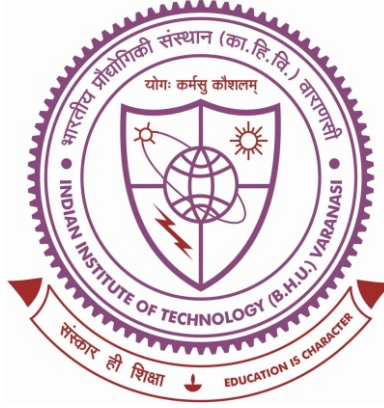


Interferometry with low coherent light and vortices: New experimental designs and results



Thesis submitted in partial fulfillment for the
Award of Degree

Doctor of Philosophy

By

Akanksha Gautam

DEPARTMENT OF PHYSICS
INDIAN INSTITUTE OF TECHNOLOGY
(BANARAS HINDU UNIVERSITY)
VARANASI - 221005
INDIA

Roll No. 19171013

Year 2024

Dedicated
To
My Dearest
Parents

*“The love, support, and belief of a loving family and friends gives you the strength to
climb any mountain”*



भारतीय
प्रौद्योगिकी
संस्थान
काशी हिन्दू विश्वविद्यालय



INDIAN
INSTITUTE OF
TECHNOLOGY
BANARAS HINDU UNIVERSITY

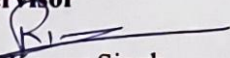
Certificate

It is certified that the work contained in the thesis titled “**Interferometry with low coherent light and vortices: New experimental designs and results**” by **Akanksha Gautam**, Roll Number **19171013**, has been carried out under our supervision and that this work has not been submitted elsewhere for a degree.

It is further certified that the student has fulfilled all the requirements of the comprehensive examination, candidacy, and SOTA for the award of a Ph.D. Degree.

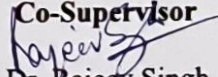
Signature:

Supervisor


Prof. Rakesh Kumar Singh
(Professor)
Department of Physics
Indian Institute of Technology
(Banaras Hindu University)
Varanasi-221005 (U.P.), India

Dr. Rakesh Kumar Singh
Professor
Department of Physics
Indian Institute of Technology
(Banaras Hindu University), Varanasi-221005

Co-Supervisor


Dr. Rajeev Singh
(Assistant Professor)
Department of Physics
Indian Institute of Technology
(Banaras Hindu University)
Varanasi-221005 (U.P.), India
Assistant Professor
Department of Physics
Indian Institute of Technology
(Banaras Hindu University)
Varanasi-221005



भारतीय
प्रौद्योगिकी
संस्थान
काशी हिन्दू विश्वविद्यालय



INDIAN
INSTITUTE OF
TECHNOLOGY
BANARAS HINDU UNIVERSITY

Declaration by the candidate

I, **"Akanksha Gautam"**, certify that the work embodied in this thesis is my own bona fide work carried out by me under the supervision of **"Prof. Rakesh Kumar Singh"** and co-supervision of **"Dr. Rajeev Singh"** from **"July 2019"** to **"December 2024"**, at the **"DEPARTMENT OF PHYSICS"**, Indian Institute of Technology (BHU), Varanasi. The matter embodied in this thesis has not been submitted for the award of any other degree/diploma. I declare that I have faithfully acknowledged and given credit to the research workers wherever their works have been cited in my work in this thesis. I further declare that I have not willfully copied any other's work, paragraphs, text, data, results, etc., reported in journals, books, magazines, reports dissertations, thesis, etc., or available on websites and have not included them in this thesis and have not cited as my work.

Date: 30.12.2024

Place: IIT (BHU), Varanasi

Signature of the Student

(Akanksha Gautam)

CERTIFICATE BY THE SUPERVISOR

It is certified that the above statement made by the student is correct to the best of my knowledge.

