Contents

List of abbreviations —— **xi**

List of notations —— **xiii**

1 Introduction —— 1

2 Fiber ring interferometry —— 8

2.1 Sagnac effect. Correct and incorrect explanations —— **8**

2.1.1 Correct explanations of the Sagnac effect —— **8**

2.1.1.1 Sagnac effect in special relativity —— **8**

2.1.1.2 Sagnac effect in general relativity —— **9**

2.1.1.3 Methods for calculating the Sagnac phase shift in anisotropic media —— **9**

2.1.2 Conditionally correct explanations of the Sagnac effect —— **10**

2.1.2.1 Sagnac effect due to the difference between the non-relativistic gravitational scalar potentials of centrifugal forces in reference frames moving with counterpropagating waves —— **10**

2.1.2.2 Sagnac effect due to the sign difference between the non-relativistic gravitational scalar potentials of Coriolis forces in reference frames moving with counterpropagating waves —— **10**

2.1.2.3 Quantum mechanical Sagnac effect due to the influence of the Coriolis force vector potential on the wave function phases of counterpropagating waves in rotating reference frames —— **11**

2.1.3 Attempts to explain the Sagnac effect by analogy with other effects —— **11**

2.1.3.1 Analogy between the Sagnac and Aharonov–Bohm effects —— **11**

2.1.3.2 Sagnac effect as a manifestation of the Berry phase —— **12**

2.1.4 Incorrect explanations of the Sagnac effect —— **12**

2.1.4.1 Sagnac effect in the theory of a quiescent luminiferous ether —— **12**

2.1.4.2 Sagnac effect from the viewpoint of classical kinematics —— **13**

2.1.4.3 Sagnac effect as a manifestation of the classical Doppler effect from a moving splitter —— **14**

2.1.4.4 Sagnac effect as a manifestation of the Fresnel–Fizeau dragging effect —— **15**

2.1.4.5 Sagnac effect and Coriolis forces —— **15**

2.1.4.6 Sagnac effect as a consequence of the difference between the orbital angular momenta of photons in counterpropagating waves —— **16**

2.1.4.7 Sagnac effect as a manifestation of the inertial properties of an electromagnetic field —— **16**

Bibliografische Informationen
http://d-nb.info/1028053770

digitalisiert durch DEUTSCHE NATIONAL BIBLIOTHEK

2.1.4.8 Sagnac effect in incorrect theories of gravitation — 16
2.1.4.9 Other incorrect explanations of the Sagnac effect — 17
2.2 Physical problems of the fiber ring interferometry — 17
2.2.1 Milestones of the creation and development of optical ring interferometry and gyroscopy based on the Sagnac effect — 17
2.2.2 Sources for additional nonreciprocity of fiber ring interferometers — 20
2.2.2.1 General characterization of sources for additional nonreciprocity of fiber ring interferometers — 20
2.2.2.2 Nonreciprocity as a consequence of the light source coherence — 21
2.2.2.3 Polarization nonreciprocity: causes and solutions — 21
2.2.2.4 Nonreciprocity caused by local variations in the gyro fiber-loop parameters due to variable acoustic, mechanical, and temperature actions — 23
2.2.2.5 Nonreciprocity due to the Faraday effect in external magnetic field — 23
2.2.2.6 Nonreciprocal effects caused by nonlinear interaction between counterpropagating waves (optical Kerr effect) — 23
2.2.2.7 Nonreciprocity caused by relativistic effects in fiber ring interferometers — 24
2.2.3 Fluctuations and ultimate sensitivity of fiber ring interferometers — 24
2.2.4 Methods for achieving the maximum sensitivity to rotation and processing the output signal — 25
2.2.5 Applications of fiber optic gyroscopes and fiber ring interferometers — 26
2.3 Physical mechanisms of random coupling between polarization modes — 28
2.3.1 Milestones of the development of the theory of polarization mode linking in single-mode optical fibers — 28
2.3.2 Phenomenological models of polarization mode coupling — 30
2.3.3 Physical models of polarization mode coupling — 31
2.3.4 Inhomogeneities arising as a fiber is drawn — 32
2.3.4.1 Torsional vibration — 32
2.3.4.2 Longitudinal vibration — 33
2.3.4.3 Transverse vibration — 33
2.3.4.4 Transverse stresses — 34
2.3.5 Inhomogeneities arising in applying protective coatings — 34
2.3.6 Inhomogeneities arising in the course of winding — 34
2.3.7 Rayleigh scattering: the fundamental cause of polarization mode coupling — 35
2.4 Application of the Poincaré sphere method... — 35
2.5 Thomas precession. Interpretation and observation issues — 36

