



Studies in Statistical Optics - Theory & Application

Emil Wolf
UNIVERSITY OF ROCHESTER

07/29/2015
Final Report

DISTRIBUTION A: Distribution approved for public release.

Air Force Research Laboratory
AF Office Of Scientific Research (AFOSR)/ RTB
Arlington, Virginia 22203
Air Force Materiel Command

REPORT DOCUMENTATION PAGE				Form Approved OMB No. 0704-0188								
The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to the Department of Defense, Executive Service Directorate (0704-0188). Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ORGANIZATION.												
1. REPORT DATE (DD-MM-YYYY) 07-27-2015		2. REPORT TYPE Final Technical Report		3. DATES COVERED (From - To) June 1, 2012 - May 31, 2015								
4. TITLE AND SUBTITLE Studies in Statistical Optics - Theory & Application				5a. CONTRACT NUMBER								
				5b. GRANT NUMBER FA9550-12-1-0284								
				5c. PROGRAM ELEMENT NUMBER								
6. AUTHOR(S) Dr. Emil Wolf				5d. PROJECT NUMBER								
				5e. TASK NUMBER								
				5f. WORK UNIT NUMBER								
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Office of Research and Project Administration University of Rochester 515 Hylan Building, RC Box 270140 Rochester, NY 14627				8. PERFORMING ORGANIZATION REPORT NUMBER								
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Air Force Office of Scientific Research 875 N. Randolph Road Arlington, VA 22203				10. SPONSOR/MONITOR'S ACRONYM(S) AFOSR								
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)								
12. DISTRIBUTION/AVAILABILITY STATEMENT Distribution A - approved for public release												
13. SUPPLEMENTARY NOTES												
14. ABSTRACT In this Final Report we summarize research carried out during the period of June 1, 2012 - May 31, 2015 under the sponsorship of the Air Force Office of Scientific Research under grant FA9550-12-1-0284. The results of our investigations were reported in 16 publications. Summaries of these publications are given on pages 5-8 of our report. The scientists who have participated in this research are listed on page 9.												
15. SUBJECT TERMS Coherence and statistical optics; scattering; propagation; reflection and refraction.												
16. SECURITY CLASSIFICATION OF: <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 33%; padding: 2px;">a. REPORT</td> <td style="width: 33%; padding: 2px;">b. ABSTRACT</td> <td style="width: 33%; padding: 2px;">c. THIS PAGE</td> </tr> <tr> <td style="height: 30px;"></td> <td></td> <td></td> </tr> </table>			a. REPORT	b. ABSTRACT	c. THIS PAGE				17. LIMITATION OF ABSTRACT		18. NUMBER OF PAGES	
a. REPORT	b. ABSTRACT	c. THIS PAGE										
					19a. NAME OF RESPONSIBLE PERSON Emil Wolf							
					19b. TELEPHONE NUMBER (Include area code) 585-275-4398							

INSTRUCTIONS FOR COMPLETING SF 298

1. REPORT DATE. Full publication date, including day, month, if available. Must cite at least the year and be Year 2000 compliant, e.g. 30-06-1998; xx-06-1998; xx-xx-1998.

2. REPORT TYPE. State the type of report, such as final, technical, interim, memorandum, master's thesis, progress, quarterly, research, special, group study, etc.

3. DATES COVERED. Indicate the time during which the work was performed and the report was written, e.g., Jun 1997 - Jun 1998; 1-10 Jun 1996; May - Nov 1998; Nov 1998.

4. TITLE. Enter title and subtitle with volume number and part number, if applicable. On classified documents, enter the title classification in parentheses.

5a. CONTRACT NUMBER. Enter all contract numbers as they appear in the report, e.g. F33615-86-C-5169.

5b. GRANT NUMBER. Enter all grant numbers as they appear in the report, e.g. AFOSR-82-1234.

5c. PROGRAM ELEMENT NUMBER. Enter all program element numbers as they appear in the report, e.g. 61101A.

