

Diffraction. Observation 8. Independence of the Pattern from the Shape and Size of the Undisturbed Part of the Beam

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Abstract

A diffraction observation scheme is proposed that makes it possible to investigate the influence of the shape and size of the undisturbed part of a quasi-parallel light beam on the spatial position of the elements of the diffraction pattern. Experimental observations of the independence of the positions of the pattern elements from this parameter were performed in the range from 0.01 to 2 mm.

1 Introduction

When searching for a rule governing the formation of a diffraction pattern near the edge of a half-plane, a metrological obstacle arose.

It consists in the dependence of the appearance of the diffraction pattern on changes in the cross-section of the passing part of the light beam. This raises the question of confidence in the measurements. Namely: does the position of a maximum of a given number change when the shape and cross-sectional area of the passing light flux are changed?

The present work addresses the question of confidence with respect to the filling of the cross-section of the light flux passing by the edge of the half-plane. The results obtained also make it possible to clarify the number of parameters determining the positions of the elements of the formed pattern.

Published studies have considered the dependence of diffraction on the shape and dimensions of an obstacle. Closer to the case considered in the present work are variants of diffraction with preservation of a straight boundary [1], with changes in the thickness of a half-plane [2, 3], as well as studies of the spatial characteristics of diffraction near plane apertures and various descriptions of diffraction by a half-plane [4].

At the same time, in the literature available to the author, no experimental study was found that considered the influence of the cross-section of the undisturbed part of the passing light flux on the positions of the maxima of the diffraction pattern.

That is, no ready experimental solution to this question was found, while ready-made experimental arrangements for carrying out such observations were absent and required development and implementation.

Under these circumstances, changing the cross-section of the undisturbed part of the flux was selected in the present work as a controlled experimental action, while the ob-

served result was the tracking of changes in the positions of the elements of the diffraction pattern.

2 Observation Method

To observe possible changes, a functional analogue of a comparator was used, consisting in observing the behavior of a selected point under substantial transformation of the image scale.

The first scale transformation was performed using a projection lens with a negative focal length, positioned in the region of interest of the diffraction pattern. After ordinary projection onto a screen, the lens provided approximately a tenfold optical scale transformation.

The second scale transformation was performed geometrically by placing the screen at an inclination. The screen was positioned at a small angle to the direction of movement of the diffraction pattern, with rotation about an axis parallel to the obstacle edge. With this arrangement, rays from the initial points of the impact parameter reached the screen earlier, while those from more distant points reached it later, resulting in additional stretching of the diffraction pattern image.

The invisible legs of the transverse cross-section of the beam were transformed into a visible hypotenuse with a magnification inversely proportional to the sine of the screen inclination angle. At an inclination angle of about 3° , the additional geometric scale transformation was approximately 20-fold.

The combination of the two transformations made it possible to obtain a substantial magnification of the diffraction image, in some modes of observation on the order of 200 times or more. High magnification was used for detailed examination of individual regions of the pattern and for searching for possible internal structure.

At the same time, the working scale was selected according to the observation task by simply changing the inclination angle of the screen. In this way, it was possible to move from observing the pattern as a whole to examining a small fragment of it with substantial spatial stretching.

For example, in one of the observation modes, the distance between two maxima in the original pattern could be represented on the screen at a scale of about 40 cm.

For obtaining such an image, the quality of the surface of extended screens is of substantial importance. The surface must be sufficiently flat so that geometric stretching is not accompanied by noticeable distortions of the image shape. In the experiment, a small screen with an extent of 55 millimeters was used, and therefore an ordinary sheet of light-colored plastic with a matte surface was used.

The sequence of obtaining images with different scales convenient for the current operation is shown in Fig. 1–3. The photographs demonstrate different scales of transformation of the diffraction pattern.

A simple change in the screen inclination angle substantially expands the possibilities for direct observation of spatial regularities, including in educational demonstrations where the small original scale makes them difficult to perceive visually.

The proposed method makes it possible to implement Observation 8 with an obviousness equivalent to that of an ordinary classroom demonstration.

3 Experimental Procedure and Result

After the diffraction pattern had been formed, plasticine markers were placed on selected maxima.

