The Optical Society of India
NEWSLETTER

Year 2, Number 1 **September, 2005**

Optical Vortices

P. SENTHILKUMARAN

Optical vortices are phase singularities, first reported in optics by Nye and Berry. An optical vortex is a point phase defect. At the defect point the phase is undefined, but in its neighborhood, phase values between 0 and $2\pi m$, (m being an integer representing topological charge of the vortex) can be found. For such an optical field to exist, the isolated point should be an amplitude null point. The wavefront has helical structure such as the one shown in Fig.1. The phase distribution of the wavefront is continuous and differentiable at every point except at the vortex core. Starting from the dark area in Fig.1, representing phase zero, one can go in a circular path to reach the phase 2π point which is represented as white area and continue going without a need to jump, because after 2π point next wavefront (*i.e.*, next helical structure) is encountered. Hence there is no phase discontinuity when 2π to zero (white to black region) phase line is crossed. and the discontinuity is only at the vortex core which is a point. Such wavefronts have attracted a lot of attention, and an explosion of research activity is witnessed in recent years due to the unique properties they posses. They carry orbital angular momentum of $m\hbar$ per photon, possess wave guiding properties, are normally stable and obey charge conservation. Though vortex is a point defect, it influences the phase distribution on whole wavefront. Some of the areas where vortices appear are: vortex solitons, diffuser synthesis, phase retrieval problems, adaptive optics, optical tweezers, optical switches, optical limiters, optical data storage, free space interconnects, optical testing, phase unwrapping, speckle fields, laser beams (LG, TEM_{01}^{*} modes), vortex crystals, astronomy, atmospheric optics and atom optics.

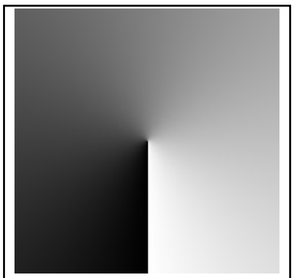

Fig.1 Phase distribution of an optical vortex

Apart from optical sciences, vortex phenomenon in wave fields, plays an important role in great number of physical processes such as microscopic structure of superfluid helium, Bose Einstein's condensate, global weather patterns, fluid dynamics, possibly in the formation of matter during the big bang, quantum chaos, Abrikosov lattice in superconductivity, and quantum Hall effect.

Optical vortices can be generated in laboratory using a phase plate which has the refractive element having variable thickness or by using a plexiglass in which a crack is made and the plate twisted. Recently a method using two wedge plate combination has been demonstrated for vortex generation. Interference of vortex beam with tilted plane wave results in fringes having fork pattern, and interference of vortex beam with spherical beam results in fringes having spiral shape. When these types of fringes are seen in an interference pattern then it is concluded that one of the interfering beams contains vortex. If such interference patterns are either recorded optically to create a hologram or computed and drawn to produce computer generated diffractive elements, they can be employed to generate vortices in the diffracted beam. Intracavity modifications using a beam-shaping element inside laser resonators can also produce vortex laser beams. Mode converters can be used outside the laser cavities for vortex generation. Vortices can also be seen in dark portions of speckle fields.

Optical vortices can be positively or negatively charged. For a positive vortex, the phase increases anti-clockwise around the singular point and for a negative vortex it is in the opposite sense. Such nomenclature (charge) is employed as there is similarity between the equi-phase lines in the vortex phase map and field lines of an electric charge. Fig.2 shows a vortex dipole in which the equi-phase lines can be seen similar to that of the field lines of an electric dipole.

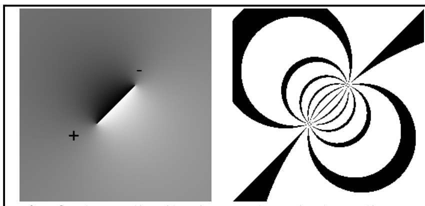

Fig. 2 Phase distribution and equi-phase lines of a positive and negative vortex pair forming a dipolar structure

Interferograms involving vortex beams are interesting to study. These types of fringe patterns are normally not encountered in optical testing methods, where closed fringes that are height difference contours of the test surface, enclosing an extrema point or fringes starting from one edge and terminating at the other edge of the interference pattern, indicating tilt, are prevalent. When vortices are involved, interferograms have fringes terminating (or originating) within the interferogram. This is because in the neighbourhood of the vortex core, all phase values are present. A simple example is the fork grating shown in

From the Editor

The OSI NEWSLETTER has completed one year of its existence. The first issue of the second year is in your hands. It has also graduated from two pages to four pages. It is hoped that this size will be sustained during year and would increase subsequently. Still it seems that not many members have received or read it. Are you getting these issues regularly? If you would like to receive the PDF copy by email, please send an email to the Editor (*asharma@physics.iitd.ac.in*). The Society would like to see the OSI NEWSLETTER become a vibrant forum for discussion and dissemination of information among the members. We should aim to increase both size and frequency in the near future. This can happen only if the members want it that way and contribute accordingly.