5d. PROJECT NUMBER. Enter all project numbers as they appear in the report, e.g. 1F665702D1257; ILIR.

5e. TASK NUMBER. Enter all task numbers as they appear in the report, e.g. 05; RF0330201; T4112.

5f. WORK UNIT NUMBER. Enter all work unit numbers as they appear in the report, e.g. 001; AFAPL30480105.

6. AUTHOR(S). Enter name(s) of person(s) responsible for writing the report, performing the research, or credited with the content of the report. The form of entry is the last name, first name, middle initial, and additional qualifiers separated by commas, e.g. Smith, Richard, J, Jr.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES). Self-explanatory.

8. PERFORMING ORGANIZATION REPORT NUMBER. Enter all unique alphanumeric report numbers assigned by the performing organization, e.g. BRL-1234; AFWL-TR-85-4017-Vol-21-PT-2.

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES). Enter the name and address of the organization(s) financially responsible for and monitoring the work.

10. SPONSOR/MONITOR'S ACRONYM(S). Enter, if available, e.g. BRL, ARDEC, NADC.

11. SPONSOR/MONITOR'S REPORT NUMBER(S). Enter report number as assigned by the sponsoring/monitoring agency, if available, e.g. BRL-TR-829; -215.

12. DISTRIBUTION/AVAILABILITY STATEMENT. Use agency-mandated availability statements to indicate the public availability or distribution limitations of the report. If additional limitations/ restrictions or special markings are indicated, follow agency authorization procedures, e.g. RD/FRD, PROPIN, ITAR, etc. Include copyright information.

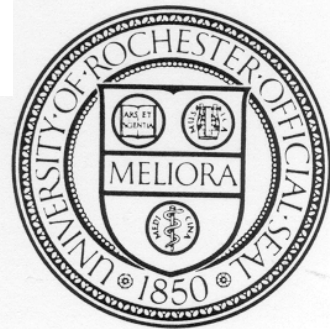
13. SUPPLEMENTARY NOTES. Enter information not included elsewhere such as: prepared in cooperation with; translation of; report supersedes; old edition number, etc.

14. ABSTRACT. A brief (approximately 200 words) factual summary of the most significant information.

15. SUBJECT TERMS. Key words or phrases identifying major concepts in the report.

16. SECURITY CLASSIFICATION. Enter security classification in accordance with security classification regulations, e.g. U, C, S, etc. If this form contains classified information, stamp classification level on the top and bottom of this page.

17. LIMITATION OF ABSTRACT. This block must be completed to assign a distribution limitation to the abstract. Enter UU (Unclassified Unlimited) or SAR (Same as Report). An entry in this block is necessary if the abstract is to be limited.



**Studies in Statistical Optics: Theory and
Application**

**Grant No: FA9550-12-1-0284
June 1, 2012 – May 31, 2015**

Final Report

Emil Wolf

**The University of Rochester
Department of Physics and Astronomy
Rochester, New York**

**Submitted to the
Air Force Office of Scientific Research**

July 27, 2015

**UNIVERSITY OF ROCHESTER
DEPARTMENT OF PHYSICS AND ASTRONOMY
ROCHESTER, NEW YORK 14627**

LIST OF CONTENTS

I.	INTRODUCTION	2
II.	LIST OF PUBLICATIONS	3
III.	SUMMARIES OF RESEARCH	5
IV.	SCIENTIFIC COLLABORATORS	9

I. INTRODUCTION

This report presents a summary of research carried out during the period June 1, 2012 – May 31, 2015 under the sponsorship of the Air Force Office of Scientific Research, under grant FA9550-12-1-0284.

The results of our investigations were reported in several publications. They are listed on page 3-4. Summaries of these publications are given on page 5-8. Scientists who have participated in the research are listed on page 9.

