Sajeev John June 16, 2025
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CURRICULUM VITAE

1. EDUCATION

1. Ph. D. Theoretical Physics (1984): Harvard University

2. S. B. Physics (1979): Massachusetts Institute of Technology

3. Sir Frederick Banting Secondary School (1975): London, Ontario

2. HONOURS AND AWARDS

1. Fellow of the Royal Society of London, May 2025-present

2. **Gerhard Herzberg Canada Gold Medal 2021** (1-million-dollar Research Prize)

3. Appointed as an **Officer of the Order of Canada**, December 2017

4. Killam Prize in Natural Sciences 2014 awarded by the Canada Council for the Arts ($100,000 prize)

5. IEEE David Sarnoff Award (International) 2013

6. Thomson Reuters Citation Laureate 2011

7. Institute of Electrical and Electronic Engineers (IEEE) Photonics Society Distinguished Lecturer Award 2009-2011

8. Distinguished Guest Professor Award, Sun Yat Sen University, China 2009-2012

9. Institute of Electrical and Electronic Engineers (IEEE) Nanotechnology Pioneer Award

(International) 2008

10. C.V. Raman Chair Professorship (2007-2008) of the Indian Academy of Sciences

11. Institute of Electrical and Electronic Engineers –Laser and Electro-Optics Society Quantum Electronics (International) Award 2007

12. Brockhouse Medal for Condensed Matter and Materials Physics 2007 (Canadian Association of Physicists)

13. Brockhouse Canada Prize 2004 ($250K research prize for best interdisciplinary collaborative research. The inaugural prize in 2004 is shared equally by Sajeev John and Geoff Ozin)

14. Rutherford Medal of the Royal Society of Canada 2004

15. Ontario Premier's Platinum Medal 2002
($1 million research prize awarded to the best researcher in any field in the province of Ontario, Canada, **one time only** prize 2002)

16. Fellow of the Optical Society of America 2003-present

17. Fellow of the American Physical Society 2002-present

18. Fellow of the Royal Society of Canada 2002-present

19. King Faisal International Prize in Science 2001
(US $200,000 awarded once every four years in physics, eligible to all scientists from around the world. In 2001, the prize was shared equally by S. John and C.N. Yang)

20. Elected as Member of the Max Planck Society of Germany and External Member of the Max Planck Institute for Microstructure Physics (2002- present)

21. Elected to the distinguished rank of "University Professor" at the University of Toronto, 2001-present

22. Canada's Honour Role (2001) McLean's Magazine "Twelve Canadians that Made a Difference"

23. Alexander von Humboldt Senior Scientist Award (Germany) 2000-2003

24. Guggenheim Fellowship (U. S. A.) (2000-2001)

25. Government of Canada Research Chair, Tier 1, 2001- 2022 (Endowment award providing $200K/year for the lifetime of the Chair)

26. Killam Research Fellowship (1998-2000) awarded by the Canada Council

27. Japan Society for the Promotion of Science Fellowship (1998)

28. Steacie Prize (1997) awarded by National Research Council of Canada for Science and Engineering

29. McLean Fellowship (1996) awarded by the University of Toronto for Mathematics, Science, and Engineering

30. Herzberg Medal (1995) awarded by the Canadian Association of Physicists

31. Meyerhof Fellowship, Weizmann Institute of Science, Israel (1990).

32. Natural Sciences and Engineering Research Council of Canada Postdoctoral Fellowship (1984-86)

33. Harvard University: Charles Bayne Aiken Fellowship (1980-81)

34. Massachusetts Institute of Technology:
    - Phi Beta Kappa
    - Sigma Xi (1979)

35. City of London, Ontario: Queen Elizabeth Scholarship (1975) for the top graduating high school student in the city

3. EXPERIENCE

1. University Professor, University of Toronto, January 1, 2001-present.

2. Adjunct Chair Professor, Soochow University, Suzhou, China Sept 2015-present

3. Distinguished Guest Professor, Sun Yat Sen University, Guangzhou, China, 2008-2011

4. Laboratory Consultant, Battelle Memorial Institute, Columbus Ohio, 2003.

5. University of Toronto, Department of Physics:
    - Full Professor: July 1, 1992 – present.
    - Associate Professor with tenure and Member of the School of Graduate Studies: July 1, 1989 - June 30, 1992.
    - Fellow, Canadian Institute for Advanced Research: July 1, 1989 - June 30, 1994, July 1, 1999 - 2014.

• Associate member, Ontario Laser and Light Wave Centre: September 1, 1989 - September 1, 1991.

• Principal Investigator, Photonics Research Ontario September 1, 1991 – 2001.

6. Meyerhof Visiting Professor of Chemical Physics, The Weizmann Institute of Science, Israel: April - June 1990.

7. Princeton University, Department of Physics, Assistant Professor: September 1, 1986 - August 31, 1989.

8. Bell Communications Research Laboratories, Red Bank, New Jersey Laboratory Consultant: January 1, 1989 - August 31, 1989.

9. Exxon Research and Engineering Laboratories, Annandale, New Jersey Laboratory Consultant: January 1, 1985 - August 31, 1989.

10. University of Pennsylvania Postdoctoral Fellow Canadian NSERC PDF: Sept. 1984 - August 1986.

11. Harvard University Ph. D. Thesis July 1984 "**Localization of Waves in a Disordered Medium**". Supervisor:
    • Prof. M. J. Stephen

12. I. B. M. Thomas J. Watson Research Centre, Yorktown Heights. Summer Research Assistant: June-August 1979.

13. Massachusetts Institute of Technology Undergraduate Thesis (1979). Applications of Density Functional and Hartree-Fock Method to obtain binding energies and densities in large nuclei. Supervisor:
    • Prof. J. W. Negele

4. CURRENT and RECENT RESEARCH AWARDS

1. **NSERC Herzberg Canada Gold Medal**, $200,000 per year (2021-2026) no overhead

2. Ontario Research Fund (ORF) Operating Grant: $100,000 per year (after overhead removed) for the period of April 1, 2019- March 31, 2024 (Solar Energy Conversion)

3. **United States Department of Energy** Operating Grant: $540,000 for the period August 15, 2010- August 31, 2013, $300,000 for the period Oct 1, 2013- Sept 30, 2015, and $450,000 for the period October 1, 2015- Sept 30, 2018.

