

MICHAEL JAMES ESCUTI

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Professional Preparation

2002 PhD in Electrical Engineering, Brown University
1999 MSc in Electrical Engineering, Brown University
1997 BS (magna cum laude) in Electrical & Computer Engineering, Drexel University

Professional Experience

2010-present Associate Professor, Dept. Electrical & Computer Engineering, NC State Univ
2004-2010 Assistant Professor, Dept. Electrical & Computer Engineering, NC State Univ
2002-2004 Post-Doc, Dept. Functional Polymers, Eindhoven Univ of Tech (Netherlands)

Honors and Awards (Selected)

2011 Alcoa Foundation Engineering Research Achievement Award, NC State University
2010 Presidential Early Career Awards for Scientists and Engineers (PECASE)
2010 Faculty Early Career Development (*CAREER*) Award, *National Science Foundation*
2004 Glenn Brown Award for *Outstanding PhD Dissertation*, International Liquid Crystal Soc
2002 *OSA/New Focus Student Award*, Top Winner, CLEO/QELS Conference
1999 Best Student Paper Award, Society for Information Display, International Symposium
1997 Citation of Excellence in Engineering Design, Drexel University

Publications and Patents Summary

Authored 28 journal articles, 50 refereed conference proceedings, 15 invited research presentations, 2 book contributions, and 3(+9) patents issued(+pending). Citation Statistics, as of September 2011 per ISI Web of Knowledge™ (across 26 journal papers counted): Accumulated Citations 469, and h-index 14

External and Internal Sponsored Research Activities

External Funding: ~ \$ 4.3M (overall), ~ \$ 3.0M (to NCSU), ~ \$ 2.8M (as PI/co-PI)
Prime Sponsors (Gov't): Natl Science Foundation, NASA, US Air Force Research Lab, DARPA
Industry Partners, Sponsors: Raytheon, SAIC, Boulder Nonlinear Sys, ImagineOptix, Teledyne

Research Experience

My current research interests are in photonics and optics, particularly on using soft-condensed materials (liquid crystals and functional polymers) and lightwave interference to create advantageous opto-electronic devices and systems, via experiment, theory, and simulation. More specifically, my current research focuses on efficient LC display technologies and systems, low-loss laser beam steering, switchable lenses, high-resolution polarization and spectral imaging, polarization-insensitive telecommunication devices, computational electrodynamics, and massively-parallel opto-fluidics.

Teaching and Mentoring Experience

I have previously graduated 4 PhD and 3 MST students as Chair, and currently advise 3 PhD and 0 MST students. I have directed 15 undergraduate researchers, and employ 2 Post-Docs. Classes Taught: ECE-200 (Intro to Electrical Circuits, Signals, Sys), ECE-303 (Electromagnetic Fields), ECE-492K (Optical Communications), ECE-492S (Organic Electronics & LCDs)

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Professional Memberships:

SPIE – International Society for Optical Engineering (2000-present), IEEE – Institute of Electrical and Electronics Engineers (1996-present), ILCS – International Liquid Crystal Society (2002-present), SID – Society for Information Display (1999-2002, 2006-present), OSA – Optical Society of America (2000-present), MRS – Materials Research Society (2001-2005)

Journal Publications (peer-reviewed)