II. LIST OF PUBLICATIONS RESULTING FROM RESEARCH SUPPORTED BY GRANT FA9550-12-1-0284 DURING THE PERIOD JUNE 1, 2012 – MAY 31, 2015

1. Fischer, T. van Dijk, T. D. Visser, and E. Wolf, "Coherence Effects in Mie Scattering", *JOSA A*, **29**, 78-84 (2012).
2. M. Lahiri and E. Wolf, "Statistical Similarity and Cross-Spectral Purity of Stationary Stochastic Fields", *Opt. Lett.*, **37**, 963-965 (2012).
3. M. Lahiri and E. Wolf, "Spectral Changes of Stochastic Beams Scattered on a Deterministic Medium", *Opt. Lett.*, **37**, pp. 2517-2519 (2012).
4. J. Rolland, K. Thompson, K. Lee, J. Tamkin Jr., T. Schmid, and E. Wolf, "Observation of the Gouy phase anomaly in astigmatic beams", *Applied Optics*, **51**, No. 15, 2902-2908 (2012).
5. J. Horng, Y. Li, and E. Wolf, "Stokes beams formed by superposition of a completely unpolarized and a completely polarized Gaussian Schell-model beam" *Optics Commun.*, **285**, 4719-4726 (2012).
6. D. Kuebel, T. D. Visser, and E. Wolf, "Application of the Hanbury Brown-Twiss Effect to Scattering from Quasi-Homogeneous Media", *Opt. Commun.*, **294**, 43-48 (2013).
7. M. Lahiri and E. Wolf, "Theory of Refraction and Reflection with Partially Coherent Electromagnetic Beams", *Physical Review A*, **86**, 043815 (2012).
8. M. Lahiri and E. Wolf, "Change in Spatial Coherence of Light on Refraction and on Reflection", *JOSA A*, **30**, 1107-1112 (2013).
9. S. B. Raghunathan, T. D. Visser, and E. Wolf, "Far-zone Properties of Electromagnetic Beams Generated by Quasi-homogeneous Sources", *Opt. Commun.*, **295**, 11-16 (2013).
10. M. Lahiri and E. Wolf, "Negative Refraction of a Partially Coherent Electromagnetic Beam", *Opt. Lett.*, **38**, 1407-1409 (2013).
11. M. Lahiri, "Quantum Theory of Coherence and Polarization of Light", *Advances in Quantum Theory*, Chapter 4, p. 77 (In Tech, Croatia, 2012).
12. M. Lahiri, "Concept of Purity in the Theory of Optical Polarization", *Opt. Letts.*, **38**, 866-868 (2013).

13. M. Lahiri and E. Wolf, "Propagation of Electromagnetic Beams of any State of Spatial Coherence and Polarization through Multilayered Stratified Media", *JOSA A*, **30**, 2547-2555 (2013).
14. E. Wolf, "Diffraction of Radiation of Any State of Spatial Coherence on Media with Periodic Structure", *Opt. Letts.*, **38**, 4023-4025 (2013).
15. M. Lahiri and E. Wolf, "Effect of Scattering on Cross-spectral Purity of Light", *Opt. Commun.*, **330**, 165-168 (2014).
16. M. Lahiri, "Coherence and Statistical Optics", Photonics:Scientific Foundations, Technology and Applications, Vol. 1, edited by David Andrews, John Wiley & Sons, 2015.

III. SUMMARIES OF PUBLICATIONS RESULTING FROM RESEARCH SUPPORTED BY GRANT FA9550-12-1-0284 DURING THE PERIOD JUNE 1, 2012 – MAY 31, 2015.

