

# Thomas M. Crawford

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Objective To inspire a diverse team of students and faculty to make new discoveries and drive fundamental innovation in single spin nanotechnology.

Education

- Ph.D. Physics 1997 University of Colorado Boulder, CO
- M.S. Physics 1995 University of Colorado Boulder, CO
- B.S. Physics 1992 Haverford College Haverford, PA

Experience 2005-Present – University of South Carolina, Columbia, SC  
Associate Professor, Physics and Astronomy and USC NanoCenter

1999-2005 - Seagate Research, Pittsburgh, PA

Research Staff Member

- Developed <1 nm stability metrology for magnetic recording technology characterization.
- Implemented ultrafast metrology for studying magnetic films and devices designed for magnetic recording at > 1 Gbit/sec data rates.
- Conducted groundbreaking research on spin wave excitations in patterned ferromagnetic elements.
- Characterized advanced recording head designs for 100 Gbit/in<sup>2</sup> and 1 Tbit/in<sup>2</sup> magnetic recording technology, (90 and 40 nm critical dimensions).
- Invented new technologies for extending the storage density and data rate of magnetic recording systems.
- Project leader for heads metrology, with a \$3.1M metrology tool budget, as part of implementing a recording head wafer fabrication line at Seagate Research.

1997-1999 – National Institute of Standards and Technology (NIST),  
Boulder, CO

National Research Council Postdoctoral Associate

- Demonstrated coherent control over magnetization dynamics at <1 ns timescales for achieving optimal switching speeds in magnetic devices.
- Studied interface magnetostriction in magnetic multilayers.
- Implemented new metrologies to identify fundamental limits to magnetic recording at nanometer length and picosecond time scales.

Awards

- Seagate Outstanding Technical Contributions award 2000, 2002
- Seagate Key Contributor award 2000, 2002, 2003
- National Research Council Postdoctoral Associateship 1997
- NIST Professional Research Experience Program Fellowship 1995

## **Learned Society Memberships**

### IEEE

IEEE Magnetics Society  
IEEE Lasers and Electro-Optics Society

### American Physical Society

Division of Condensed Matter Physics  
Forum on Industrial and Applied Physics  
Forum on Physics and Society  
Topical Group on Magnetism and its Applications

### American Society for Precision Engineering

### Sigma-Xi

Inducted in 1993, full member in 1995

### South Carolina Academy of Science

Member since 2006

## Publications

1. T. M. Crawford, R. J. M. van de Veerdonk, M. D. Bedillion, W. Koelmans, A. K. Langzettel, B. P. O'Connor, B. Novotnak, and B. Lane *Seven-axis tester with servo-controlled fly-height for magnetic recording metrology*. Proc. Of ASPE October 2006.
2. M. R. Fitzsimmons, T. J. Silva, and T. M. Crawford. *Surface oxidation of Permalloy thin films*. Phys. Rev. B **73** 014420 (2006).
3. M. Covington, Y. Yang, T. M. Crawford, N. J. Gokemeijer, and M. A. Seigler, *Magnetization dynamics driven by spin momentum transfer*. Proc. SPIE Int. Soc. Opt. Eng. **5843** 11 (2005).
4. N. J. Gokemeijer, T. W. Clinton, T. M. Crawford, and M. Johnson, *Direct Measurement of Magnetic Recording Head Field Using a Microscopic InAs Hall Sensor on a Contact Write/Read Tester*. J. Magn. Magn. Mat. **290** 254 (2005).
5. N. J. Gokemeijer, T. W. Clinton and T. M. Crawford, and M. Johnson, *Recording head metrology at sub-100 nm device dimensions*. J. Appl. Phys. **97**, 083912 (2005)
6. J. Moritz, B. Dieny, J. P. Nozieres, R. J. M. van de Veerdonk, T. M. Crawford and D. Weller, *Magnetization dynamics and thermal stability in patterned media*. Appl. Phys. Lett. **86**, 063512 (2005).
7. S. Tamaru, J. A. Bain, R. J. M. van de Veerdonk, T. M. Crawford, M. Covington and M. H. Kryder, *Measurement of magnetostatic mode excitation and relaxation in Permalloy films using scanning Kerr imaging*. Phys. Rev. B **70** 104416 (2004).
8. Y. Ding, T. J. Klemmer and T. M. Crawford, *A coplanar waveguide permeameter for studying high frequency properties of soft magnetic materials*. J. Appl. Phys. **96** (5), p. 2969. (2004).
9. J. Moritz, L. Buda, B. Dieny, J. P. Nozieres, R. J. M. van de Veerdonk, T. M. Crawford and D. Weller, *Writing and reading bits on pre-patterned media*. Appl. Phys. Lett., **84**(9): p. 1519. (2004).
10. T. M. Crawford, M. Covington and G. J. Parker, *Time-domain excitation of quantized magnetostatic spin-wave modes in patterned NiFe thin film ensembles*. Phys. Rev. B, **67**: p. 024411. (2003).
11. M. Covington, T. M. Crawford and G. J. Parker, *Time-resolved measurement of propagating spin waves in ferromagnetic thin films*. Phys. Rev. Lett., **89**(23): p. 237202. (2002).