- EDITOR

Fig.3, in which five vortices are involved. This type of interferogram is mostly used to detect the presence of vortex in an optical wavefront and recently spiral interferometry is suggested for optical testing where maximum and minimum points on the test surface are clearly distinguishable.

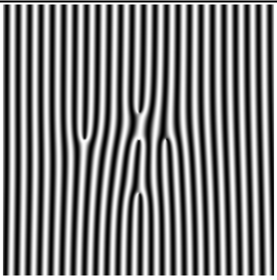

Fig. 3 Interferogram involving optical vortices

The presence of optical vortices in a wavefront sometimes is detrimental, since they cause stagnation problems in designing optical diffusers and in phase retrieval algorithms, digital holography, adaptive optics, and in phase unwrapping. Since they are stable and influence the whole phase distribution, any local modification of the wavefront to eliminate them does not help in iterative procedures.

Currently in our group, we have been investigating the diffraction of singular beams and use of vortices in optical testing techniques & in optical tweezers.

Optical vortices are thus interesting field formations, which occur in a variety of practical situations and are useful for studies in several branches of optics.

Further reading

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(*Dr. P. Senthilkumaran is at Physics Department, IIT Delhi; Email: psenthil@physics.iitd.ac.in)*

Optics Directory of India

Work on the *Optics Directory of India* is in progress. Please send your entries immediately to ensure their inclusion. For format, please see the first two issues of the OSI NEWSLETTER or contact the undersigned.

- Anurag Sharma

What's in a Name?

VIVEK SINGH

Opening at random any page of a scientific or technical journals, or even of a magazine, one is likely to encounter phrases like "photonic band gap materials, photonic crystals and super lattices,[1-4] *etc*. These are appropriate and useful terms for materials and devices and hold out a promise for very rich technological applications[1-4]. Here I would like to point out that certain classes of structures, which have held the interest of researchers for many years fall into these classes, but unfortunately have not been referred to by these prestigious authors. One of the germinal ideas in these new fields of study is discussed authoritatively in classic book of Brillouin on wave propagation in periodic structures[5]. The shift of emphasis which the very general idea of Brillouin received in the field of solid state physics with electrons as "waves" and the atomic lattice as the periodic structure gave rise to forbidden and allowed bands of wave numbers leading to the marvellous development of semiconductor physics and technology. In the photonic band gap materials light waves take the place of electron waves and arrays of periodically placed regions of materials with different refractive indices take the place of the atomic lattice. Among of the founders of this new field of study are Yablonovitch[1], John[2] and Joannopoulos.[3] Long before these people began their work, researchers in the field of microwave travelling wave tubes (TWTs) started their very important work on microwave generation.[6-7] Somehow none of these researchers could think of the happy phrase "photonic band gap", although they did find photonic band gaps in the microwave region of the EM spectrum and made good technical applications of these gaps. The periodic slow wave structure in their case was a conducting helical winding, which could be in the sheath helical or tape helical form. With this hindsight, we may now include all the TWTs in the class of photonic band gap structures. We, however, do not know how many of the researchers in microwave tubes will be delighted by this new designation of their field.

We may mention here that some workers in optical waveguides have recently considered waveguides with conducting helical windings on the core-cladding boundary.[8-9] The fast wave periodic structures also can be called photonic band gap structures in the near infrared region of the EM spectrum. The large number of claddings of a Bragg fiber[10-11] also reminds one of photonic crystal.

More than a decade ago, Ojha[12] *et al.* and Rao[13] *et al.* considered stacks of planar and circular waveguides, with periodic refractive index profiles. Those structures were shown to have allowed and forbidden ranges of frequencies for light transmission and it was suggested that they could be used as optical filters. Here the periodic refractive index profile stands for the lattice structure and lightwave stands for "electron wave". This structure is a very close relative of photonic band gap materials. This similarity of approach between the works of Ojha *et al*. and Yablonovitch, John and others has not been noticed and has been generally ignored.

It is also possible that I am unaware of the other researches along similar line. In a recent communication Vikram[14] *et al.* have shown that the spicules of the deep sea 'glass' sponge Euplectella have remarkable fiber-optical properties. Nature in many cases anticipates man-made structures. It is not unlikely that photonic gap structure, photonic crystals and super-lattice *etc*. will very soon be encountered by the researchers in biological sciences.

