Research Interests of Dr. Paul Danehy

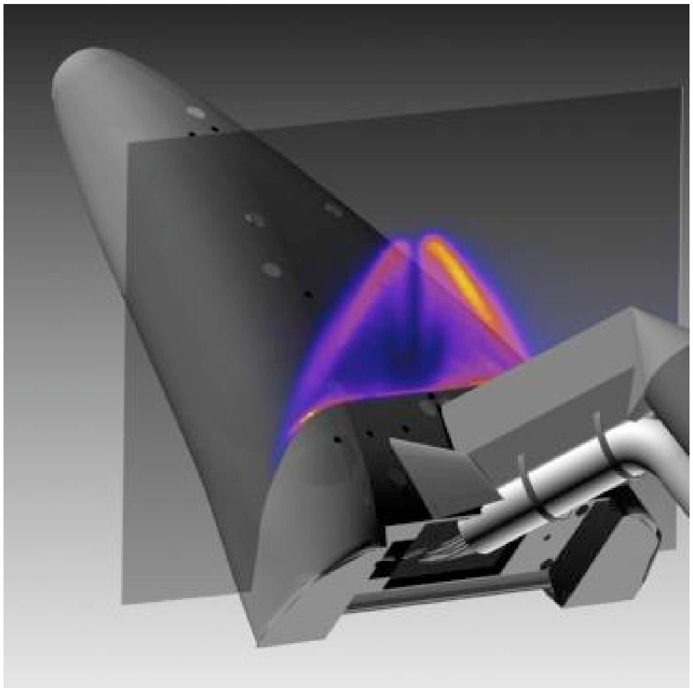
Brief Biography: I'm a research scientist at NASA Langley Research Center, in Hampton Virginia. I'm also an Assistant Adjunct Professor in the Physics Department at College of William and Mary. I lead a group of about 10 NASA employees, contractors, PhD, MS, and undergraduate students and postdocs in developing laser based measurement techniques for NASA applications. Primarily we develop methods for studying hypersonic flow in wind tunnels and combustion. Combustion experiments include both lab-based subsonic combustion experiments and supersonic combustion experiments associated with SCRAMJET engine development in wind tunnels. In 1995 I got my PhD in Mechanical Engineering at Stanford University where I took as many Physics classes as I could. I then spent 5 years as a post-doc and then faculty member in the Physics Department at the Australian National University in Canberra Australia.

My research is Physics based, but has applications in Aerospace and Mechanical Engineering. It also has applications in atmospheric sciences and the medical field. My research involves atomic and molecular spectroscopy, lasers, advanced imaging and image processing, optics, nonlinear optics, statistical mechanics and continuum mechanics (fluid dynamics). This research field presents an opportunity for Physicists to explore the fundamental interaction between light and matter while contributing to NASA's space exploration initiatives. Below are some examples of current research topics, along with a publication list from the group.

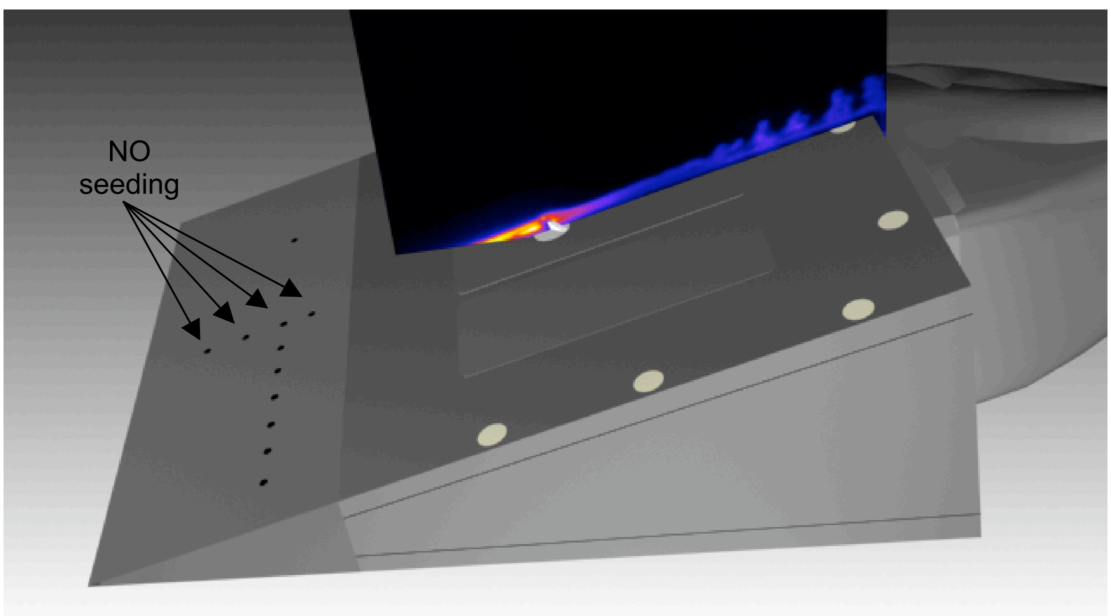
Nitric Oxide Planar Laser-Induced Fluorescence (NO PLIF)