1. **Fischer, T. van Dijk, T. D. Visser, and E. Wolf, “Coherence Effects in Mie Scattering”, *JOSA A*, 29, 78-84 (2012).**
The scattering of a partially coherent beam by a deterministic, spherical scatterer is studied. In particular, the Mie scattering by a Gaussian Schell-model beam is analyzed. Expressions are derived for (a) the extinguished power, (b) the radiant intensity of the scattered field, and (c) the encircled energy in the far field. It is found that the radiant intensity and the encircled energy in the far field depend on the degree of coherence of the incident beam, whereas the extinguished power does not.
2. **M. Lahiri and E. Wolf, “Statistical Similarity and Cross-Spectral Purity of Stationary Stochastic Fields”, *Opt. Lett.*, 37, 963-965 (2012).**
In practical situations, one often generates a beam by superposition of two or more light beams. The beam generated by superposition displays, in general, different spectral properties than do the original beams. However, there are some optical beams, called cross-spectrally pure beams, which can generate a light beam of identical spectral distribution on superposition. The relationship between cross-spectral purity and spatial coherence has been the subject of investigations for some time. Recently, a concept of so-called statistical similarity has been introduced which provides a new way to elucidate complete spatial coherence. In this Letter, we discuss some implications of statistical similarity of an optical field on its cross-spectral purity.
3. **M. Lahiri and E. Wolf, “Spectral Changes of Stochastic Beams Scattered on a Deterministic Medium”, *Opt. Lett.*, 37, pp. 2517-2519 (2012).**
It is well known that scattering of a polychromatic plane wave by a random medium, i.e., by a medium whose refractive index varies randomly with position, may produce frequency shifts of spectral lines. It has been a common perception that a random medium is required for generation of such spectral shifts by scattering. In this Letter we show that such a phenomenon occurs even when the refractive index of the medium is a deterministic function of position. We also show that this phenomenon may be used to obtain information about the structure of a deterministic medium.
4. **J. Rolland, K. Thompson, K. Lee, J. Tamkin Jr., T. Schmid, and E. Wolf, “Observation of the Gouy phase anomaly in astigmatic beams”, *Applied Optics*, 51, No. 15, 2902-2908 (2012).**
The Gouy phase anomaly, well established for stigmatic beams, is validated here for astigmatic beams. We simulate the predicted Gouy phase anomaly near astigmatic foci using a beam propagation algorithm integrated within lens design software. We then compare computational results with experimental data acquired using a modified Mertz–Sagnac interferometer. Both in simulation and in experiment, results show that a $\pi/2$ -phase change occurs as the beam passes through each of the astigmatic foci, experimentally validating results derived in a recent paper by Visser and Wolf [*Opt. Commun.* 283, 3371–3375 (2010)].
5. **J. Horng, Y. Li, and E. Wolf, “Stokes beams formed by superposition of a completely unpolarized and a completely polarized Gaussian Schell-model beam” *Optics Commun.*, 285, 4719-4726 (2012).**

Analytic expressions and computed examples are given to elucidate the coherence and polarization properties of Stokes beams, i.e. beams formed by superposition of a completely unpolarized and a completely polarized electromagnetic Gaussian Schell-model beam. We found that superposition of such two beams cannot form a Stokes beam with a constant state of polarization on propagation. An additional constraint on the source plane parameters of the two Gaussian Schell-model beams is proposed. The resultant Stokes beam with a constant state of polarization on propagation is found to be a Gaussian Schell-model beam with the same variances as the two constituent Gaussian Schell-model beams. However, the modulus of the Gaussian intensity distributions across the source planes of these beams may be different.

