James E. Durnin, Ph.D.

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Innovative Technical Leader

- Over 20 years experience in Technology Research and Development, with 12 patents.
- Broad engineering background with world class expertise in mathematical modeling, optimization techniques, statistical analysis, the design of optical and magnetic data storage systems, electromagnetic vector diffraction, and intraocular lens modeling.
- Expert in "Design for Six Sigma" (DFSS) tools, metrics, and methodology.

Consulting 2004 – Present

Optimal Results, Apple Valley, MN

- Developed and optimized predictive formulas for calculating intraocular lens (IOL) power using standard biometric data in cataract surgery. Developed thick lens models of IOLs from first principles to test and fine tune the predictive models.
- Developed novel graphical tools to visualize the topology of the human eye and accurately calculate wavefront aberrations induced by anatomical variations.
- Led metrics-driven Product/Process development for equipment manufacturing.

Sole Proprietor 2004 – Present

Optimal Results, Apple Valley, MN

- Developed a powerful new algorithm which is universally applicable to solving problems in global multi-objective optimization with constraints, and implemented it as an Excel application.
- This proprietary algorithm can handle all types of functions and constraints – everything from smooth and differentiable to discontinuous and discrete – and it converges orders of magnitude more rapidly than the Genetic Algorithm (which is the method most commonly used to solve for the global optima of non-smooth, non-convex functions).
- Developed unique graphical analysis tools which make use of the data generated by the algorithm to allow the user to visualize and understand the entire multi-dimensional solution space of whatever problem is being solved.

Director, Design for Six Sigma (DFSS) 2000- 2004

Seagate Technology, Shakopee, MN

- Led ongoing development of corporate metrics, training curricula, and tools. DFSS is a quality improvement initiative which emphasis the development and use of predictive system models in every phase of product design and development.
- Created SeaDOT (Seagate Design Optimization Tool), an Excel application which enables engineers to optimize the design of their probabilistic system models using automated Monte Carlo simulation.
- Created the Seagate DFFS Scorecard and QFD software for managing all critical-to-quality design variables and specifications.

Senior Staff Development Engineer, Recording Heads Operation 1997 - 2000

Seagate Technology, Bloomington, MN

- Defined and directed the modeling and performance characterization of Near-Field Magneto-Optical recording heads and media. Developed Electromagnetic Vector Diffraction models to predict the performance of Near Field MO storage heads and media. My modeling lead to the prediction of a novel source of noise and the development of methods to eliminate or reduce such noise

- Initiated and coordinated projects with researchers at the University of Rochester and the University of Minnesota.
- Inventor or co-inventor of 8 patents in the area of Near-Field Optical Storage Technology.

Senior Research Scientist, Optical Data Storage Research Labs 1988 - 1997
Eastman Kodak Company, Rochester, NY

- Invented, patented, and brought to commercialization a novel type of thin-film/pre-groove design for CD-R media which resulted in Kodak being one of the first two companies granted "Orange Book" certification for CD-R media.
- Manager for group of ten research scientists, post-docs, engineers, and technicians.
- Technical Representative for Eastman Kodak regarding HDCD, SD, and DVD optical disk formats. Provided technology assessments to marketing for DVD-related strategic planning and product roadmap development. Managed the technical activities required to support DVD-R and DVD-RAM Working Group meetings in Japan.
- Technical Team Lead for development of Kodak proprietary DVD-R media.
- Conducted theoretical modeling and experimental investigations of high-speed data recording to optimize the write strategies (i.e., laser pulsing schemes) adopted for use in the Kodak high speed CD Writer.
- Developed a novel scalar diffraction readout model for the design and analysis of CD-R media. Extensively used by the media development labs, this model greatly reduced development time by providing estimates of optimum groove profile and dye layer parameters, thereby eliminating costly, time-consuming matrix experiments.
- Developed vector diffraction readout models to quantify the effects of substrate birefringence on optical readout signals and set tolerances on polarization-sensitive components in optical heads.

Research Associate, Institute of Optics 1987 - 1988
University of Rochester, Rochester, NY

- Conducted pioneering theoretical and experimental studies of Bessel beams, also known as Non-Diffracting beams. This innovative work has stimulated many subsequent research efforts by scientists spanning many different disciplines. (see attached news articles below)

EDUCATION:

Ph.D.	Optics, University of Rochester, 1987.
M.S.	Electrophysics, Polytechnic Institute of New York, 1980.
B.S.	Electrical Engineering, Polytechnic Institute of New York, 1979.

AWARDS AND FELLOWSHIPS:

• University of Rochester: Institute of Optics Research Fellowship.
• Polytechnic Institute of New York: Dept. of E.E. Research Fellowship,
Institute Honors Program, and Presidential Distinguished Scholarship Award.