Signature: 
Supervisor

Prof. Rakesh Kumar Singh

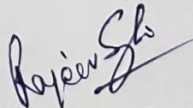
Dr. Rakesh Kumar Singh

Professor

Department of Physics

Indian Institute of Technology

(Banaras Hindu University), Varanasi-221005


Co-Supervisor

Dr. Rajeev Singh
Assistant Professor

Department of Physics

Indian Institute of Technology

(Banaras Hindu University)

Varanasi-221005


Head of the Department

Prof. Sandip Chatterjee
HEAD/विभागाध्यक्ष

भौतिकी विभाग/Deptt. of Physics

भा0प्रौ0सं0/(का0हि0वि0)/IIT (BHU)

वाराणसी/Varanasi-221005



भारतीय
प्रौद्योगिकी
संस्थान
काशी हिन्दू विश्वविद्यालय



INDIAN
INSTITUTE OF
TECHNOLOGY
BANARAS HINDU UNIVERSITY

Copyright transfer certificate

Title of the Thesis: Interferometry with low coherent light and vortices: New experimental designs and results

Name of the Student: Akanksha Gautam

Copyright Transfer

The undersigned hereby assigns to the Institute of Technology (Banaras Hindu University) Varanasi all rights under copyright that may exist in and for the above thesis submitted for the award of the “*DOCTOR OF PHILOSOPHY*” .

Date: 30.12.2024

Place: IIT (BHU), Varanasi

Signature of the Student

(Akanksha Gautam)

Note: However, the author may reproduce or authorize others to reproduce material extracted verbatim from the thesis or derivative of the thesis for the author's personal use provided that the source and the Institute's copyright notice are indicated.

Acknowledgments

No accomplishment is truly ours alone, it's the sum of every hand that helped, every heart that believed, and every voice that encouraged. Even the strongest individuals need the hands of others to build a ladder to their dreams.

*Firstly, I would like to thank my research supervisor, **Prof. Rakesh Kumar Singh**, for his guidance and motivation. His valuable ideas, suggestions, and discussions have greatly contributed to the completion of this work. I also extend my gratitude to my co-supervisor, **Dr. Rajeev Singh**, for his support and encouragement during challenging times.*

*I am sincerely thankful to the Head of the Department, **Prof. Sandip Chatterjee**, for providing the necessary facilities for my research. I express my appreciation to my RPEC members, **Prof. Rajendra Prasad** (Department of Physics, IIT BHU) and **Dr. Sanjay Singh** (School of Materials Science and Technology, IIT BHU), for their inspiration and valuable suggestions throughout the course of this research.*

*I am also grateful to **Prof. C. S. Narayanamurthy** and **Dr. Dinesh Narayana Naik** (IIST, Thiruvananthapuram) as well as **Dr. Gyanendra Sheoran** (NIT, Delhi) for generously providing lab facilities. I have learned a great deal from **Dr. Naik**, whose insightful discussions and support have been invaluable. Additionally, I am thankful for the opportunity to collaborate with **Prof. P. Senthilkumaran** (IIT, Delhi).*

I would like to express my heartfelt thanks to all the faculty members of the Department of Physics for their encouragement and motivation throughout my research journey. I also extend my gratitude to the non-teaching staff of the department for their support.

*I would like to acknowledge **Inspire**, and my institute **IIT BHU** for providing me financial support to do my research, and present my work in various conferences.*

*I have been fortunate to have exceptionally encouraging professors during my postgraduate studies who inspired me to pursue a career in research. I would like to express my heartfelt gratitude to **Dr. A. K. Dutta**, **Dr. Y. Choyal**, and **Dr. G. Mishra** for their invaluable guidance, motivation, and unwavering support throughout my academic journey. Their encouragement has been instrumental in shaping my aspirations and steering me toward the path of research.*

*I am deeply appreciative of the assistance provided by **Athira T. S.**, **Surashree Chechi**, **Deepak**, **Chirang**, **Harikrishnan**, **Amit**, **Souvik**, **Binduja**, and **Jaspal** from IIST*

(Thiruvananthapuram), as well as **Dr. Gaurav, Nishant, and Priya** from NIT (Delhi), **Gauri** (IIT, Delhi), for their unconditional help during my collaborative research work.

I wish to thank my lab companions and friends, **Sourav, Sarita, Dr. Tushar, Tanushree, Mohit, Amit, Ankita, Prateek** and all the members of the Laboratory of Information Photonics and Optical Metrology, Department of Physics, IIT (BHU), for creating a supportive and friendly environment that enabled me to carry out my research effectively.