4. NSERC operating grants: $113,000 per year, April 1, 2009- March 31, 2019; $41,000 per year, April 1, 2019- March 31, 2021
(no overhead charges)

5. CIfAR research grant: $30,000 per year (1998-2013) no overhead

6. **Brockhouse Canada Prize**: $250,000 lump sum (2004) no overhead

7. **Ontario Premier's Platinum Medal**: $1 million, lump sum (2002) no overhead

8. NSERC operating grant: $66,150 per year for five years. April 1, 1999 – March 31, 2004 (no overhead).

9. NSERC operating grant: $86,000 per year for five years. April 1, 2004 - March 31, 2009 (no overhead)

10. Photonics Research Ontario Grant: $62,000 per year until 2000, "Photonic Band Gap Materials" (amount indicated is after overhead is removed)

11. McLean Fellowship: $100,000 (1996).

12. New Energy and Industrial Technology Development Organization of Japan Grant: $40-50K per year (1997-2000) "Tunable Photonic Crystals".

13. NSERC grant: (Collaborative Activities Program) $330,000 (2000-2001) (no overhead)

14. NSERC grant: (CRO Program) $120,000 per year (2000-2005) (no overhead).

5. PATENTS

1. Sajeev John, G. Ozin, E. Chomski, F. Meseguer, and C. Lopez, "Photonic Band Gap Materials based on Silicon", U.S. Patent 7,333,264, March 2008.

2. Sajeev John and Kurt Busch, "Electro-actively Tunable Photonic Crystals" U.S. patent 6,813,064 B2, November 2, 2004.

3. V. Abraham, Sajeev John, P.K. John, "An Optical Oil Quality Sensor" U.S. Patent 6,717,667 B2, April 6, 2004.

4. Sajeev John and Ovidiu Toader, "Photonic Band Gap Materials based on Spiral Posts in a Lattice" U.S. Patent 6,589,334 B 2, July 8, 2003.

5. P. Kuang, S. Lin, A. Post, Sajeev John, S. Eyderman, M.L. Hsieh, "High Absorption Photovoltaic Material and Methods for Making the Same" U.S. Patent 20,190,140,115, May 9, 2019

6. PUBLICATIONS

1. S. K. Burley, S. O. John and J. Nuttall; SIAM Journal of Numerical Analysis, 18, #5, 919 (1981) "Vector Orthogonal Polynomials"

2. Sajeev John, H. Sompolinsky and Michael J. Stephen; Phys. Rev., B 27, 5592 (1983) "Localization in a Disordered Elastic Medium Near Two dimensions"

3. Sajeev John and Michael J. Stephen; Phys. Rev., B 28, 6358 (1983) "Wave Propagation and Localization in a Long Range Correlated Random Potential"

4. Sajeev John and Michael J. Stephen; J. Phys. C Letters, 17, L559 (1984) "Electronic Density of States in a Long Range Correlated Potential"

5. **Sajeev John; Phys. Rev. Lett., 53, 2169 (1984) "Electromagnetic Absorption in a Disordered Medium near a Photon Mobility Edge"**

6. Sajeev John; Phys. Rev., B 31, 304 (1985) Localization and "Absorption of Waves in a Weakly Dissipative Disordered Medium"

7. **Sajeev John and T. C. Lubensky; Phys. Rev. Lett., 55, 1014 (1985) "Spin Glass State of a Randomly diluted Granular Superconductor"**

8. Sajeev John and T. C. Lubensky; Phys. Rev., B 34, 4815 (1986) "Phase Transitions in Granular Superconductors near a Percolation Threshold"

9. Sajeev John and Morrel Cohen; Phys. Rev., B 34, 2428 (1986) "The Relationship between the Path-Integral and Scaling Theories of Small Polarons"

10. Sajeev John, C. Soukoulis, Morrel H. Cohen and E. N. Economou; Phys. Rev. Lett., 57, 1777 (1986) "Theory of the Electron Band Tails and the Urbach Optical Absorption Edge"

11. **Sajeev John; Phys. Rev. Lett., 58, 2486 (1987) "Strong Localization of Photons in Certain Disordered Dielectric Superlattices"**

12. Sajeev John; Physical Review, B 35, 9291 (1987) "Localization and the Density of States for an Electron in a Quantized Elastic Continuum"

13. Sajeev John, M. Y. Chou and M. H. Cohen, C. M. Soukoulis; Phys. Rev., B 37, 6963 (1988) "Density of States for an Electron in a Correlated Gaussian Random Potential: Theory of the Urbach Tail"

14. Fred Mackintosh and Sajeev John; Phys. Rev., B 37, 1884 (1988) “Coherent Backscattering of Light in the Presence of Time Reversal Non-invariant and Parity Violating Media”

15. S. Etemad, R. Thompson, M. J. Andrejco, Sajeev John and F. Mackintosh; Phys. Rev. Lett., 59, 1420, (1987) “Weak Localization of Photons: Termination of Coherent Random Walks by Absorption and Confined Geometry”

16. C. Grein and Sajeev John; Phys. Rev., B 36, 7457 (1987) “Polaronic Band Tails in Disordered Solids: Combined Effects of Static Randomness and Electron-phonon Interactions”

17. 17. Sajeev John; Condensed Matter Physics Vol. XIV no. 4, pg. 193 (1988), “The Localization of Light and other Classical Waves in a Disordered Medium”

18. 18. Sajeev John; World Scientific Series on Directions in Condensed Matter Physics, edited by P. Sheng (1989) “Localization of Waves in a Disordered Medium”