PUBLICATIONS:

- R. Roy, R. Short, J. Durnin, and L. Mandel, "First-passage-time distributions under the influence of quantum fluctuations in a laser," Phys. Rev. Lett. **45**, 1486 (1980).
- J. Durnin and H.L. Bertoni, "Acoustic propagation over ground having inhomogeneous surface impedance," J. Acoust. Soc. Am. **70**, 852 (1981).
- J. Durnin, C. Reece, and L. Mandel, "Does a photodetector always measure the rate of arrival of photons?" J. Opt. Soc. Am. **71**, 115 (1981).
- J. Durnin, "Continuously self-imaging fields of infinite aperture," J. Opt. Soc. Am. A **2**, p110 (1985).
- J. Durnin, J.J. Miceli, Jr., and J.H. Eberly, "Diffraction-free beams," J. Opt. Soc. Am. A **3**, p128 (1986).
- J. Durnin and J.H. Eberly, "Limits to resolution in time-dependent spectral analysis of pulses," J. Opt.

Soc. Am. A **3**, 2019 (1986).

- J. Durnin, "Exact solutions for nondiffracting beams. I. The scalar theory," J. Opt. Soc. Am. A **4**, 651 (1987).
- J. Durnin, J.J. Miceli, Jr., and J.H. Eberly, "Diffraction-free beams," Phys. Rev Lett. **58**, 1499 (1987).
- J. Durnin, J.J. Miceli, Jr., and J.H. Eberly, "Comparison of Bessel and Gaussian beams," Opt.Lett. **13**, 79 (1988).
- J. Durnin, "The Optics of CD-Recordable Discs," Invited Paper, published in the proceedings of the 1996 OSA Annual Meeting.
- J. Durnin, “Comparison of standard and confocal methods for detecting ROM and MO signals,” accepted for presentation at the 1998 OSA Annual Meeting.

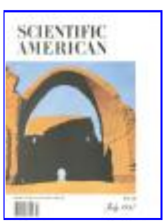
PATENTS:

- No. 6868,048 (US) “Data Storage System Having Thermally Activated Readout,” J.E. Durnin et al., 2005.
- No. 6,775,100 (US) “Laser Assisted Track Width Definition and Radial Control with Magnetic Recording,” J.E. Durnin et al., 2004.
- No. 6,688,743 (US) “Method and Apparatus to determine Fly Height of a Recording Head,” J.E. Durnin et al., 2004.
- No. 6,545,970 (US) “Near-Field Magneto Optical Head having Read and Write Apertures,” J.E. Durnin and E.C. Gage, 2003.
- No. 6,473,383 (U.S.): “Single Source Optical Disc Data Storage System,” J.E. Durnin et al., 2002.
- No. 6,466,525 (U.S.): “Optical Disc Data Storage System,” J.E. Durnin et al., 2002.
- No. 6,396,115 (U.S.): “Detector Layer for an Optics Module,” J.E. Durnin et al., 2002.
- No. 6,324,129 (U.S.): “Near Field Magneto-Optical Head having Read and Write Pinhole Apertures,” J.E. Durnin, E.C. Gage, 2001.
- No. 5,675,568 (U.S.): “Laser Power Control in an Optical Recording System to Compensate for Variations in Mark Length resulting from a Wobbled Groove,” R.A. Hajjar, J.E. Durnin, and C.K. Eastman, 1997.
- No. 5,500,266 (U.S.): “Spin-Coating Compensation for an Optical Storage Medium using a Substrate Groove Profile Gradient,” J.E. Durnin, 1996.
- No. 4,887,885 (U.S.): "Diffraction Free Arrangement," J.E. Durnin and J.H. Eberly, 1989.
- No. 4,852,973 (U.S.): "Diffraction Free Arrangement," J.E. Durnin and J.H. Eberly, 1989.

NEWS ARTICLES REVIEWING MY NON-DIFFRACTING BEAMS

J. Maddox, “Making light-spots travel further,”
Nature 327 p.183 (1987).

J. Hecht, “Diffraction-free beams produced at Rochester,”
Lasers and Optronics
August p.40 (1987).



Editors, “Keeping it together,”
Scientific American
July p.29 (1987).

R. Ruthen, “Beating the spread,”
Scientific American
April p.28 (1989).

J. Maddox, "Making light-spots travel further," **Nature** 327 p.183 (1987).

Making light-spots travel further

Careful shaping of the profile of a light beam makes it possible to increase greatly the distance over which the peak intensity is not degraded by diffraction.