6. **D. Kuebel, T. D. Visser, and E. Wolf, “Application of the Hanbury Brown-Twiss Effect to Scattering from Quasi-Homogeneous Media”, *Opt. Commun.*, 294, 43-48 (2013).**
The scattering from a wide class of random scatterers, so-called quasi homogeneous scattering media, is studied by the use of the Hanbury Brown–Twiss effect. In particular the two-point correlation of intensity fluctuations and their variance in the far field are analyzed. A new reciprocity relation is derived, and expressions for the correlation of intensity fluctuations for several different types of scattering potentials are obtained. The results indicate the possibility of distinguishing, for example, hollow scatterers from solid ones.
7. **M. Lahiri and E. Wolf, “Theory of Refraction and Reflection with Partially Coherent Electromagnetic Beams”, *Physical Review A*, 86, 043815 (2012).**
Laws of refraction and reflection of light are governed by the classic Fresnel formulas. These formulas are not applicable to partially coherent light. We develop a general theory of refraction and reflection of electromagnetic beams of any state of coherence. We find that coherence properties of such beams change, in general, on refraction and on reflection at a planar interface.
8. **M. Lahiri and E. Wolf, “Change in Spatial Coherence of Light on Refraction and on Reflection”, *JOSA A*, 30, 1107-1112 (2013).**
Partially coherent light beams are encountered both in classical and in quantum optics. In this paper, we propose a novel technique for controlling coherence properties of such beams in laboratory environment. The technique is based on the fact that coherence properties of partially coherent electromagnetic beams, in general, change on refraction and on reflection, and that the changes can be controlled by varying the angle of incidence.
9. **S. B. Raghunathan, T. D. Visser, and E. Wolf, “Far-zone Properties of Electromagnetic Beams Generated by Quasi-homogeneous Sources”, *Opt. Commun.*, 295, 11-16 (2013).**
We derive expressions for the far-zone properties of electromagnetic beams generated by a broad class of partially coherent sources, namely those of the quasi-homogeneous type. We use these reciprocity relations to study the intensity distribution, the state of coherence and the polarization properties of such beams.
10. **M. Lahiri and E. Wolf, “Negative Refraction of a Partially Coherent Electromagnetic Beam”, *Opt. Lett.*, 38, 1407-1409 (2013).**

A theory of usual (positive) refraction of partially coherent electromagnetic beams has been developed recently. In this Letter, we discuss the theory of negative refraction of a partially coherent electromagnetic beam. We show that negative refraction can produce change in spatial coherence of such a beam.

11. **M. Lahiri, “Quantum Theory of Coherence and Polarization of Light, *Advances in Quantum Theory*, Chapter 4, p. 77 (In Tech, Croatia 2012).**
The article presents a review of recent results obtained in the quantum theory of optical coherence and optical polarization. The emphasis is on coherence theory in the space-frequency domain. Polarization properties of photons in an interference experiment are also discussed, from the viewpoint of wave-particle duality.
12. **M. Lahiri, “Concept of Purity in the Theory of Optical Polarization”, *Opt. Letts.*, 38, 866-868 (2013).**
It was shown some time ago that the space-time and the space-frequency degrees of polarization of a stochastic electromagnetic beam are not equivalent to each other. It is not possible, in general, to obtain a formal relationship between them. In this Letter, we discuss certain conditions under which they are directly related. These conditions lead to the concept of polarization-purity. If an optical beam obeys these conditions, its space-frequency degree of polarization has the same value at all frequencies present in the spectrum, and the value is equal to the space-time degree of polarization.
13. **M. Lahiri and E. Wolf, “Propagation of Electromagnetic Beams of any State of Spatial Coherence and Polarization through Multilayered Stratified Media”, *JOSA A*, 30, 2547-2555 (2013).**
We present a theory of propagation of a partially coherent and partially polarized electromagnetic beam through a multilayered stratified medium. The analysis shows that spatial coherence and polarization properties of the beam change, in general, on propagation through such a medium. We illustrate the results by example.
14. **E. Wolf, “Diffraction of Radiation of Any State of Spatial Coherence on Media with Periodic Structure”, *Opt. Letts.*, 38, 4023-4025 (2013).**
A general formula is derived for the spectral density distribution in the far zone, produced by the diffraction of a beam of any state of spatial coherence on a medium with a spatially periodic structure. The formula may be used to determine the structure of crystals from the diffraction of partially coherent x-ray beams.
15. **M. Lahiri and E. Wolf, “Effect of Scattering on Cross-spectral Purity of Light”, *Opt. Commun.*, 330, 165-168 (2014).**
The concept of cross-spectral purity was introduced by Mandel in connection with the modulation of spectral distribution of optical fields in superposition experiments. It is now known that spectral distribution of light can also change on scattering. We investigate the effect of scattering on cross-spectral purity. We show that the purity is, in general, not preserved on scattering. We also discuss some conditions under which it can be preserved at certain pairs of points in the far-zone.
16. **M. Lahiri, “Coherence and Statistical Optics”, *Photonics: Scientific Foundations, Technology and Applications*, Vol. 1, edited by David Andrews, John Wiley & Sons,**