3 Development of the theory of interaction between polarization modes — 38
3.1 Phenomenological estimates of the random coupling — **38**
3.1.1 Small perturbation method — **38**
3.1.2 Expanding the scope of the small perturbation method by partitioning the fiber into segments whose length is equal to the depolarization length — **40**
3.2 A physical model of the polarization mode coupling — **41**
3.2.1 A model of random inhomogeneities in SMFs with random twists of the anisotropy axes — **41**
3.2.2 Connection between the polarization holding parameter and statistics of random inhomogeneities — **42**
3.2.3 Polarization holding parameter in the case of random and regular twisting — **45**
3.2.4 Statistical properties of the polarization modes for fibers with random inhomogeneities — **47**
3.3 Evolution of the degree of polarization of nonmonochromatic light — **55**
3.3.1 Small perturbation method — **55**
3.3.2 A method for modeling random twists — **57**
3.3.3 A mathematical method for modeling random twists in the presence of a regular twist — **63**
3.3.4 Analytical calculation of the limiting degree of polarization of nonmonochromatic light — **68**
3.3.5 Increasing of the correlation length of nonmonochromatic light traveling through a single-mode fiber with random inhomogeneities — **69**
3.4 Anholonomy of the evolution of light polarization — **72**

4 Experimental study of random coupling between polarization modes — 76
4.1 A rapid method for measuring the output polarization state — **76**
4.2 Method for measuring the polarization beat length and ellipticity — **79**
4.3 Experimental comparison of the accuracy of different methods — **86**
4.4 Influence of winding of single-mode fibers on the amount of the polarization holding parameter — **89**
4.5 Experimental study of the polarization degree evolution of light — **92**
4.6 Method of fabricating ribbon single-mode fibers — **93**
4.7 Method for removing the effect of photodetector dichroism — **95**

5 Fiber ring interferometers of minimum configuration — 98
5.1 Polarization nonreciprocity of fiber ring interferometers — **98**
5.2 Fiber ring interferometers with a single-mode fiber circuit... — **107**

5.3 Zero shift, deviation, and drift of fiber ring interferometers — **110**
5.3.1 Applicability conditions for the ergodic hypothesis — **110**
5.3.2 Influence of the amount of random twist of the fiber — **131**
5.3.3 Influence of the location of the random inhomogeneity — **131**
5.3.4 Influence of the mutual coherence of nonmonochromatic light in the main and orthogonal polarization modes at the point of inhomogeneity — **132**
5.3.5 Approximate calculation of the temperature zero drift — **132**
5.3.6 Calculation of the zero shift deviation of the FRI by the small perturbation method — **136**
5.3.7 Calculation of the zero shift deviation with the extended small perturbation method — **139**
5.3.8 Calculation of the zero shift deviation by the method of mathematical modeling of random inhomogeneities — **139**
5.3.8.1 Zero shift deviation of an FRI with a high-birefringence fiber — **140**
5.3.8.2 Zero shift deviation of an FRI with a low-birefringence fiber — **142**
5.3.9 Calculation of the zero shift deviation of FRIs — **144**
5.4 Domains of application of the different methods for calculating PN — **146**

6 Fiber ring interferometers of nonstandard configuration — 148
6.1 New type of nonmonochromatic light depolarizer for FRIs — **148**
6.2 Zero drift and output signal fading in an FRI with a polarizer — **156**
6.2.1 Small perturbation method. The quasi-axis model — **156**
6.2.2 Extended small perturbation method — **157**
6.2.3 Method of mathematical modeling of random inhomogeneities in fibers — **158**
6.3 Fiber ring interferometers without a polarizer — **163**
6.3.1 FRIs with circularly polarized input light — **164**
6.3.2 Modulation method for removing the zero shift in a fiber ring interferometer without a polarizer — **167**
6.3.3 Fiber ring interferometer with a depolarizer of nonmonochromatic light — **169**
6.3.4 Fiber ring interferometer with a circuit made from a uniformly twisted fiber — **170**
6.3.5 Zero shift deviation in FRIs without a polarizer and with a circuit made from a high-birefringence fiber in a limited temperature range — **171**