I find myself at a loss for words to express my heartfelt appreciation, gratitude, and indebtedness to my dearest friends **Neha, Shweta, Prashant Ji, Swarnima, Avani, Preeti, Pratyasha, Diksha, and Sourav** for their unwavering support throughout this journey. True friendship is a treasure, and these incredible individuals have been my family away from home. They walked alongside me every step of the way, offering their kindness, understanding, and unwavering belief in me. In moments of uncertainty, they stood as pillars of strength. During emergencies, they were always by my side, helping me navigate through the toughest times. Their selfless care, whether accompanying me when I was unwell or simply lending a listening ear, has meant more than words can convey. These cherished friends have been a constant source of comfort, joy, and resilience, sharing not only in my challenges but also in my triumphs. I am truly blessed to have such extraordinary people in my life, and I will forever be grateful for their unconditional support and love.

I would also like to express my sincere appreciation to my colleagues, and friends **Neelam, Manisha, Himani, Anuvrat, Samiksha, Pawan, Santosh, Sachin, Aashish, Shivam, Harsh, Kaustubh, Vindya, Swayangsiddha, Soumya di, Tulika di, Rajnandini di, Srishti di, Uma di** for their lively friendship and support.

I would also like to express my heartfelt gratitude to the family—Aunty and Uncle—with whom I stayed during my three-month research collaboration in Kerala. Being in a completely new environment, far from my own family, their support and kindness meant a great deal to me. They made my stay comfortable and helped me feel at home during this period. I am also deeply thankful to **Anu**, whose assistance in connecting me with them made this experience possible. Their generosity and warmth will always hold a special place in my heart.

At last, but always foremost in my heart, I would like to express my deepest gratitude to my loving parents, **Mrs. Bharti Gautam and Mr. Kushal Singh Gautam**, for their unconditional love, unwavering support, and constant encouragement throughout this journey. They have been my guiding light, always believing in me and standing by my side

*through every challenge. Without their support, nothing would have been possible. Parents embody the purest form of love—a love that is selfless, enduring, and always directed toward wanting the best for their children. I am also grateful to my sisters, **Mohita** and **Shubhakankshi**, and my brothers-in-law, **Jeetendra** and **Rajveer**, for their constant belief in me and for always celebrating my achievements with pride and happiness. To my brothers, **Mohit**, **Rohit**, and **Shobhit**, thank you for your encouragement and the joy you bring into my life. A special mention to my dear niece **Gauri**, and my nephews **Tejas**, **Suryansh**, and **Praaru**, whose pure emotions and innocent smiles never fail to brighten my days. Their presence fills my life with happiness and heals every worry. I am, and will always be, eternally grateful and indebted to my incredible parents and family for being my greatest strength and source of inspiration.*

Lastly, I want to take a moment to thank myself for walking this path with unwavering determination and staying true to the principles I hold dear. Navigating this journey has not been without its challenges, yet I chose perseverance over doubt and growth over comfort. I am proud of the resilience and strength I have shown, and for embracing every experience as an opportunity to learn and evolve.

This journey has taught me invaluable lessons—about life, about perseverance, and about myself—that will remain with me forever. It is a testament to the power of self-belief and commitment, and I am deeply grateful for the person I have become through it all.

*With profound gratitude, I acknowledge the silent strength and guidance of **Mahadev**. Banaras holds a special place in my heart—not just for its rich cultural heritage, but for the spiritual solace, comfort and clarity it has offered me. In moments of doubt, it was the serenity of the temples and peaceful walks along the ghats that gave me strength to keep going.*

Akanksha

Table of contents

Certificate	v
Declaration by the candidate	vii
Copyright transfer certificate	ix
Acknowledgments	xi
Table of contents	xv
List of figures	xix
Chapter 1	29
Introduction	29
1.1 Light sources	31
1.1.1 Coherent light sources	31
1.1.2 Incoherent light sources	32
1.2 Interferometry with coherent light beams	33
1.2.1 Visibility of interference fringes	35
1.2.2 Advantages and applications of interferometry	36
1.3 Optical vortex and interferometry	37
1.3.1 Generation of an optical vortex	39
1.3.1.1 Spiral phase plate	39
1.3.1.2 Mode converters	40
1.3.1.3 Spatial light modulator	41
1.3.1.4 Direct generation from laser cavity	42
1.3.2 Detection of an optical vortex	44
1.3.2.1 Interferometric techniques	45
1.3.2.2 Diffraction techniques	46
1.3.3 Application of optical vortices	48
1.3.3.1 Particle trapping	48
1.3.3.2 Optical communication	50
1.3.3.3 Spiral interferometry	52
1.4 Low coherent source	53
1.5 Concept of optical coherence	54
1.5.1 Types of coherence	55
1.5.1.1 Temporal coherence	56
1.5.1.2 Spatial coherence	56
1.5.2 Interference of arbitrary light source	58
1.5.3 Generation of spatial coherence on propagation	61
1.5.4 The van Cittert-Zernike theorem	63
1.5.5 Measurement of spatial coherence	65
1.5.5.1 Young's interferometer	66
1.5.5.2 Wavefront folding interferometer	68
1.5.5.3 Reversed-wavefront interferometer	70
1.5.5.4 Multiple apertures	72
1.5.5.5 Sagnac-type interferometers	74
1.5.6 Unified theory of coherence and polarization	77

