exiting the region of interference overlap and subsequent spatial separation, the possibility of phase superposition between the beams is lost; however, the interference pattern persists within each of the beams. This suggests that, in regions where interference is traditionally observed, the pattern is not formed directly on the screen but is instead projected as a manifestation of events occurring at the locations where light interacts with the optical apparatus.

Conclusion. In the absence of external influences (changes in boundary conditions), the mechanism of phase superposition of light fields is no longer realized, and no new diffraction or interference phenomena arise in a freely propagating beam. This allows regions of light interaction with external objects to be regarded as physically significant and primary sources of formation of interference and diffraction structures.

Implication. For this reason, shifting the focus of investigation directly to regions of changing boundary conditions (the near-field diffraction zone) acquires fundamental methodological significance.

Observation 2. Spatial Separation of Stages in the Diffraction Process ("Diffraction Step")

Objective of the observation. To identify the spatial locations where active physical processes occur during the formation of a diffraction pattern by varying boundary conditions.

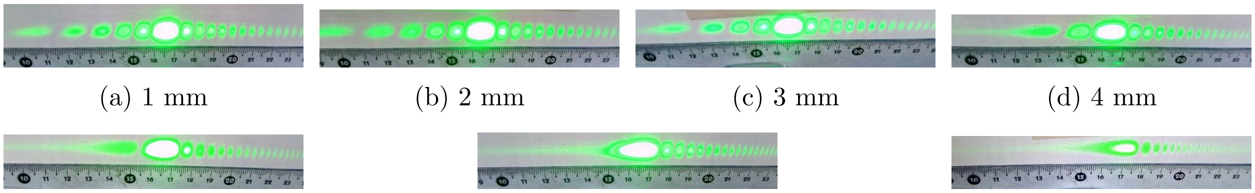
Introduction and methodological justification. In contrast to two-beam interference, where the resulting pattern is formed through sequential operations of beam splitting and recombination, diffraction on standard objects is usually perceived as a single, spatially inseparable process. This makes it difficult to experimentally isolate and independently investigate intermediate stages of diffraction pattern formation.

At the same time, there is a significant difference between diffraction patterns formed by closely spaced and spatially separated boundaries. In classical slit-based diffraction schemes, a small separation between boundaries produces a wide-angle intensity distribution, whereas single or significantly separated interactions yield substantially narrower intensity distributions, typically associated with the regimes traditionally referred to as Fresnel and Fraunhofer diffraction [2–5]. This suggests the possible existence of intermediate stages in the spatial evolution of the beam that are sensitive to the distance between regions of light–obstacle interaction.

To investigate this empirical fact, a modified diffraction slit was implemented. The first half-plane was placed at the initial point of beam interaction, while the second was shifted further along the beam propagation direction. In projection onto a plane perpendicular to the optical axis, this configuration corresponds to a standard slit; however, the physical interaction points of light with the edges are spatially separated along the propagation direction.

This experimental configuration is further referred to as the "diffraction step", and the longitudinal distance between the half-planes is referred to as the step size.

Observation results. It was found that, when varying the step size in the range from 0 to ∼15 cm (for a green laser beam), two independent wide-angle diffraction patterns are observed in the geometrical shadow regions of the corresponding half-planes on a distant screen.



(a) 1 mm

(b) 2 mm

(c) 3 mm

(d) 4 mm

(e) 5 mm

(f) 6 mm

(g) 8 mm

Figure 1: Spatial evolution of the interference field in the near zone under successive changes of the longitudinal step size of the setup from 1 mm to 8 mm (frames correspond to steps of 1, 2, 3, 4, 5, 6, and 8 mm). The frames capture the moment of redistribution of the intensity pattern. The linear scale represents the macroscopic scale of the process.

The obtained results indicate a coupled (coordinated) influence of both boundaries on the intensity distribution within the specified distance range. With further increase in the step size, the influence of the half-planes gradually separates; their effects on the beam become predominantly independent, and eventually the mutual influence is lost—no wide-angle diffraction pattern is formed.

The diffraction pattern associated with the second (farther) half-plane was found to be significantly more sensitive to changes in the step size and aperture width. As the aperture narrows, a sequential cyclic shift of dark fringes is observed, emerging from the central maximum and moving toward the periphery of the screen with pronounced acceleration.