- 1) J. Kim, C. Oh, S. Serati, and M.J. Escuti, “Efficient, wide-angle, nonmechanical beam steering via polarization gratings,” *Applied Optics* **50**, no. 17, pp. 2636-2639, 2011.
- 2) M. Kudenov, M.J. Escuti, E. Dereniak, and K. Oka, “White light channeled imaging polarimeter using broadband polarization gratings” *Applied Optics* **50**, no. 15, 2283-2293, 2011.
- 3) E. Nicolescu, C. Mao, A. Fardad, and M.J. Escuti, “Polarization-independent variable optical attenuator using liquid crystal polarization gratings,” *IEEE Journal of Lightwave Technology*, **vol. 28**, no. 21, pp. 3121-3127, 2010.
- 4) E. Nicolescu and M.J. Escuti, “Polarization-independent tunable optical filters using bilayer polarization gratings,” *Applied Optics*, **vol. 49**, no. 20, pp. 3900-3904, 2010.
- 5) C. Packham, M. Escuti, J. Ginn, C. Oh, I. Quijano, and G. Boreman, “Polarization Gratings: A Novel Polarimetric Component for Astronomical Instruments,” *Publications of the Astronomical Society of the Pacific*, **vol. 122**, no. 898, pp. 1471-1482, 2010.
- 6) C. Oh, J. Kim, J.F. Muth, S. Serati, and M.J. Escuti, “High-Throughput, Continuous Beam Steering Using Rotating Polarization Gratings”, *IEEE Photonics Technology Letters*, **vol. 22**, no. 4, pp. 200-202, 2010.
- 7) R.K. Komanduri and M.J. Escuti, “Highly Efficient Reflective Liquid Crystal Polarization Gratings,” *Applied Physics Letters*, **vol. 95**, art. num. 091106, 2009.
- 8) P.F. McManamon, P.J. Bos, M.J. Escuti, J. Heikenfeld, S. Serati, H. Xie, and E.A. Watson, “A Review of Phased Array Steering for Narrowband Electro-Optical Systems,” *Proceedings of the IEEE*, **vol. 97**, no. 6, pp. 1078-1096, 2009.
- 9) C. Oh and M.J. Escuti, “Achromatic diffraction from polarization gratings with high efficiency,” *Optics Letters*, **vol. 33**, pp. 2287-2289, 2008.
- 10) C. Sanchez, F. Verbakel, M.J. Escuti, C.W.M. Bastiaansen, and D.J. Broer, “Printing of Monolithic Polymeric Micro-Structures using Reactive Mesogens,” *Advanced Materials*, **vol. 20**, no. 1, pp. 74-78, 2008.
- 11) C. Oh and M.J. Escuti, “Numerical Analysis of Polarization Gratings Using the Finite-Difference Time-Domain Method,” *Physical Review A*, **vol. 76**, no. 4, num. 043815, 2007.
- 12) R.K. Komanduri and M.J. Escuti, “Elastic Continuum Analysis of the Liquid Crystal Polarization Grating,” *Physical Review E*, **vol. 76**, no. 2, num. 021701, 2007.
- 13) R.K. Komanduri, W.M. Jones, C. Oh, and M.J. Escuti, “Polarization-Independent Modulation for Projection Displays Using Small-Period LC Polarization Gratings,” *Journal of the Society for Information Display*, **vol. 15**, no. 8, pp. 589-594, 2007.
- 14) C. Oh and M.J. Escuti, “Time-domain analysis of periodic anisotropic media at oblique incidence: an efficient FDTD implementation,” *Optics Express*, **vol. 14**, no. 24, pp. 11870-11884, 2006.
- 15) B.-J. de Gans, C. Sánchez, D. Kozodaev, M.J. Escuti, C. Bastiaansen, D.J. Broer, and U.S. Schubert, “Optimizing photo-embossed gratings: A gradient library approach,” *Journal of Combinatorial Chemistry*, **vol. 8**, no. 2, pp. 228-236, 2006.