1.5.7 Measurement of vectorial spatial coherence.....	80
1.5.7.1 Young’s interferometer.....	81
1.5.7.2 Vectorial coherence holography	84
1.5.7.3 Apertures.....	86
1.5.7.4 Intensity correlation	87
1.5.7.5 Self-referencing holography	92
1.6 Vortices in low coherent light.....	94
1.7 Objective of the thesis.....	95
Chapter 2	97
Interferometry with coherent light and vortices.....	97
2.1 Introduction.....	99
2.2 Theoretical basis and simulation results	101
2.2.1 OAM spectrum generation with spiral slit.....	101
2.2.2 OAM spectrum generation with pinhole masks.....	103
2.2.3 OAM mode spectrum with $\pm l$ modes.....	106
2.3 Experiment.....	108
2.4 Results and discussion	109
2.5 Conclusion	114
Chapter 3	115
Characterization of sources with arbitrary coherence.....	115
3.1 Introduction.....	117
3.2 Measurement of cross-spectral density matrix	120
3.2.1 Theoretical basis	120
3.2.2 Experiment and results discussions	122
3.3 Effect of polarization on cross-spectral density matrix	136
3.3.1 Theoretical basis	137
3.3.2 Experiment and results discussions	141
3.4 Conclusion	148
Chapter 4	149
Vortices in low coherent light by lithography: Generation and analysis.....	149
4.1 Introduction.....	151
4.2 Principle	155
4.2.1 Generation of coherence vortex with varying modes	155
4.2.2 Generation of coherence vortex with $\pm l$ modes	159
4.3 Simulation results.....	159
4.4 Experiment.....	162
4.5 Results and discussions.....	164
4.6 Conclusion	169
Chapter 5	171
Digital generation of coherence vortices	171

5.1 Introduction.....	173
5.2 Digital generation using DMD.....	176
5.2.1 Theoretical basis	176
5.2.2 Experiment and results discussions	177
5.3 Digital generation using SLM.....	182
5.3.1 Theoretical background	182
5.3.2 Simulation results.....	184
5.3.3 Experiment and results discussions	186
5.4 Conclusion	190
Chapter 6	191
Conclusion	191
6.1 Summary	193
6.2 Future Work.....	195
Bibliography	197
List of Publications	219