As the controlled action, the position of the laser relative to the edge of the half-plane was changed in the direction of the periphery of the impact parameter. The displacement was performed using a coordinate stage with a step of about 0.01 mm, as a result of which the depth of penetration of the edge into the light flux and, accordingly, the size of its undisturbed part were gradually changed.

Thus, in the experiment, the geometry of that part of the light flux passing by the edge of the half-plane was successively changed, while the position of the edge itself and the other principal elements of the experimental arrangement were preserved.

Observation began with a barely noticeable opening of part of the flux and continued until the beam was completely opened. The positions of the plasticine markers relative to the diffraction pattern were directly monitored using the transformed image.

As the undisturbed part of the flux increased, the previously observed maxima retained their positions. In particular, a plasticine marker placed on one of the maxima maintained its correspondence with the same maximum throughout the entire displacement. A marker placed on another, more distant maximum maintained the same correspondence.

Thus, an increase in the depth of penetration of the edge into the flux was not accompanied by displacement of the previously formed maxima.

At the same time, as the cross-section of the flux increased, additional elements of the pattern appeared.

The change in cross-section was also accompanied by a change in the visibility of the pattern: as the illuminated part of the flux increased, the overall illumination increased, the minima became less pronounced, and some maxima ceased to be reliably distinguishable.

This change in visibility was not accompanied by a change in the positions of those maxima whose positions could be monitored.

Consequently, within the limits of the experiment performed, a change in the size of the undisturbed part of the flux changed the composition and visibility of the observed pattern, but did not change the positions of the already formed maxima, as shown in Fig. 4 and Fig. 5 — photographs taken with substantially different degrees of beam overlap.

Thus, each subsequent change in the pattern did not alter its preceding state, but supplemented it with new, additionally appearing elements.

4 Discussion

The metrological question formulated in the Introduction concerned the possible influence of the degree of filling of the light-flux cross-section on the spatial positions of the elements of the diffraction pattern. The experimental data obtained in the present work provide a direct answer to this question: a change in the size of the undisturbed part of the flux in the range from 0.01 to 2 mm was not accompanied by displacement of the previously formed maxima.

The revealed independence of the coordinates of the maxima from the depth of penetration of the edge into the light beam shows that a change in the geometry of the undisturbed part of the passing flux is not a determining parameter for the positions of the already formed elements of the diffraction pattern under the investigated conditions.

At the same time, the accompanying effects recorded — changes in pattern visibility, reduction in the prominence of the minima, and increasing general background illumina-