12. S. Tamaru, J. A. Bain, R. J. M. van de Veerdonk, T. M. Crawford, M. Covington and M. H. Kryder, *Imaging of quantized magnetostatic modes using spatially resolved ferromagnetic resonance*. J. Appl. Phys., **91**(10): p. 8034. (2002).
13. M. K. Minor, T. M. Crawford, T. J. Klemmer, Y. Peng and D. E. Laughlin, *Stress dependence of soft, high moment and nanocrystalline FeCoB films*. J. Appl. Phys., **91**(10): p. 8453. (2002).
14. G. Ju, R. J. M. van de Veerdonk, S. Tamaru, T. M. Crawford, G. Parker, Y. Kubota, M. L. Wu, S. Batra, D. Weller and J. A. Bain, *High frequency dynamics of the soft underlayer in perpendicular magnetic recording*. J. Appl. Phys., **91**(10): p. 8052. (2002).
15. S. Batra, M. Covington, T. M. Crawford, B. Crue, P. A. A. van der Heijden, J. Jayashankar, E. C. Johns, M. H. Kryder, K. Minor, R. Rottmayer, U. Tran and J. West, *A perpendicular write head design for high-density recording*. IEEE Trans. Magn., **38**(1): p. 157. (2002).
16. T. D. Leonhardt, R. J. M. van de Veerdonk, P. A. A. van der Heijden, T. W. Clinton and T. M. Crawford, *Comparison of perpendicular and longitudinal magnetic recording using a contact write/read tester*. IEEE Trans. Magn., **37**(4): p. 1580. (2001).
17. T. M. Crawford, P. Kabos and T. J. Silva, *Coherent control of precessional dynamics in thin film permalloy*. Appl. Phys. Lett., **76**(15): p. 2113. (2000).
18. S. E. Stupp, M. A. Baldwinson, P. McEwen, T. M. Crawford and C. T. Rogers, *Thermal asperity trends*. IEEE Trans. Magn., **35**(2): p. 752. (1999).
19. T. J. Silva, C. Lee, T. M. Crawford and C. T. Rogers, *Inductive measurement of ultrafast magnetization dynamics in thin Permalloy films*. J. Appl. Phys., **85**(11): p. 7849. (1999).
20. T. J. Silva and T. M. Crawford, *Methods for determining switching speeds in magnetic head materials*. IEEE Trans. Magn., **35**(2): p. 671. (1999).
21. G. Sandler, H. N. Bertram, T. J. Silva and T. M. Crawford, *Origins of the damping constant in thin NiFe films*. J. Appl. Phys., **85**(8): p. 5080. (1999).
22. S. E. Russek, T. M. Crawford and T. J. Silva, *Study of NiFe/Al/Al<sub>2</sub>O<sub>3</sub> heterostructures by the second-harmonic magneto-optic Kerr effect*. J. Appl. Phys., **85**(8): p. 5273. (1999).
23. T. M. Crawford, T. J. Silva, C. W. Teplin and C. T. Rogers, *Subnanosecond magnetization dynamics in thin NiFe films observed using the second-harmonic magneto-optic Kerr effect*. Appl. Phys. Lett., **74**(22): p. 3386. (1999).