19. Sajeev John, T. C. Lubensky and J. Wang; Phys. Rev., B 38, 2533 (1988) “Diamagnetism of Percolative Granular Superconductors and Diluted Josephson Arrays”

20. M. H. Cohen, M. Y. Chou., E. N. Economou, Sajeev John and C. M. Soukoulis; IBM J. Rs. Develop. Vol. 32 No. 1 (1988), “Band Tails, Path Integrals, Instantons, Polarons and all That”

21. Sajeev John and R. Rangarajan; Phys. Rev., B 38, 10101 (1988) “Optimal Structures for Classical Wave Localization: An Alternative to the Ioffe-Regel Criterion”

22. C. Grein and Sajeev John; Sol. State Comm., 70, 87 (1989) “Temperature Dependence of the Fundamental Optical Absorption Edge in Crystals and Disordered Semiconductors”

23. P. W. Anderson, Sajeev John, G. Baskaran, B. Doucot and S. Liang; “Fermions and Topology in the Two-Dimensional Quantum Antiferromagnet”, Princeton University Press (1989)

24. Sajeev John and C. H. Grein; Reviews of Solid State Science Vol 4 no. 1 pg. 1-60 (1990), “Instantons, Polarons, Localization and the Urbach Optical Absorption Edge in Disordered Semiconductors”

25. C. Grein and Sajeev John; Phys. Rev., B 39, 1140 (1989) “Temperature Dependence of the Urbach Edge: A Theory of Multiple Phonon Absorption and Emission Sidebands”

26. F. C. Mackintosh and Sajeev John; Phys. Rev., B 40, 2383 (1989) “Diffusing-wave Spectroscopy and Multiple Scattering of Light in Correlated Random Media”

27. Sajeev John; “Analogies in Optics and Microelectronics”, ed. W. van Haeringen and D.

Lenstra (1990), Pg. 105, Kluwer Academic Publishers, "Photon Localization: The Inhibition of Electromagnetism in Certain Dielectrics"

28. C. H. Grein and Sajeev John; Phys. Rev., B 41, 7641 (1990) "Effects of Acoustic and Optical Phonon Sidebands on the Fundamental Optical Absorption Edge in Crystals and Disordered Semiconductors"

29. **Sajeev John and J. Wang; Physical Rev. Letters, 64, 2418 (1990) "Quantum Electrodynamics Near a Photonic Band Gap: Photon Bound States and Dressed Atoms"**

30. Sajeev John and Puru Voruganti; Phys. Rev., B 43, 10815 (1991) "Spiral Antiferromagnetism and the Doping Induced Closure of the Mott-Hubbard Gap"

31. Sajeev John; Physics Today, pg. 32, May 1991 (cover story), "The Localization of Light: Electrodynamics of a New Class of Dielectrics"

32. Sajeev John and Jian Wang; Phys. Rev., B 43 12,772 (1991) "Quantum Optics of Localized Light in a Photonic Bandgap"

33. Sajeev John, Puru Voruganti and W. Goff; Phys. Rev., B 43 13,365 (1991) "Electronic and Magnetic Features of Twisted SDW States in the 2-D Hubbard Model"

34. Sajeev John; Physica, B 175, 87 (1991) "Quantum Electrodynamics of Localized Light"

35. P. Voruganti, A. Golubentsev and Sajeev John; Phys. Rev. B 45 13945 (1992), "Conductivity and Hall Effect in the Two Dimensional Hubbard Model"

36. Sajeev John Photonic Band Gaps and Localization edited by C. Soukoulis, Plenum Press N. Y. (1993) pg. 1-22 "The Localization of Light".

37. V. Shalaev, M. Moskovits, A. Golubentsev and Sajeev John; Physica A 191, pg. 352 (1992), "Scattering and Localization of Light on Fractals"

38. Sajeev John and N. Akozbek; Physical Review Letters 71, 1168 (1993), "Nonlinear Optical Solitary Waves in a Photonic Bandgap"

39. Sajeev John and A. Golubentsev; Physical Review Letters 71, 3343 (1993), "Topological Magnetic Solitons in the two-dimensional Mott-Hubbard Gap"

40. **Sajeev John and A. Golubentsev Physical Review B51, 381 (1995) "Spin-flux and Magnetic Solitons in an Interacting Two-Dimensional Electron Gas: Topology of Two-Valued Wavefunctions".**

41. Sajeev John and Tran Quang; Physical Review A, 50, 1764 (1994), "Spontaneous Emission near the Edge of a Photonic Bandgap."

42. Sajeev John Confined Electrons and Photons, Erice Summer School Lectures 1993. Edited by E. Burstein and C. Weisbuch, Plenum Publishing Company (1995) “Localization of Light in Disordered and Periodic Dielectrics”

43. Sajeev John and Tran Quang Physical Review Letters 74, 3419 (1995) “Localization of Superradiance near a Photonic Band Gap”

44. Sajeev John and Axel Muller-Groeling Physical Review B 51, 12989, (1995) “Mean-field Energies of Spin-Flux Phases”

45. Sajeev John and Tran Quang Physical Review A 52, 4083 (1995) “Photon Hopping Conduction and Collectively Induced Transparency in a Photonic Bandgap”

46. Sajeev John and Tran Quang Physical Review Letters 76, 1320 (1996) “Quantum Optical Spin-glass State of Impurity Two-level Atoms in a Photonic Bandgap”

47. Sajeev John, Gendi Pang, and Yumin Yang Progress in Biomedical Optics, SPIE vol. 2389, 64 (1995) “Multiple Light Scattering Tomography: Beyond the Diffusion Approximation”

48. Sajeev John, Gendi Pang, and Yumin Yang Journal of Biomedical Optics, Volume 1, No. 2, 180 (1996) “Optical Coherence Propagation and Imaging in a Multiple Scattering Medium”