On the face of things, as schoolboys know, it is a kind of nonsense to think that it may be possible to arrange for a beam of light whose physical dimensions are finite to propagate through space without becoming broader and more diffuse because of diffraction. The usual and simplest explanation is based on Huygens's principle: each point on the instantaneous wavefront of a propagating beam can be thought of as the source of an outwardly propagating shell of radiation. For radiation propagating outwards from a point source, the wavefronts are spherical, and a sequence of ever-larger spherical wavefronts is obtained by the mutual interference of the hypothetical spherical wavelets travelling outwards from neighbouring points on each spherical surface. In the days when the lumeniferous aether was all the rage, this simple picture was one way of relating the supposed elastic properties of the aether to such quantities as the velocity of light and the electrodynamic constants of the vacuum. The same result obtains for plane waves travelling in one direction which are infinite in extent in the planes perpendicular to the direction of travel. All that is elementary. Equally, it is readily imagined that a plane wave which is not infinite in its lateral extent cannot travel without spreading. The Huygens wavelets near the middle of each wave front may interfere destructively except along another plane surface displaced slightly downstream, but the Huygens wavelets spreading from near the edges of the wavefront will not be neatly cancelled out by their neighbours except along the surface of the displaced plane, so that the travelling beam becomes fuzzy at the edges.

Of necessity, the spreading-out obtains simply as a consequence of the finite size of the propagating beam, and occurs even in a vacuum. The distance over which a beam of circular cross-section r will remain reasonably compact is measured by its cross-sectional area divided by the wavelength (which is why those who would use lasers in defences against ballistic missiles must think of building instruments with very large cross-section).

But now, it seems, there is a way round the problem. J. Durnin of the Institute of Optics at the University of Rochester has apparently managed to find a solution of the wave equation which represents a beam of light of finite cross-section which is immune from this diffraction phenomenon. Moreover, Durnin and two colleagues at the same university, J.J. Miceli and J.H. Eberly, have been able to construct in the laboratory a realization of Durnin's wave (*Phys. Rev. Lett.* **58**, 1499; 1987). Maddeningly, Durnin's account of his discovery, which will no doubt eventually explain how he came by his solution, is cited as "in the press with *J. Opt. Soc. Am.*" (Physicists — and physics journals — are becoming terribly cavalier in this respect, chiefly under the influence of their huge trade in preprints. It seems nowadays quite common that articles based on pre-prints appear in print before the originals that inspired them. It is more unusual that an experiment to confirm the correctness of a theory should appear in advance of the explanation. But either way, the practice is confusing.)

Not unexpectedly, the beam is really rather special. The intensity is far from uniform across the cross-section of the beam but, rather, consists of a relatively intense central spot surrounded by an infinite series of annular rings of light whose intensity is inversely proportional to their radius (measured from the central spot). The fact that this description may be reminiscent of the diffraction plates by means of which the high-definition Schmidt sky-cameras are constructed is far from coincidental; in both cases, the trick is a solution of the wave equation which, in cylindrical coordinates, represents a beam travelling along the axial direction z; the solution of interest is then the product of an oscillatory function of z and the Bessel function of the first kind of zeroth order, known in the trade as $J_0(ar)$, where a is a constant and r is the off-axis distance.

The most striking feature of this beam profile is that it represents a sharp central peak surrounded by a sequence of oscillations which tail off to zero inversely with the distance. The half-width of the central spot is inversely proportional to the constant a. It simply requires a little differentiation to show that the function is indeed a solution of the wave equation. But the fact that the oscillatory function of z is multiplied in the solution by a function of the radius only shows that the profile of the beam is literally unchanged on propagation, at least so long as the space in which the wave is travelling is for practical purposes infinite.

How to realize this state of affairs in the laboratory? What Durdin and his colleagues have done is to place an annular slit illuminated by well-collimated light in the focal plane of a lens of comparable dimensions. The slit must not be so narrow as to cause diffraction effects on its own account nor so wide as to confuse the lens. The output from the lens is a conical band of light. Direct measurement shows that the on-axis beam will propagate for roughly 1 m (under the conditions of the experiment) without substantial degradation of the central spot (whereafter it quickly falls to zero). Direct measurement has shown that a comparable spot-like beam with a gaussian profile decreases in intensity by an order of magnitude in a few centimetres.

The immediate application of this development is in those circumstances in which it is sought to make laser beams travel vast distances with undiminished intensity. It is worth noting that a perfectly collimated wave from a 2-cm diameter laser will have lost much of its central intensity after travelling for 1 km in a vacuum. Because the distance increases with the square of the radius, the modestly larger instruments have markedly better performance, but if it is in practice possible to enhance the distance over which the central intensity is not degraded by something like a factor of 100 by an appropriate shaping of the beam, many now impractical tasks will be possible (or present jobs can be done with smaller instruments). Curiously enough, there is no reference to the Strategic Defense Initiative among the references.

One curious problem remains. One of the other lessons learned at school is that the diffraction of a beam of finite cross-section is not merely an annoying consequence of Huygens' principle but a consequence of Heisenberg's uncertainty principle. But Durnin and his colleagues appear to have improved on that by a factor of a hundred or thereabouts. What can be the explanation? The authors provide the answer off their own bat: the explanation is that, although the central and practically important feature of the Bessel beam is its narrow central spot, the outlying annular rings of light intensity imply that the beam is, for practical purposes, infinite in its lateral dimensions. Both Huygens and Heisenberg survive.

John Maddox