

Curriculum Vitae

Donald Harrison Barnhart, Ph.D.

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Donald Barnhart has been developing optical design and analysis software in Wolfram Research's *Mathematica* since 1991. His *Optica* software package, introduced in 1994, is used by thousands of scientists across the world. Donald developed the world's first successful high-resolution holographic instrument to measure three-dimensional velocity fields in fluids, the results of which appeared on the front cover of *Applied Optics* in 1994 and are cited in more than 200 publications. Donald received the Rank Prize in 2001 for the best electro-optics Ph.D. dissertation in the United Kingdom. The optics group to which he belonged at Loughborough University received the Queen's Anniversary Prize, awarded personally by the Queen at Buckingham Palace. Since 2004, Donald has been the chief optical scientist for iCyt Mission Technology, a Sony USA subsidiary that produces flow cytometers for stem cell and cancer research, in addition to his ongoing *Optica* business.

iCyt

Since the completion of my Ph.D. in 2001, I have accumulated a wide range of experience and expertise in both academic and industrial settings. For the past seven years, I have served as the principal optical scientist for i-Cyt Mission Technology (now a subsidiary of Sony). I have designed and developed nearly all of the optical subsystems used in the flow cytometers produced by i-Cyt today. With a retail price tag of more than a million dollars per unit, these flow cytometers are a confluence of the most advanced optical, electronic, and signal processing hardware technologies available. My role and responsibilities at i-Cyt have allowed me to test the limits of optical design and oversee the entire optical product development process from conception through to production for dozens of commercial systems. My role at i-Cyt also has enabled me to experience firsthand the entire business development cycle from which a small startup company evolves and grows into part of one the largest and most prestigious corporations in the world, Sony.

Mathematica

A close association with Wolfram Research since its founding in 1988 has allowed me to acquire and maintain a very high level of proficiency in the *Mathematica* computer language, which I have applied to a wide range of applications, including spatial modeling and the *Optica* product discussed next.

Optica

I have been experimenting with optical models in *Mathematica* since 1991. This has culminated in a business venture to create optical design and analysis software called *Optica*, which was initially released in 1994 and originally distributed by Wolfram Research. In 2004, I licensed my *Optica* business to i-Cyt. More recently, in 2009, I founded my own business, Barnhart Optical Research, LLC, which distributes *Optica* through its Optica Software division and now supports a wide range of research and development efforts as well.

Since their introduction, my optical modeling products have been used by thousands of scientists across the world at businesses and academic institutions such as Lawrence Livermore, Los Alamos, NASA, Sandia National Laboratory, Harvard, Oxford, Cambridge, Microsoft, Canon, Northrop Grumman, Intel, the Jet Propulsion Laboratory, and, of course, Sony. In order to support *Optica*, I regularly correspond with scientists from around the world who are working on a diverse array of optical applications that include solar energy, extreme ultraviolet lithography, laser systems, and telescopes. Constant exposure to the technical concerns of other scientists has given me a unique insider's perspective on a wide range of topics that all use the cutting edge of technology. Most recently, I have employed *Mathematica* and *Optica* in the high-performance computing (HPC) environment at R-Systems to solve a modeling problem in 14 days that would have required three years to run on a single laptop computer.

Academic Reputation

I completed my Ph.D. work in 2001¹, receiving the highly competitive Rank Prize for the best electro-optics Ph.D. dissertation in the United Kingdom, and our optics group at Loughborough University received the Queen's Anniversary Prize, for which I traveled to Buckingham Palace and personally met the Queen of England. In 1994 I established an international reputation in my field when, building on work done for my master's degree, I demonstrated the world's first successful holographic instrument to measure three-dimensional velocity fields in fluids². This accomplishment was reported on the front cover of *Applied Optics* journal⁹ and resulted in a patent³. I have since earned recognition as a founder of the holographic velocimetry discipline and as a world leader in holographic metrology work. The 1994 *Applied Optics* article has alone been cited on more than 185 occasions in refereed journal publications of other authors.

