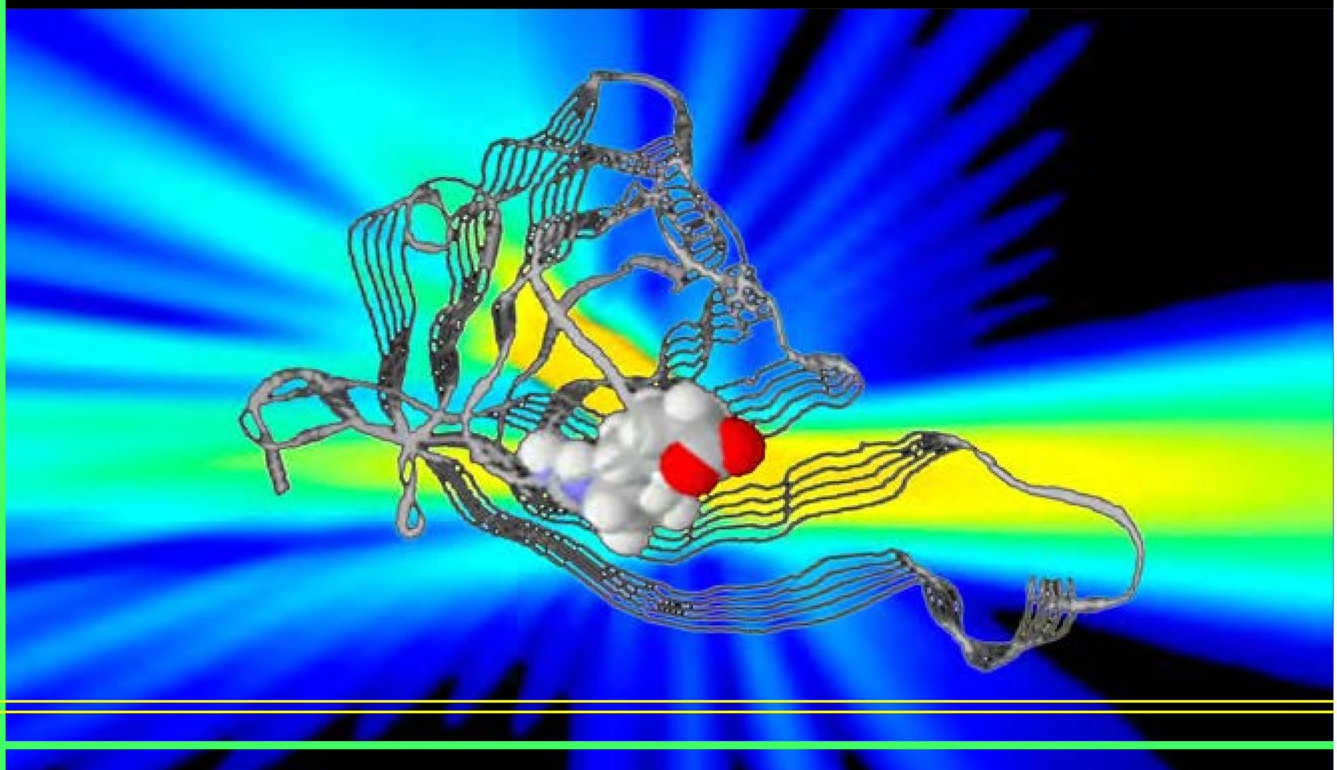
CENTER FOR LASER APPLICATIONS



CENTER OF EXCELLENCE

FIVE YEAR REPORT

2007-2011

THE UNIVERSITY of TENNESSEE

SPACE INSTITUTE

Tullahoma, Tennessee

Welcoming Remarks

The Center for Laser Applications (CLA) at the University of Tennessee Space Institute is pleased to present a five-year review of the research projects funded by the Center and external sources for fiscal years 2007 through 2011.

Over the past five years, The Center for Laser Applications supported the research efforts of eight UTSI Center-associated faculty who have made significant advancements in vision research, laser materials processing, chemical synthesis, single-molecule detection, nanotechnology, biotechnology, biomedical research, computational physics, plasma physics, laser-induced optical breakdown and fluid physics phenomena and electromagnetics. As a result of this research CLA faculty members were awarded two U.S. patents with several additional patents pending.

Productivity among Center faculty has been outstanding over the past five years. Center faculty obtained $7,622,952 in industry and federal funding to continue ongoing projects and begin new ones. Research expenditures from this funding amounted to $5,743,320. The appropriations received from the Tennessee Higher Education Commission amounted to $4,557,968 during the same time period. CLA benefited not only from external funding and state appropriations, but also from the American Reinvestment and Recovery Act funds. In total, these funds pay for the general operations of the Center and the research conducted in CLA, including the Center support staff, laboratory supplies, maintenance, travel for faculty and students to conferences, and research experiences for summer interns. Capital equipment must also come from this budget. In the past five years we have been fortunate to obtain a class 1000 clean room with a femtosecond nanomaching station and photolithography capability, a revitalized chemistry laboratory with a secondary ion mass spectrometer, an optomec LENS machine for direct metal deposition, a modular fluorometer / phosphorimeter for fluorescence studies, a pulsed laser deposition system, and a JEOL 6320F field emission scanning electron microscope. With these capabilities CLA has been successful in the pursuit of new capabilities and new sources of funding.

In spite of difficult economic times our research expenditures have been maintained as shown in the Comparative Summary of Accomplishments (p. 9). We are enthusiastic about our opportunities for the future and proud of the past accomplishments and hope you enjoy the research summaries that follow in this five-year review.