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- 16) C. Sanchez, M.J. Escuti, C. van Heesch, C. Bastiaansen, and D.J. Broer, "TiO₂ nanoparticle-photopolymer composites for volume holographic recording," *Advanced Functional Materials*, **vol. 15**, no. 10, pp. 1623-1629, 2005.
- 17) C. Sanchez, M.J. Escuti, C. van Heesch, C. Bastiaansen, and D.J. Broer, "An efficient illumination system for LCDs incorporating an anisotropic hologram," *Applied Physics Letters*, **vol. 87**, no. 9, art. no. 094101, 2005.
- 18) C. Sánchez, B.-J. de Gans, D. Kozodaev, A. Alexeev, M.J. Escuti, C. van Heesch, T. Bel, U.S. Schubert, C. Bastiaansen, and D.J. Broer, "Photoembossing of periodic relief structures using polymerization induced diffusion: A combinatorial study," *Advanced Materials*, **vol. 17**, no. 21, pp. 2567-2571, 2005.
- 19) M.J. Escuti and G.P. Crawford, "Holographic Photonic Crystals," *Optical Engineering*, **vol. 43**, no. 9, pp. 1973-1987, 2004.
- 20) M.J. Escuti and G.P. Crawford, "Mesoscale three-dimensional lattices formed in polymer dispersed liquid crystals: a diamond-like face centered cubic," *Molecular Crystals and Liquid Crystals*, **vol. 421**, pp. 23-36, 2004.
- 21) M.J. Escuti, J. Qi, and G.P. Crawford, "A tunable face-centered-cubic photonic crystal formed in holographic-polymer dispersed liquid crystals," *Optics Letters*, **vol. 28**, no. 7, pp. 522-524, 2003. Highlighted in the "News" section of the July 2003 issue of *Scientific American*.
- 22) M.J. Escuti, J. Qi, G.P. Crawford, "Two-dimensional tunable photonic crystal formed in a liquid crystal/polymer composite: threshold behavior and morphology," *Applied Physics Letters*, **vol. 83**, no. 7, pp. 1331-1333, 2003. Selected to appear in the *Virtual Journal of Nanoscale Science & Technology*.
- 23) M.J. Escuti and G.P. Crawford, "Polymer Dispersed Liquid Crystals as Tunable Photonic Crystals," *Polymer News*, **vol. 28**, pp. 205-212, 2003.
- 24) M.J. Escuti, D.R. Cairns, and G.P. Crawford, "Optical-strain characteristics of anisotropic polymer films fabricated from a liquid crystal diacrylate," *Journal of Applied Physics*, **vol. 95**, no. 5, pp. 2386-2390, 2004.
- 25) M. Vilfan, B. Zalar, A. K. Fontecchio, M. Vilfan, M.J. Escuti, G.P. Crawford, and S. Zumer, "Deuteron NMR study of molecular ordering in a holographic-polymer-dispersed liquid crystal," *Physical Review E*, **vol. 66**, no. 2, 021710, 2002.
- 26) M.J. Escuti, P. Kossyrev, G.P. Crawford, T. Fiske, J. Colegrove, and L. Silverstein, "Expanded viewing-angle reflection from diffuse holographic-polymer dispersed liquid crystal films," *Applied Physics Letters*, **vol. 77**, no. 26, pp. 4262-4264, 2000.
- 27) M.J. Escuti, C.C. Bowley, G.P. Crawford, and S. Zumer, "Enhanced dynamic response of the in-plane switching liquid crystal display mode through polymer stabilization," *Applied Physics Letters*, **vol. 75**, no. 21, pp. 3264-3266, 1999.
- 28) M.J. Escuti, C.C. Bowley, G.P. Crawford, and S. Zumer, "A model of the fast-switching polymer-stabilized in-plane-switching configuration," *Journal of the SID*, **vol. 7**, no. 4, pp. 285-288, 1999.

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Conference Proceedings (peer-reviewed)