49. Sajeev John and Tran Quang Physical Review Letters 76, 2484 (1996) “Resonant Nonlinear Dielectric Response in a Photonic Band Gap Material”

50. Sajeev John, Lectures given at the NATO Advanced Study Institute, Porto Elounda Greece, June 1995, edited by C. M. Soukoulis, Plenum Press (1996) “Localization of Light: Theory of Photonic Band Gap Materials”

51. Sajeev John and Gendi Pang Physical Review A 54, 3642 (1996) “Theory of Lasing in a Multiple Scattering Medium”

52. Sajeev John and Tran Quang
Physical Review A 54, 4479 (1996) “Optical Bistability and Phase Transitions in a Doped Photonic Band Gap Material”

53**. Sajeev John and Tran Quang Physical Review Letters, 78, 1888 (1997) “Collective Switching and Inversion without Fluctuation of Two-Level Atoms in Confined Photonic Systems”**

54. Sajeev John, Mona Berciu and A. Golubentsev Europhysics Letters, 41, (1), 31 (1998) “Midgap States of a Two-Dimensional Antiferromagnetic Mott Insulator: Electronic Structure of Meron-Vortices”

55. Sajeev John and Valery Rupasov Physical Review Letters, 79, 821 (1997) “Multi-photon

Localization and Propagating Quantum Gap Solitons in a Frequency Gap Medium"

56. Tran Quang, M. Woldeyohannes, Sajeev John and G. S. Agarwal Physical Review Letters, 79, 5238 (1997) "Coherent Control of Spontaneous Emission Near a Photonic Band Edge: A Single-Atom Optical Memory Device"

57. Tran Quang and Sajeev John Physical Review A, 56, 4273 (1997) "Resonance Fluorescence near a Photonic Band Edge: Dressed-State Monte Carlo Wave-function Approach"

58. Sajeev John Nature, 390, 661 (1997) "Frozen Light"

59. Mona Berciu and Sajeev John Physical Review B 57, 9521 (1998) "Charged Bosons in a Doped Mott Insulator: Electronic Properties of Domain Wall Solitons and Meron-Vortices"

60. Neset Akozbek and Sajeev John Physical Review E 57, 2287 (1998) "Optical Solitary Waves in Two- and Three-Dimensional Nonlinear Periodic Structures"

61. Neset Akozbek and Sajeev John Physical Review E 58, 3876 (1998) "Self-Induced Transparency Solitary Waves in a Doped Photonic Band Gap Material"

62. Sajeev John and V. Rupasov Europhysics Letters 46, 326 (1999) "Quantum Self-Induced Transparency in Frequency Gap Media"

63. Kurt Busch and Sajeev John Physical Review E 58, 3896 (1998) "Photonic Band Gap Formation in Certain Self-Organizing Systems"

64. Nipun Vats and Sajeev John Physical Review A 58, 4168 (1998) "Non-Markovian Quantum Fluctuations and Superradiance Near a Photonic Band Edge"

65. Mona Berciu and Sajeev John Physical Review B 59, 15143 (1999) "Multi-Soliton Configuration in a Doped Antiferromagnetic Mott Insulator: A Numerical Study"

66. **Kurt Busch and Sajeev John Physical Review Letters 83, 967 (1999) "Liquid Crystal Photonic Band Gap Materials: The Tunable Electromagnetic Vacuum"**

67. Mesfin Woldeyohannes and Sajeev John Physical Review A 60, 5046 (1999) "Coherent Control of Spontaneous Emission Near a Photonic Band Edge: A Qubit for Quantum Computation"

68. S. W. Leonard, H. van Driel, K. Busch, S. John et al. Applied Physics Letters 75, 3063 (1999) "Attenuation of Optical Transmission within the bandgap of thin two-dimensional macroporous silicon photonic crystals"

69. S. W. Leonard, J. P. Mondia, H. van Driel, O. Toader, S. John et al. Physical Review B, R2389 (2000) "Tunable Two-Dimensional Photonic Crystals via Liquid Crystal Infiltration"

70. M. Berciu and Sajeev John Physical Review B 61, 10,015 (2000) "Quantum Dynamics of Charged and Neutral Magnetic Solitons: Spin Charge-Separation in the one-dimensional Hubbard model"

71. M. Berciu and Sajeev John Physical Review B 61, 16,454 (2000) "D-wave charge carrier pairing and non-Fermi-liquid behaviour in a purely repulsive 2D electron system"

72. A. Blanco...., Sajeev John et al. Nature 405, no. 6785, 437 (2000) "Large Scale Synthesis of a Silicon Photonic Band Gap Material with a Complete Three-Dimensional Gap Near 1.5 Microns"

73. M. Woldeyohannes, Sajeev John and V. Rupasov Physical Review A 63, 13814 (2001) "Resonance Raman Scattering in Dispersive Media and Photonic Band Gaps"

74. K. Busch, N. Vats, Sajeev John and B. Sanders Physical Review E 62, 4251 (2000) "Radiating Dipoles in Photonic Crystals"

75. M. Berciu and Sajeev John, Physica B 296 (1-3) page 143-155 (2001) "A Microscopic Model for D-Wave Charge Carrier Pairing in High Tc Superconductors: What Happens when Electrons Somersault?"