William Hofmeister

Director, Center for Laser Applications

Research Professor of Materials Science and Engineering

Center for Laser Applications Five Year Report 2007-2011

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This report is published by the University of Tennessee Center for Laser Applications

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Introduction

The Center for Laser Applications (CLA) at the University of Tennessee Space Institute was established in 1984 as a state funded Center of Excellence to provide outstanding capabilities in research, education, and technology transfer in the area of laser applications. CLA began as an active multi-disciplined and collaborative research group at UTSI with expertise and significant industrial and university-based experience in phenomena related to the interactions of lasers with gases, liquids, and solids. The diverse background of the faculty and staff and the strong mission-related research programs of CLA provide a blend of applied and basic research that is unusual for universities.

Mission Statement

The CLA mission is to advance laser applications in spectroscopy and materials synthesis. We pursue our mission in three areas:

1) Education
   - Provide a quality education to UTSI students with emphasis on apprenticeship
   - Generate opportunities for undergraduate and high school student research
2) Innovation
   - Develop a world class reputation for research and innovation
3) Service
   - Assist businesses in development and implementation of technology
   - Increase interest in STEM areas, i.e. support science education for local students and teachers

Focus Areas

The focus of the mission-related research programs of the Center is the application of lasers and associated technology to bio / nanophotonics, materials science, laser materials interaction, and spectroscopy. These focus areas of specialization were selected to correspond to known areas of scientific and engineering challenges and to areas of development and regional and national needs.

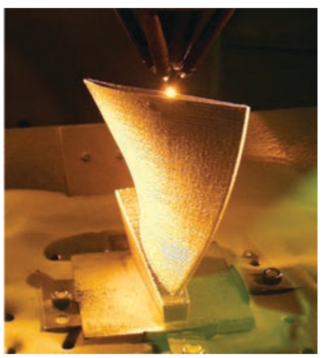
Bio/Nanophotonics

- Lloyd Davis - single molecule spectroscopy of biomolecules in confined spaces
- Ying-Ling Chen - vision research and modeling of human vision systems
- William Hofmeister and Lino Costa - devices for cellular chemotaxis
- Jacqueline Johnson - storage phosphor materials for mammography
- George Murray - colorimetric detection of bioactive molecules

Materials Science

- George Murray - synthesis of molecularly imprinted polymers
- William Hofmeister - solidification, direct metal deposition and femtosecond nano-structuring of materials
- Lino Costa - phase transformations, laser cladding and modeling of direct metal deposition
- Lloyd Davis - trapping and diagnostics of quantum dots
- Christian Parigger - laser-induced materials physics
- Jacqueline Johnson - development of glass imaging material

Laser Materials Interaction



Finite Element Modeling of Three Dimensional Freeform Fabrication

- Lino Costa - laser cladding and femtosecond laser machining
- William Hofmeister - direct metal deposition and femtosecond nanostructuring of materials
- Trevor Moeller - laser ablation dynamics and modeling of laser ablation for space propulsion
- Lloyd Davis - femtosecond fabrication of nanofluidic and wave guide devices

Spectroscopy

- Charles Johnson - Mössbauer spectroscopy
- Christian Parigger - ultrasensitive spectroscopy
- Lloyd Davis - single molecule spectroscopy
- Ying-Ling Chen - combustion diagnostics
- George Murray - Raman and electrochemical spectroscopy

Non-Equilibrium Fluid Physics

- Trevor Moeller - plasma physics and combustion
- Christian Parigger - laser-plasma physics, combustion and fluid phenomena, and computational modeling

Personnel

Dr. William Hofmeister, Research Professor of Materials Science and Engineering, was appointed Director of the Center in 2005. Dr. Hofmeister added two faculty members to the Center to support the goals set by the UTSI revitalization plan to develop a program in Materials Science while maintaining the excellence in the forefront of spectroscopy and laser materials modification. In 2007 new hire Dr. Jacqueline Johnson promptly secured a major grant from the National Institutes of Health for the development of materials for mammography. The following year Dr. George Murray joined CLA. Dr. Murray's research in molecular recognition for biomedical applications secured grants from NSF, Raptor Detection and Ambiocore, Inc. Coupled with Dr. Hofmeister's work in Freeform Fabrication, these projects represent a solid foundation for Materials Science at UTSI. Dr. Lloyd Davis' research in single molecule spectroscopy received a major boost with a DARPA grant in collaboration with Hofmeister and colleagues at Vanderbilt University, and an NIH grant with Dr. Steven Soper at LSU. Dr. Ying-Ling Chen's work with eye modeling and diagnostics has been advanced with two grants from NIH and collaboration with Dr. Ming Wang of Wang Vision Institute. Dr. Trevor Moeller continues to serve the aerospace establishment with a number of grants and task orders with Arnold Engineering Development Center. Dr. Christian Parigger continues to collaborate on various experimental, theoretical and computational modeling and joint efforts with national and international Universities and National Laboratories in the areas of laser physics, laser applications and laser-induced phenomena.

Dr. Murray checks the performance of molecular sequestration beads.

Collaborations

A significant fraction of the research and development program of the Center is supported by state, regional, and national industries. CLA actively collaborates with the Center for Industrial Services to provide studies for Tennessee industries, and CLA has also formed long-term research partnerships with regional and national industries. Supplementing these activities are research programs sponsored by the traditional federal agencies, the National Institutes of Health, the National Science Foundation, and National Laboratories at Oak Ridge and Albuquerque, over and above numerous collaborations with national and international Universities, and the nearby Arnold Engineering Development Center. These diverse research activities, an attractive student-to-faculty ratio, and outstanding facilities, combine to offer an unusual apprenticeship experience for diligent graduate students.