- 1) M.W. Kudenov, M.J. Escuti, E.L. Dereniak, and K. Oka, "Spectrally broadband channeled imaging polarimeter using polarization gratings," *Proc. SPIE – Polarization Science and Remote Sensing*, **vol. 8160**, art. no. 816031, 2011.
- 2) E. Seo, H.C. Kee, Y. Kim, S. Jeong, H. Choi, S. Lee, J. Kim, R.K. Komanduri, and M.J. Escuti, "Polarization Conversion System Using A Polymer Polarization Grating," *SID Symposium Digest*, **vol. 42**, pp. 540-543, 2011.
- 3) Y. Li, J. Kim, M.J. Escuti, "Experimental realization of high-efficiency switchable optical OAM state generator and transformer," *Proc. SPIE - Laser Beam Shaping XII*, **vol. 8130**, art. no. 813015, 2011.
- 4) (invited) R.K. Komanduri, K.F. Lawler, and M.J. Escuti, "A liquid crystal shutter for unpolarized broadband light," *Proc. SPIE – Acquisition, Tracking, Pointing, and Laser Systems Technologies XXV*, **vol. 8052**, art. no. 805227, 2011.
- 5) J. Kim, M.N. Miskiewicz, S. Serati, and M.J. Escuti, "Demonstration of large-angle nonmechanical laser beam steering based on LC polymer polarization gratings," *Proc. SPIE – Acquisition, Tracking, Pointing, and Laser Systems Technologies XXV*, **vol. 8052**, art. no. 805229, 2011.
- 6) J. Kim and M.J. Escuti, "High-efficiency quasi-ternary design for nonmechanical beam-steering utilizing polarization gratings," *Proc. SPIE – Advanced Wavefront Control: Methods, Devices, and Applications VIII*, **vol. 7816**, art. no. 781614, 2010.
- 7) Y. Li and M.J. Escuti, "Orbital angular momentum controlling using forked polarization gratings," *Proc. SPIE – Laser Beam Shaping XI*, **vol. 7789**, art. no. 778914, 2010.
- 8) J. Kim and M.J. Escuti, "Demonstration of polarization grating imaging spectropolarimeter (PGIS)," *Proc. SPIE - Polarization: Measurement, Analysis, and Remote Sensing IX*, **vol. 7672**, art. no. tbd, 2010.
- 9) C. Oh, J. Kim, J.F. Muth, and M.J. Escuti, "A New Beam Steering Concept: Risley Gratings," *Proc. SPIE - Advanced Wavefront Control: Methods, Devices, and Applications VII*, **vol. 7466**, art. no. 746619, 2009.
- 10) J. Kim and M.J. Escuti, "Demonstration of The Polarization Grating Imaging Spectropolarimeter," *Proc. SPIE - Imaging Spectrometry XIV*, **vol. 7457**, art. no. 745716, 2009.
- 11) R.K. Komanduri, C. Oh, and M.J. Escuti, "Polarization Independent Projection Systems Using Thin Film Polymer Polarization Gratings and Standard Liquid Crystal Microdisplays," *SID Symposium Proceedings*, **vol. 40**, pp. 487-490, 2009.
- 12) C. Oh, R.K. Komanduri, B.L. Conover, and M.J. Escuti, "Polarization-Independent Modulation Using Standard Liquid Crystal Microdisplays and Polymer Polarization Gratings," *International Display Research Conference*, **vol. 28**, pp. 298-301, 2008.
- 13) B.L. Conover, and M.J. Escuti, "Laboratory teaching modules on organic electronics and liquid crystal displays for undergraduate and graduate education," *Proc. MRS - Symposium H: Physics and Technology of Organic Semiconductor Devices*, art. no. H8.3, 2008.
- 14) C. Packham, M.J. Escuti, G. Boreman, I. Quijano, J.C. Ginn, B. Franklin, D.J. Axon, J.H. Hough, T.J. Jones, P.F. Roche, M. Tamura, C.M. Telesco, N. Levenson, J.M. Rodgers, and J.P. McGuire, "Design of a mid-IR polarimeter for SOFIA," *Proc. SPIE - Ground-based and Airborne Instrumentation for Astronomy II*, **vol. 7014**, art. no. 70142H, 2008.
- 15) B.L. Conover and M.J. Escuti, "Anisotropic Particle Motion In Optical Landscapes Modeled Via The T-Matrix Optical Scattering Approach," *Proc. SPIE - Optical Trapping and Optical Micromanipulation V*, **vol. 7038**, art. no. 703819, 2008.
- 16) R.W. Going, B.L. Conover, and M.J. Escuti, "Electrostatic Force And Torque Description Of Generalized Spheroidal Particles In Optical Landscapes," *Proc. SPIE - Optical Trapping and Optical Micromanipulation V*, **vol. 7038**, art. no. 703826, 2008.
- 17) C. Oh and M.J. Escuti, "Electrically Switchable Achromatic Liquid Crystal Polarization Gratings On Reflective Substrates," *Proc. SPIE - Liquid Crystals XII*, **vol. 7050**, art. no. 705019, 2008.