76. Ovidiu Toader, Sajeev John and K. Busch, Optics Express vol.8, no. 3, pg. 271- (2001) "Optical Trapping, Field Enhancement, and Laser Cooling in Photonic Crystals"

77. M. Florescu and Sajeev John, Physical Review A 64, 033801 (2001) "Single Atom Switching and NonMarkovian Dynamics in a Coloured Vacuum"

78. Ovidiu Toader and Sajeev John, Science vol. 292, 1133 (2001) "Proposed Square Spiral Microfabrication Architecture for Large Three-Dimensional Photonic Band Crystals"

79. Sajeev John, Les Houches Lectures, NATO Advanced Study Institute on Coherent Atomic Matter Waves, volume LXXII, EDP Sciences, Paris and Springer-Verlag, New York, page 481-531, "Photonic Band Gap Materials: A New Frontier in Quantum and Nonlinear Optics"

80. Kurt Busch and Sajeev John, Photonic Crystals and Light Localization in the 21st Century NATO Science Series C, Volume 563, pg. 41 (2001) "Tunable Photonic Crystals"

81. Sajeev John, Ovidiu Toader, Kurt Busch, Encyclopedia of Science and Technology, Third Edition, Volume 12, pg. 133 (2002) Academic Press "Photonic Bandgap Materials: A Semiconductor for Light"

82. Sajeev John and Marian Florescu, Journal of Optics A: Pure and Applied Optics 3, S103 (2001) “Photonic Band Gap Materials: Towards an All-Optical Micro-Transistor”

83. Scott Kennedy, Michael Brett, Ovidiu Toader, and Sajeev John, Nano Letters Vol. 2, No. 1, 59, (2002) “Fabrication of Tetragonal Square Spiral Photonic Crystals”

84. H. Miguez, …. Sajeev John et. al. Advanced Materials 13, No.21, 1634 (2001) “Photonic Band Gap Engineering in Germanium Inverse Opals by CVD”

85. Nipun Vats, K. Busch, Sajeev John, Physical Review A 65, 043808 (2002) “Theory of Fluorescence in Photonic Crystals”

86. P. Marowicz…. P.N. Prasad, Sajeev John, Optics Letters 27, no. 5, 351 (2002) “Two-photon excited upconverted emission spectrum from dyes incorporated in photonic crystals”

87. Lucia Florescu, Kurt Busch, and Sajeev John, J. Optical Society of America B19, 2215 (2002) “Semi-classical Theory of Lasing in Photonic Crystals”

88. Ovidiu Toader and Sajeev John, Physical Review E66, 016610 (2002) “Spiral Photonic Crystals: A Robust Architecture for Micro-fabrication of Materials with Large Three-Dimensional Photonic Band Gaps”

89. M. Woldeyohannes and Sajeev John, Journal of Optics B: Quantum and Semiclass. Opt. 5, R43-R82 (2003) “Coherent Control of Spontaneous Emission near a Photonic Band Edge”

90. A. Chutinan, Sajeev John, and O. Toader, Physical Review Letters 90, 123901 (2003) “Diffractionless Flow of Light in All-Optical Micro-chips”

91. O. Toader, M. Berciu, and Sajeev John, Physical Review Letters 90, 233901 (2003) “Photonic Band Gap Materials based on Tetragonal Lattices of Slanted Pores”

92. Tim Chan and Sajeev John, Physical Review E68, 046607 (2003) “Blueprint for Wafer-Scale 3D Photonic Band Gap Synthesis by Photo-electrochemical Etching”

93. O. Toader and Sajeev John, Physical Review E 70, 046605 (2004) “Photonic Band Gap Enhancement in Dielectrics with a Frequency Dependent Dielectric Function”

94. M. Florescu and Sajeev John, Physical Review A 69, 053810 (2004) “Resonance Fluorescence in Photonic Band Gap Waveguide Architectures: Designing the Vacuum for All-Optical Switching”

95. S. Kennedy, M. Brett, O. Toader, and Sajeev John, Journal of Photonics and Nanostructures, Vol. 1, Issue 1, 37 (2003) “Optical Properties of a Silicon Square Spiral Photonic Crystal”

96. Lucia Florescu and Sajeev John Physical Review E 70, 036607 (2004) "Lasing in a random amplifying medium: Spatiotemporal characteristics and nonadiabatic atomic dynamics "

97. Lucia Florescu and Sajeev John, Physical Review Letters 93, 013602 (2004) "Photon Statistics and Optical Coherence Properties of Light Emission from a Random Laser"

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99. R. Z. Wang and Sajeev John, Physical Review A 70, 043805 (2004) "Engineering the Electromagnetic Vacuum for Controlling Light with Light in a Photonic Band Gap Micro-chip"

100. R.Z. Wang and Sajeev John, Journal of Photonics and Nanostructures 2, 137 (2004) "Sculpting the vacuum in a photonic band gap micro-chip''

101. R.Z. Wang and Sajeev John "Engineering Thermal Spontaneous Emission in Photonic Crystals Filaments: Towards a more Efficient Light Bulb? "

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105. Sajeev John, Ovidiu Toader, and Alongkarn Chutinan, IEICE Trans. Electron, Vol. E87-C, No. 3, 266 (2004) "Photonic Band Gap Architectures for Micro-fabrication and Diffractionless Optical Networking"

106. Lucia Florescu and Sajeev John, Physical Review E 69, 046603 (2004) "Theory of Photon Statistics and Optical Coherence in a Multiple-Scattering Random Laser Medium"

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85 (11), 1895 (2004)
"Direct Two-Photon Writing and Characterization of Slanted Pore Photonic Crystals"

110. Dragan Vujic and Sajeev John, Physical Review A 72, 013807 (2005)
"Pulse re-shaping in photonic crystal waveguides and micro-cavities with Kerr-nonlinearity: Critical Issues for all-optical switching"

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112. Tim Chan, Ovidiu Toader, and Sajeev John, "Photonic Band Gap Synthesis by Optical Interference Lithography" Physical Review E 71, 046605 (2005)

113**.** G. von Freymann, V. Kitaev, T. Chan, Sajeev John, G. Ozin, M. Deubel, **M.** Wegener, Journal of Photonics and Nanostructures 2, 191-198 (2004), "Sub-nanometer precision tuning of the optical properties of three-dimensional polymer-based photonic crystals ".

114. G. von Freymann, Sajeev John, S. Wong, S. Kitaev, G. Ozin, Applied Physics Letters 86, 053108 (2005), "Measurement of group velocity dispersion for finite size three-dimensional photonic crystals in the near infrared spectral region ".