More recently, the results of my work have been twice published in the Proceedings of the Royal Society of London⁶, a venerable organization headed at one point by Sir Isaac Newton. In addition, I have held research collaborations with groups from five different European universities that include: Loughborough University (England), the University of Delft (Holland), University of Oldenburg (Germany), University of Zaragoza (Spain), and University of Marburg (Germany). I regularly give invited presentations in numerous venues. I most recently gave an invited presentation on optical design and high performance computing at the Coalition for Academic Scientific Computation meeting held in Arlington VA (March 2011).

Other Research Interests

In addition to the topics mentioned above, over the years I have maintained a strong interest in spatial modeling and remote sensing of ecological systems, most notably, the Illinois tall grass prairie. Since 1987 I have been actively involved in reconstructing the prairie ecosystem on our family farm. The Barnhart Prairie Nature Preserve now includes more than 110 acres of restored prairie. I hope that research projects carried out on this land will allow me to pursue my interest in new applications of spatial modeling and remote sensing to precision agriculture.

Other research interests include three-dimensional shape measurement, three-dimensional displays, high performance computing, and holographic microscopy. I am particularly interested in application of digital holography to flow-cytometry.

Teaching Interests

My accumulated technical knowledge and real world practical expertise in research and development, industrial design, and entrepreneurship have prepared me, I believe, to offer students a rich learning experience. For the past five years, I have regularly been invited to teach optics classes at the University of Illinois as a visiting lecturer. I would enjoy a larger and more formal opportunity to engage with students in both theoretical and practical contexts.

Professional Experience

2009-Present	Founder/owner of Barnhart Optical Research LLC, a research and development company with <i>Optica Software</i> as a division.
2004-Present	Principal optical scientist at i-Cyt/Sony in the design and production of flow cytometers.
1995 – Present	Author of <i>Optica</i> and business consultant in professional optical design Optical design software program
December 2002- June 2003	University of Illinois at Urbana-Champaign Department of Theoretical and Applied Mechanics, Urbana, IL Research Associate, Post Doc, Measurement of supersonic micro-detonations
2001 – July 2002	Loughborough University, Mechanical Engineering Dept., England Research Associate, Post Doc, Advanced development of holographic metrology systems
1995 – 1998	Loughborough University, Mechanical Engineering Dept., England Research Associate, Post Doc, Development of holographic velocimetry system
1991– 1995	University of Illinois at Urbana-Champaign Department of Theoretical and Applied Mechanics Production of holographic PIV with Professor Ron Adrian
1989 – 1991	University of Illinois at Urbana-Champaign Department of Electrical Engineering Set up a holographic teaching laboratory
1989 (1 semester)	Parkland Community College, Champaign, IL Department of Physics Taught engineering mechanics: statics
1987 – 1989	Set up own business called <i>Holoflex</i> , Urbana, IL Research and development of holographic stereograms

1984 (summer) University of Illinois at Urbana-Champaign
Department of Electrical Engineering
Internship, integrated circuit clean room fabrication facility

Education

1995 – 2001 Loughborough University, England
Degree: Ph.D. Course: Optical/Mechanical Engineering
Dissertation title: Whole-field holographic measurements of three-dimensional displacement in solid and fluid mechanics

1989 - 1994 University of Illinois at Urbana-Champaign
Degree: M.S. Course: Electrical Engineering
Dissertation title: Phase-conjugate holographic system for high resolution particle image velocimetry

1984 - 1987 University of Illinois at Urbana-Champaign
Degree: B.S. Course: Electrical Engineering

1982 – 1984 Bradley University, Peoria, IL
Course: Electrical Engineering

1978 - 1982 University High School, Urbana, IL

Foreign Language Skills

German – speak, read, write

Portuguese – presently learning Brazilian Portuguese

Awards

2001 **The Rank Prize Funds** for the best Electro-optics Ph.D. Dissertation in the United Kingdom, £ 1,000.00 award

2000 **Queen's Anniversary Prize for Higher and Further Education**
The Optical Engineering Group at Loughborough won the coveted Queen's Anniversary Prize during 2000. As an active player in the Optical Engineering Group, several research projects that I was highly involved with were submitted as part of the group's portfolio for this award. This is a prestigious prize in the United Kingdom.