In contrast, the intensity distribution associated with the first half-plane changes much more weakly and maintains a high degree of spatial stability. This led to the hypothesis that, after interaction with the first half-plane, an extended spatial structure forms within the beam, consisting of alternating regions of increased and decreased intensity. In the experiment, these are interpreted as a kind of "transmission and suppression zones", oriented parallel to the obstacle edge. This description is phenomenological and serves as a qualitative representation of the observed spatial structure, since direct observation of the phase distribution was not performed within the present experimental setup.

As the step size approaches the boundary of the regime of coupled interaction, a gradual reduction in the number of maxima and their broadening is observed. This behavior suggests the existence of an intermediate spatial structure of the beam that continuously evolves during propagation.

Additionally, it was found that decreasing the aperture near the boundary of the mutual-influence regime is accompanied by a characteristic elongation of the first maximum toward the geometrical shadow, forming a sharp droplet-like shape. This indicates an inhomogeneous angular redistribution of beam intensity in the immediate vicinity of the half-plane edge.

Conclusions. The experimental results obtained with the diffraction step indicate the existence of intermediate stages in the spatial evolution of a light beam following interaction with a macroscopic obstacle. The data suggest the formation of an extended spatial structure within the beam, whose parameters depend on the macroscopic geometry of the system and can be modified by additional interaction with the second boundary. To directly investigate this structure in the near field, additional observations using a projection method were carried out, as discussed in Observation 3.

Observation 3. Investigation of the Beam Spatial Structure in the Near Zone (Projection Method)

Objective. To directly visualize and investigate the internal spatial structure of a light beam in the immediate vicinity of an obstacle edge (near zone) in order to examine the proposition that local spatial structuring of the beam occurs after interaction with a half-plane obstacle.

Experimental Method. To record the intensity distribution directly within the beam, a projection-based optical arrangement was employed, consisting of a short-focus negative (diverging) lens and a distant fixed observation screen. Under conventional diffraction observation conditions, the recording plane primarily captures the integrated far-field pattern, making direct analysis of the beam's internal structure at short distances from the obstacle difficult.

When the negative lens is introduced, the light-intensity distribution existing in the lens plane is projected onto the distant screen with substantial linear magnification. For parallel or weakly diverging beams, such a projection is equivalent to a magnified image of the beam cross-section. The negative lens converts a local coordinate within the beam cross-section into a ray deflection angle, which is subsequently mapped back into a coordinate on the observation screen.

The local divergence of the rays not only provides magnification but also reduces the probability of secondary spatial overlap. In combination with the large screen distance, this divergence provides high spatial resolution. The test procedure consisted of sequential scanning of the beam along the propagation direction by moving the lens away from the edge of a single half-plane obstacle.

Results. Beam scanning revealed a series of distinct alternating bands within the main beam cross-section without any noticeable change in the overall beam width. These bands were found to be parallel to the edge of the half-plane obstacle, non-uniformly distributed, and dependent in both spatial frequency and total number on the degree of beam obstruction by the half-plane.

Scanning from the obstacle edge toward the observation screen revealed the following regular features: In the immediate vicinity of the half-plane edge, the bright components of the structure exhibit minimal transverse width and obtained results indicate the existence of an intermediate stage in beam evolution between the region of direct interaction with the obstacle and the formation of the final diffraction pattern in the far field. The observed structure substantially influences the intensity distribution arising from interactions between spatially separated obstacles and may determine the conditions under which their actions become coupled or remain independent.

At the same time, the mechanism by which a second half-plane influences the formation of the wide-angle diffraction pattern associated with the first half-plane remains an open question. In particular, it is not yet clear whether the decisive factor is the longitudinal separation between the two half-planes (the step height) or the geometrical trajectory of the beam itself.

