هيكل الدوامة الضوئية

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مستخلص:

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الدوامة الضوئية (المعروفة –أيضًا– باسم دوامة الكم الضوئي)، تعتبر من المفاهيم المهمة لفهم سلوك شعاع الضوء في المجال المغناطيسي بكثافة مختلفة ومتغيرة. تحصر الدوامة الضوئية طبيعة موجة الضوء. يتم إجراء عدد كبير من الأبحاث والدراسات للكشف عن ظاهرة الدوامة الضوئية،

فيما يتعلق بهذا ، تلعب الدراسة التي أجراها Curtis،J.E.and rGrie دورًا حيويًا لفهم هذه الظاهرة بشكل شامل. قبل هذه الدراسة لم تكن الدوامة الضوئية ظاهرة مهمة للدراسة حيث كانت المعلومات الأولية والمحدودة متاحة حول هذا الموضوع. فهناك الكثير من التطبيقات لهذه الظاهرة، للاستفادة من مزايا هذه التطبيقات بأكثر الطرق فعالية ، يُجري الكثير من العمل البحثي.

Introduction:

Helical modes of light can be focused into toroidal optical traps known as optical vortices, which are capable of localizing and applying torques to small volumes of matter. Measurements of optical vortices created with the dynamic holographic optical tweezer technique reveal an unsuspected dependence of their structure and angular momentum flux on their helicity. These measurements also provide evidence for a novel optical ratchet potential in practical optical vortices[2].

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The optic science has emerged as one of the most important and turbulent fields of science. There are a lot of new and innovative applications in existence in the current era. When any wave of light or laser beam passes through a disruptive atmosphere, it results into a number of different applications, especially in the field of optical communication. Basically, a turbulent or disruptive environment is a form of an inhomogeneous medium, for which the refractive index generally shows the function of time and position. In the recent years, the behavior of light waves and laser beams in a highly turbulent environment, has become one of the most current and interesting areas of research for scientists and scholars. Through a number of researches done on the topic, a number of new scientific phenomena and concepts have been revealed. In relation to this, the concept of vortex in optical waves is one of the important concepts of optical science. For revealing this concept in more detailed there are a lots of studies has been done.

The paper is mainly focusing on the study done by [Curtis, J.E. and Grier, D.G] for revealing the structure of optical vortex. The research work done by authors is providing a brief overview about the actual concept of vortex in optical waves. Further, the paper is also providing various studies based on the topic which has been taking place prior to this study. The study done by Curtis, J.E. and Grier, D.G is considered as a base study on the phenomena of optical vortex. There were a lot of studies which took place in the light of this study. The implications of this study have impacted the practices and general believes related to this phenomena. This can be reflected in the later studies. Several studies are also presented in the paper.

Before the paper written by Curtis, J.E. and Grier, D.G, there was a limited amount of conceptual information available. The research work done on the optical vortex phenomena was providing the elementary information about the origin of optical vortex and about the structure of optical vortex. Rozas Law, C.T, D.,. and Swartzlander, G. A.conducted their research on the optical vortex phenomena. They provided a brief overview about how did a beam of light dislocate in the fluctuated magnetic field. According to them, the origin of this vortex of optical waves is the result of behavior of optical waves in a disruptive environment. When an optical or laser beam is passed through an inhomogeneous environment in the laboratory conditions, a variation in amplitude of the beam is subjected to be produced at a random basis because of the fluctuation in the function of position and time. This fluctuation in the environment also leads to vary the phase of beam and spread the reflective radiation pattern on the plane. The output is received on this plane for observation.

The authors further illustrated that the intensity of the light beam is also subjected to be fluctuated in this situation. At one condition, when the overall intensity of the light beam reaches to zero or its lowest point, the optical beam starts to twist like a screw. The impression of this twisting can be received on the observational plane, which is a solid optical trap. Generally, light beam travels in the direction of its axis. But, when this effect is applied to the beam, the beam is subjected to be twisted just like a screw around the axis of its travel. Because of this, the impression of the effect of optical vortex can be recorded on a solid and plane surface as a ring of light. A dark hole is also subjected to be noticed at the center of the ring. This ring of light, which contains a point of darkness at its center, is termed as the reflection of the optical vortex [5].