24. T. M. Crawford, C. T. Rogers, T. J. Silva and Y. K. Kim, *Nonlinear optical investigations of magnetic heterostructures*. J. Appl. Phys., **81**(8): p. 4354. (1997).
25. T. M. Crawford, C. T. Rogers, T. J. Silva and Y. K. Kim, *Second-harmonic magneto-optic Kerr effect from spin-valve test structures and correlation with magnetoresistance response*. IEEE Trans. Magn., **33**(5): p. 3598. (1997).
26. T. M. Crawford, Ph.D. Dissertation, *A nonlinear magneto-optical investigation of magnetic surfaces and interfaces*. Ann Arbor: UMI. (1997).
27. T. J. Silva, T. M. Crawford, C. T. Rogers and Y. K. Kim, *Observation of surface oxide properties by second-harmonic magneto-optic Kerr effect in Ni<sub>81</sub>Fe<sub>19</sub> films*. OSA Technical Digest Series, **11**: p. 299. (1996).
28. T. M. Crawford, C. T. Rogers, T. J. Silva and Y. K. Kim, *Observation of the transverse second-harmonic magneto-optic Kerr effect in Ni<sub>81</sub>Fe<sub>19</sub> films*. Appl. Phys. Lett., **68**(11): p. 1573. (1996).
29. T. M. Crawford, C. T. Rogers, T. J. Silva and Y. K. Kim, *Transverse and longitudinal second-harmonic magneto-optic Kerr effect observed from Ni<sub>81</sub>Fe<sub>19</sub> thin film multilayers*. IEEE Trans. Magn., **32**(5): p. 4087. (1996).
30. T. Crawford, J. Marr, B. Partridge and M. Strauss, *VLA observations of ultraluminous IRAS galaxies: active nuclei or starbursts?* The Astrophysical Journal, **460**: p. 225 (1996).
31. M. D. Matlin, R. S. Gioggia, N. B. Abraham, P. Glorieux and T. Crawford, *Polarization switch in a Zeeman laser in the presence of dynamical instabilities*. Optics Communications, **120**: p. 204. (1995).
32. T. Crawford, *VLA observations of ultraluminous infrared galaxies, in 1991 Undergraduate Symposium on Research in Astronomy*. Williams College: Keck Northeast Astronomy Consortium. (1991).

## Patents

1. G. J. Parker, T. M. Crawford, R. E. Rottmayer, P. A. A. van der Heijden and S. Batra, *Perpendicular magnetic recording head having a reduced field under the return pole and minimal eddy current losses*. Seagate Technology LLC: U. S. # 7,099,121 (2006).
2. T. W. Clinton, T. M. Crawford. *Method and apparatus for precessional switching of the magnetization of a storage medium using a transverse write field*. Seagate Technology LLC: US # 6,985,318 (2006).
3. T. M. Crawford, M. Covington, G. J. Parker. *Magnetic recording head including spatially-pumped spin wave mode writer*. Seagate Technology LLC: US # 6,954,331. (2005).
4. T. M. Crawford, M. Covington, T. W. Clinton. *Photoconductive optical write driver for magnetic recording*. Seagate Technology LLC: US # 6,903,891. (2005).
5. M. Covington, T. M. Crawford. *Magnetization sensor for sensing the write field characteristics of a perpendicular or longitudinal recording head*. Seagate Technology LLC: US # 6,798,624. (2004).
6. M. Covington, T. M. Crawford, G. J. Parker and P. A. A. van der Heijden, *Write head for high anisotropy media*. Seagate Technology LLC: U.S. # 6,785,092. (2004).
7. T. M. Crawford, *Recording head for applying a magnetic field perpendicular to the magnetizations within magnetic storage media*. Seagate Technology LLC: U.S. # 6,717,770. (2004).
8. B. W. Crue, S. Khizroev, D. Litvinov and T. M. Crawford, *Perpendicular magnetic recording head having a flux focusing main pole*. Seagate Technology LLC: U.S. # 6,671,128. (2004).
9. T. M. Crawford, *Recording head with oppositely directed microstrip waveguide conductors to induce a magnetic write field for longitudinal or perpendicular magnetic recording*. Seagate Technology LLC: U.S. # 6,693,768. (2003).