Graduate Student Support

Over the past five years CLA supported 36 graduate students with a combination of external research funding, UTSI support, ARRA and THEC funds.

- Materials Science

  PhD: Sameer Paital, Anoop Samant, Sandip Harimkar and Greg Engleman

  MS: Anil Kumar Kurella, Matthew Parrish, Deepak Rajput, Russell Lee Leonard and Mahn Vu
- Mechanical Engineering

  MS: Daniel Rooney, Sonya Nelson, Jeffrey King, Sarah Cothran, Densu Aktas, Nicholas Lister, Richard Joel Thompson, Kent Wilcher, Marcus Conner and Russell Gardner, and Nehemiah Williams
- Electrical Engineering and Computer Science

  MS: Isaac Lescano-Mendoza
- Physics

  PhD: Kevin Baker, David Ball, and Bo Tan

  MS: Karen Norton, Matt Dackman, James Aiken, Jesse Ogle, Lei Shi,

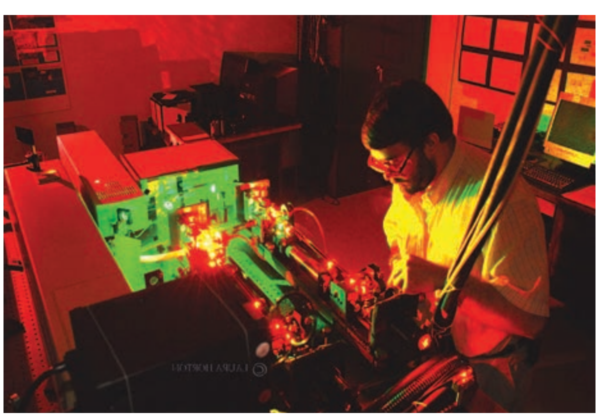
  James Guan, You Li, Jason King, Jesse Labello, Justin Crawford, James Germann,

  and William Robinson

Post Doctoral Support

The Center supports post doctoral fellows for continuing education and research support. Currently, Dr. Brian Canfield is working in the Davis lab on single molecule spectroscopy. Mr. Robert Rhodes continues to support the nonequilibrium fluid physics research with Dr. Moeller. Dr. Abhilasha Verma is completing her first year working on molecular imprinting polymer for protein sequestration and Dr. George Owens recently joined Professor Murray's group as a post doc. Last year Dr. José Lino Vasconcelos da Costa, a specialist in laser processing, was promoted to Research Assistant Professor at UTSI. Past post doctoral fellows include: Dr. Paul Shen, Luna Innovations, Dr. Yelena White continues research with femtosecond laser processing and currently is an Assistant Professor of Physical Science for the Physics Department at East Georgia College. Dr. Zbigniew Sikorski remains active in the area of computational modeling and Dr. Xiaoxuan "Shaun" Li is a Materials Engineer at Secat, Inc. in Kentucky.

Post Doc Abhilasha Verma



Post Doc Brian Canfield

Outreach and Enrichment Programs

CLA is dedicated to impacting our community in a positive way with meaningful interactions. Faculty, staff and graduate students contribute to interactions with local students and teachers. We have worked hard to develop mini-courses, summer camps, and engaging enrichment programs to offer to local teachers and all levels of students from public schools to home school programs. To date 5,333 students and 141 teachers have participated in a learning experience presented by the faculty, staff, and students in CLA. The laboratory regularly hosts adult groups such as the Coffee County Leadership Program and the Precision Machinists. In addition, the graduate students have traveled to many schools in the community for events such as Friday School at Sewanee Elementary, Fantastic Fridays at Cowan Middle School and the Science Club at Shelbyville High School.

GRAs Jason King and Joel Thompson engaging student in optics enrichment program.

The ASM Materials Camp engaged high school students in learning about alternative energy strategies to performing a live play pertinent to the week's activities in the auditorium. TECH camp provided interactive, hands-on projects that facilitated career awareness and opened eyes to the excitement of scientific discovery to rising middle school students. The UTSI / CLA Computational Science camp hosted middle and high school students, as well as science and math teachers an opportunity to study computational astrophysics, meteorology, agriculture, genomics, epidemiology, pharmacokinetics, and programs using languages such as gnuplot, Perl, and NetLogo.

CLA has worked with the Tullahoma Hands On Science Center (HOSC) to provide educational experiences to alternative school students through a grant from the Peyback foundation. In 2010, UTSI teamed with the HOSC to win a grant to site a Fireball Network station at UTSI with an exhibit at the HOSC. The Fireball Network tracks meteors in the night sky. In 2010 UTSI moved its summer enrichment programs for younger learners to the HOSC as summer camp programs and assists in delivering those programs at the HOSC.

Science teachers and HOSC Bill Boss

Research Accomplishments and Five year Benchmark

Our research mission is growing. The funding provided by the Tennessee Higher Education Commission, coupled with support from the university, provided valuable leverage for sponsored research. The research awards continue to increase. This growth is possible because of the dedication of our faculty and the support of THEC and UTSI.

CLA remains active in Outreach and Business Development. The faculty are active in scientific conferences and local business meetings. Productivity among Center faculty has been outstanding during the last five year period. During fiscal years 2007 through 2011, Center faculty published 125 peer-reviewed articles, 10 books and presented at 122 regional, national, and international meetings.