List of figures

Fig. 1.1 Interference with a monochromatic source.	34
Fig. 1.2 Optical vortices of different topological charge with their intensity, phase and three-dimensional (3D) phase profile.	38
Fig. 1.3 Schematic of the generation of an optical vortex beam with SPP.....	39
Fig. 1.4 Schematic of the generation of an optical vortex beam with $\pi/2$ converter.	40
Fig. 1.5 Schematic of the generation of an optical vortex beam using SLM.....	41
Fig. 1.6 Intra-cavity laser beam shaping using SLM [63].	44
Fig. 1.7 Schematic of the Mach-Zehnder interferometer for measurement of an optical vortex beam. BS: Beam splitter, M: mirror, SPP: spiral phase plate.....	45
Fig. 1.8 Diffraction patterns: (a) Aperture diffraction method: triangular aperture [72], (b) Cylindrical lens diffraction method [82], (c) Grating diffraction method: gradually changing period grating [80].....	48
Fig. 1.9 Schematic of experimental configuration of conventional optical tweezers [95].	50
Fig. 1.10 Free-space optical communication using polarization mutiplexing [99].	51
Fig. 1.11 Sample profile of a surface (a) Normal interferogram. (b) Spiral interferogram [100].....	53
Fig. 1.12 Schematic diagram of the Young’s interference experiment.	57
Fig. 1.13 The average intensity distribution (a) coherent superposition (b) partially coherent superpositon (c) incoherent superposition [134].....	60
Fig. 1.14 Illustration demonstrating the emergence of spatial coherence during propagation.	62
Fig. 1.15 Spatial coherence generation from an incoherent source [134].	63
Fig. 1.16 (a) Measurement system. (b) Arrangement of the micromirrors, Young’s slits, and the laser spot [141].....	68
Fig. 1.17 Schematic of a 1D folding WFI [144].....	69
Fig. 1.18 Schematic of a 1D RWI.....	71
Fig. 1.19 Measurement of spatial coherence using nonredundant array (NRA) of apertures, L: Lens, CCD: Camera [151].....	74
Fig. 1.20 Measurement of spatial coherence using Sagnac shearing interferometer.....	75
Fig. 1.21 Schematic diagram of the Young’s interference experiment for the measurement of CSD matrix [188].	82
Fig. 1.22 Schematics of the experimental setup based on Young’s interferometer [202].	86
Fig. 1.23 Schematics of the experimental setup for synthesis and analysis of BCP matrix [204].....	89
Fig. 1.24 Schematics of the experimental setup based on generalized HBT approach [206].	91

Fig. 1.25 Schematics of the experimental setup based on self-referencing holography [208].	93
Fig. 1.26 Existing techniques for coherence measurement.....	96
Fig. 2.1 Schematics of propagation of a plane wave through (a) annular aperture (b) spiral slit.....	102
Fig. 2.2 Schematics of the different apertures (a) annular, (d) and (g) spirals with different $\mathbf{r}\mathbf{0}$; (b), (e), and (h) the corresponding simulated amplitude of complex field; (c), (f), and (i) the corresponding simulated phase of complex field.....	103
Fig. 2.3 Schematics of the discretized binary spiral pinhole masks (a) single spiral, (e) three spirals, and (i) five spirals; (b), (f), and (j) the corresponding simulated amplitude of complex field; (c), (g), and (k) the corresponding simulated phase of complex field; (d), (h), and (l) the corresponding OAM power spectrum.....	105
Fig. 2.4 Schematics of the pinhole gears (a) $l = \pm 2$, (e) $l = \pm 3$, and (i) $l = \pm 4$; (b), (f), and (j) the corresponding simulated amplitude of complex field; (c), (g), and (k) the corresponding simulated phase of complex field; (d), (h), and (l) the corresponding OAM power spectrum.....	107
Fig. 2.5 Experimental setup: SF: Spatial Filter, L: Lens, BS: Beam Splitter, PM: Binary Pinhole Mask, M: Mirror, CCD: Charge-Coupled Device.....	109
Fig. 2.6 Pipeline for the Fourier fringe analysis, where FT denotes Fourier Transform and IFT denotes Inverse Fourier Transform.....	111
Fig. 2.7 Experimental results. (a) single spiral, (e) three spirals, and (i) five spirals; (b), (f), and (j) the corresponding simulated amplitude of complex field; (c), (g), and (k) the corresponding simulated phase of complex field; (d), (h), and (l) the corresponding OAM power spectrum.....	112
Fig. 2.8 Experimental results. Schematics of the pinhole gears (a) $l = \pm 2$, (e) $l = \pm 3$, and (i) $l = \pm 4$; (b), (f), and (j) the corresponding simulated amplitude of complex field; (c), (g), and (k) the corresponding simulated phase of complex field; (d), (h), and (l) the corresponding OAM power spectrum.....	113
Fig. 3.1 Recording of incoherent object hologram by the CSD.....	121
Fig. 3.2 Experimental set up: P, Polarizer; L, Lens; BRT, Birefringent Resolution Target; MO, Microscopic Objective; PBS, Polarization Beam Splitter; M, Mirror; HWP, Half Wave Plate; QWP, Quarter Wave Plate.....	123
Fig. 3.3 Laboratory experimental setup.....	123
Fig. 3.4 Polarization-state trajectories on the Poincaré sphere.....	126
Fig. 3.5 Experimentally measured matrix element $W_{xy}(\alpha - \mathbf{1r}, \alpha\mathbf{r})$ for polarized light: (a)-(e) Five experimentally recorded interferograms for phase shifts (a) 0 (b) $\pi/2$ (c) π (d) $3\pi/2$ (e) 2π , and (f) constructed fringe visibility (g) corresponding phase.....	129
Fig. 3.6 Elements of cross-spectral density matrix for polarized light: fringe visibility of (a) $W_{xx}(\alpha - \mathbf{1r}, \alpha\mathbf{r})$ (b) $W_{xy}(\alpha - \mathbf{1r}, \alpha\mathbf{r})$ (c) $W_{yx}(\alpha - \mathbf{1r}, \alpha\mathbf{r})$ (d) $W_{yy}(\alpha - \mathbf{1r}, \alpha\mathbf{r})$, corresponding phase of (e) $W_{xx}(\alpha - \mathbf{1r}, \alpha\mathbf{r})$ (f) $W_{xy}(\alpha - \mathbf{1r}, \alpha\mathbf{r})$ (g) $W_{yx}(\alpha - \mathbf{1r}, \alpha\mathbf{r})$ (h) $W_{yy}(\alpha - \mathbf{1r}, \alpha\mathbf{r})$ and reconstructed vector source elements (i) $I_{xx}\mathbf{r}$ (j) $I_{xy}\mathbf{r}$ (k) $I_{yx}\mathbf{r}$ (l) $I_{yy}\mathbf{r}$ (colour bar shown above the Figs. (a)-(d) and Figs. (e)-(h) are same for all the Figs.).....	131