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- 18) J. Kim, C. Oh, M.J. Escuti, L. Hosting, and S. Serati, "Wide-Angle Nonmechanical Beam-Steering Using Thin Liquid Crystal Polarization Gratings," *Proc. SPIE - Advanced Wavefront Control: Methods, Devices, and Applications VI*, **vol. 7093**, art. no. 709302, 2008.
- 19) J. Kim and M.J. Escuti, "Snapshot Imaging Spectropolarimeter Utilizing Polarization Gratings," *Proc. SPIE - Imaging Spectrometry XIII*, **vol. 7086**, art. no. 708603, 2008.
- 20) E. Nicolescu and M.J. Escuti, "Polarization-Independent Tunable Optical Filters Based On Bilayer Polarization Gratings," *Proceedings of the SPIE - Optics & Photonics Conference*, **vol. 7050**, art. no. 705018, 2008.
- 21) R.K. Komanduri, C. Oh and M.J. Escuti, "Reflective Liquid Crystal Polarization Gratings With High Efficiency And Small Pitch," *Proc. SPIE - Liquid Crystals XII*, **vol. 7050**, art. no. 70500J, 2008.
- 22) R.K. Komanduri, C. Oh, M.J. Escuti, and D.J. Kekas, "Late-News Paper: Polarization-Independent Liquid Crystal Microdisplays," *Society for Information Display Symposium Digest*, **vol. 39**, pp. 236-239, 2008.
- 23) E. Nicolescu and M.J. Escuti, "Portable Spectrophotometer Based on Polarization Independent Tunable Optical Filters," *Proceedings of the SPIE - Optics & Photonics Conference*, **vol. 6661**, art. no. 666105, 2007.
- 24) E. Nicolescu and M.J. Escuti, "Polarization-Independent, Tunable Optical Filters Based On Liquid Crystal Polarization Gratings," *Proceedings of the SPIE - Optics & Photonics Conference*, **vol. 6654**, art. no. 665405, 2007.
- 25) R.L. Kellogg and M.J. Escuti, "DAZLE: A New Approach to Adaptive Imaging," *Proceedings of the SPIE - Optics & Photonics Conference*, **vol. 6714**, art. no. 67140H, 2007.
- 26) C. Oh and M.J. Escuti, "Achromatic Polarization Gratings as Highly Efficient, Thin-Film, Polarizing Beamsplitters for Broadband Light," *Proceedings of the SPIE - Optics & Photonics Conference*, **vol. 6682**, art. no. 668211, 2007.
- 27) C. Oh and M.J. Escuti, "Achromatic Diffraction Using Reactive Mesogen Polarization Gratings," *Society for Information Display Symposium Digest*, **vol. 38**, pp. 1401-1404, 2007.
- 28) M.J. Escuti and W.M. Jones, "A Polarization-Independent Liquid Crystal Spatial-Light-Modulator," *Proceedings of the SPIE - Optics & Photonics Conference*, **vol. 6332**, art. no. 63320M, 2006.
- 29) M.C. Ozturk and M.J. Escuti, "A New Introductory Course On Signals, Circuits and Systems," *American Society for Engineering Education Annual Conference*, **vol. 2532**, art. no. 2473, 2006.
- 30) M.J. Escuti, C. Oh, C. Sanchez, C. Bastiaansen, and D.J. Broer, "Simplified Spectropolarimetry Using Reactive Mesogen Polarization Gratings," *Proceedings of the SPIE - Optics & Photonics Conference*, **vol. 6302**, art. no. 630207, 2006.
- 31) B.L. Conover and M.J. Escuti, "The response of particles with anisotropic shape within an optical landscape and laminar flow," *Proceedings of the SPIE - Optics & Photonics Conference*, **vol. 6326**, art. no. 632614, 2006.
- 32) C. Oh, R. Komanduri, and M.J. Escuti, "Finite-difference-time-domain analysis of polarization gratings," *Proceedings of the SPIE - Optics & Photonics Conference*, **vol. 6326**, art. no. 632638, 2006.
- 33) C. van Heesch, C. Sanchez, M.J. Escuti, D.J. Broer, and C. Bastiaansen, "Holographic phase gratings in back and frontlights for liquid crystal displays," *Proceedings of the SPIE - Optics & Photonics Conference*, **vol. 6355**, art. no. 635501, 2006.
- 34) W.M. Jones, C. Oh, R. Komanduri, and M.J. Escuti, "Polarization-Independent Modulation for Projection Displays Using Small-Period LC Polarization Gratings," *International Display Research Conference*, **vol. 26**, art. no. 12.5, 2006.
- 35) M.J. Escuti and W.M. Jones, "Polarization independent switching with high contrast from a liquid crystal polarization grating," *Society for Information Display Symposium Digest*, **vol. 37**, pp. 1443-1446, 2006.