Further, (Molina-Terriza) revealed various types of wave front dislocations of singular light beams. According to them, there are certain types of dislocations, which are shown by a light beam; and the screw like dislocation is the most common type of dislocation among them. According to the scientists, in this type of dislocation or vortex, there is an area of darkness where the light intensity is subjected to disappear. The entire intensity of the light is distributed around this dark hole in a helical form. The phase of this light intensity can be calculated by the formula $2\pi m$ (where m is the topological charge on the vortex). Further, the scientist also elaborated that these vortex are dynamic in nature and for this reason, the optical vortex appears in different optical settings, such as speckles, optical cavity, and dough-nut mode of laser beam, according to different environment [3].

The paper published by i Curtis, J.E. and Grier, D.G. s providing the comprehensive detail about the optical vortex, significantly. They gave a mathematical explanation of this structure of optical vortex. They explained the structure on the basis of scalar diffraction theory. According to them, the phase factor of a helical movement of laser light beam, which is denoted by ψ ®, is directly proportional to the polar angle, which is denoted by θ. This polar angle is created around the axis of beam in a helical form. The intensity of the relationship between phase factor and polar angle determines the helical structure of the optical vortex. This relationship can also be presented in mathematical terms as below[3]:

$$\psi (r) = u(r, z)\, e^{-ikz}\, e^{im\theta}$$

In the above equation

$$k = k\hat{z}$$

which represents the wave factor of the light or laser beam. u(r, z) represents the radical profile of the field at Z position, through which the light beam is to be passed. Further, m shows the topological charge of the vortex which is created because of the variability of the intensity of the magnetic field. This topological charge is also termed as the integral winding numbers. At the center of the beam axis, where r = 0, no helical movement is found. As the value of r increases, the helical nature of the light beam also increases. In this way with every increment in the phase factor, laser or light beam creates a new helical beam around the axis of the beam [2]. The overall structure of the optical vortex, which was noticed by Curtis, J.E. and Grier, D.G. in their experiment, is presented as below:

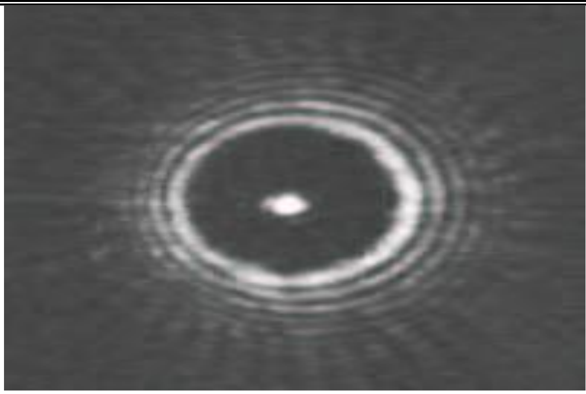

Fig.1 Image f the resulting optical vortex.[2]

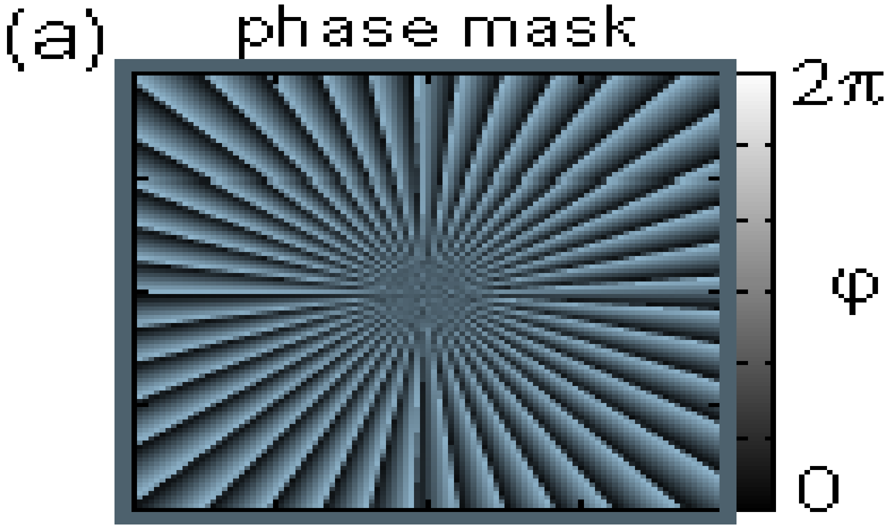

Fig. 3-Conventional diagram of holographic twists in the optical vortex
(Source: Galvez, E.J.