Fig. 3.7 Elements of cross-spectral density matrix for unpolarized light: fringe visibility of (a) $W_{xx}(\alpha - 1\mathbf{r}, \alpha\mathbf{r})$ (b) $W_{xy}(\alpha - 1\mathbf{r}, \alpha\mathbf{r})$ (c) $W_{yx}(\alpha - 1\mathbf{r}, \alpha\mathbf{r})$ (d) $W_{yy}(\alpha - 1\mathbf{r}, \alpha\mathbf{r})$, corresponding phase of (e) $W_{xx}(\alpha - 1\mathbf{r}, \alpha\mathbf{r})$ (f) $W_{xy}(\alpha - 1\mathbf{r}, \alpha\mathbf{r})$ (g) $W_{yx}(\alpha - 1\mathbf{r}, \alpha\mathbf{r})$ (h) $W_{yy}(\alpha - 1\mathbf{r}, \alpha\mathbf{r})$, reconstructed vector source elements (i) $I_{xx}\mathbf{r}$ (j) $I_{xy}\mathbf{r}$ (k) $I_{yx}\mathbf{r}$ (l) $I_{yy}\mathbf{r}$ (colour bar shown above the Figs. (a)-(d) and Figs. (e)-(h) are same for all the Figs.).....	132
Fig. 3.8 Propagated vector source matrix elements for polarized light: (a)-(e) $I_{xx}\mathbf{r}$ (f)-(j) $I_{xy}\mathbf{r}$ (k)-(o) $I_{yx}\mathbf{r}$ (p)-(t) $I_{yy}\mathbf{r}$ at different distances $z = -30\text{ mm}$, $z = -20\text{ mm}$, $z = 0$, $z = 20\text{ mm}$ and $z = 30\text{ mm}$	135
Fig. 3.9 Schematic representation of measurement of two-point correlation in the far-field from an incoherent source, L: Lens.	139
Fig. 3.10 Schematic illustration of a DWD [269].	140
Fig. 3.11 Experimental setup Square Sagnac Radial Shearing Interferometer: P: Polarizer, DWD: Double Wedge Depolarizer, L: Lens, PBS: Polarization Beam Splitter, M: Mirror, HWP: Half Wave Plate, QWP: Quarter Wave Plate, CCD: Charge-Coupled Device. ...	143
Fig. 3.12 Four experimentally recorded interferograms for phase-shifts 0 , $\pi/2$, π , and $3\pi/2$ for $W_{xy}(\alpha - 1\mathbf{r}, \alpha\mathbf{r})$ (a1) - (d1) unpolarized LED (a2) - (d2) diagonally polarized polarizer (a3) - (d3) DWD.....	145
Fig. 3.13 Elements of CSD matrix for three different cases (a1) - (d2) unpolarized LED, (a3) - (d4) diagonally polarized polarizer, and (a5) - (d6) DWD. In different sets, the absolute value of CSD matrix elements <i>i.e.</i> fringe visibility values are represented using $gsqr\mathbf{1}, \mathbf{r2}$, and the corresponding phases using $\phi sqr\mathbf{1}, \mathbf{r2}$	146
Fig. 4.1 Schematic diagram for tailoring two-point spatial coherence function.....	156
Fig. 4.2 Schematics of the discretized binary spiral pinhole apertures. (a) single spiral, (e) three spirals, and (i) five spirals; (b), (f), and (j) the corresponding simulated absolute values of complex spatial coherence function; (c), (g), and (k) the corresponding simulated phase values of complex spatial coherence function; (d), (h), and (l) the corresponding TC mode power spectrum.	161
Fig. 4.3 Schematics of the pinhole gears. Binary pinhole masks for OAM modes with (a) $l = \pm 2$, (e) $l = \pm 3$, and (i) $l = \pm 4$; (b), (f), and (j) the corresponding simulated absolute values of complex spatial coherence function; (c), (g), and (k) the corresponding simulated phase values of complex spatial coherence function; (d), (h), and (l) the corresponding TC mode power spectrum.	162
Fig. 4.4 Experimental setup: PA: Binary Pinhole Aperture L: Lens, PBS: Polarization Beam Splitter, M: Mirror, QWP: Quarter Wave Plate, P: Polarizer, CCD: Charge-Coupled Device.	164
Fig. 4.5 Recorded interference patterns for a single spiral with phase-shifts (a) 0 , (b) $\pi/2$, (c) π , and (d) $3\pi/2$	166
Fig. 4.6 Experimental results. (a) single spiral, (e) three spirals, and (i) five spirals; (b), (f), and (j) the corresponding absolute values of the complex spatial coherence function; (c), (g), and (k) the corresponding phase values of the complex spatial coherence function; (d), (h), and (l) the corresponding TC mode power spectrum.	167
Fig. 4.7 Experimental result for pinhole gears. Binary pinhole masks for TC modes with (a) $l = \pm 2$, (e) $l = \pm 3$, and (i) $l = \pm 4$; (b), (f), and (j) the corresponding absolute values	