Comparative Summary of Accomplishments

Benchmark Data	FY 2007-2011 Cumulative	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
Publications						
Peer-reviewed articles	125	32	39	16	23	15
Book or book chapters	10	0	1	0	4	5
Presentations						
International	32	3	13	1	8	7
National	90	16	27	9	10	28
Research Awards						
External funding received	$7,622,952	$1,606,876	$1,073,818	$1,235,021	$1,676,546	$2,030,691
THEC State Appropriations	$4,557,968	$889,300	$906,100	$883,900	$965,200	$913,468
Research expenditures	$5,743,320	$546,122	$1,039,067	$1,280,931	$1,481,810	$1,395,390

Despite the current funding environment, Center faculty continue to make excellent progress in ongoing projects, gaining national and international recognition for their expertise and accomplishments. Details of current faculty research are provided in the Faculty Reports section (pp. 13-21).

Center faculty have successfully adapted to the increased competition for federal and corporate funds. Total research funding increased greatly from $546,122 in 2007 to $1,395,390 in 2011. This shift in funding reflects the faculty's aggressive and successful search for support in response to the increased competition for federal funds. Figure 1 shows the breakout of research expenditures from external contracts compared with THEC expenditures for the five year period.

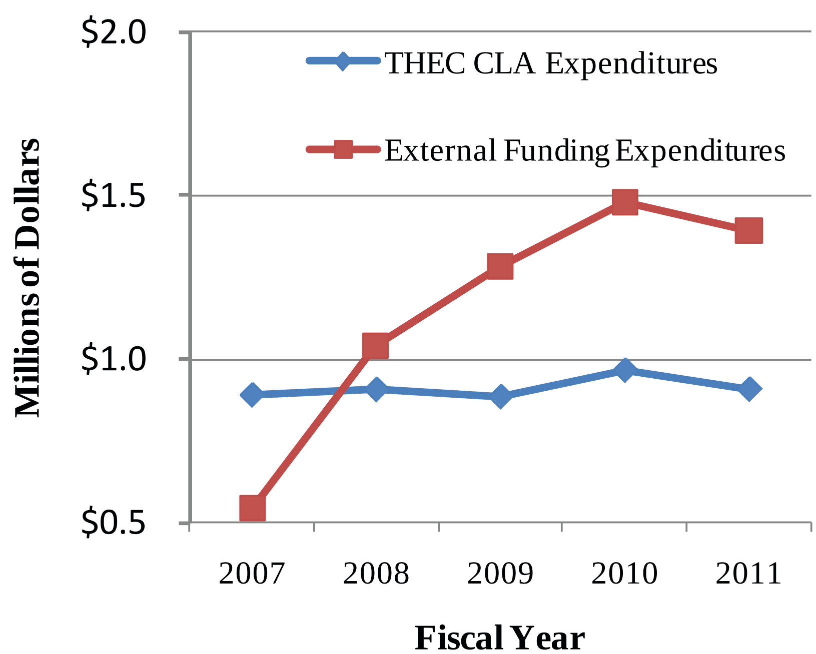


Figure 1: Research expenditures from external contracts and grants compared with THEC expenditures for the five year period.

Future Directions

The University of Tennessee Space Institute's direction is changing from education and research to research and education; placing the greater emphasis on externally funded research. The Center for Laser Applications will follow that trend as well. We have built a vibrant multi-disciplinary research team broadly working in photonics, biophotonics, spectroscopy, laser materials interactions, plasma and non-equilibrium physics, fluid physics and computational modeling. These efforts will continue. Moving forward, the goal of CLA will be to involve more of the UTSI and UTK faculty and students in research using our laboratory resources. Currently, exploratory research is carried out guided by the Principals in CLA. In the future, exploratory research directions for the Center will be solicited from the faculty-at-large in the form of white paper proposals, and resources will be allocated based on this proposal process. We are confident that this plan will help serve the broader science community.

Today, the Institute's reduced size is such that maintaining separate accounting and support functions for CLA is no longer efficient, and these functions will be absorbed into the Institute's infrastructure. The administrative savings will be applied to furthering the research mission of CLA.

Laboratory space is one of CLA's greatest assets and in the future we will work to "broaden the tent" to make use of the facilities for more investigators. For example, we look forward to working with UT Research Foundation's ASSET program. CLA's space and infrastructure will contribute to the success of that program.

CLA Budget

CENTERS OF EXCELLENCE / ACTUAL, PROPOSED, AND REQUESTED BUDGET
University of Tennessee Space Institute, Center for Laser Applications