## Invited Talks

1. T. M. Crawford. *Nanoscale magnetism: How far can we go?* Vanderbilt University, VINSE Colloquium, 4/18/07
2. T. M. Crawford. *Nanoscale magnetism: How far can we go?* College of Charleston Physics Department Colloquium 11/7/06.
3. T. M. Crawford. *Seven-axis tester with servo-controlled fly height for magnetic recording metrology* – American Society for Precision Engineering Annual Meeting, Monterey, CA 10/19/06
4. T. M. Crawford. *Nanoscale magnetism: How far can we go?* UAB Physics Department Colloquium 4/14/06.
5. T. M. Crawford. *Nanoscale magnetism: How far can we go?* USC Physical Chemistry seminar series. 2/27/06.
6. T. M. Crawford. *Controlling magnetization dynamics in patterned ferromagnets.* Southeastern Ultrafast Conference, Tallahassee, FL. 1/20/2006.
7. T. M. Crawford. *Making your Ipod hold more songs: Disc drive nanotechnology and its need for metrology.* Seminar at the Center for Precision Metrology, UNC-Charlotte, 2005
8. T. M. Crawford. *Physics of Disc Drives.* Seminar at Key Technologies, Baltimore, MD. 2004.
9. T. M. Crawford. *Fluids in disc drives.* Fluid dynamics class lecture. Haverford College. 2004.
10. T. M. Crawford. *Physics of disc drives.* Senior Seminar/Department colloquium. Haverford College. 2004.
11. T. M. Crawford. *Challenges of advancing disc drive technology.* Penn State Nanomanufacturing Technology Symposium. State College, PA. 2001.
12. T. M. Crawford. *Challenges of advancing disc drive technology.* Carnegie Mellon University, Eta Kappa Nu Engineering Honor Society Seminar Series. Pittsburgh. 2001.
13. T. M. Crawford. *Magnetodynamic excitations in patterned ferromagnetic thin film ensembles.* Materials Research Society Fall Meeting. Boston. 2001.
14. T. M. Crawford. *Ultrafast Magnetization Dynamics.* AVS Magnetic Interfaces and Nanostructures Conference. Seattle, WA. 1999.

15. T. M. Crawford. *Magneto-optical investigations of surfaces and interfaces in magnetic multilayers*. Physics seminar series, Univ. of Colorado, Colorado Springs. Colorado Springs. 1998.
16. T. M. Crawford. *The second-harmonic magneto-optic Kerr effect: applications for interface magnetism, magnetodynamics*. Data Storage Systems Center Seminar Series. Carnegie Mellon University. 1998.
17. T. M. Crawford. *Second-harmonic magneto-optic Kerr effect from magnetic materials*. Y. R. Shen's nonlinear optics group at Univ. of California, Berkeley. Berkeley, CA. 1997.
18. T. M. Crawford. *Second-harmonic magneto-optic Kerr effect from magnetic materials*. Research seminar series: IBM Almaden Research Center. San Jose, CA. 1997.
19. T. M. Crawford. *Nonlinear optical investigations of magnetic heterostructures*. Magnetism and Magnetic Materials Conference. Atlanta, GA. 1996.