115. Georg von Freymann, Sajeev John, Vladimir Kitaev, Geoffrey A. Ozin, Advanced Materials, Vol. 17, Issue 10, 1273-1276 (2005), "Enhanced coupling to slow photon modes of three-dimensional graded colloidal photonic crystals''

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7. EXPLANATION OF RESEARCH CONTRIBUTIONS

I describe below my eight most significant research contributions
(see also www.physics.utoronto.ca/~john):

1. Light Localization and Photonic Band Gaps. I initiated the **field of classical wave localization** through a series of papers during **1983 and 1984** that I published while at Harvard University [see for instance Sajeev John and M. J. Stephen, Physical Review B 28, 6358, (1983)]. While this early work focused on elastic waves, it provided a clear basis for the generalization to electromagnetic waves. The **field of photon localization and photonic band gaps (PBG)** was initiated by two papers that I published in Physical Review Letters in **1984 ["Electromagnetic Absorption in a Disordered Medium near a Photon Mobility Edge" PRL 53, 2169 (1984)] and 1987 ["Strong Localization of Photons in Certain Disordered Dielectric Superlattices" PRL 58, 2486 (1987)]**. The original 1984 paper on light localization was followed immediately by key experiments on coherent backscattering of light by groups in Amsterdam and in France. A commentary on the early, pioneering work of 1984 was published by Prof. P.W. Anderson (Physics Nobel Laureate 1977) in Philosophical Magazine B52, 505-509 (1985). My paper of 1987 represents the **starting point for the field of Photonic Band Gap Materials**, a rapidly growing field which crosses the boundaries between physics, chemistry, engineering, and mathematics.

Electromagnetism is the fundamental mediator of interactions in condensed matter and atomic physics. It is rare that such a basic interaction can be modified in a specific manner, leading to fundamentally new physical phenomena. From the standpoint of applied science, localized modes of light act as ideal high quality optical cavities important in the design of low threshold micro-lasers for use in optoelectronic devices and optical communication networks. **Localization of light is already employed** in hollow core photonic band gap fibers for guiding light in air. This is useful in high bandwidth, dispersionless, lossless **transmission of optical information**. It is also used for high intensity laser light delivery for **laser surgery** through an endoscope, without damage to the fiber itself.

The potential significance of light localization and PBG materials may be compared to that of semiconductor physics. **Photonic band gap materials are the optical analogues of semiconductors in the electronics industry**. Rather than a periodic array of atoms that scatter and thereby modify the energy-momentum relation of electrons, these materials consist of periodically modulated dielectrics on the scale of the wavelength of light that scatter and confine photons.

Another important practical **application of light trapping is for solar energy harvesting using photonic crystal thin films**. Using the newly discovered phenomenon of "parallel to interface refraction" [Physical Review A 78, 023825 (2008)], it is possible to trap and absorb a much larger number of photons throughout a broad cone of incident angles and a broad range of frequencies. This will greatly enhance the overall efficiency of solar cells.

2. Quantum Optics. After joining the faculty of the University of Toronto in 1989, my research has focused on the **consequences of photon localization and**

photonic band gap materials in the context of quantum electrodynamics [see for instance Physical Review Letters 64, 2418 (1990)]. These novel consequences are related to the fact that when an atom or molecule with a resonant optical transition of frequency coincident with the photonic band gap is placed inside a PBG material, spontaneous emission of light from the atom is inhibited. Instead, light remains localized in the vicinity of the atom in the form of a **photon-atom bound state.** During the subsequent 15 years I published a series of papers describing the important consequences of this effect. These include **zero-threshold laser activity**, lasing without a cavity mode [Phys. Rev. Lett. 74, 3419 (1995)], **low threshold nonlinear optical response** [Phys. Rev. Lett. 76, 2484 (1996)] and optical bistability, all**-optical transistor action** [Phys. Rev. Lett. 78, 1888 (1997)], **single-atom optical memory** [Phys. Rev. Lett. 79, 5238 (1997)], and quantum optical gap solitons. These provide the fundamental principles for more specific device applications. The **foundation that has been laid by these papers** has attracted the involvement of scientists from **the field of quantum optics**. These theoretical predictions have provided a driving force for the microfabrication of high quality PBG materials on the optical wavelength scale, in which these novel physical phenomena and device applications may be realized. We have demonstrated that **charge carrier (electron-hole) dynamics in a semiconductor quantum well** can be significantly modified by the electromagnetic environment of the PBG [Physical Review Letters 99, 046801 (2007)]. Bound electron-hole pairs (excitons) can have very long lifetimes with respect to radiative recombination. The effective mass of the exciton can be reduced by four orders of magnitude through dressing by photonic band edge photons. Moreover, the exciton-photon coupling strength in suitable multiple-quantum-well PBG structures can exceed the room temperature scale. This may lead to novel quantum effects such as **Bose-Einstein condensation of excitons at room temperature** and new types of excitonic lasers [Nature Magazine Scientific Reports **4**, 7432 (2014)].

A very striking discovery [Physical Review Letters 103, 233601 (2009)] is that nearly **complete coherent control of the excitation dynamics of quantum dots by picosecond optical pulses in a photonic band gap waveguide**. It is possible to achieve and maintain complete inversion of quantum dots at microwatt power levels. Inversion and down conversion is achieved on picosecond time scales with red and blue detuned optical pulses, respectively. This provides a basis for a **multi-wavelength channel all-optical transistor in a photonic band gap microchip that can perform optical logic and optical information processing**.