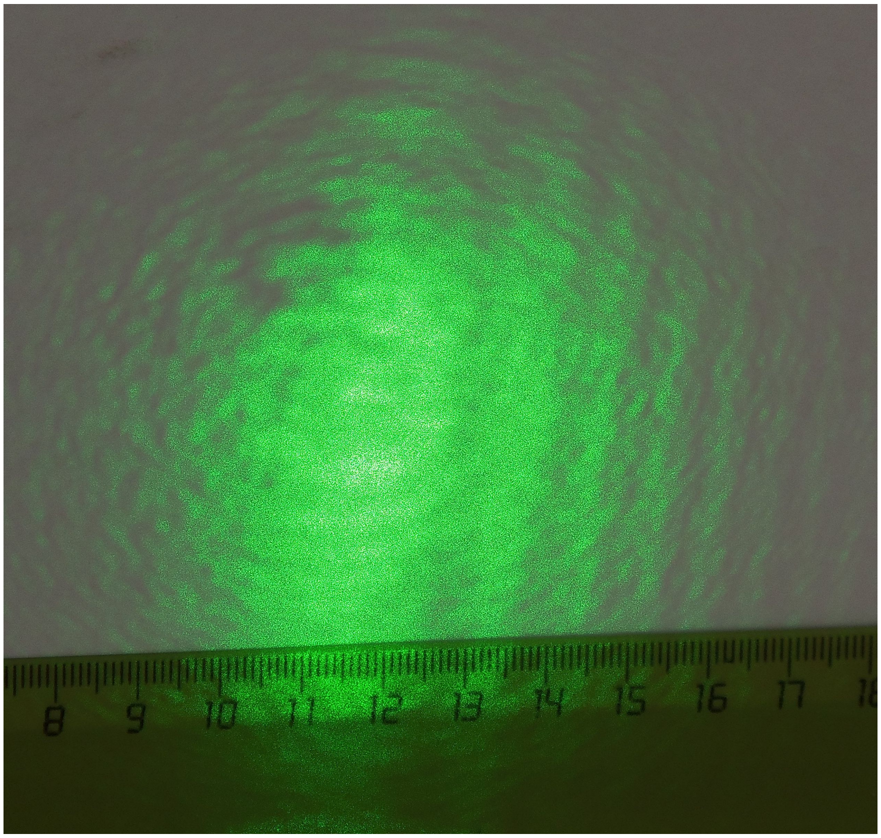


Figure 2: Near-field visualization of the internal light beam structure implemented via the projection method. The multi-fold linear magnification reveals a well-defined layered intensity modulation with alternating concentric regions of increased and decreased density. The embedded metric scale provides a precise macroscopic reference for the spatial calibration of the beam cross-section parameter.

Observation 4. Separation of the Geometric Optical Path of the Beam in the Diffraction Step and the Distance Between Half-Planes

Objective of the observation. To investigate the key parameter governing the existence of mutual coherence between the elements of the diffraction step.

Experimental methodology and results. To analyze the mechanisms underlying the coupling between the half-planes, the dynamics of the light field were studied under conditions in which a difference was introduced between the geometric optical path of the beam and the actual spatial separation between the half-planes. For this purpose, an enlarged diffraction slit configuration was used.

The setup was arranged such that the beam first interacted with only one half of the slit, propagated through it, then was reflected by a return mirror, and on the return path interacted with the second half of the slit. This configuration allowed the optical path length (geometric path) between the interaction points to be increased by several tens of times compared to the actual physical distance between the half-planes of the step.

It was experimentally established that the mechanism responsible for the formation of the wide-angle diffraction pattern propagates along with the geometric optical path of the beam and does not depend on the actual spatial distance between the interaction points in the laboratory frame. Mutual influence between the half-planes is preserved for the same values of the geometric path length between interaction points—approximately 15 cm.

This observation indicates that, within the regime of mutual influence, the beam acquires spatiotemporal modifications whose region of propagation subsequently overlaps with the second half-plane of the step. As a result, an intensity distribution with pronounced angular broadening is formed on the distant screen, corresponding to the wide-angle diffraction regime.

Since it was found that the source of the wide-angle diffraction pattern is the internal structure of the beam, the influence of the second half-plane can be more consistently interpreted in terms of geometric overlap of interaction zones. The second half-plane is embedded within the structured region formed after interaction with the first half-plane, while the first half-plane is itself embedded within the pre-structured region associated with the second half-plane.

In other words, the diffraction process consists of two active stages of comparable spatial extent:

1. **"Pre-diffraction" stage:** Involves preliminary structuring of the light field prior to the geometrical plane of the obstacle.
2. **Diffraction stage:** Active redistribution process continuing after passage past the half-plane.

Additionally, it was observed that in the interaction region downstream of the second half-plane, elongation of intensity maxima toward the geometrical shadow occurs, indicating a nonlinear character of angular intensity redistribution in the beam.

Conclusions. This observation provides experimental evidence for a pre-structuring of the beam ("pre-diffraction"). The results indicate that modifications of the spatial intensity distribution are initiated not only at the plane of interaction with the obstacle but also within the adjacent propagation region preceding the second boundary. This region can be interpreted as one in which conditions for the subsequent formation of the observed pattern are already established.

The mechanism responsible for the formation of the wide-angle pattern is thereby clarified: it is experimentally shown that the final wide-angle distribution arises from the combined action of two spatially separated boundaries, each of which alone does not produce a comparable angular broadening. The key factor is the spatial superposition of the diffraction region of the first boundary and the pre-diffraction region of the second boundary. To separately observe the resulting layered structures under conditions of their interaction within the step configuration, Observation 5 was conducted.