1994 World's first successful holographic velocimetry measurement presented on front cover of *Applied Optics* journal.¹⁸

1987 The best Engineering Open House Exhibit, Department of Electrical Engineering Holographic Pattern Recognition

- 1985 Member of Electrical Engineering Society, Eta Kappa Nu
- 1984 Member of Engineering Honor Society, Tau Beta Pi

Professional Interests

As the lead developer of *Optica Software*, I am continually developing this software as a consultant for new business applications in a wide range of professional settings involving optical systems design and modeling.

A second professional interest involves the development of a fully digital holographic camera with numeric reconstruction of the digitized holographic information. In particular, I am using a photochromic material known as bacteriorhodopsin (BR) as a temporary optical storage buffer to allow the holographic information to be digitally scanned¹. This use of BR for digital holography is a completely new concept that I have personally originated. In contrast to a CCD camera sensor, which can only record millions of pixels, a digital holographic camera based on BR can record 10-100 billion pixels of information. This corresponds to a holographic object space that occupies 1-10 cubic centimeters volume with sub-micron spatial resolution. The two principal applications of this instrument are in the areas of biomedicine and nanotechnology research:

- 1.three-dimensional, velocity-field mapping of fluids, surfaces, and surface-flow interaction,
- 2.digital holographic microscope for high-resolution, volumetric imaging.

A third interest is the development of new optical instrumentation for remote sensing. This interest is connected with a personal endeavor to restore more than 100 acres of farmland into native tall grass prairie (see below). Although my experience in this research area is still limited, I wish to develop new instrumentation for mapping out species distributions in high-diversity, natural plant communities, such as the tall grass prairie, on a spatial scale that enables the individual plants to be accurately located, identified, and cataloged. In addition, the same instrumentation can have applications in commercial agriculture, for which research/business funding is more abundantly available.

Techniques in high resolution, three-dimensional shape measurement.

Publications and Presentations

Thesis Work

- (1) Barnhart, D. H. 2001, Whole-field holographic measurements of three-dimensional displacement in solid and fluid mechanics, *Ph.D. Thesis*, Loughborough University, UK.
- (2) Barnhart, D. H. 1994, Phase Conjugate Holographic System for High Resolution Particle Image Velocimetry, *M.S. Thesis*, University of Illinois at Urbana-Champaign.

Patent

- (3) Barnhart, D. H., Adrian, R. J., and Papen, G. C. Stereo multiplexed holographic particle image velocimeter *United States Patent*, 1996, August 20, Patent Number 5,548,419.