3. Materials Science. Since coming to Canada, I have contributed extensively to the **design and synthesis of photonic band gap (PBG) materials and PBG micro-circuits.** The synthesis of large scale, high quality PBG materials with a complete gap centered near 1.5 microns is one of the holy grails of photonics and materials science. The **theoretical roadmap** for materials synthesis that we published [K. Busch and S. John, Physical Review E 58, 3896 (1998)] is one of **the key papers referred to by materials scientists worldwide** in their efforts to synthesize PBG materials using self-assembly methods. Following this initial theoretical paper, I assembled and led an international group of materials chemists and experimental physicists to synthesize the world's first silicon inverse-opal PBG material with the required photonic band gap. Our results were published in **Nature Magazine [Nature 405, no. 6785, 437 (2000)]** and featured on the CBC National News. Prior to this work, the precise infiltration of silicon into a 3D template structure was not demonstrated anywhere in the world and was believed to be impossible by most materials scientists. Our results, published in Nature, opened an important new route for 3D PBG micro-fabrication.

Following this initial achievement in materials synthesis, we invented a new photonic crystal design suited to a different fabrication process known as Glancing Angle Deposition (GLAD). Our new Square Spiral photonic band gap architecture was published in **Science Magazine [O. Toader and Sajeev John, Science vol. 292, 1133 (2001)]** and was awarded a U.S. Patent (6,589,334 B2 July 8, 2003). We worked with the group of Prof. Mike Brett (inventor of the GLAD method) at the University of Alberta to fabricate and characterize the square spiral PBG material: S. Kennedy, M. Brett, O. Toader, and Sajeev John, Journal of Photonics and Nanostructures, Vol. 1, Issue 1, 37 (2003) "Optical Properties of a Silicon Square Spiral Photonic Crystal".

Our next major achievement in materials synthesis makes use of the technique of **optical lithography.** I have worked in collaboration with the experimental group of Prof. Martin Wegener at Karlsruhe University, Germany in the direct laser writing (DLW) of PBG architectures in polymer templates [Applied Physics Letters 85 (11), 1895 (2004)]. We have then shown, for the first time in the world, that polymer templates can be accurately replicated with silicon using a double inversion process [**Advanced Materials 18 (4): 457+ Feb 17 (2006) "New route towards three-dimensional photonic band gap materials: Silicon double inversion of Polymeric Templates''].** This work demonstrates that any PBG architecture amenable to simple optical lithography in a suitable photoresist can be duplicated in silicon. This enables the fabrication of a broad range of PBG architectures, previously not possible.

We made an important breakthrough in the large-scale and facile production of 3D photonic band gap materials through the invention of a **PBG Optical Phase Mask:** [T. Chan, O. Toader, and Sajeev John Physical Review E 73, 046610 (2006) "Photonic Band Gap Formation by Optical Phase Mask Lithography'']. The phase mask encodes the entire 3D PBG architecture onto a nearly planar (thin plate) diffraction grating. By illuminating the phase plate from above with a single laser beam, a photoresist below the plate can be exposed with a desired PBG architecture. This will make the manufacture of 3D PBG materials simpler than it has ever been.

4. Multiple-Light-Scattering Spectroscopy. An off shoot my work on **multiple light scattering** and photon localization is a **new spectroscopic technique known as "Diffusing Wave Spectroscopy"**. Together with my first Ph.D. student, I published a theoretical paper [**F. Mackintosh and Sajeev John, Physical Review B40, 2383 (1989)]** which is referenced by most of the experimental groups active in the use of multiple light scattering as a spectroscopic tool. It is directly based on my earlier paper **"**Wave Propagation and Localization in a Long-Range-Correlated

Random Potential" **[Sajeev John and M. Stephen, Physical Review B28, 6358 (1983)]**. Another major application of this theoretical analysis is in the field of **diagnostic medical imaging** [see for instance **S. John et. al., Journal of Biomedical Optics 1 (2), 180 (1996)**]. Using multiple scattering of near-infrared light, it is possible to image brain and breast tumors non-invasively and inexpensively. Unlike X-rays that use very short wavelength radiation and magnetic resonance imaging that uses very long wavelength radiation, near IR light is an intermediate frequency probe which is sensitive to metabolic processes such as the local oxygenation level of hemoglobin. Earlier methods based on the diffusion theory of light in tissue provide resolution on the scale of a millimeter. My theoretical model provides the possibility of resolution on the scale of 10 microns. The multiple light scattering technique holds the **possibility of early detection of tumors during the early metabolic stages of formation before structural damage takes place.** During the past several years, my group has developed a theoretical model for high resolution optical imaging based on measurement of the optical Wigner coherence function in tissue. This may ultimately provide a medical imaging tool suitable for the office of the primary care physician.

Related to the theory of multiple light scattering in disordered media is the phenomenon of **random lasing**. With my group at the University of Toronto, I have published two of the original theoretical papers describing (i) how this effect occurs in a photon diffusion model **[Sajeev John and G. Pang Physical Review A 54, 3642 (1996) "Theory of Lasing in a Multiple Scattering Medium"]** and (ii) the long sought after quantum statistical properties of light emission from the random laser **[L. Florescu and Sajeev John, Physical Review E 69, 046603 (2004) "Theory of Photon Statistics and Optical Coherence in a Multiple-Scattering Random Laser Medium"].**

5. First Principles Theory of the Fundamental Optical Absorption Edge in Semiconductors. I obtained a detailed microscopic solution of the long-standing unsolved problem of linear exponential band tails and absorption edges universally observed in disordered semiconductors. This includes a comprehensive description of static disorder, thermal disorder, polaronic effects, multiple phonon sidebands and band structure effects, and has led to quantitative agreement between theory and experiment. This also paves the way to a quantitative description of sub-gap electronic and optical processes in disordered solids with the level of accuracy of the band theory of crystalline solids.

6. Superconductivity. In the field of superconductivity, I published two papers in 1985 and 1986, **predicting a novel glass phase in granular superconducting materials**. **This phase was discovered experimentally in 1986** along with high temperature superconductors by Dr. Karl Alex Muller (1987 Nobel Laureate in physics). Dr. Muller cites my 1985 and 1986 papers which preceded his discovery.