Observation 5. Separate Observation of the Individual Properties of the Diffraction Structure and the Pre-Diffraction Structure During Their Joint Interaction (Method of Spatial Beam Structure Marking)

Objective of the observation. To experimentally refine the degree of autonomy of diffraction and pre-diffraction structures during their interaction in diffraction step configurations.

Experimental methodology. To distinguish and analyze beam structure elements formed by different obstacles, a method of assigning geometric marker features to individual layers was employed. The experimental configuration was implemented as a combination of a vertically oriented needle (a drawing pin) and a half-plane. The needle was positioned in the front-right region, while the half-plane was placed further along the beam path on the left, with a slight counterclockwise inclination of its edge. In combination, this formed a diffraction step together with a spatial wedge-shaped slit.

In this configuration, the light beam underwent double structuring: it first formed a system of narrow vertical stripes associated with diffraction on the needle, and subsequently an inclined layered structure associated with the half-plane. On a distant screen, an inclined diffraction pattern from the half-plane was recorded, overlaid with vertical marker stripes corresponding to the beam structure generated after interaction with the needle.

Observation results. During analysis of the interaction between the two diffraction systems, a characteristic spatial feature was identified: in regions of the screen corresponding to dark layers formed by the inclined half-plane, the vertical marker stripes originating from the needle were significantly weakened or locally suppressed. Visually, this manifested as a localized attenuation of marker stripes in specific regions, topologically resembling shielding or shadow-cut effects, as shown in Fig. 3 and Fig. 4.

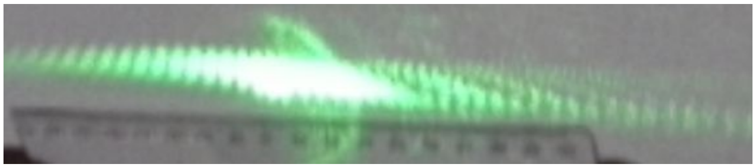


Figure 3: Visualization of the spatial interaction of light-field structures in the needle–half-plane configuration using marker stripes. A localized deformation and “shadow-cut” effect is observed in the central beam region.

A key factor revealed in the analysis of beam dynamics is the behavior of the stripes themselves under changes in system geometry. The experiment does not show a classical redrawing of an interference pattern on the screen, but rather a coordinated displacement of entire sets of layers. Each half-plane forms its own distinct group of layers.

When the half-planes are brought closer together and the diffraction region of the first half-plane overlaps with the pre-diffraction region of the second, all layers associated with the first half-plane are deflected toward its geometrical shadow, while layers formed near the edge of the second half-plane shift toward the geometrical shadow of the second half-plane. The deflection angle of the first half-plane is uniquely determined by the longitudinal step size of the diffraction step.

Importantly, this displacement is not accompanied by disappearance or destruction of the layers. After leaving the interaction region, they persist as stable spatial structures, shifted relative to

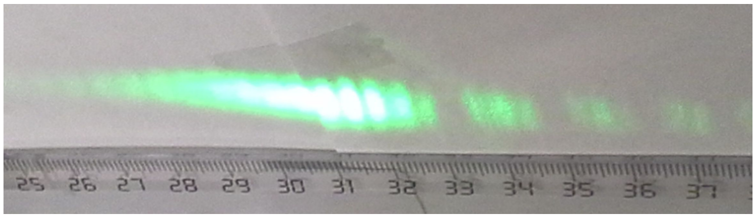


Figure 4: Spatial modulation of the light field in a parallel-edge configuration ("straight needle – straight half-plane"). The digitized ruler scale fixes parameters of regular alternation of light channels and their isolation within the geometrical shadow region of the large-scale pattern of the half-plane.

their original positions. Individual layers equipped with geometric markers preserve these markers throughout the entire observed displacement process. The marker does not undergo spatial averaging or noticeable diffusion across the beam cross-section, remaining bound to the same layer in which it was initially registered.

It was additionally established that the number of observed layers associated with the first half-plane remains constant when varying the step size. The observed displacement is accompanied only by minor deformation of the overall diffraction pattern compared to the magnitude of its spatial shift. Thus, changes in the pattern position occur predominantly through coordinated transport of already existing layers rather than through their destruction, disappearance, or reformation.