	FY 2010-11 Actuals			FY 2011-12 Proposed			FY 2012-13 Requested		
	Matching	Appropr.	Total	Matching	Appropr.	Total	Matching	Appropr.	Total
Expenditures	433,913	869,194	1,303,107	471,749	943,497	1,415,246	427,977	855,955	1,283,932
Salaries									
Faculty	61,389	122,777	184,166	60,500	121,000	181,500	50,000	100,000	150,000
Other Professional	105,000	226,434	331,434	158,750	317,500	476,250	135,000	270,000	405,000
Clerical / Supporting	38,657	77,314	115,971	30,750	61,500	92,250	15,000	30,000	45,000
Assistantships	25,297	50,594	75,891	30,000	60,000	90,000	32,500	65,000	97,500
Total Salaries	230,343	477,120	707,463	280,000	560,000	840,000	232,500	465,000	697,500
Longevity	2,281	4,563	6,844	450	900	1,350	550	1,100	1,650
Fringe Benefits	61,514	129,619	191,133	74,727	149,453	224,180	60,000	120,000	180,000
Total Personnel	294,138	611,302	905,440	355,177	710,353	1,065,530	293,050	586,100	879,150
Non-Personnel									
Travel	10,000	39,988	49,988	21,000	42,000	63,000	35,000	40,000	75,000
Software		5,427	5,427			0			0
Books & Journals			0			0			0
Other Supplies	12,714	70,319	83,033	54,497	83,949	138,446	64,177	68,355	132,532
Equipment	103,900	34,279	138,179	11,825	48,695	60,520	10,000	110,000	120,000
Maintenance		3,703	3,703	3,750	7,500	11,250	2,500	5,000	7,500
Scholarships			0			0			0
Consultants			0			0			0
Renovation			0			0			0
Other (Specify)			0			0			0
Printing, Dupl, Binding		2,701	2,701	1,250	2,500	3,750	1,250	2,500	3,750
Communication		821	821			0			0
Prof Serv & Memberships		4,275	4,275	1,750	3,500	5,250	1,750	3,500	5,250
Rentals		5,433	5,433	2,000	4,000	6,000	2,000	4,000	6,000
Student Fees	13,161	30,924	44,085	15,000	30,000	45,000	18,250	36,500	54,750
Contractual & Special Svc		12,086	12,086	5,500	11,000	16,500	0	0	0
Entertainment			0			0			0
Cost Share		47,936	47,936			0			0
Total Non-Personnel	139,775	257,892	397,667	116,572	233,144	349,716	134,927	269,855	404,782
GRAND TOTAL	433,913	869,194	1,303,107	471,749	943,497	1,415,246	427,977	855,955	1,283,932
Revenue									
New State Appropriation		906,880	906,880		815,195	815,195		855,955	855,955
Carryover State Appropriation		89,246	89,246		128,302	128,302			0
ARRA Carryover		1,370	1,370			0			0
New Matching Funds	433,913		433,913	471,749		471,749	427,977		427,977
Carryover from Previous Matching Funds			0			0			0
Total Revenue	433,913	997,496	1,431,409	471,749	943,497	1,415,246	427,977	855,955	1,283,932

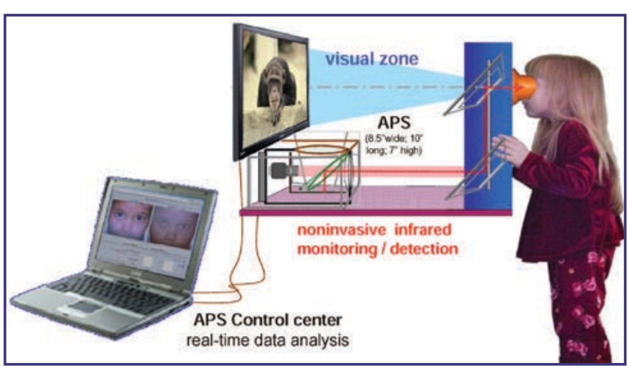
Vision Science Research

Ying-Ling Chen
Research Assistant Professor
PhD, University of Tennessee
Space Institute

For several years, Professor Chen's biophysics vision research in CLA has pioneered the development of realistic computer-based eye modeling and ophthalmic simulation that ranges in application from the optical design of ophthalmic instrumentation to refractive surgery, intraocular lenses, spectacle lens, contact lens design, bio-optical engineering, and medical education. Professor Chen has been awarded two NIH grants to develop a novel adaptive photorefraction technology to detect early keratoconus disorder, the major cause of laser surgery failure in the US, and realistic eye modeling research.

In 2008 and 2011, Professor Chen and Dr. J.W.L. Lewis obtained two U.S. patents through The University of Tennessee Research Foundation (UTRF) for the adaptive photoscreening (APS) technology. The figure below depicts the first APS prototype in pediatric application as it is designed to perform binocular automatic examinations without the use of medical professionals. The system includes a child-friendly screen that can display an animated video to attract the attention, control the accommodation and ocular fixation, and interact with examinees throughout the required infrared measurement procedures. The complete evaluation procedure includes assessments in binocular near- or far-sightedness, astigmatism, ocular motility / alignment, and optical opacity. The monocular design of the innovation is applied for detection at cornea abnormalities including dry eye, keratoconus, cataract, and corneal scars. The APS application also has the potential to extend to the detection of mental problems such as post traumatic stress disorder, dyslexia, and physical / emotional abuse through detection of the hand-eye-stimulus interaction. Adult human data has been obtained to show the feasibility of the technique. Professor Chen collaborates with the Wang Vision Institute in Nashville to progress in the study of children and young adults. Recently, Professor Chen obtained the support from the Wal-Mart Vision center in Tullahoma, TN for clinical studies of school-age children, and approval by the UTK Institutional Review Board has been achieved.

Professor Chen plans to submit two 5-year R01 proposals to NIH. One is in "Pediatric Vision Screening", and the second is the extension of "Eye Modeling Research," The second proposal is planned to include in the model of the optical characteristics of the motion and breakup of the three immiscible liquids of the tear film, lens cataract, floaters in the vitreous, and retinal characteristics. The development and establishment of effective collaboration will be critical for this work. Both proposals will require extensive research for developing the technology and acquiring persuasive human data.