of complex spatial coherence function; (c), (g), and (k) the corresponding phase values of complex spatial coherence function; (d), (h), and (l) the corresponding TC mode power spectrum.....	168
Fig. 5.1 (a) Schematic diagram of light diffracted through SLM (b) The three possible mirror states in DMD: on, parked, and off [18].....	174
Fig. 5.2 Schematic diagram for recording two-point correlation function.	177
Fig. 5.3 Experimental set up: LED: Light Emitting Diode; WF: Wavelength Filter; L: Lens; DMD: Digital Micromirror Device; M: Mirror; P: Polarizer; PBS: Polarization Beam Splitter; QWP, Quarter Wave Plate.	179
Fig. 5.4 Laboratory experimental setup.	179
Fig. 5.5 Recorded interference patterns for two spirals with phase-shifts (a) 0, (b) $\pi/2$, (c) π , and (d) $3\pi/2$	180
Fig. 5.6 Experimental results. (a) two spirals, (e) three spirals, and (i) four spirals; (b), (f), and (j) the corresponding absolute values of the two-point spatial coherence function; (c), (g), and (k) the corresponding phase values of the two-point spatial coherence function.	181
Fig. 5.7 Schematic diagram for recording two-point correlation function.	183
Fig. 5.8 Schematic illustration of the far-field with the corresponding flow chart.....	185
Fig. 5.9 Simulation results: Amplitude distribution of the complex correlation function for (a) $l = 1$, (b) $l = 2$, and (c) $l = 1.5$. Phase distribution of the complex spatial correlation function for (d) $l = 1$, (e) $l = 2$, and (f) $l = 1.5$	186
Fig. 5.10 Experimental setup square Sagnac radial shearing interferometer: L: lens, BS: beam splitter, SLM: spatial light modulator. PBS: polarization beam splitter, M: mirror, QWP: quarter wave plate, P: polarizer.	187
Fig. 5.11 Experimental results: Amplitude distribution of the complex correlation function for (a) $l = 1$, (b) $l = 2$, and (c) $l = 1.5$. Phase distribution of the complex spatial correlation function for (d) $l = 1$, (e) $l = 2$, and (f) $l = 1.5$	190