This set of observations indicates a high degree of spatial stability and individual persistence of the observed layers and is consistent with the existence of mutual deflecting interaction between two sets of autonomous structures formed by different elements of the diffraction step.

Conclusions.

- The spatial marking method experimentally confirms that individual layers preserve their geometric markers, number, and internal identity during spatial displacement of the pattern.
- The transformation of the diffraction pattern geometry occurs primarily through coordinated spatial deflection and transport of intact layer ensembles, rather than through their local destruction or reformation at new screen coordinates.
- A pronounced spatial selectivity of interaction within the light field is observed, in which regions of minimal intensity (dark layers) formed by one obstacle locally suppress or weaken marker features generated by another.
- The high stability and reproducibility of the observed effects indicate their macroscopic character and weak sensitivity to the local microstructure of obstacle edges. This motivated further testing of reproducibility under changes in macroscopic geometry of the setup, which led to Observation 6.

Observation 6. Verification of the invariance of macroscopic effects with respect to microgeometry, shape, and surface quality of obstacle edges

Experimental methodology. In order to eliminate light-scattering mechanisms associated with microdefects of edge surfaces and to test the overall robustness of the observed results, the precision sharp edges (razor blades) used in the diffraction step were replaced by two massive steel cylinders approximately 3 cm in diameter. The cylinders were arranged according to a similar spatially separated stepped-slit configuration. The cylinder surfaces were intentionally left unprepared, unpolished, and retained traces of rough mechanical (lathe) machining.

The test procedure, as in Observation 2, consisted of longitudinal separation of the objects (variation of the step size) and modulation of the transverse gap between them.

In a control experiment designed to evaluate complex macroscopic boundary profiles under identical conditions, a common household object—a standard metal dining fork—was introduced as a multi-edge obstacle in the path of the beam.

Experimental results. The observations demonstrated that the character of wide-angle diffraction pattern formation, the topology of shadow bands, and the overall stability of result reproduction do not visually change upon replacement of precision blades with rough cylindrical surfaces. The effects of spatial beam structuring, including the droplet-like deformation of the central maximum and selective interaction of intensity regions, fully preserve their dynamical behavior.

Even when using a multi-edge structure such as a dining fork (Fig. 5), the key parameters of the diffraction outcome were fully reproduced. The structuring is governed by macroscopic geometry rather than microscopic surface finish.

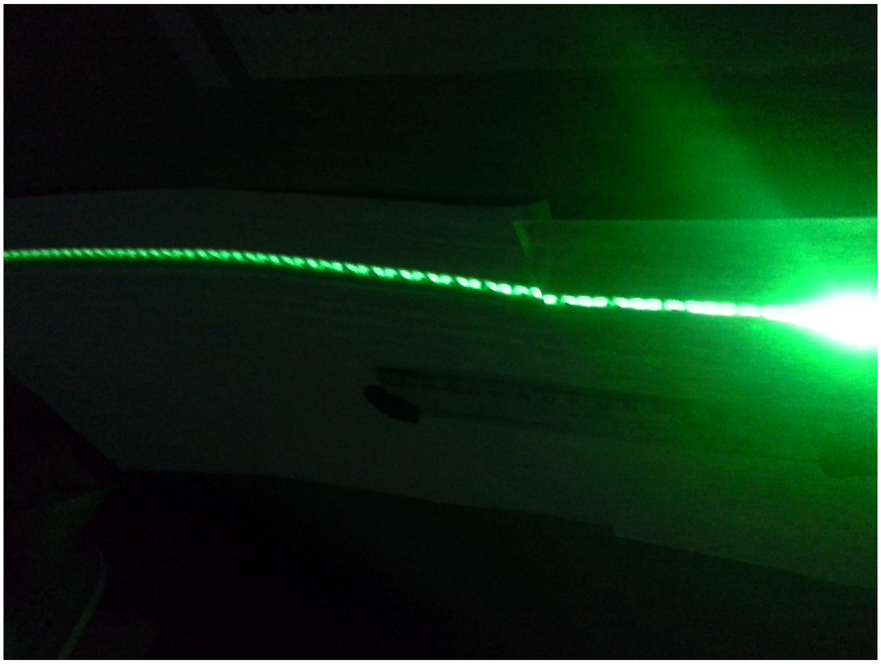


Figure 5: Verification of diffraction-step effects using a metal fork, demonstrating macroscopic invariance with respect to multi-edge geometry.