Primary Applications at NASA Langley: Flow visualization, temperature, velocity measurements in hypersonic wind tunnels; contributes to understanding of flow behavior in hypersonic wind tunnels.
Contributions to NASA Programs: Fundamental Aeronautics: Hypersonics, Exploration, Space Shuttle Return-to-Flight Program

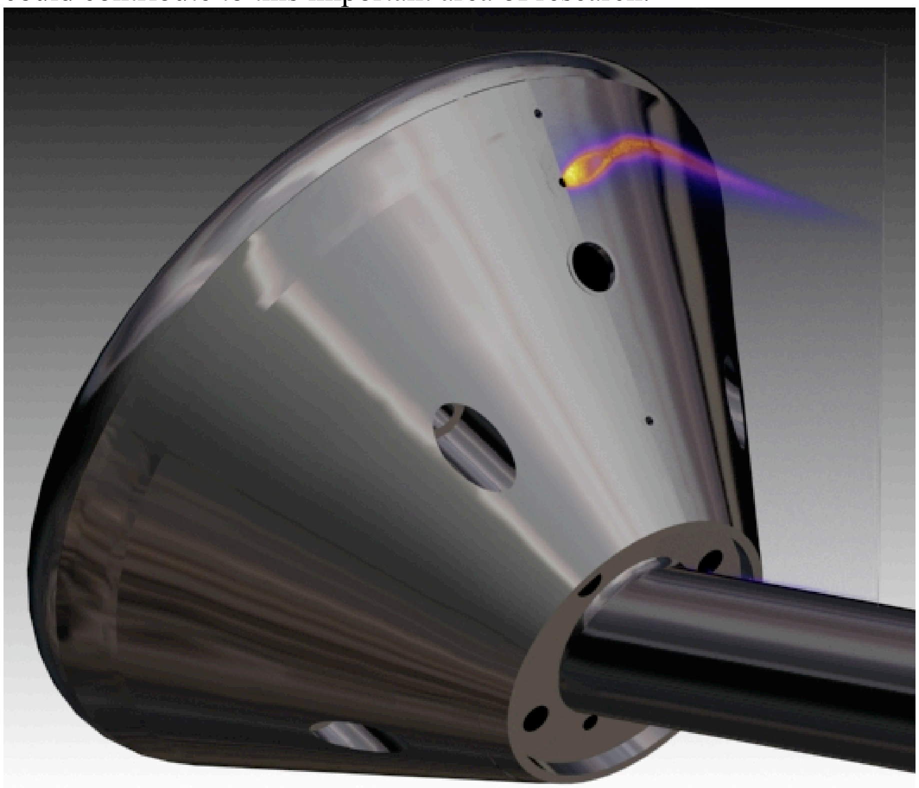
NO PLIF uses a pulsed, tunable UV laser to excite nitric oxide that has been seeded into a hypersonic wind tunnel. The laser beam is formed into a sheet, and an intensified CCD camera images the resulting fluorescence, visualizing of a slice of the flowfield. If the spectroscopy of NO is understood and exploited, quantitative measurements can also be made. Thusfar, we have only scratched the surface of making quantitative measurements using NO PLIF at Langley. Primarily we have used NO PLIF to visualize the transition from laminar to turbulent flow, which is a critically important and poorly understood process that affects many different space vehicles including the Space Shuttle Orbiter and Crew Exploration Vehicle. Current opportunities exist to develop and apply temperature, velocity and pressure imaging methods using NO PLIF. Examples of NO PLIF images are shown below. The PLIF images have been superimposed upon computer renderings of the actual models tested in the wind tunnel.



The figure above shows an experimental image of the upper-surface flow structure on a fuselage-only X-33 wind tunnel model at Mach 10, obtained at NASA Langley Research Center. The nitric oxide was seeded into the tunnel flow from the nose of the model. Flow is from top left to bottom right. The false-color image allows visualization of the counter-rotating wake vortex structure. The image is from Reference 27.



This image, from Reference 22, shows the flow of a trace of NO seeded into the boundary layer flowing over a flat plate with a small protruding 'trip' that forces the flow to transition to from laminar to turbulent. Flow is from left to upper right across the plate. A prior experiment with no trip showed a smooth, laminar flow across the full length of the plate. These trips were designed to simulate conditions of a recent space shuttle flight were a protruding piece of "gap filler" had to be removed in an on-orbit space walk by the astronauts so that the flow would not transition to turbulence prematurely, which might have resulted in the loss of the shuttle due to excessive heating. The above experiment was a recent demonstration experiment, showing how NO PLIF could contribute to this important area of research.