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(Vivek Singh is at Department of Physics, University Institute of Engineering and Technology, C.S.J.M. University, Kanpur (dr_vivek_singh@yahoomail.com)

Remembering Dr. D. Sen

KEHAR SINGH

Born March 27, 1923, Dr. Debabrata Sen obtained his M. Sc. (Physics) degree in 1944 from Delhi University and then Ph.D. and a D.I.C. (Chemical Technology) in 1952 from Imperial College London. His Doctoral work concerned optics of flames. Dr. Sen served at the National Physical Laboratory (NPL) New Delhi during the period 1953-83 and superannuated as Scientist 'G'. He worked at the same laboratory from 1984 to 1989 as Emeritus Scientist. During 1946-48 he worked at the Institute of Science, Bombay in the area of 'Combustion spectroscopy'.

I first came in contact with Dr. Sen in Oct. 1964 when he gave a course of lectures on 'Interferometric testing of optical components' at the IIT Delhi, to the first batch of students of Post-M.Sc. Diploma in 'Applied Optics'. Very shy by nature, he left impression on us as a silent researcher. By then, working with modest facilities, he had published mainly in collaboration with Dr. P. Hariharan, about 25 papers in journals of repute. Students of some later batches at IIT Delhi were also benefited by his lectures. I used to take the students to NPL for a visit of the Standards Division in which Dr. Sen worked, and thus came in close contact with him. He used to spare time for discussions happily, thus encouraging and motivating the young researchers in their pursuit of knowledge. Dr. Sen's work has been highly cited in research papers, books*, and review articles. He had a wide circle of friends and admirers abroad. Many researches whom I met at various international seminars used to talk with high regard about his contributions in the area of interferometry. Dr. Sen was indeed one of the 'pioneers' in the area of 'Interferometry' and helped in many ways to further the awareness of this discipline so as to set-up programs of studies in various Institutions.

Dr. Sen provided striking stimulant and support to the Optical Society of India at its formative stages. He served many times on the Executive Committee of the OSI, and eventually served as its Vice-President, and President (1980-83). He also served as a member of the Editorial Board of the Society's journal. He was given Optical Society of India Award in 1994 in recognition of his outstanding contributions to Optics. Dr. Sen breathed his last on May 27, 1994.

*See *e.g.* D. Malacara, Ed. *Optical Shop Testing*, II Ed. (John Wiley & Sons, Inc.1992)

(*Prof. K. Singh is at Physics Department, IIT Delhi. He was the President of the OSI during 1991-93. Email: kehars@physics.iitd.ac.in*)

Partial List of Publications of Dr. D. Sen

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URSI and Photonics

Radio science encompasses the knowledge and study of all aspects of electromagnetic fields and waves. The International Union of Radio Science (*Union Radio-Scientifique Internationale*, URSI), a non-governmental and non-profit organisation under the International Council for Science, is responsible for stimulating and coordinating, on an international basis, studies, research, applications, scientific exchange, and communication in the fields of radio science. Included within the objectives are the following:

1. to encourage and promote international activity in radio science and its applications, for the benefit of humanity;
2. to encourage the adoption of common methods of measurement, and the intercomparison and standardisation of the measuring instruments used in scientific work;
3. to stimulate and co-ordinate studies of:
   a. the scientific aspects of telecommunications using electromagnetic waves, guided and unguided;
   b. the generation, emission, radiation, propagation, reception, and detection of fields and waves, and the processing of the signals embedded in them.
4. to represent radio science to the general public, and to public and private organizations.

The scientific activities of the URSI are organized in ten commissions. The Commission-D is concerned with Electronics and Photonics. The Commission promotes research and reviews new development in:

1. Electronic devices, circuits, systems and applications;
2. Photonic devices, systems and applications;
3. Physics, materials, CAD, technology and reliability of electronic and photonic devices, with particular reference to radio science and telecommunications.

The Commission deals with devices for generation, detection, storage and processing of electromagnetic signals together with their applications, covering all frequencies, including those in the microwave and optical domains.

The Commission has representation from each member countries. Professor K. Thyagarajan of IIT Delhi represents India on this Commission-D.

Every three years the URSI holds its General Assembly. The 23rd General Assembly is being held in New Delhi during October 23-29, 2005. Each commission prepares a report on the activities for the preceding three years for presentation at the General Assembly. Prof. Thyagarajan prepared a report of the R & D in Photonics in India during 2002-2005 for this purpose. The preamble of the report is given in the adjoining box. The full report in electronic form can be had either from Prof. Thyagarajan (ktrajan@physics.iitd.ac.in) or from the editor of the OSI NEWSLETTER.

