Propagation of Engineered Beams through Photorefractive Materials

A Thesis

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By

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To

my parents & grandparents

DECLARATION

I, **Mr. Vaity Pravin Prabhakar**, S/o Mr. Vaity Prabhakar Nathuram, resident of F-205, PRL residences, Navrangpura, Ahmedabad 380009, hereby declare that the research work incorporated in the present thesis entitled, **"Propagation of Engineered Beams through Photorefractive Materials"** is my own work and is original. This work (in part or in full) has not been submitted to any University for the award of a Degree or a Diploma. I have properly acknowledged the material collected from secondary sources wherever required. I solely own the responsibility for the originality of the entire content.

Date:

Vaity Pravin Prabhakar

Signature of the candidate

CERTIFICATE

I feel great pleasure in certifying that the thesis entitled, **"Propagation of Engineered Beams through Photorefractive Materials"** by Mr. Vaity Pravin Prabhakar is under my guidance. He has completed the following requirements as per Ph.D regulations of the University.

(a) Course work as per the university rules.

(b) Residential requirements of the university

(c) Regularly submitted six monthly progress reports

(d) Presented his work in the departmental committee

(e) Published/accepted minimum of one research paper in a referred research journal,

I recommend the submission of thesis.

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Countersigned by

Head of the Department

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Pravin

ABSTRACT

The photorefractive (PR) materials, which show nonlinear response to an incident light, have already proved their importance in various applications. These applications include two wave mixing, four wave mixing, phase conjugation and optical data storage. The advantage of these materials is that they show nonlinearity at very low laser powers (μW) unlike Kerr materials which require very high power. In this thesis, we have found experimentally and numerically, new solutions for the nonlinear paraxial wave equation (PWE) with the PR nonlinearity for beams engineered in our laboratory using computer-generated holography. These beams include dipole & quadrupole vortices, Hermite-Gaussian (HG) beams, Laguerre-Gaussian (LG) beams, Bessel beams, Airy beams and superposed LG beams. We have studied their dynamics in free space to make a comparison with the nonlinear dynamics. It also helps us to characterize these beams.

In this thesis work, we have studied both linear and nonlinear dynamics of dipole and quadrupole vortices. The linear dynamics of these beams is found to be unstable which is verified with exact analytical expression. However, in presence of nonlinearity they form stable structures while propagating through a photovoltaic PR medium.

We have formed dark ring beams using LG modes and studied their propagation through PR medium. It is found that the dark ring beam breaks to form quadrupole vortex in the presence of defocusing nonlinearity, instead of forming dark ring soliton. These results suggest that dipole and quadrupole vortices may be the solutions of nonlinear PWE with the PR nonlinearity.

We have studied propagation dynamics of non-diffracting, self-accelerated Airy beams through the PR medium with self-focusing nonlinearity. We observe interaction amongst their lobes as they propagate in the PR medium. The result shows that self-trapped, self-accelerated beam can not exist in the PR medium. We have also examined propagation dynamics of HG beams, superposed LG beams and Bessel beams in the PR medium.

Keywords: photorefractive, nonlinear, singular optics; computer holography

LIST OF PUBLICATIONS

A. Publications in Journals

1. Ashok Kumar, Pravin Vaity, Yedhu Krishna, and R. P. Singh, *Engineering the size of dark core of an optical vortex*, Opt. Laser Eng. 48, 276-281 (2010).

2. Ashok Kumar, Pravin Vaity, and R. P. Singh, *Diffraction characteristics of an optical vortex passing through an aperture-iris diaphragm*, Opt. Commun. 28, 4141-4145, (2010).

3. Ashok Kumar, Pravin Vaity, and R. P. Singh, *Crafting the core asymmetry to lift the degeneracy of optical vortices*, Opt. Express 19, 6182-6190, (2011).

4. Ashok Kumar, Shashi Prabhakar, Pravin Vaity and R. P. Singh, *Information content of optical vortex field*, Opt. Lett. 36, 7-9, (2011).

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7. Pravin Vaity and R. P. Singh, *Topological charge dependent propagation of optical vortices under quadratic phase transformation*, Opt. Lett. 37 1301-1303 (2012).

8. Pravin Vaity and R. P. Singh, *Generation of quadrupoles through instability of dark rings in photorefractive media*, J. Opt. Soc. Am. B (to be published).

9. Pravin Vaity and R. P. Singh, *Measuring orbital angular momentum of light using simple convex lens*, Submitted to Opt. Lett.

10. Pravin Vaity and R. P. Singh, *Structurally stable dipole and quadrupole vortex in photorefractive media*, Submitted to Phys. Rev. A.

B. Full Length Conference Papers

1. Pravin Vaity, Ashok Kumar, and R. P. Singh, *Experimental study of power decay of optical vortices in photorefractive material* National Laser Symposium-09, 75, Jan 13-16, 2010 at BARC Mumbai, India.

2. Ashok Kumar, Pravin Vaity, and R. P. Singh, *Decay of high order elliptical optical vortices* National Laser Symposium-19, 3153, Dec 1-4, 2010 at RRCAT Indore, India.

3. Pravin Vaity, Ashok Kumar, Shashi Prabhakar, and R. P. Singh, *2-D Airy beam propagation through photorefractive materials* Photonics-2010, Proc. SPIE 8173, 81730N-81730N-6, (2010).

4. Ashok Kumar, Shashi Prabhakar, Pravin Vaity, and R. P. Singh, *Two point correlation function for optical vortices* Photonics-2010, 556, Dec 12-15, 2010, at IIT Guwahati, India.

5. Ashok Kumar, Pravin Vaity, and R. P. Singh, *Degeneracy of optical vortices and the core asymmetry* XXXV OSI Symposium- International Conference on Contemporary Trends in Optics and Optoelectronics, 342, Jan 17-19, 2011 at IIST Thiruvananthapuram, India.

6. R. P. Singh, Ashok Kumar, Pravin Vaity, and Shashi Prabhakar, *Dynamic light scattering of optical vortices* XXXV OSI Symposium- International Conference on Contemporary Trends in Optics and Optoelectronics, 37, Jan 17-19, 2011 at IIST Thiruvananthapuram, India.

7. R. P. Singh, Pravin Vaity, Ashok Kumar, S. G. Reddy, and A. Aadhi *Dynamics of Fractional Charge Optical Vortices,* International Conference on Trends in Optics and Photonics (IConTOP), 217, Dec 7-9, 2011 at SINP, Kolkata, India.

8. Pravin Vaity and R. P. Singh *Measurement of Topological Charge of Optical Vortex Using Airy Function,* International Conference on Trends in Optics and Photonics (IConTOP), 221, Dec 7-9, 2011 at SINP, Kolkata, India.

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