The **microscopic mechanism for high temperature superconductivity** is still an unsolved problem in theoretical physics. While at the University of Toronto, beginning with a Physical Review Letter in 1993, **I introduced the concept of spin-flux** and topological magnetic solitons as a possible microscopic starting point for a first principles theory of non-Fermi liquid behavior in the normal state of these superconductors. The proposal is a major departure from existing models of the cuprate superconductors. It suggests that a **fundamental Law of Nature** remains to be recognized before a clear microscopic understanding of high Tc superconductivity is possible. This Law of Nature is the existence of a new quantum number in a correlated electron system that manifests itself when an electron undergoes a "somersault" in its internal coordinate system as it traverses a closed loop in external coordinate space. This classical somersault trajectory can be described in terms of a "flux" that couples directly to the spin of the electron rather than its charge. This leads to the appearance of quantized spin-flux, an entirely new degree of freedom in a many-electron system. In this novel many-electron state exhibiting spin-flux, charge carriers added to the antiferromagnetic normal state are clothed by vortex textures in the antiferromagnetic background. We have shown that these charged solitons are bosonic collective modes and can **explain non-Fermi liquid behavior and d-wave charge carrier pairing** in a purely repulsive, interacting electron system. Remarkable agreement has been found between this theory and numerous independently observed electronic, magnetic, and optical properties of the high temperature superconductors. For a review see [M. Berciu and Sajeev John, Physica B 296 (1-3) page 143-155 (2001) **["A Microscopic Model for D-Wave Charge Carrier Pairing in High Tc Superconductors: What Happens when Electrons Somersault?"].** For further quantitative comparison with experimental observations see [M. Berciu and Sajeev John, Physical Review B 69, 224515 (2004) **["Incommensurate magnetic neutron scattering in cuprate high Tc superconductors: Evidence for charged meron-vortices"].** This theory represents first-principles, microscopic theory of numerous fundamental features of the cuprate superconductors.

7. Solar Energy Harvesting. In my recent work at the University of Toronto, I have demonstrated the efficacy of thin-film photonic crystals for solar light trapping and electrical power generation. The first of these photonic crystals consisted of nanowires or conical nano-pore arrays. These structures absorb more sunlight than a longstanding benchmark known as the Lambertian limit. The novel underlying physics of these solar cell architectures comes from an effect known as **Parallel-to-Interface Refraction** and subsequent **light-trapping in slow group velocity modes**. With only one micron (equivalent bulk thickness) of silicon it is possible to absorb nearly 85% of all available sunlight in the wavelength range of 400-1000 nm. This enables a one-micron silicon photonic crystal to achieve the power conversion efficiency of the best commercial silicon solar cells that use up to 300 microns of silicon **["Solar light trapping in slanted conical pore photonic crystals: beyond statistical ray trapping ", J. of Applied Physics 113, 154315 (2013)].** The overall power conversion efficiency of the resulting one-micron photonic crystal solar cells is in the range of 17%-25%.

Recently we have demonstrated through precise numerical simulations the possibility of **flexible, thin-film solar cells, consisting of crystalline silicon, to achieve power conversion efficiency above 30% [Beyond 30% Conversion Efficiency in Silicon Solar Cells: A Numerical Demonstration," S. Bhattacharya**

& Sajeev John, Scientific Reports, 9, 12482 (2019)]. This is close to the Shockley-Queisser thermodynamic limit of 32.3% and **well above the current world record of 26.7%.** Our optimized photonic crystal architecture consists of a 15-micron thick cell patterned with inverted micro-pyramids with lattice spacing comparable to the wavelength of near-infrared light, enabling strong wave-interference-based light trapping and absorption. This also involves an **Interdigitated Back Contact (IBC) geometry**. These results are obtained by exact numerical simulation of Maxwell's wave equations for light propagation throughout the cell architecture and a state-of-the-art model for charge carrier transport and Auger recombination:
https://www.youtube.com/watch?v=L6ER2K9lts8.

I have worked closely with an experimental group at Rensselaer Polytechnic Institute (USA) to demonstrate broadband solar absorption beyond the Lambertian limit in two types of thin-silicon photonics crystals. I am leading another international collaboration, involving the Institute of Solar Energy Research Hamelin Germany, Swinburne University of Technology Australia, and the University of Toronto, to realize my prediction of thin-silicon photonics crystal solar cells with efficiencies beyond 30%.

8. Medical Diagnostics using a Lab-in-a-Photonic-Crystal. Together with a PhD student of mine at the University of Toronto, I have introduced a theoretical prescription for a physically realizable Lab-in-a-Photonic-Crystal optical biosensor that can instantaneously detect and discriminate multiple disease-markers, both quantitatively and combinatorically, in a single spectroscopic measurement. **[Logical discrimination of multiple disease-markers in an ultra-compact nano-pillar lab-in-a-photonic-crystal, A. Al-Rashid and Sajeev John, J. Appl. Phys. 126, 234701 (2019)].** This optical biosensor is a promising paradigm for **portable, ultra-compact and inexpensive medical testing**. It enables diagnosing diseases at early stages in a primary care setting using a minimal amount of blood serum or other fluid, without requiring expensive, time-consuming, external laboratory testing. A square-lattice photonic crystal of nanopillars with fixed height but differentiated cross sections within a narrow flow-channel is used for cascaded transmission of light through a **photonic bandgap**. This photonic band gap contains a central waveguide mode and two separated edge waveguide modes. The nanopillar array is placed on a thin layer of high-refractive-index backing material resting on a glass substrate with fluid and biomarker flow along the waveguide direction. A variety of spectral fingerprints are identified as various disease-marker combinations bind to specific lines of nanopillars. Various diseases or various stages of a given disease are detected and differentiated through the inter-play of central-waveguide resonances with edge modes and three-dimensional index-guided bulk modes. This offers a distinctive mechanism for **instantaneous disease diagnosis using a minimal volume of fluid sample**.