2015. This article presents a review of coherence properties and of statistical properties of light.

IV. SCIENTIFIC COLLABORATORS

In addition to Professor Emil Wolf, the Principal Investigator for this grant, the following scientists have taken part in the research:

FISHER, D.	Research and Technology Directorate, NASA Glenn Research Center, Cleveland, Ohio 44135, USA
HORNG, J.	Department of Electro-Optical Engineering, National United University, No.1, Lien-Da, Kung-Ching Li, Miao-Li, Taiwan 360, ROC
KUEBEL, D.	Department of Physics and Astronomy, University of Rochester, Rochester, NY
LAHIRI, M.	Department of Physics and Astronomy, University of Rochester, Rochester, NY and IQOQI, and Faculty of Physics, Boltzmanngasse 3, 1090 Vienna, Austria
LEE, K.	The Institute of Optics, University of Rochester, 275 Hutchison Road, Rochester, New York 14627, USA
LI, Y.	P.O. Box 975, Great River, NY 11739, USA
NEVINS, T.	Department of Physics and Astronomy, University of Rochester, Rochester, NY
RAGHUNATHAN, S.B.	Faculty of Electrical Engineering, Mathematics and Computer Science, Delft University of Technology, Delft, The Netherlands
ROLLAND, J.	The Institute of Optics, University of Rochester, 275 Hutchison Road, Rochester, New York 14627, USA
SCHMID, T.	The Institute of Optics, University of Rochester, 275 Hutchison Road, Rochester, New York 14627, USA
TAMKIN, J.	The Institute of Optics, University of Rochester, 275 Hutchison Road, Rochester, New York 14627, USA
THOMPSON, K.	Synopsys, Inc., 3 Graywood Lane, Pittsford, New York 14534, USA
VAN DIJK, T.	Graduate Student, Department of Physics and Astronomy, Free University, Amsterdam, The Netherlands
VISSER, T.	Professor, Department of Physics and Astronomy, Free University, Amsterdam, The Netherlands

1.

1. Report Type

Final Report

Primary Contact E-mail**Contact email if there is a problem with the report.**

ewlupus@pas.rochester.edu

Primary Contact Phone Number**Contact phone number if there is a problem with the report**

585-275-4398

Organization / Institution name

University of Rochester

Grant/Contract Title**The full title of the funded effort.**

Studies in Statistical Optics - Theory & Application

Grant/Contract Number**AFOSR assigned control number. It must begin with "FA9550" or "F49620" or "FA2386".**

FA9550-12-1-0284

Principal Investigator Name**The full name of the principal investigator on the grant or contract.**

Dr. Emil Wolf

Program Manager**The AFOSR Program Manager currently assigned to the award**

Dr. Arje Nachman

Reporting Period Start Date

06/01/2012

Reporting Period End Date

05/31/2015

Abstract

Our research has been concerned with statistical properties of radiation in scattering processes which resulted in publications dealing with coherence effects in Mie scattering. We generalized the well-known Gouy phase anomaly from stigmatic to astigmatic beams. We extended the theory of refraction and reflection of electromagnetic beams of any state of spatial coherence. We presented new results relating to the concept of purity and introduced the concept of polarization purity. We analyzed spectral changes of stochastic beams, generated on deterministic media. Propagation of light beams through multi-layered stratified media was studied. Also, effects of scattering on cross-spectral purity of light was studied.

Distribution Statement**This is block 12 on the SF298 form.**

Distribution A - Approved for Public Release

Explanation for Distribution Statement**If this is not approved for public release, please provide a short explanation. E.g., contains proprietary information.****SF298 Form****Please attach your SF298 form. A blank SF298 can be found [here](#). Please do not password protect or secure the PDF****The maximum file size for an SF298 is 50MB.**

DISTRIBUTION A: Distribution approved for public release.