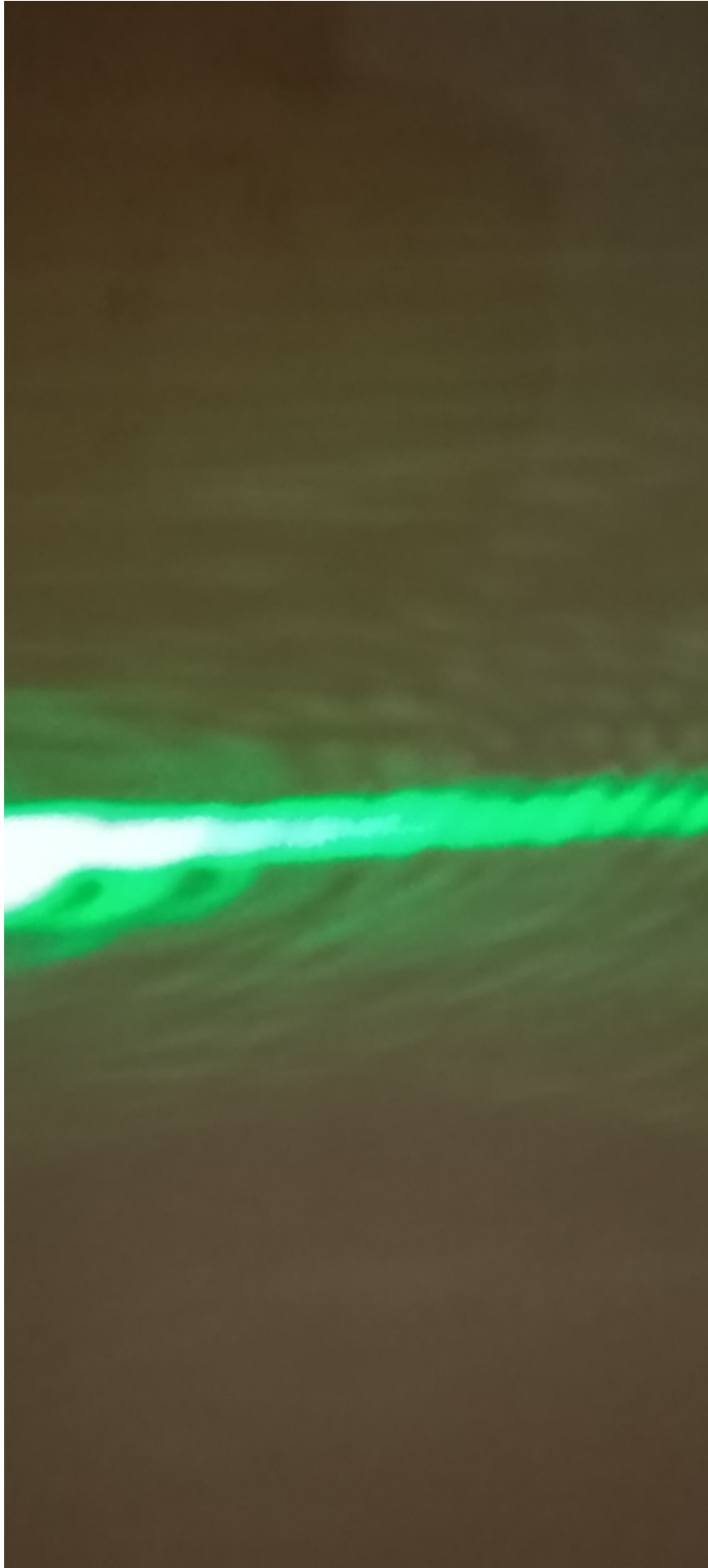


Figure 1: Initial diffraction pattern obtained without additional scale-transformation means.



Figure 2: Diffraction pattern with the screen rotated.