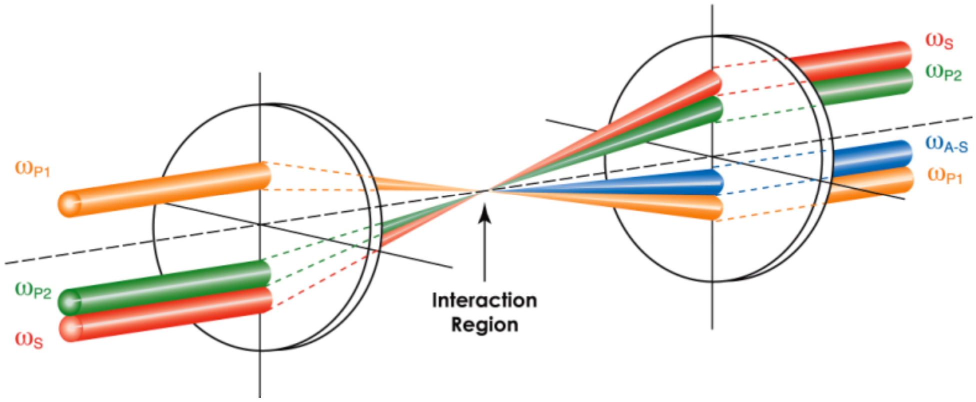


In this image, a "Crew Exploration Vehicle" model, similar to the Apollo command module capsule was tested in a Mach 10 wind tunnel. The false-color plume shows PLIF of NO-seeded nitrogen simulating a Reaction Control System (RCS) Jet use to steer the vehicle during entry. The flow is from top left to bottom right. At higher flowrates, the jet became turbulent. The trajectory, shape and flapping of this jet can be characterized by the NO PLIF method and will be used to compare with aeronautical and aeroheating models used to design the new CEV which will return astronauts from the Moon and Mars.

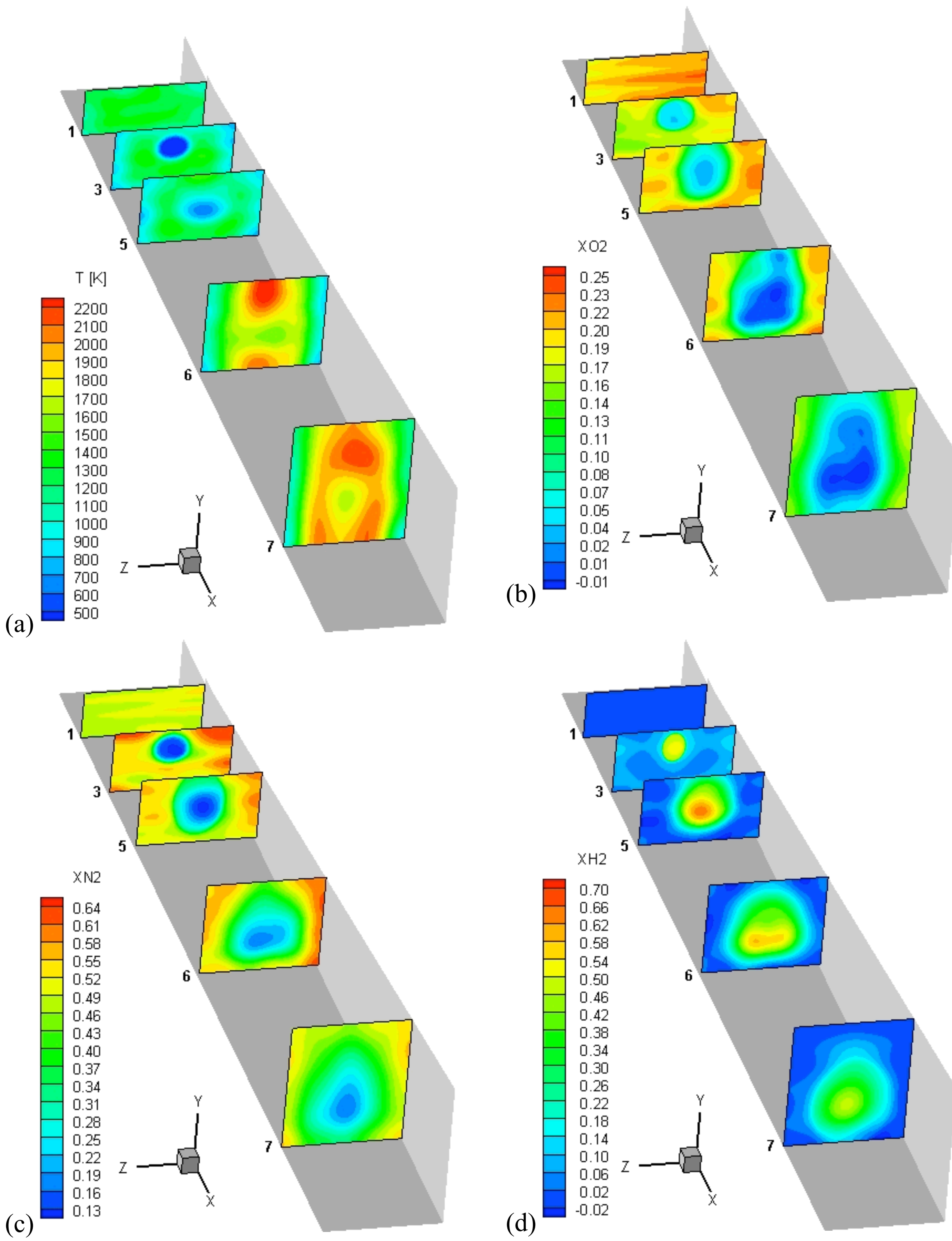
Dual-Pump Coherent Anti-Stokes Raman Spectroscopy (DP-CARS)