Refereed Journals and Invited Publications

- (4) Barnhart D. (2009), "Windows® HPC server 2008 dramatically reduces the iCyt® design cycle," <http://www.microsoft.com/hpc>
- (5) "Partially coherent extreme ultraviolet interference lithography for 16 nm patterning research," M. Goldstein, A. Wuest, and D. Barnhart, *Applied Physics Letters* 93, 083110 (2008)
- (6) Optical Mounts: Stress-free mounting enables diffraction-limited performance, D. Barnhart and A. Williamson, *Laser Focus World*, April 2007
- (7) Barnhart, D. H., New software tools facilitate the development of better holographic systems, *Holography, Newsletter of SPIE's International Technical Group on Holography*, June issue, Vol. 16, No. 1, 2005.
- (8) Barnhart, D. H., Koek, W. D., Juchem, T., Hampp, N. A., Coupland, J. M., and Halliwell, N. A., Bacteriorhodopsin (BR) as a high-resolution, high-capacity buffer for digital holographic measurements, March 19, 2004, *Meas. Sci. Technol.*, Vol. 15, pp 639-646, (2004).
- (9) Chan, V. S. S., Koek, W. D., Barnhart, D. H., Juchem, T., Hampp, N. A., Coupland, J. M., and Halliwell, N. A., "Application of holography to fluid flow measurements using bacteriorhodopsin (BR).," *Meas. Sci. Technol.*, Vol. 15, pp 647-655, (2004).
- (10) Barnhart, D. H., Halliwell, N. A., Coupland, J. M. Holographic velocimetry with Object Conjugate Reconstruction (OCR): Simultaneous velocity mapping in fluid and solid mechanics, *Proceedings of the Royal Society of London*, (submitted in 2003).
- (11) Barnhart, D. H., Chan, V. S. S., Halliwell, N. A. and Coupland, J. M. Holographic velocimetry using object-conjugate reconstruction (OCR): a new approach for simultaneous, 3-D displacement measurement in fluid and solid mechanics, *Experiments in Fluids*, 2002, Vol. 33, pp 770 - 780.
- (12) Barnhart, D. H., Halliwell, N. A., Coupland, J. M. Object Conjugate Reconstruction (OCR): A step forward in holographic metrology, *Proceedings of the Royal Society of London*, Jun 17 2002, Vol. 458, pp 2083-2097.
- (13) Barnhart, D. H., Holographic velocimetry, *Holography, SPIE's International Technical Group Newsletter*, Vol. 12, No. 2, 2001.
- (14) Barnhart, D. H., Halliwell, N. A. and Coupland, J. M. Holographic particle image velocimetry: cross-correlation analysis using a conjugate reconstruction geometry, *Optics and Laser Technology*, 2000, Vol. 32, pp 527-533.
- (15) Barnhart, D. H., Adrian, R. J. and Papen, G. C. Phase-conjugate holographic system for high-resolution particle-image velocimetry, *Applied Optics*, 1994, October 20, Vol. 33, no. 30, pp 7159-7170.

Guest Lecturer at the University of Illinois

- (16) Barnhart D. (2008-2010), Guest lecturer for the past three years in the ECE 460 optics courses (invited by Prof. Gabriel Popescu), Electrical and Computer Engineering Department, University of Illinois, Urbana.
- (17) Barnhart D. (2005), Guest lecturer for ECE 200 Explorations Seminar Series (invited by Prof. Seth Hutchinson), Electrical and Computer Engineering Department, University of Illinois, Urbana, October.

Selected Invited Talks

- (18) Barnhart D. (2011), Invited speaker at Coalition for Academic Scientific Computation, "HPC, Flow Cytometry, and Optical Design," CASC Meeting, Arlington, VA, March 16.
- (19) Barnhart D. (1993-2010), Invited speaker for the past seventeen years, "Optical Modelling with Optica," Wolfram Research Annual Developer's Conference, October.
- (20) Barnhart D. (2010), "Grid Computing and Optical Design using Optica and Mathematica 7," University of Rochester, Hopkins Center Seminars, March 17.
- (21) Barnhart D. (2009), "Grid Computing and Optical Design using Optica and Mathematica 7," University of Illinois, iOptics Seminar, November 19.
- (22) Barnhart D. (2009), "Grid Computing and Optical Design," R Systems HPC 360 Conference Champaign, IL, October 19.
- (23) Barnhart D. (2007), "Holographic measurement with application to flow-cytometry," International Workshop on Digital Holographic Reconstruction and Optical Tomography for Engineering Applications, Loughborough, England, April 24.
- (24) Barnhart D. (2003), Keynote speaker, "Bacteriorhodopsin (BR) as a high-resolution, high-capacity buffer for digital holographic measurements," First International Workshop on Holographic Velocimetry, Loughborough, England, May.

Conference Publications

- (25) Barnhart, D. Holographic measurement with application to flow-cytometry, *Proceedings for the International Workshop on Digital Holographic Reconstruction and Optical Tomography for Engineering Applications*, April 2007, Loughborough, England.
- (26) Chan, V. S. S., Koek, W. D., Barnhart, D. H., Poelma, C., Ooms, T. A., Bhattacharya, N., Braat, J. J. M., and Westerweel J., HPIV using Polarization Multiplexing Holography in Bacteriorhodopsin (bR), *13th International Symposium on Applications of Laser Techniques to Fluid Mechanics*, July 2004, Lisbon, Portugal.
- (27) Koek, W. D., Barnhart, D., Chan, V. S. S., Bhattacharya, N., Westerweel, J., and Braat, J. J. M., "HPIV using polarization multiplexing holography in bacteriorhodopsin (bR)," *21st International congress of theoretical and applied mechanics*, (Warsaw, Poland, 2004), paper FM10L_11899.