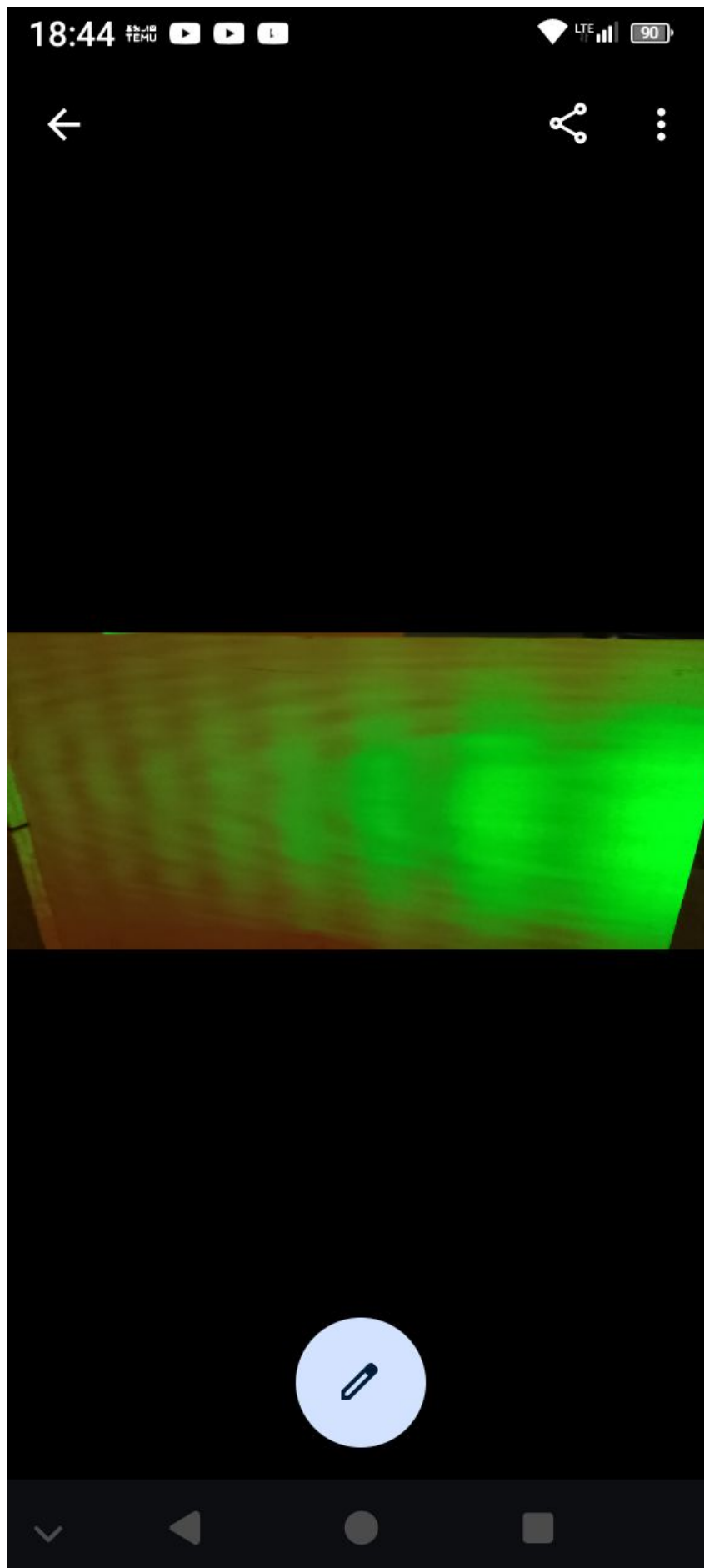


Figure 3: Diffraction pattern with an additional rotation of the screen.