<u>Primary Applications at NASA Langley</u>: temperature and composition measurements in combustion flows, especially in supersonic combustion applicable to scramjet engines; provides quantitative data for developing new chemistry and turbulence models for predicting supersonic combustion and building scramjet-powered vehicles.
<u>Contributions to NASA Programs</u>: Fundamental Aeronautics: Hypersonics

The DP-CARS technique is a nonlinear optical technique in which three laser beams cross, focus and interact with a gas flow to generate a fourth laser beam which is analyzed to determine the temperature and composition of a flowfield at the crossing point. An important feature of this method is that all the interacting beams are, in fact, spatially coherent laser beams, so the technique can be used to make remote measurements in conditions where there is limited optical access, for example in ducts through thin, slotted windows, such as scramjet engines.



In our current use, the three input beams are yellow, green and red. The red beam is spectrally broadband while the yellow and green are spectrally narrow. The combination of the yellow and red beams probe O_2 Raman resonances, while the combination of green and red beams probe N_2 Raman resonances. Both pairs of beams also probe H_2 resonances and all three beams are required to complete the CARS process. The spectrally broad blue beam then contains information about the concentration of N_2, O_2 and H_2 as well as the temperature (from the shape of these spectra).



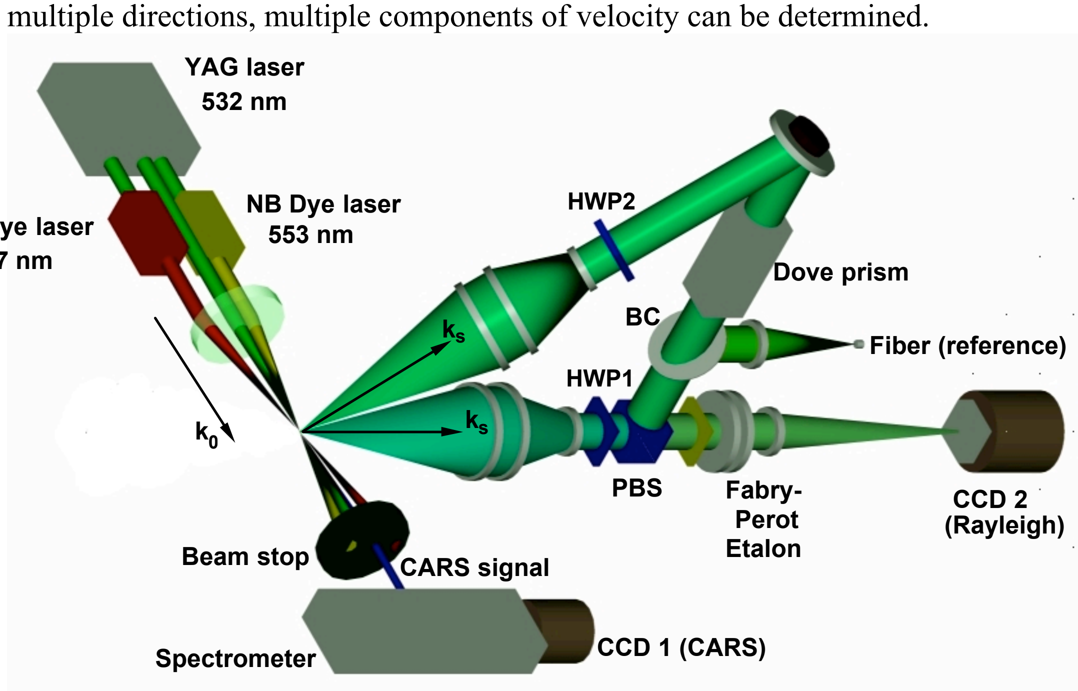
Plots of (a) mean temperature (b) mean O_2 mole fraction, (c) mean N_2 mole fraction, (d) mean H_2 mole fraction at Mach 7 enthalpy for the vectored-fuel-injection case (Reference 35).

The figure above shows how DP-CARS mapped the temperature and composition fields in a supersonic combustor. Flow is from top left to bottom right. Hot air enters the duct at the top left, cold H_2 fuel is injected from the top wall and then burns as the flow propagates downstream, elevating the temperature. These data have been used by several research groups around to world to test and improve their computational methods.

Interferometric Rayleigh Scattering (IRS)

Primary Applications at NASA Langley: multi-point, multi-component velocity measurements in any flows, temperature and density measurements flows with known composition; provides quantitative data for developing new and turbulence models and for detailed understanding of hypersonic flows.
Contributions to NASA Programs: Fundamental Aeronautics: Hypersonics and Supersonics

The IRS method uses a single laser beam to generate Rayleigh scattering (the strongest from of scattering from a clean gas). An interferometer is used to analyze the Rayleigh scattering spectrum. This spectrum shows thermal broadening of the scattered light caused by the scattering of the monochromatic laser light off the randomly-moving molecules. This allows the temperature to be measured. The intensity of the scattering is proportional to the gas density, allowing density to be measured. If the gas has a non-zero velocity, the Rayleigh spectrum will be Doppler shifted from the simultaneously measured reference light. Thus, the velocity can be measured. If the laser light is viewed from multiple directions, multiple components of velocity can be determined.