#### **Contributed talks and posters**

1. R. Heaton and T. M. Crawford *The Use of Magnetic Recording for Nanoscale Metrology*. American Society for Precision Engineering – Accepted for poster presentation. October, 2007.
2. B. Knaus, S. Garzon, and T. M. Crawford. *Au-thiol magnetism for sensing applications*. Nanoelectronic devices Defense and Security Conference. Crystal City, Virginia. Poster Presentation. 2007.
3. T. M. Crawford. *Reader width metrology beyond 100 Gbit/in<sup>2</sup>*. INTERMAG Conference. Boston. 2003.
4. R. J. M. van de Veerdonk, T. M. Crawford, S. Wang, X. W. Wu, A. K. Langzettel, A. J. L. Febre, S. Batra and D. Weller. *Remanent dynamic coercivity measurements below 1 ns timescales for perpendicular and longitudinal recording media*. Magnetism and Magnetic Materials Conference. Tampa, FL. 2002.
5. M. Patwari, T. M. Crawford, M. Covington and K. Y. Guslienko. *High frequency magnetization dynamics in square and cylindrical NiFe dots*. Magnetism and Magnetic Materials Conference. Tampa, FL. 2002.
6. S. Tamaru, J. A. Bain, R. J. M. van de Veerdonk, T. M. Crawford, M. Covington and M. H. Kryder. *Imaging of quantized magnetostatic modes using spatially*



- resolved ferromagnetic resonance*. INTERMAG Conference. Amsterdam, NL. (This talk was invited) 2002.
7. T. M. Crawford, M. Covington and G. J. Parker. *Controlled Magnetostatic Mode Pumping in Patterned Magnetic Thin Films*. Magnetism and Magnetic Materials Conference. Seattle, WA. 2001.
  8. M. Covington, T. M. Crawford and G. J. Parker. *Propagating spin wave modes in patterned magnetic elements*. Magnetism and Magnetic Materials Conference. Seattle, WA. 2001.
  9. S. Tamaru, J. A. Bain, R. J. M. van de Veerdonk, T. M. Crawford, M. Covington and M. H. Kryder. *Imaging of quantized magnetostatic modes using spatially resolved ferromagnetic resonance*. Magnetism and Magnetic Materials Conference. Seattle, WA. 2001.
  10. T. M. Crawford, M. Covington and G. J. Parker. *Ultrafast magnetization dynamics in micron-scale patterned shapes of thin film Permalloy*. Joint INTERMAG/Magnetism and Magnetic Materials Conference. San Antonio, TX. 2001.
  11. M. K. Minor, T. M. Crawford, T. J. Klemmer, Y. Peng and D. E. Laughlin. *Stress dependence of soft, high moment and nanocrystalline FeCoB films*. Joint INTERMAG/Magnetism and Magnetic Materials Conference. San Antonio, TX. 2001.
  12. T. D. Leonhardt, R. J. M. van de Veerdonk, P. A. A. van der Heijden, T. W. Clinton and T. M. Crawford. *Comparison of perpendicular and longitudinal magnetic recording using a contact write/read tester*. Joint INTERMAG/Magnetism and Magnetic Materials Conference. San Antonio, TX. 2001.
  13. G. Ju, R. J. M. van de Veerdonk, S. Tamaru, T. M. Crawford, G. Parker, Y. Kubota, M. L. Wu, S. Batra, D. Weller and J. A. Bain. *High frequency dynamics of the soft underlayer in perpendicular magnetic recording*. Joint INTERMAG/Magnetism and Magnetic Materials Conference. San Antonio, TX. 2001.
  14. T. M. Crawford, P. Kabos and T. J. Silva. *Coherent control of magnetization dynamics observed using pump-probe magneto-optic sampling with second-harmonic MOKE*. Magnetism and Magnetic Materials Conference. Miami, FL. 1998,
  15. G. Sandler, H. N. Bertram, T. J. Silva and T. M. Crawford. *Origins of the damping constant in thin NiFe films*. Magnetism and Magnetic Materials Conference. Miami, FL. 1998