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- 36) W.M. Jones, B.L. Conover, and M.J. Escuti, "Evaluation of projection schemes for the liquid crystal polarization grating operating on unpolarized light," *Society for Information Display Symposium Digest*, **vol. 37**, pp. 1015-1018, 2006.
- 37) C. Oh, R. Komanduri, and M.J. Escuti, "FDTD and elastic continuum analysis of the liquid crystal polarization grating," *Society for Information Display Symposium Digest*, **vol. 37**, pp. 844-847, 2006.
- 38) C. Sanchez, B.J. de Gans, D. Kozodaev, A. Alexeev, M.J. Escuti, C. van Heesch, T. Bel, U.S. Schubert, C. Bastiaansen, and D.J. Broer, "Polymerization-induced diffusion as a tool to generate periodic relief structures: a combinatorial study," *Proceedings of the SPIE*, **vol. 6136**, art. no. 61360H, 2006.
- 39) J. Qi, M.J. Escuti, and G.P. Crawford, "Modeling of Three-Dimensional Structured Liquid Crystal/Polymer Dispersions for Reflective Displays", *Int. Display Manufacturing Conf.*, **vol. 3**, art. no. P2-13, 2003.
- 40) M.J. Escuti and G.P. Crawford, "Viewing-angle Compensation in LCDs: Modeling of Fiber Optic Face Plates", *Int. Display Manufacturing Conf.*, **vol. 3**, art. no. P2-20, 2003.
- 41) M.J. Escuti and G.P. Crawford, "Switchable Photonic Lattices with Polymer Dispersions of Liquid Crystals", *Polymer Preprints*, **vol. 43**, pp. 540-541, 2002.
- 42) M.J. Escuti and G.P. Crawford, "The Electro-Optic Effects of 3D Lattices in H-PDLC Reflective Displays," *Asia Display Symposium Digest*, **vol. 8**, art. no. LCST-08, 2002.
- 43) M.J. Escuti and G.P. Crawford, "Fiber-Optic Faceplate Viewing-Angle Compensation in LCDs," *Asia Display Symposium Digest*, **vol. 8**, art. no. LCST-07, 2002.
- 44) M.J. Escuti and G.P. Crawford, "Tailoring Morphology in Holographic-Polymer Dispersed Liquid Crystals for Reflective Display Applications," *Society for Information Display Symposium Digest*, **vol. 33**, pp. 550-553, 2002.
- 45) M.J. Escuti and G.P. Crawford, "Polymer Dispersed Liquid Crystals as Mesoscale 2D and 3D Lattices," *Materials Research Society Symposium Proceedings*, **vol. 709**, pp. 293-298, 2002.
- 46) M.J. Escuti, D. Cairns, J. Vedrine, and G.P. Crawford, "Optical-strain characteristics of ordered reactive mesogen films for viewing-angle compensation," *Society for Information Display Symposium Digest*, **vol. 32**, pp. 870-873, 2001.
- 47) M.J. Escuti, P.Kossyrev, and G.P. Crawford, "Enhanced Viewing Volume of Holographic LC/Polymer Dispersions," *Asia Display Symposium Digest*, **vol. 6**, pp. 110-115, 2000.
- 48) M.J. Escuti, P. Kossyrev, C.C. Bowley, S. Danworaphong, G.P. Crawford, T.G. Fiske, J. Colegrove, L.D. Silverstein, A. Lewis, and H. Yuan, "Diffuse H-PDLC Reflective Displays: An Enhanced Viewing-Angle Approach," *Society for Information Display Symposium Digest*, **vol. 31**, pp. 766-769, 2000.
- 49) A.K. Fontecchio, M.J. Escuti, C.C. Bowley, B. Sethumadhavan, G.P. Crawford, L. Li, and S. Faris, "Spatially Pixelated Reflective Arrays from Holographic-Polymer Dispersed Liquid Crystals," *Society for Information Display Symposium Digest*, **vol. 31**, pp. 774-777, 2000.
- 50) M.J. Escuti, C.C. Bowley, G.P. Crawford, and S. Zumer, "A Model of the Fast-Switching Polymer-Stabilized IPS Configuration," *Society for Information Display Symposium Digest*, **vol. 30**, pp. 32-35, 1999. (Best Student Paper Award)