We have recently combined the IRS method with CARS. The combined setup is shown in the above figure from Reference 26. The IRS system is shown on the right side of the image while CARS is shown on the left. This system measures temperature, composition and 2 components of the gas velocity. It is optimized to study high-temperature supersonic combustion flows.

Recent Publications (Since 2000):

(preprints of many of these publications can be downloaded from the NASA Technical Report Server (NTRS): http://ntrs.nasa.gov/)

Refereed Journal Publications:

1. S. O'Byrne, P. M. Danehy, S. A. Tedder, and A. D. Cutler, "Dual-Pump Coherent Anti-Stokes Raman Scattering Measurements in a Supersonic Combustor" AIAA Journal (in press).
2. D. Bivolaru, P. M. Danehy and J. W. Lee, "Intracavity Rayleigh-Mie scattering for multipoint two-component velocity measurement", Optics Letters, Vol. 31, No. 11 p. 1645-1647, June (2006).
3. S. O'Byrne, P. M. Danehy, A. F. P. Houwing, Investigation of hypersonic nozzle flow uniformity using NO fluorescence, Shock Waves Journal, May, Pages 1 - 7, DOI 10.1007/s00193-006-0013-6, URL http://dx.doi.org/10.1007/s00193-006-0013-6 (2006).
4. D. W. Alderfer, G. C. Herring, P. M. Danehy, T. Mizukaki, and K. Takayama, "Submicrosecond temperature measurement in liquid water with laser-induced thermal acoustics", Appl. Opt. Vol. 44, No. 14, 10 May, pp. 2818-2826 (2005).
5. J.G. Smith Jr., J.W. Connell, K.A. Watson, and P. M. Danehy, "Optical and thermo-optical properties of space durable polymer/carbon nanotube films: Experimental results and empirical equations", Polymer, v. 46 n. 7, pp 2276-2284 (2005).
6. A. A. Dorrington, T. W. Jones, P. M. Danehy, R. S. Pappa, "Laser-induced fluorescence photogrammetry for dynamic characterization of transparent and aluminized membranes" AIAA Journal, vol. 42, no. 10, 1 Oct., pp. 2124-2129 (2004).
7. A. A. Dorrington, T. W. Jones and P. M. Danehy "Photophysics of Laser Dye-Doped Polymer Membranes for Laser-Induced Fluorescence Photogrammetry,"Applied Optics, Vol. 43, No. 36, Dec. 20, p. 6629-6638 (2004).
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9. P. C. Palma, P. M. Danehy, A. F. P. Houwing, "Fluorescence Imaging of Rotational and Vibrational Temperature in a Shock Tunnel Nozzle Flow," AIAA Journal, Vol. 41, no. 9, Sept. p. 1722-1732 (2003).
10. R. S. Pappa, J. T. Black, J. R. Blandino, T. W. Jones, Paul M. Danehy, and Adrian A. Dorrington, "Dot-Projection Photogrammetry and Videogrammetry of Gossamer Space Structures" Journal of Spacecraft and Rockets, Vol. 40 No. 6, pp. 858-867, Nov-Dec (2003).
11. R. P. Lucht, V. V. Natarajan, C. D. Carter, K. D. Grinstead Jr., J. R. Gord, P. M. Danehy, G. J. Fiechtner, R. L. Farrow, "Dual-pump coherent anti-Stokes Raman scattering temperature and CO_2 concentration measurements," AIAA Journal Vol. 41, No. 4, April p. 679-686 (2003).
12. P. M. Danehy, S. O'Byrne, A.F.P. Houwing, J.S. Fox, D.R. Smith "Flow-tagging velocimetry for hypersonic flows using fluorescence of nitric oxide," AIAA Journal v. 41, n. 2, p. 263-271 (2003).
13. M. J. Gaston, A.F.P. Houwing, N.R. Mudford, P.M. Danehy, J.S. Fox, "Fluorescence imaging of mixing flowfields and comparisons with computational fluid dynamic simulations" Shock Waves Journal v. 12, n. 2, p. 99-110 (2002).
14. D.-H. Yu, J.-H. Lee, J.S. Chang, J.-S. Ryu, J.W. Hahn, P.M. Danehy, "Effects of laser beam temporal pulse shape on the signal strength and spectral line-shape of forward degenerate four-wave mixing," J. Opt. Soc. Am. B, 18(8), 1111-1118, (2001).
15. P. M. Danehy; P. Mere; M. J. Gaston; S. O'Byrne; P. C. Palma; A. F. P. Houwing "Fluorescence Velocimetry of the Hypersonic, Separated Flow over a Cone," AIAA Journal, v. 39(7), p. 1320-1328 (2001).
16. J. S. Fox; S. O'Byrne; A. F. P. Houwing; A. Papinniemi; P. M. Danehy; N. R. Mudford**, "**Fluorescence Visualization of Hypersonic Flow Establishment over a Blunt Fin," AIAA Journal, v. 39(7), p. 1329-1337 (2001).
17. A.A. Dorrington, R. Künnemeyer, P.M. Danehy, "Reference beam storage for long-range low-coherence pulsed Doppler LIDAR", Applied Optics-LP, Vol. 40(18), 3076-3081 (2001).
18. A.F.P. Houwing, D.R. Smith, J.S. Fox, P.M. Danehy and N.R. Mudford, "Laminar boundary layer separation at a fin-body junction in a hypersonic flow" Shock Waves Journal , Vol. 11(1), pp. 31-42, (2001).
19. J. S. Fox, A. F. P. Houwing, P. M. Danehy, M. J. Gaston, N. R. Mudford, S. L. Gai, "Mole-Fraction-Sensitive Imaging of Hypermixing Shear Layers," Journal of Propulsion and Power, Journal of Propulsion and Power, 17(2), p. 284-292, (2001).