16. S. E. Russek, T. M. Crawford and T. J. Silva. *Study of NiFe/Al/Al<sub>2</sub>O<sub>3</sub> heterostructures by the second-harmonic magneto-optic Kerr effect*. Magnetism and Magnetic Materials Conference. Miami, FL 1998.
17. T. M. Crawford, P. Kabos and T. J. Silva. *Coherent Control of Magnetization Dynamics in Thin Film Permalloy*. The Magnetic Recording Conference (TMRC) Heads. Boulder, CO. (Poster) 1998.
18. T. M. Crawford. *Coherent Control of Magnetization Dynamics in Thin Film Permalloy*. National Storage Industry Consortium Annual Meeting. Monterey, CA. 1998.
19. T. M. Crawford *Time-resolved magneto-optics of magnetic heterostructures*. Joint INTERMAG/Magnetism and Magnetic Materials Conference. San Francisco, CA. 1998.
20. T. M. Crawford, T. J. Silva, and C. T. Rogers. *A new coplanar waveguide permeameter for time-resolved studies of frequency limits in soft magnetic materials*. NSIC Extremely High Density Recording meeting. Berkeley, CA. 1997.
21. T. M. Crawford. *Second-harmonic magneto-optic Kerr Effect*. NSIC Annual Meeting. Monterey, CA. 1997.
22. T. M. Crawford. *Second-harmonic magneto-optic Kerr effect from spin-valve devices: correlation with magnetoresistance*. American Physical Society March Meeting. Kansas City, MO. 1997.
23. T. M. Crawford. *Surface magnetization dynamics observed using the second-harmonic magneto-optic Kerr effect*. American Vacuum Society - Magnetic Interfaces and Nanostructures. San Jose, CA. 1997.
24. T. M. Crawford, C. T. Rogers, T. J. Silva and Y. K. Kim. *Second-harmonic magneto-optic Kerr effect from spin-valve devices: correlation with magnetoresistance*. INTERMAG conference. New Orleans, LA. 1997.
25. T. M. Crawford. *Nonlinear magneto-optics of magnetic surfaces and interfaces*. American Physical Society March Meeting. St. Louis, MO. 1996.
26. T. M. Crawford and C. T. Rogers. *Transverse and Longitudinal second-harmonic magneto-optic Kerr effect*. (Poster) INTERMAG conference. Seattle. 1996.

### **Research Associate Supervision**

1. Anjan Barman, Ph. D. – 2006. (Research Assistant Professor) – Presently Assistant Professor of Physics at the Indian Institute of Technology, Delhi, India
2. Samir Garzon, Ph. D. 2007- (Research Assistant Professor) – currently in group

### **Graduate Student Advising**

1. **Robert Heaton** – M. S. Physics 2007 – Currently project manager at Space and Naval Warfare Center (SPAWAR), Charleston, SC
2. **David McCree** – M. S. Physics 2007 (expected) (titular advisor) – Currently with Doty Scientific Inc., Columbia, SC
3. **Brad Knaus** – current Ph. D. candidate
4. **Longfei Ye** – current Ph. D. candidate (co-advising with R. A. Webb)
5. **Jonathan Stenbeck** – Graduate Student

### **Undergraduate student research supervision**

1. **Jason Henderson** – Summer 2006
2. **Jonathan Stenbeck** – Summer 2006
3. **Oliver Gothe** – Summer 2006
4. **Kate Drafts** (high school student) – Summer 2006. **Drafts** won 3<sup>rd</sup> place in the written paper competition at the 2007 South Carolina Junior Academy of Science Annual Meeting for her project: “*Effect of deposition rate and angle on nanostructuring of evaporated silver films*”
5. **Josh Hendrickson** – Summer 2007
6. **Ian Baird** (USC Honors College fellowship) Summer 2007
7. **Brandon Eubanks** – Summer 2007