Conclusions. The obtained data indicate that, in the macroscopic dynamics of diffraction, requirements for precision surface quality and ideal edge sharpness are not critical. In such processes, the contribution of local surface microdefects is effectively averaged out and does not exert a determining influence on the overall geometry of the diffraction outcome. This is consistent with the previously obtained result regarding the spatial extent of the beam structuring region on the order of hundreds of millimeters (the local coherence/coordination zone is approximately 15 cm).

Phenomenology of Spatial Segregation of Layers

The observed effect of preservation of individual geometric markers within deflected layers, as well as the stability of the number of layers observed in the shadow of the first half-plane under variation of the diffraction-step spacing, experimentally suggests the existence of stable spatial structures that preserve their identity and internal organization during the formation of the final pattern.

The fact that a marked layer is displaced as a single entity without noticeable diffusion or spatial averaging across the beam cross-section goes beyond the traditional interpretation of interference fringes as local maxima and minima of a continuous field intensity.

This result opens the possibility of alternative physical interpretations. The observed invariance of layers and their coordinated geometric deflection raises the question of additional mechanisms of spatial organization of the optical field in the near-diffraction zone. In particular, the data allow consideration of models involving spatially localized and stable energy-transport channels that retain their individuality under changes in the geometry of the diffraction system.

In this context, it is reasonable to consider hypotheses linking the observed behavior of layers to possible mechanisms of spatial quantization of light-field parameters in the vicinity of macroscopic boundaries of material bodies. The results themselves do not allow an unambiguous choice between competing physical interpretations; however, they impose new experimental constraints that any adequate theory of near-field diffraction must satisfy.

A detailed theoretical separation and mathematical formulation of these approaches should be the subject of separate fundamental studies.

Conclusion

In the present work, an approach to investigating the spatial evolution of light beams in the near field of macroscopic obstacles was proposed and experimentally implemented. The developed methodological framework ("diffraction step," direct projection magnification method, and spatial marking method) enabled controlled manipulation of the beam during intermediate stages of diffraction pattern formation.

Based on the performed observations and their photographic documentation, the following conclusions were drawn:

1. **Beam Structuring and Near-Field Layers:** Interaction of a light beam with a half-plane is accompanied by the formation of a spatially confined region of transverse structuring appearing at distances on the order of 15 cm before the obstacle (pre-diffraction zone) and smoothing out over a comparable distance after it. Within this region, a pronounced layered structure is observed, consisting of alternating bright and dark regions (phenomenologically designated as transmission and suppression zones) oriented parallel to the obstacle edge. The minimum width and maximum contrast of bright fringes are achieved in the plane of the edge-projected cross-section.

2. **Nonlinear Deflection Dynamics:** Under variation of the longitudinal step of the diffraction structure within the investigated range, characteristic features of shadow-band distribution in the geometrical shadow region of the first half-plane are preserved. The influence of the second half-plane manifests primarily as angular deformation of the adjacent beam region, with a strongly nonlinear dependence of the deflection magnitude on the alignment section. The largest deflection is experienced by structural regions passing in close proximity to the second edge, while distant regions are affected significantly less.

3. **Superposition of Interacting Regions:** A necessary condition for the formation of a stable wide-angle diffraction pattern is the spatial overlap of diffraction layers from the first half-plane with the pre-diffraction layers of the second half-plane. Optical path increment analysis confirms that this process is governed by the geometric ray trajectory rather than the physical distance between objects in space.

4. **Spatial Marking and Selectivity:** Spatial marking experiments revealed a pronounced spatial selectivity of the observed effects: low-intensity regions (dark layers) formed by one boundary are accompanied by attenuation or suppression of markers generated by the other obstacle, demonstrating a macroscopic shielding effect.

5. **Invariance to Microgeometry:** The observed effects are invariant with respect to the microgeometry and shape of obstacles: replacement of sharp precision blades with rough machined steel cylinders of 3 cm diameter does not alter the topology of shadow bands or beam dynamics, indicating a volumetric, macroscopic character of the field restructuring.

The obtained results indicate the possibility of representing diffraction pattern formation as a set of spatially separated stages accessible to direct visual observation and instrumental control. The proposed approach opens new perspectives for studying the spatial dynamics of diffraction processes, the formation of structured light beams, and the development of robust macroscopic interferometric schemes.

In this regard, further experiments are suggested on the transmission of localized portions of structured beams through macroscopic slits and spatially separated obstacles under conditions excluding direct interaction of the main intensity maximum with obstacle edges. Such studies may help clarify the causal mechanisms of diffraction pattern formation in the near field and contribute to the development of new methods of spatial microprobing and high-localization optical registration.

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