Patents Issued or Pending

- 1) M.J. Escuti, C. Sanchez, C.W.M. Bastiaansen, and D.J. Broer, *US Patent No. 7,692,759*, "Polarization gratings in mesogenic films", issued 2010.
- 2) M.J. Escuti, G.P. Crawford, and R.C. Allen, *US Patent No. 7,006,747*, "Optical devices incorporating photo reactive polymers", issued 2006.
- 3) C. Sanchez, C. Bastiaansen, D.J. Broer, M.J. Escuti, and C. van Heesch, *European Patent No. WO2006041278*, "Waveguide Comprising An Anisotropic Diffracting Layer", issued 2006.

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- 4) M.J. Escuti, J. Kim, C. Oh, and S. Serati, submitted Apr. 2009, "Beam Steering Using Stacked Liquid Crystal Polarization Gratings", *Intl. Appl. No. PCT/US2010/043861*.
- 5) M.J. Escuti, C. Oh, R. Komanduri, B.L. Conover, and J. Kim, US Patent Application, "Polarization-Independent Liquid Crystal Display Devices Including Multiple Polarization Grating Arrangements and Related Devices", *PCT Appl. No. US2008/011611*.
- 6) M.J. Escuti, US Patent Application, "Methods of Fabricating Switchable Liquid Crystal Polarization Gratings on Reflective Substrates and Related Devices", *US Patent Appl. No. 60/912,036*.
- 7) M.J. Escuti and C. Oh, US Patent Application, "Multi-Layer Achromatic Liquid Crystal Polarization Gratings and Related Fabrication Methods", *US Patent Appl. No. 60/912,039*.
- 8) M.J. Escuti, C. Oh, and R. Komanduri, US Patent Application, "Low-Twist Chiral Nematic Liquid Crystal Polarization Gratings and Related Fabrication Methods", *US Patent Appl. No. 60/912,044*.
- 9) M.J. Escuti, R.K. Komanduri, J. Kim, K.F. Lawler, *NCSU Invention Disclosure*, being prepared for US Patent Application (NCSU Ref. 11-156; MBSS Ref. 5051-804PR), Sept. 2011.
- 10) M.J. Escuti, R.K. Komanduri, K.F. Lawler, *NCSU Invention Disclosure*, being prepared for US Patent Application (NCSU Ref. 12-029; MBSS Ref. 5051-805PR), Sept. 2011.
- 11) C. van Heesch, C. Sanchez, M.J. Escuti, C. Bastiaansen, and D.J. Broer, *International Appl. No. WO2006064431*, "Porous holographic film".
- 12) M.G. Debije, C. Bastiaansen, D.J. Broer, M.J. Escuti, and C. Sanchez, *International Appl. No. WO2006088369*, "Luminescent Object And Utilisation Thereof".