20. M. Gutfleisch, D.I. Shin, T. Dreier, P.M. Danehy, “Mid-infrared laser-induced grating experiments of C_2H_4 and NH_3 from 0.1-2 MPa and 300-800 K”, Applied Physics B, Vol. 71, p, 673-680 (2000).
21. P. C. Palma, S. G. Mallinson, S. B. O’Byrne, P. M. Danehy, and R. Hillier, "Temperature measurements in a hypersonic boundary layer using planar laser-induced fluorescence," AIAA Journal, Vol. 38, No. 9, p. 1769-1772 (2000).

Full-Length Conference Publications

† awarded “best paper” at conference

§ awarded “outstanding paper” at conference

* indicates invited paper for first named author

22. P.M. Danehy, A.P. Garcia, S. Borg, A.A. Dyakonov, S.A. Berry, J.A. Wilkes Inman, D.W. Alderfer, "Fluorescence visualization of hypersonic flow past triangular and rectangular boundary-layer trips", AIAA-2007-0536, 45th AIAA Aerospace Sciences Meeting, Reno Nevada, January 8-11 (2007).
23. S. Tedder, D. Bivolaru, P. M. Danehy, M.C. Weikl, F. Beyrau, T. Seeger, A. D. Cutler “Characterization of a Combined CARS and Interferometric Rayleigh Scattering System”, AIAA Paper 2007-0871, 45th AIAA Aerospace Sciences Meeting and Exhibit, Reno, Nevada, January 8-11 (2007).
24. A. D. Cutler, G. Magnotti, R. Baurle , D. Bivolaru , S. Tedder , P. M. Danehy, M.C. Weikl, F. Beyrau, and T. Seeger, “Development of Supersonic Combustion Experiments for CFD Modeling”, AIAA Paper 2007-0978, 45th AIAA Aerospace Sciences Meeting and Exhibit, Reno, Nevada , January 8-11 (2007).
25. D.W. Alderfer, P.M. Danehy, J.A. Wilkes Inman, K.T. Berger, G.M. Buck, and R. J. Schwartz, “Fluorescence Visualization of Hypersonic Flow Over Rapid Prototype Wind-Tunnel Models” AIAA Paper 2007-1063 45th AIAA Aerospace Sciences Meeting and Exhibit, Reno, Nevada, Jan. 8-11 (2007).
26. D. Bivolaru, P. M. Danehy, K. D. Grinstead, Jr., S. Tedder, A. D. Cutler, “Simultaneous CARS and Interferometric Rayleigh Scattering” AIAA AMT-GT Technology Conference, San Francisco, AIAA-2006-2968 June (2006).
27. *§P. M. Danehy, J. A. Wilkes, D. W. Alderfer, S. B. Jones, A. W. Robbins, D. P. Patry and R. J. Schwartz “Planar laser-induced fluorescence (PLIF) investigation of hypersonic flowfields in a Mach 10 wind tunnel” AIAA AMT-GT Technology Conference, San Francisco, AIAA-2006-3442 June, (2006).
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29. D. Bivolaru, P. M. Danehy, J. W. Lee and R. Gaffney, A. D. Cutler, “Single-Pulse Multi-point Multi-Component Interferometric Rayleigh Scattering Velocimeter” AIAA Paper 2006-836 44th AIAA Aerospace Sciences Meeting and Exhibit, Reno, Nevada, Jan. 9-12, 2006.
30. J. A. Wilkes, C. Glass, P. M. Danehy and R. J. Nowak, “Fluorescence Imaging of Underexpanded Jets and Comparison with CFD” AIAA Paper 2006-910 44th AIAA Aerospace Sciences Meeting and Exhibit, Reno, Nevada, Jan. 9-12, 2006.
31. J. A. Wilkes, P. M. Danehy, and R. J. Nowak, "Fluorescence Imaging Study of Transition in Underexpanded Free Jets" 21st International Congress on Instrumentation in Aerospace Simulation Facilities, Sendai, Japan, Aug. 29-Sept. 1, 2005.
32. *P. M. Danehy, S. O’Byrne, S. Tedder, A. D. Cutler “Coherent Anti-Stokes Raman Spectroscopy (CARS) Measurements in Supersonic Combustors at NASA Langley Research Center”, JANNAF 40th CX/ 28th APS / 22nd PSHS / 4th MSS Joint Meeting, Charleston, South Carolina, June 13-17, 2005.
33. P. M. Danehy, J. R. Gord, F. Grisch, D. Klimenko and W. Clauss “CARS Temperature and Species Measurements For Air Vehicle Propulsion Systems”, presented at the NATO Research and Technology Organization (RTO) AVT-124 Specialist Session on “Recent Developments in Non-Intrusive Measurement Technology for Military Application on Model-and Full-Scale Vehicles”, Budapest, Hungary, April 25-28, 2005.
34. J. M. Wells, T. W. Jones, P. M. Danehy, “Polarization and Color Filtering Applied to Enhance Photogrammetric Measurements of Reflective Surfaces,” 46th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics & Materials Conference, Austin, Texas, AIAA-2005-1887, April 18-21, 2005.