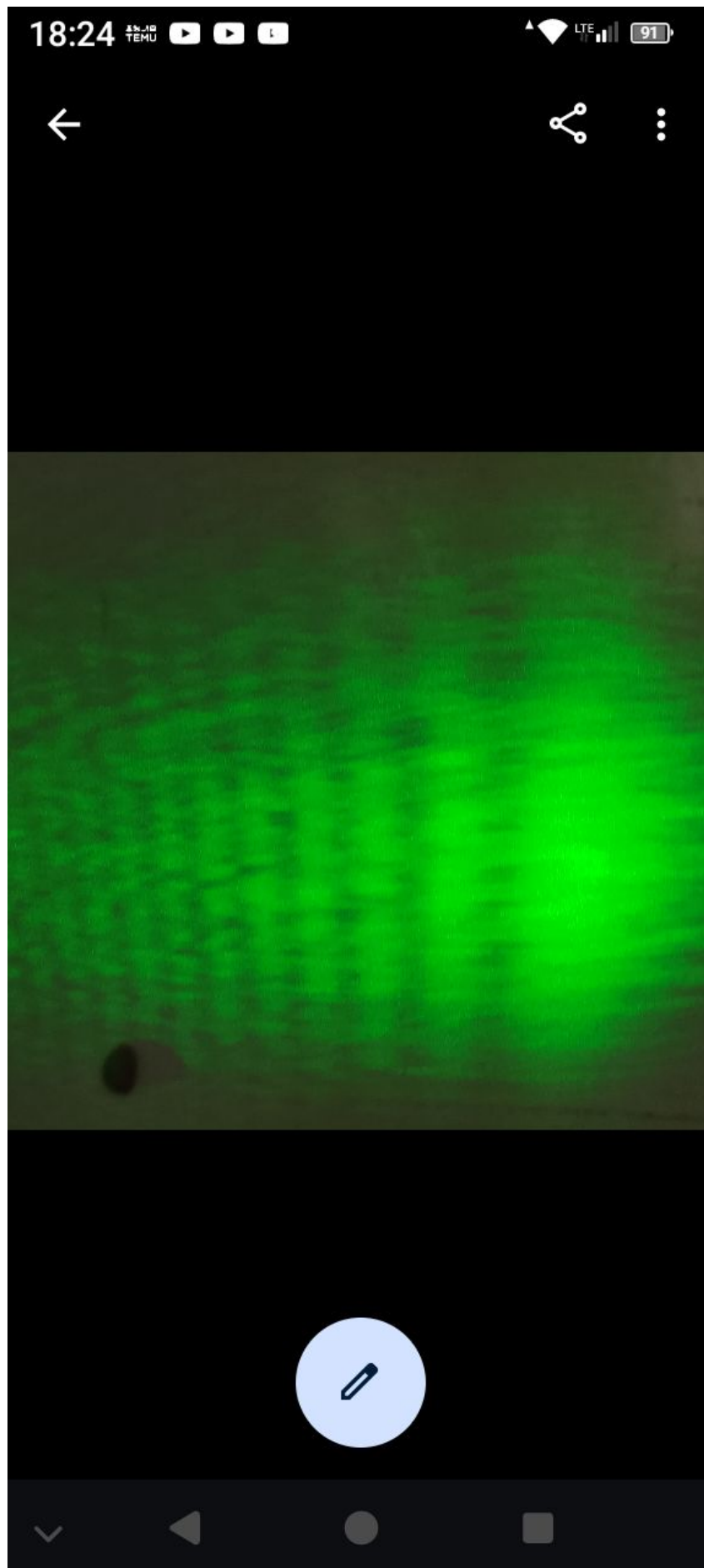


Figure 4: Diffraction pattern with a small cross-section of the passing light flux. The plasticine marker fixes the coordinate of the selected maximum.



Figure 5: Diffraction pattern with a flux cross-section close to the appearance of general background illumination. The position of the maximum relative to the marker remains unchanged.

tion with increasing open part of the beam — show that a change in the cross-section affects the composition and conditions of visual observation of the pattern. At the same time, the appearance of additional elements and changes in their visibility occur without disruption of the positions of the previously formed maxima.

Thus, a change in the filling of the cross-section may change the observed composition and visibility of the diffraction pattern, but within the investigated range it does not lead to a change in the spatial positions of the already formed elements.

The result obtained is relevant for subsequent measurements of the spatial structure of the diffraction pattern: if the coordinates of the maxima are the parameter under investigation, the size of the undisturbed part of the flux in the investigated range need not be regarded as a mandatory controlled parameter.

Successful tracking of the positions of the selected maxima became possible due to the combination of optical and geometric scale transformations. The double transformation made it possible to make the presence or absence of a displacement directly observable and controllable, including when the original spatial scale of the pattern was small.

The results obtained provide an experimental basis for further investigation of the regularities of the spatial formation of the diffraction pattern and for testing the mutual influence of elements in more complex diffraction arrangements.

5 Conclusion

The performed study makes it possible to formulate the following conclusions:

1. It was experimentally established that, during the interaction of a quasi-parallel light flux with a single half-plane, changing the size of its undisturbed part in the range from 0.01 to 2 mm does not cause spatial displacement of the previously formed maxima and minima of the diffraction pattern.
2. The change in the shape of the undisturbed part of the flux was an accompanying factor and likewise did not affect the shape and position of the observed maxima.
3. A distinction between the spatial positions of the elements of the diffraction pattern and the conditions of their visual observation was demonstrated: when the cross-section of the flux changes, the density of the observed layers, the composition of visible elements, and the level of general background illumination change, whereas the positions of the previously formed maxima remain unchanged.
4. During the observations, a combination of screen inclination and a projection lens with a negative focal length was tested. The combination of optical and geometric scale transformations made it possible to substantially increase the observed scale of the diffraction pattern — in some modes up to 200 times or more — while maintaining free access to the observation location. In the observations performed, the arrangement provided stable tracking of selected elements of the pattern.
5. The observations show that, when studying the positions of maxima, the size of the undisturbed part of the flux passing by the edge of a single half-plane in the range from 0.01 to 2 mm, as well as the shape of this part of the flux, are metrologically insignificant parameters under the investigated conditions and need not be controlled in subsequent analogous experiments.

6. The developed arrangement for controlled variation of the geometry of the flux with opto-geometric scale transformation can be used as a basic (reference) configuration for identifying effects of mutual influence between elements in more complex multicomponent diffraction arrangements.

References

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