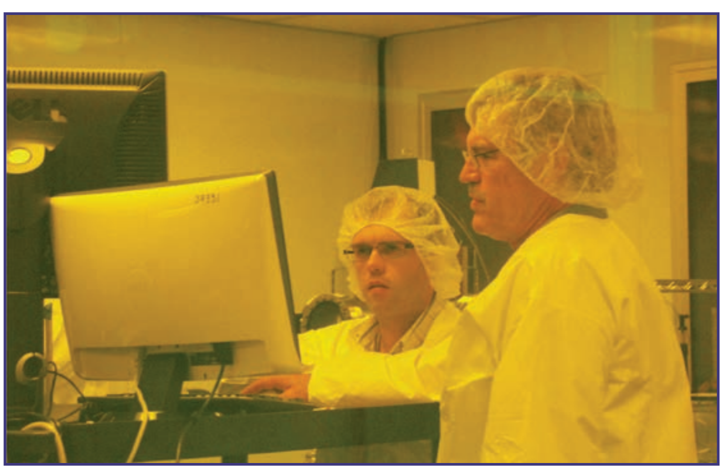
Materials Science Research

José Lino Vasconcelos da Costa
Research Assistant Professor
PhD, Instituto Superior Tecnico
Univesidade Tecnica de Lisboa

Dr. Lino Costa received a Ph.D. in Materials Engineering in 2008, from Instituto Superior Tecnico, Universidade Tecnica de Lisboa, after successfully defending a dissertation on laser powder deposition of tool steels, which is a process simulation using finite element analysis.

Lasers provide material scientists with exciting new ways of developing novel and oftentimes unexpected applications for materials, either by radically changing their properties or by shaping them into totally new forms. Rapidly and precisely, lasers can materialize these transformations over a wide range of size scales, from a few nanometers up to many meters.

Dr. Lino Costa's work involves the modeling, development and application of various laser materials processing techniques that are of current interest as rapid fabrication tools to a number of fields, including Solid Freeform Fabrication via Laser Powder Deposition and Laser Induced Surface Improvement (LISI™) for surface protection purposes. He is also involved in developing femtosecond laser micromachining techniques suitable for fabrication of micro and nanofluidic lab-on-a-chip devices in transparent dielectric materials such as fused silica. Recently, a new generation of microfluidic devices for imaging of cells during chemotaxis have been developed and tested. Biomolecular gradients play an important role in various biological processes, such as tissue development, immune response, cancer metastasis and allergic inflammation. Investigation of cell chemotaxis using these novel microfluidic devices may lead to a better understanding of these processes and help find appropriate treatments for a host of diseases.



Lino Costa and William Hofmeister in the clean room.

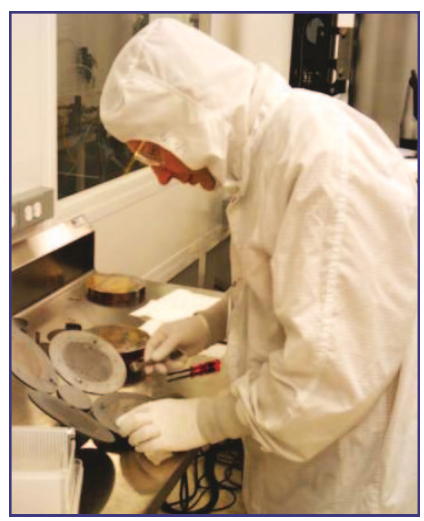
Ultrasensitive Spectroscopy

Lloyd M. Davis

BH Goethert Professor of Physics
PhD, University of Auckland, New Zealand
Visiting Fellow at JILA (NIST and UC Boulder), Fall 2010
Visiting Researcher, University of Auckland, Spring 2011
Senior Member of OSA 2010, Senior Member of SPIE 2011

Professor Davis is a pioneer of single-molecule detection and spectroscopy in solution, having coauthored the first experiments to successfully demonstrate detection and spectroscopic measurements on a single fluorophore in solution in the late 1980's, the first experiments on single-molecule detection within a "lab-on-a-chip" device in the 1990's, and some of the first experiments on single-molecule imaging for 3rd generation DNA sequencing in the early 2000's, which subsequently led to commercial instrumentation that can sequence an entire genome within days. In recent years, single-molecule spectroscopy has become a key tool in a number of other enabling scientific breakthroughs, resulting in intensive world-wide research activity.

Professor Davis's group continues to make important contributions in development of new experimental techniques, as well as modeling and simulations to guide new applications. During the past 5 years, the focus has included a number of externally supported projects, including: (1) Applications of single-molecule measurements in pharmaceutical drug discovery, initially sponsored by Abbott and subsequently by the NIH; (2) Development of new methods for ultrasensitive fluorescence microscopy in bioimaging and biotechnology, sponsored by the NIH; (3) Development of a platform for trapping and performing measurements on a single fluorescently labeled protein molecule, sponsored by DARPA; (4) Development of an instrument at Vanderbilt for trapping and performing ultrasensitive spectroscopic measurements on single nanoparticles, sponsored by the NSF; and (5) Study of fluorescence emission from single ultrasmall quantum dots for high efficiency lighting, sponsored the NSF. Many of the experiments require nanofluidic devices and research on fabrication methods has been supported by user access at the Center for Nanophase Materials Science (CNMS), at ORNL.



At the CNMS, Professor Davis is loading a fused silica wafer for fabricating nanochannel devices, which are used in CLA's single-molecule experiments.