35. S. A. Tedder, S. O'Byrne, P. M. Danehy, A. D. Cutler "CARS Temperature and Species Concentration Measurements in a Supersonic Combustor with Normal Injection", AIAA Paper 2005-0616, 43rd Aerosciences Meeting and Exhibit, Reno NV, Jan 10-13, 2005.
36. A. D. Cutler, B, T. Beck, J. A. Wilkes, J. P. Drummond, D. W. Alderfer, P. M. Danehy, "Development of a pulsed combustion actuator for high-speed flow control," AIAA Paper 2005-1084, 43rd Aerosciences Meeting and Exhibit, Reno NV, Jan 10-13, 2005.
37. *P. M. Danehy and D. W. Alderfer, "Survey of Temperature Measurement Techniques for Studying Underwater Shock Waves", Proceedings of the International Symposium of Interdisciplinary Shock Wave Research, ISISW, Matsushima, Sendai, Japan, March 22-24, 2004, p. 95-104.
38. A. A. Dorrington, T. W. Jones, P. M. Danehy, R. S. Pappa, "Membrane vibration analysis above the Nyquist limit with fluorescence videogrammetry", SEM X Congress, June, 2004.
39. S. O'Byrne, P. M. Danehy, A. D. Cutler, "Dual-Pump CARS Thermometry and Species Concentration Measurements in a Supersonic Combustor," AIAA Paper 2004-0710, 42nd Aerosciences Meeting and Exhibit, Reno NV, Jan 5-8, 2004.
40. A. D. Cutler, P. M. Danehy, S. O'Byrne, C. G. Rodriguez, J. P. Drummond "Supersonic combustion experiments for CFD model development and validation," AIAA Paper 2004-0266, 42nd Aerosciences Meeting and Exhibit, Reno NV, Jan 5-8, 2004.
41. P. M. Danehy, S. O'Byrne, A. D. Cutler, C. G. Rodriguez, "Coherent Anti-Stokes Raman Scattering (CARS) as a Probe for Supersonic Hydrogen-Fuel/Air Mixing," JANNAF APS/CS/PSHS/MSS Joint Meeting, Colorado Springs, CO, Dec. 1-5, 2003.
42. J. A. Wilkes, D. W. Alderfer, S. B. Jones, and P. M. Danehy "Portable fluorescence imaging system for hypersonic flow facilities," JANNAF APS/CS/PSHS/MSS Joint Meeting, Colorado Springs, CO, Dec. 1-5, 2003.
43. A. B. Gojani, P. M. Danehy, D. W. Alderfer, T. Saito, K. Takayama, "Development of laser-induced grating spectroscopy for underwater temperature measurement in shock wave focusing regions," SPIE International Symposium on Optical Systems Design, Saint-Etiennes, France, September 2003.
44. S. O'Byrne, P. M. Danehy, A. D. Cutler, **"**$N_2/O_2/H_2$ Dual-pump CARS: validation experiments" 20th International Congress on Instrumentation in Aerospace Simulation Facilities, August, 2003.
45. S. O'Byrne, P. M. Danehy, A. F. P. Houwing, **"**PLIF temperature and velocity distributions in laminar hypersonic flat-plate flow" 20th International Congress on Instrumentation in Aerospace Simulation Facilities, August, 2003.
46. A. A. Dorrington, T. W. Jones, P. M. Danehy, R. S. Pappa, "Laser-induced fluorescence photogrammetry for dynamic characterization of transparent and aluminized membranes", 39th AIAA Joint Propulsion Conference, Huntsville Alabama, AIAA Paper 2003-4798, July 2003.
47. *P. M. Danehy, A. A. Dorrington, A. D. Cutler, R. DeLoach, "Response Surface Methods for Spatially-Resolved Optical Measurement Techniques", AIAA Ground Testing Conference, Reno NV, AIAA Paper 2003-0648, January 2003.
48. R. S. Pappa, J. T. Black, J. R. Blandino, T. W. Jones, Paul M. Danehy, and Adrian A. Dorrington, "Dot-Projection Photogrammetry and Videogrammetry of Gossamer Space Structures", 21st International Modal Analysis Conference (IMAC XXI), Kissimmee, Florida, February 3-6, 2003.
49. Thomas W. Jones, Adrian A. Dorrington, Paul L. Brittman, Paul M. Danehy, "Laser-Induced Fluorescence for Photogrammetric Measurement of Transparent or Reflective Aerospace Structures", 49th International Instrumentation Symposium, Orlando Florida, May 2003.
50. P.M. Danehy, R. DeLoach, A.D. Cutler, "Application of Modern Design of Experiments to CARS Thermometry in a Supersonic Combustor", AIAA Paper 2002-2914, June 2002.
51. S. O'Byrne, P.M. Danehy and A.F.P. Houwing, "Nonintrusive Temperature and Velocity Measurements in a Hypersonic Nozzle Flow", 22nd AIAA Aerodynamic Measurement Technology and Ground Testing Conference, St Louis, MI AIAA Paper 2002-2917 June 2002.
52. A.D. Cutler, G.S. Diskin, P.M. Danehy, J.P. Drummond Fundamental Mixing and Combustion Experiments for Propelled Hypersonic Flight 38th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, AIAA-2002-3879, July 2002.
53. Cutler, A.D., Danehy, P.M., Springer, R.R., DeLoach, R., Capriotti, D.P., "CARS Thermometry in a Supersonic Combustor for CFD Code Validation," AIAA Paper 2002-0743, 2002.
54. E. Fraval, P. M. Danehy, A.F.P. Houwing, "Single-Shot Broadband Coherent Anti-Stokes Raman Scattering Measurements in a Free Piston Shock Tunnel Nozzle Expansion," in Proceedings of 23rd International Symposium on Shock Waves, Fort Worth, Texas, Published by The University of Texas at Arlington, Arlington, Texas, USA. (CD ROM), p. 396-402, pap. num. 1717, July 22-27 (2001).
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56. S. O'Byrne, P. M. Danehy, A.F.P. Houwing, S. Mallinson, P. Palma, "Temperature and Velocity Measurements in a Hypersonic Boundary Layer," in Proceedings of 23rd International Symposium on Shock Waves, Fort Worth, Texas, Published by The University of Texas at Arlington, Arlington, Texas, USA. (CD ROM), p. 1595-1601, pap. num. 1720, July 22-27 (2001).
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58. R. P. Lucht,, V. N. Velur, G. J. Fiechtner, C. D. Carter, K. D. Grinstead Jr., J. R. Gord, P. M. Danehy, R. L. Farrow, "Measurements of temperature and CO_2 concentration by dual-pump coherent anti-Stokes Raman scattering," AIAA Paper 2001-0417 (2001).
59. F. P. Houwing, D. R. Smith, J. S. Fox, P. M. Danehy, N. R. Mudford, "Fluorescence imaging and velocimetry of laminar separation at a fin-body junction in a hypersonic flow", Proceedings from SPIE, the International Society for Optical Engineering, No. 4183 [4183-97], p. 807-818 (2001).