(*With excerpts from the URSI website: http://www.ursi.org*)

Forthcoming Events

International Conference on Optics and Optoelectronics (ICOL-2005)
(XXXI OSI Symposium)
Dehradun, December 12-15, 2005
Contact: Dr. Ashok Kaul, Convener, ICOL-2005, IRDE, Dehradun – 248 008
URL: http://www.icol2005.com

Seminar on Optics of Photonic Band-gap Materials (PBG-2005)
Kharagpur, October 29-30, 2005
Contact: Dr. P.K. Datta, IIT Kharagpur – 721 002
URL: http://www.iitkgp.ac.in/pbg/index.htm

National Workshop on Optical & Spectroscopic Methods for Sensor Instrumentation (NWOSMS-2005)
Manipal , Sept. 21-Oct. 7, 2005
Contact: Dr.R.Bhattacharya, Adjunct Professor, Manipal Institute of Technology, MAHE, Manipal, 576 104 (Karnataka) India

Fifth DAE-BRNS National Laser Symposium (NLS-5)
Vellore, December 7-10, 2005
Contact: Secretary, NLS-5, LSED, CAT, PO: CAT, Indore – 452 013

International Conference on Electronic and Photonic Materials, Devices and Systems (EPMDS – 2006)
Kolkata, January 4-6, 2006
Contact: Convener, EPMDS-2006, Department of Electronic Science, University of Calcutta, 92 A.P.C. Road, Kolkata – 700 009
URL: http://www. ElectronicScience-EPMDS.org

XXVIII General Assembly of International Union of Radio Science (URSI)
New Delhi, October 23-29, 2005
URL: http://www.ursiga2005.org

One-day Seminar on Optics and Photonics
IIT Madras, Chennai, January 6, 2006
Organized by: IIT Madras SPIE Students Chapter
Contact: Dr. N.K.Mohan (nkmohan@iitm.ac.in)

Suggestions & Contributions

A regular publication this OSI NEWSLETTER can be sustained only through active participation of the members and we seek suggestions to improve its contents and presentation. We also seek contributions from members to various columns of the OSI NEWSLETTER. In additions to the columns in this and the earlier issues, the future issues will also have interesting anecdotes/incidents involving optics or members, historical notes and any other information that could be useful or interesting to the members. Readers are particularly urged to send their responses/reactions to this and earlier issues. Contributions and proposals may please be sent to the editor. The next issue is scheduled for December, 2005. Members who want to receive the future issues of the OSI NEWSLETTER by email may send their email addresses to the editor.

R & D in Photonics in India during 2002-2005

K. THYAGARAJAN

(Preamble)

The field of Photonics, which emerged with the invention of the laser in 1960, deals with generation, detection, transmission, storage, processing, *etc*. of photons (light). During the past four decades it has found and continues to find innumerable applications in communication, sensing, spectroscopy, metrology, basic sciences, *etc*. There are a number of Institutes in India where work in the general area of Photonics is being carried out. The present report is a compilation of the activities in some of the Institutes in the area of Photonics during the past three years.

The R&D work in Photonics can be broadly classified into the following areas:

1. Fiber optics
2. Optical communications and networking
3. Optoelectronic devices
4. Photonic crystals
5. Quantum optics
6. Integrated optics
7. Nonlinear optics
8. Adaptive optics
9. Lasers
10. Bio Photonics
11. Instrumentation
12. Miscellaneous

The report includes activities in the above areas carried out at the following institutes in India during the past three years:

1. Bhabha Atomic Research Center (BARC), Mumbai.
2. Center for Advanced Technology (CAT), Indore
3. Center for Development of Telematics (C-DoT), Delhi
4. Central Electronics Engineering Research Institute (CEERI), Pilani
5. Central Glass and Ceramics Research Institute (CGCRI), Kolkata
6. Cochin University of Science and Technology (CUSAT), Kochi
7. Indian Institute of Science (IISc), Bangalore
8. Indian Institute of Technology Bombay (IITB)
9. Indian Institute of Technology Delhi (IITD)
10. Indian Institute of Technology Kanpur (IITK)
11. Indian Institute of Technology Kharagpur (IITKgp)
12. Indian Institute of Technology Madras (IITM)
13. Instruments Research Development Establishment (IRDE), Dehradun
14. Jawaharlal Nehru University (JNU), Delhi
15. Laser Science and Technology Center (LASTEC), Delhi
16. National Physical Laboratory (NPL), Delhi
17. Raman Research Institute (RRI), Bangalore
18. Society for Applied Microwave Electronics Engineering and Research (SAMEER), Mumbai
19. Tata Institute of Fundamental Research (TIFR), Mumbai.

(*Full report in electronic form can be had either from Prof. Thyagarajan (ktrajan@physics.iitd.ac.in) or from the editor of the OSI NEWSLETTER.*)

Edited by Professor Anurag Sharma, Physics Department, Indian Institute of Technology Delhi, New Delhi – 110016 (Email: asharma@physics.iitd.ac.in)
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