As a Visiting Fellow at JILA in Boulder, Colorado, Professor Davis worked on laser spectroscopy and controlled laser manipulation of living cells in microfluidic devices for genetic engineering of fluorescent proteins, which are used in single-molecule experiments. As a Visiting Researcher at The Photon Factory, the University of Auckland, Professor Davis devised and tested a new method for rapid fabrication of nanofluidic channels and optical waveguides by direct writing with a single pulse from an amplified femtosecond laser. Invention disclosures have resulted from the projects at JILA and Auckland. Professor Davis is an External Associate of the Vanderbilt Institute for Integrative Biosystems Research (VIIBRE) and a founding member of the UTK Center in Chemical Physics.

Laser Materials Processing

William Hofmeister

Research Professor of Materials Science and Engineering
PhD, Vanderbilt University
Director of the Center for Laser Applications,
University of Tennessee Space Institute
Adjoint Professor of Materials Science and Engineering, Department of Electrical Engineering and Computer Science, Vanderbilt University
University of Canterbury Visiting Erskine Fellow, February-April, 2011
Fellow of ASM International

Professor Hofmeister came to UTSI five years ago to become Director of the Center for Laser Applications following eighteen years on the faculty of Vanderbilt University. His primary interest is in laser processing of materials. He has extensive experience in laser additive manufacture. Dr. Hofmeister was one of the developers of the Laser Engineered Net Shaping (LENS™) process at Sandia National Laboratories and holds a patent for a feedback control system for that process. He has built an additive manufacturing laboratory at the Center for Laser Applications. He is working with NASA, the US Air Force and private industry to develop sensors and control strategies for additive manufacture using electron beam technologies.

Currently, Professor Hofmeister is developing femtosecond laser ablation techniques for the fabrication of micro and nanofluidic devices for biological applications. He is an External Associate of the Vanderbilt Institute for Integrative Biosystems Research (VIIBRE) and holds two patents for bioreactors with members of VIIBRE. CLA has a state-of-the-art nanofabrication facility in our clean room with a femtosecond laser coupled to a microscope with three dimensional nanopositioning stages. CLA has built devices for the study of cell migration during chemotaxis with the Janetopolis group in Vanderbilt's Department of Biological Sciences. With Melissa Skala this collaboration was recently awarded a Discovery Grant for "Microfluidic Intravital Windows for Local Antiangiogenic Cancer Inhibition," Dr. Hofmeister's group is working on utilizing high aspect nanoholes to fabricate nanoneedles for in situ probing of intercellular function.

Laser surface engineering has been a research area at CLA for a number of years and UTRF holds of patents for the Laser Induced Surface Improvement (LISI™) process. Dr. Hofmeister has continued to expand the uses of the LISI process to ultra-high temperature materials with ATI Stellram, for transportation rails with the Transportation Technology Center, Inc., and for high speed friction and wear surfaces for the Holloman High Speed Test Track. Professor Hofmeister worked with the Diamond Microelectronics Group at Vanderbilt University on the synthesis of diamond films and carbon nanotubes for field emission, diode and triode applications. He currently has a project with CFDRC to develop nanotube emitters for travelling wave amplifiers. Professor Hofmeister's research in nucleation and solidification kinetics led to three space flight experiments in the 1990's to study the effects of fluid flow on nucleation using the TEMPUS facility on IML-2, MSL-1, and MSL-1R. Dr. Hofmeister was principal investigator for the TEMPUS Incandescence Measurement Instrument Project, which designed and implemented an infrared pyrometer on the existing TEMPUS flight hardware. TEMPUS experiments were conducted by "telescience" operation in low earth orbit using modeling and simulation software, which Dr. Hofmeister developed for the space flight experiments.

Professor Hofmeister is active in professional societies and outreach to the local community. Last year he served as President of the Tullahoma Hands on Science Center. He frequently works with the University of Tennessee Center for Industrial Services to assist local industry such as Fischer USA, Nissan, Walker Die Casting, and Jarden Zinc, with materials-related problem solving.