These findings of the paper significantly impact on the general principles of optical vortex. The authors described more rational and significant mathematical modal which can explain the structure and different properties related to this type of dislocation of the optical waves. This study provides a conceptual framework on which, further research work is conducted in the field.

Later research work on the optical vortex based on the paper

After the paper written by Curtis, J.E. and Grier, D.G. different researches and studies have taken place. In the light of techniques provided by Curtis, J.E. and Grier, D.G., Padgett, M. [4] studied about this phenomenon of light waves. According to him, when in laboratory conditions, spiral form of light waves are focused into a solid optical trap, the resulting nature of the light waves is known as optical vortex. Through this vortex of optical waves, maximum torque can be localized and applied to the matters that have small volume. For measuring the intensity of integration in the effect of optical vortex, i.e. how many twists in a particular light beam can take place, a typical scientific measurement is used which is termed as topological charge. If the topological charge of the wave is higher, more twists can take place in the wave and consequently, more torque can be induced on the matter Padgett, M..

Further, with the help of techniques and theories provided by Galvez, E.J., Curtis, J.E. and Grier, D.G. also studied about this phenomenon of optical beams. According to the researcher, in some special conditions, a light beam shows a specific structure which is similar to hurricanes, tornadoes, and water spouts. For revealing the structure of optical vortex, the scientist conducted an experiment, and found a spiral interference pattern, which is shown in the figure below:

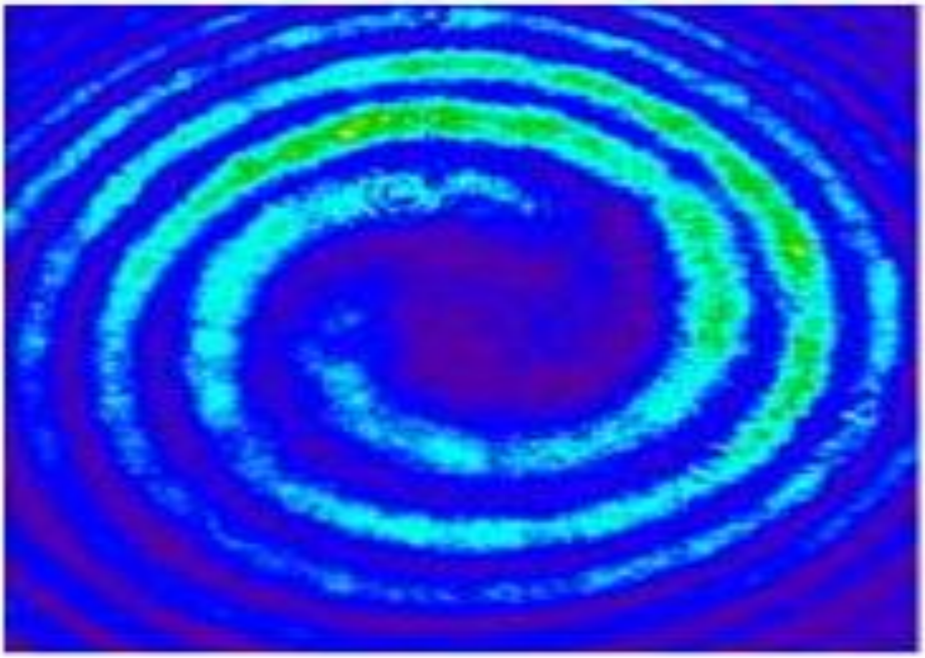

Fig.3 spiral interference pattern

(Source: Galvez, E.J.

In this structure, the optical vortex is presented like forks in the fringe pattern. In this structure, a phase dislocation is denoted with the help of the fork. The intensity of the projection of optical beam as optical vortex is directly dependent upon the topological charge of the vortex, which is generated because of fluctuation in the intensity of external magnetic field. Galvez, E.J.

Conclusion

The phenomenon of optical vortex is one of the important concepts for understanding the behavior of a light beam in magnetic field with different and variable intensity. The optical vortex also confines the wave nature of the light. In today's scenario, a large number of researches and studies are being conducted for revealing the phenomenon of optical vortex.

In relation to this, the study conducted by plays a vital role to understand this phenomenon comprehensively. Before this study, the optical vortex was not considered as an important phenomenon for study. Limited and elementary information was available on the topic.The studies bought a significant change in the scenario. A lot of attention has been given to dislocation of light wave. There are a lot of applications of this phenomenon of light beam. For availing the advantages of these applications in the most efficient manner, a lot of research work is going on.

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