Invention Disclosures (first step in patent process):

60. D. Bivolaru, P. M. Danehy, J. W. Lee, "Multi-Point, Multi-Component Interferometric Rayleigh/Mie Doppler Velocimeter", NASA disclosure of invention and new technology (including software), LAR-17235-1 (2005). (Patent Application Submitted)
61. A. A. Dorrington, P. M. Danehy, T.W. Jones, R. S. Pappa, J. W. Connell, W. K. Belvin, "Thin, High-contrast Targets for Ultralightweight Structures", NASA disclosure of invention and new technology (including software), LAR-16858-1, (2004). (Patent Application Submitted)
62. A. A. Dorrington, P. M. Danehy, T.W. Jones, R. S. Pappa, J. W. Connell, "Measurement system for in-space gossamer structure deployment", NASA disclosure of invention and new technology (including software), LAR-16596-1, (2003).
63. P. M. Danehy, A. A. Dorrington. "Micro-LiDAR for In-Flight Flow Velocimetry and Boundary Layer Control", NASA disclosure of invention and new technology (including software), LAR 16538-1, (2002).**
64. P. M. Danehy, T. W. Jones, J Connell, K. Belvin, K. A. Watson, "Photogrammetry Method for Transparent, Reflective or Dark Surfaces", NASA disclosure of invention and new technology (including software), LAR-16426-NP, (2001).

**indicates that patents applications are being prepared and will be submitted in 2007

Other Publications:

65. P. Danehy, T. Jones, J. Connell, K. Belvin, and K. Watson, "Laser-Induced-Fluorescence Photogrammetry and Videogrammetry", NASA Photonics Tech Briefs, LAR-16426, v. 28, n. 7, p. 8a-10a, (2004).
66. R. S. Pappa, J. T. Black, J. R. Blandino, T. W. Jones, Paul M. Danehy, and Adrian A. Dorrington, "Dot-Projection Photogrammetry and Videogrammetry of Gossamer Space Structures" NASA TM-2003-212146 (2003).

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