- (28) Koek, W. D., Barnhart, D., Chan, V. S. S., Bhattacharya, Juchem, T., Hampp, N., Westerweel, J., and Braat, J. J. M., "Wavelength Shifted Reconstruction with Bacteriorhodopsin for Holographic Particle Image Velocimetry," in *Organic Holographic Materials and Applications*, K. Meerholz, Ed., Proc. SPIE 5216, 147-155 (2003).
- (29) Barnhart, D. H., Hampp, N., Halliwell, N. A., and Coupland, J. M. Digital holographic velocimetry with bacteriorhodopsin (BR) for real-time recording and numeric reconstruction, *11th International Symposium on Applications of Laser Techniques to Fluid Mechanics*, July 2002, Lisbon, Portugal.
- (30) Chan, V. S. S., Barnhart, D. H., Halliwell, N. A. and Coupland, J. M. Unified system for holographic measurement in fluid and solid mechanics: use of the system for 3D velocity measurement in fluids through a thick curved window, *SPIE Proceedings* Vol.. 3783, 1999, October, pp 14-22.
- (31) Chan, V. S. S., Barnhart, D. H., Garner, C. P., Halliwell, N. A. and Coupland, J. M. Unified system for holographic measurement in fluid and solid mechanics: application of the system to volumetric flow measurement in an internal combustion engine, *SPIE Proceedings* Vol.. 3783, 1999, October, pp 110-117.
- (32) Barnhart, D. H., Chan, V. S. S., Halliwell, N. A. and Coupland, J. M. A unified system for 3D holographic displacement and velocity measurements in fluid and solid mechanics: design and construction of the recording camera and interrogation assembly, *SPIE* paper No. 3783-17, 1999.
- (33) Barnhart, D. H., Chan, V. S. S., Halliwell, N. A. and Coupland, J. M. A unified system for holographic measurement in fluid and solid mechanics: use of the system for 3D displacement measurement on surfaces, *Proceedings of optical science engineering and instrumentation* SPIE paper No. 3783-24, 1999.
- (34) Barnhart, D. H., . Chan, V. S. S., Garner, C. P., Halliwell, N. A. and Coupland, J. M. volumetric three-dimensional flow measurement in IC engines using holographic recording and optical correlation analysis, *IMEchE Conference Transaction 1998-2*, 1998, April 16-17, pp 51-61.
- (35) Barnhart, D. H., Halliwell, N. A. and Coupland, J. M. Three-dimensional displacement measurements in fluid and solid mechanics: development of an optical processor, Presented at *IMEchE Conference*, University of Reading, 1996, September.
- (36) Barnhart, D. H., Adrian, R. J., Meinhart, C., and Papen, G. C., Phase-conjugate holographic system for high-resolution particle image velocimetry through thick-walled curved windows, *Proceedings SPIE* Vol. 2545, 1995, June, Interferometry VII: Applications, pp 321-332.
- (37) Barnhart, D. H., Papen, G. C. and Adrian, R. J. Recent results of a phase-conjugate holographic system for high-resolution particle image holography, *Proceedings SPIE* Vol.. 2333, 1995, February, Fifth International Symposium on Display Holography, pp 321-332.
- (38) Adrian, R. J., Meinhart C. D., Barnhart D. H., and Papen, G. C. An HPIV system for turbulence research, FED-Vol. 148, Holographic Particle Image Velocimetry ASME, 1993, pp 17-21.
- (39) Barnhart, D. H., Papen, G. C. and Adrian, R. J. Phase conjugate image reconstruction for HPIV systems, FED-Vol. 148, Holographic Particle Image Velocimetry ASME, 1993, pp 13-15.
- (40) Barnhart, D. H., Papen, G. C. and Adrian, R. J. Holographic particle image velocimetry, *Proceedings SPIE*, Vol. 1600, 1992, January, International Symposium on Display Holography, pp 357-365.

References

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