Upload the Report Document. File must be a PDF. Please do not password protect or secure the PDF . The maximum file size for the Report Document is 50MB.

Upload a Report Document, if any. The maximum file size for the Report Document is 50MB.

Archival Publications (published) during reporting period:

1. Fischer, T. van Dijk, T. D. Visser, and E. Wolf, "Coherence Effects in Mie Scattering", JOSA A, 29, 78-84 (2012).
2. M. Lahiri and E. Wolf, "Statistical Similarity and Cross-Spectral Purity of Stationary Stochastic Fields", Opt. Lett., 37, 963-965 (2012).
3. M. Lahiri and E. Wolf, "Spectral Changes of Stochastic Beams Scattered on a Deterministic Medium", Opt. Lett., 37, pp. 2517-2519 (2012).
4. J. Rolland, K. Thompson, K. Lee, J. Tamkin Jr., T. Schmid, and E. Wolf, "Observation of the Gouy phase anomaly in astigmatic beams", Applied Optics, 51, No. 15, 2902-2908 (2012).
5. J. Horng, Y. Li, and E. Wolf, "Stokes beams formed by superposition of a completely unpolarized and a completely polarized Gaussian Schell-model beam" Optics Commun., 285, 4719-4726 (2012).
6. D. Kuebel, T. D. Visser, and E. Wolf, "Application of the Hanbury Brown-Twiss Effect to Scattering from Quasi-Homogeneous Media", Opt. Commun., 294, 43-48 (2013).
7. M. Lahiri and E. Wolf, "Theory of Refraction and Reflection with Partially Coherent Electromagnetic Beams", Physical Review A, 86, 043815 (2012).
8. M. Lahiri and E. Wolf, "Change in Spatial Coherence of Light on Refraction and on Reflection", JOSA A, 30, 1107-1112 (2013).
9. S. B. Raghunathan, T. D. Visser, and E. Wolf, "Far-zone Properties of Electromagnetic Beams Generated by Quasi-homogeneous Sources", Opt. Commun., 295, 11-16 (2013).
10. M. Lahiri and E. Wolf, "Negative Refraction of a Partially Coherent Electromagnetic Beam", Opt. Lett., 38, 1407-1409 (2013).
11. M. Lahiri, "Quantum Theory of Coherence and Polarization of Light", Advances in Quantum Theory, Chapter 4, p. 77 (In Tech, Croatia, 2012).
12. M. Lahiri, "Concept of Purity in the Theory of Optical Polarization", Opt. Letts., 38, 866-868 (2013).
13. M. Lahiri and E. Wolf, "Propagation of Electromagnetic Beams of any State of Spatial Coherence and Polarization through Multilayered Stratified Media", JOSA A, 30, 2547-2555 (2013).
14. E. Wolf, "Diffraction of Radiation of Any State of Spatial Coherence on Media with Periodic Structure", Opt. Letts., 38, 4023-4025 (2013).
15. M. Lahiri and E. Wolf, "Effect of Scattering on Cross-spectral Purity of Light", Opt. Commun., 330, 165-168 (2014).

16. M. Lahiri, "Coherence and Statistical Optics", Photonics:Scientific Foundations, Technology and Applications, Vol. 1, edited by David Andrews, John Wiley & Sons, 2015.

Changes in research objectives (if any):

None

Change in AFOSR Program Manager, if any:

None

Extensions granted or milestones slipped, if any:

None

AFOSR LRIR Number

LRIR Title

Reporting Period

Laboratory Task Manager

Program Officer

Research Objectives

Technical Summary

Funding Summary by Cost Category (by FY, \$K)

	Starting FY	FY+1	FY+2
Salary			
Equipment/Facilities			
Supplies			
Total			

Report Document

Report Document - Text Analysis

Report Document - Text Analysis

Appendix Documents

2. Thank You

E-mail user

Jul 27, 2015 14:15:39 Success: Email Sent to: ewlupus@pas.rochester.edu