7 Geometric phases in optics. The Poincaré sphere method — 172
7.1 Application of the Poincaré sphere method — **172**
7.1.1 Analysis of the properties of the Pancharatnam phases. The Poincaré sphere — **172**

7.1.1.1 Type I Pancharatnam phase — 172
7.1.1.2 Type II Pancharatnam phase — 173
7.1.2 Birefringence in SMFs due to mechanical deformations — 175
7.1.2.1 Kinematic phase in SMFs — 175
7.1.2.2 Bending induced linear birefringence of SMFs — 176
7.1.2.3 Twisting-induced circular birefringence of SMFs. The spiral polarization modes — 176
7.1.3 Rytov effect and the Rytov–Vladimirskii phase in SMFs and FRIs in the case of noncoplanar winding — 177
7.1.3.1 Rytov effect in the FRI circuit fiber — 177
7.1.3.2 Rytov–Vladimirskii phase and PP2 in SMFs with noncoplanar winding — 179
7.1.3.3 Rytov phase detection in FRIs — 180
7.2 Polarization nonreciprocity in FRIs. Nonreciprocal geometric phase — 182
7.3 Determination of a polarization state ensuring the absence of NPDCM — 189
7.4 Criticism of unsubstantiated hypotheses relating to geometric phases — 191
7.5 Opto-mechanical analogies relating to light propagation in SMFs — 195
7.5.1 The analogy between the Rytov effect polarization optics and Ishlinskii effect in classical mechanics — 195
7.5.2 An opto-mechanical analogy of an SMF with twisting of the linear birefringence axes — 198

8 Time-dependent, nonlinear, and magnetic effects — 201
8.1 Influence of the second harmonic of the phase modulation frequency — 201
8.1.1 In-phase and quadrature components of the parasitic phase modulation — 201
8.1.2 Numerical estimates of the incidental phase modulation — 203
8.1.3 Optimal harmonic of the phase modulation frequency — 206
8.2 Experimental investigation of the piezo transducer's nonlinearity — 207
8.3 Methods for removing the influence of the nonlinear Kerr effect — 209
8.4 Influence of random inhomogeneities on the Faraday zero shift deviation — 215

9 Relativistic effects in optical and non-optical ring interferometers — 220
9.1 Sagnac effect for waves of any nature in special relativity — 220
9.1.1 Sagnac effect in the laboratory frame of reference — 220

9.1.2 Sagnac effect in a rotating frame of reference. Zeno's relativistic paradox — **223**
9.2 Non-optical Sagnac sensors of angular velocity — **226**
9.2.1 A ring interferometer based on slow acoustic or magnetic waves — **226**
9.2.1.1 Advantages of using slow waves in ring interferometers — **226**
9.2.1.2 Choosing an optimal frequency of the slow waves in ring interferometers — **227**
9.2.1.3 A method for detecting the phase difference between counterpropagating waves in slow-wave ring interferometers — **229**
9.2.2 A ring interferometer based on de Broglie waves of pions — **232**
9.3 Influence of Thomas precession on the zero shift — **236**
9.3.1 Thomas precession as a corollary of Ishlinskii's solid angle theorem applied to the angle of relativistic aberration — **236**
9.3.1.1 Thomas precession — **236**
9.3.1.2 Ishlinskii's theorem as a classical analogue of Thomas precession — **237**
9.3.1.3 Observed rotation of an object rapidly moving in a circular path and Thomas precession — **238**
9.3.1.4 Physical meanings of the Thomas precession and Ishlinskii angle — **241**
9.3.2 Influence of Thomas precession on the zero shift of ring interferometers based on de Broglie waves of matter particles with spin — **241**
9.4 Potential usage of FRIs for detecting fundamental effects — **243**
9.4.1 Verification of the basic postulates of special and general relativity using FRIs — **243**
9.4.2 Analysis of the possibility of detecting nonreciprocal effects with FRIs — **246**

10 Conclusion — 250

Index — **299**