Mössbauer Spectroscopy

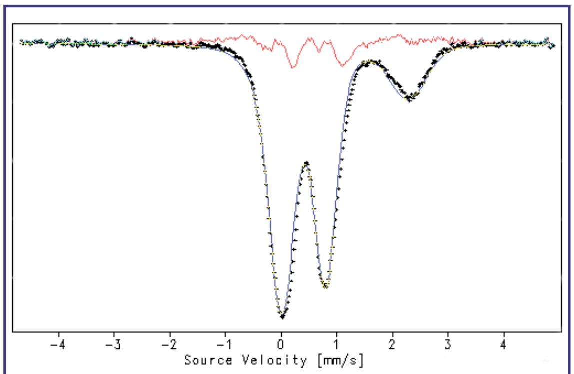
Charles Johnson

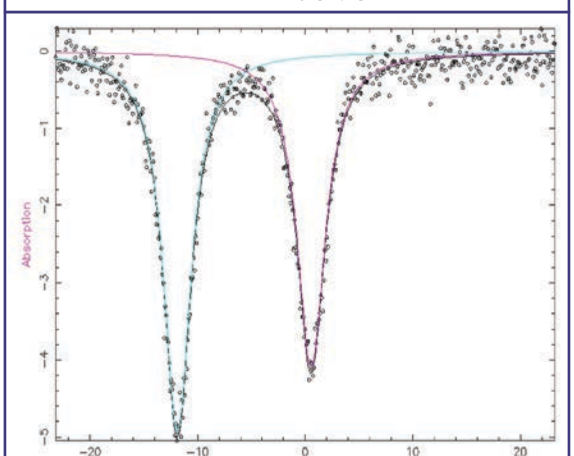
Associate Director, UTSI

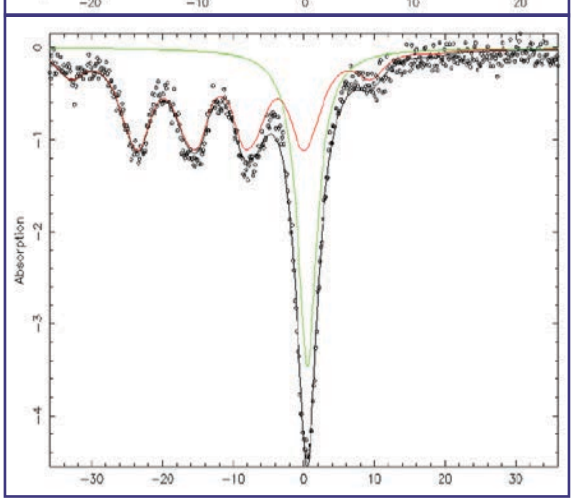
Emeritus Professor of Physics, University of Liverpool, England

M.A., Oxford University, England

D. Phil., Oxford University, England

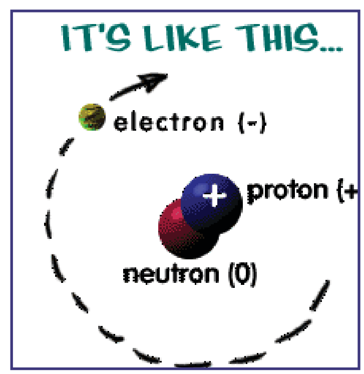






Dr. Charles Johnson earned his doctorate on low temperature nuclear orientation at Oxford. He continued this research on a Fulbright Fellowship at the University of California at Berkeley. He then worked on the Mössbauer Effect in National Laboratories (Harwell, UK and Argonne, USA) for a decade before being appointed to the Lyon Jones Chair of Physics at the University of Liverpool. His research interests were magnetism and biological molecules, mainly studied with the Mössbauer Effect. He retired in 1997 but continued to do research at Argonne National Laboratory, the University of Northern Illinois and more recently at the University of Tennessee Space Institute.

Mössbauer Spectroscopy (MS) is to materials like fingerprints are to humans. MS takes a fingerprint of a material and shows you what it is! Materials are made of atoms composed of protons and neutrons at the center and electrons on the outside. (See illustration below: “IT'S LIKE THIS...”)



For special elements such as iron and europium, MS can tell you how many electrons are present on the outside – this is called “valency”. Iron (Fe) can have a valency of 2 or 3 and so can europium (Eu). At UTSI we work on several materials containing iron and europium and the valency makes the material behave in very different ways. For instance, the magnetic properties change greatly in iron-containing materials and the luminescence (light output) varies greatly in europium depending on the valency. We are working on tiny particles called nanoparticles and disordered materials such as glasses containing Fe and Eu. (See example opposite for how different the fingerprints look!)

Transparent Storage Phosphor Materials for Mammography

Jacqueline Johnson
Associate Professor
Materials Science and Engineering
B.Sc., University of Liverpool, England
Ph.D., University of Liverpool, England

Dr. Johnson completed her doctorate in solid state physics in the research area of magnetic phase transitions in single crystals using Mössbauer Spectroscopy at the University of Liverpool in 1985. After working as a professor in Liverpool John Moores University in science, she joined the Intense Pulsed Neutron Source Division jointly with the Materials Science Division at Argonne National Laboratory in the United States. At Argonne her research moved from the crystalline state to the amorphous state in studying the structure of glasses. After a 2-year period in administration, she returned to research to develop a new mammography system using a glass-ceramic plate. In 2007, Dr. Johnson returned to academia at the University of Tennessee Space Institute and continues to synthesize and characterize amorphous materials pertaining to medical devices and is a member of the Mechanical, Aerospace and Biomedical Engineering Department.

Breast cancer deaths have been declining since 1990, but the disease annually kills 40,000 women. Better imaging technology is crucial in lowering deaths and increasing early diagnosis and prevention.

Professor Johnson's research broadly covers detectors, sensors and imaging technologies. The current focus is on next-generation x-ray imaging technology that can provide superior resolution and enable fast, low-cost screening for mammography.

The new system is based on a glass-ceramic plate, which is transparent to lessen light scattering, and a readout device, designed specifically to maximize the efficiency of the glass-ceramic material. The novel sensors use europium activated nanoparticles that are "embedded" in glass to store x-ray images like a reusable film. The image plates are read with a scanning laser and then stored and analyzed using a computer.

The advantages over traditional photographic film and scintillating screens include reusability, wide dynamic range and direct digitization. The work was honored with an R&D 100 Award in 2007 and a patent in 2011.

In addition to the image research Dr. Johnson has a fundamental research project with Amanda Petford-Long of Northwestern University and Argonne National Laboratory to study the growth of the nanoparticles by in situ Transmission Electron Microscopy. The interface kinetics between the nanoparticles and the glass matrix are also being studied.

Dr. Johnson's research is currently funded by the National Institutes of Health, National Institute of Biomedical Imaging and Bioengineering, Award Number R01EB006145 and the National Science Foundation Award # DMR 1001381.

In addition to work on glass ceramics, Dr. Johnson also does research in the area of diamond-like carbon coatings for biomedical implants such as heart stents, bronchoscopes and hip implants.

Nonequilibrium Fluid

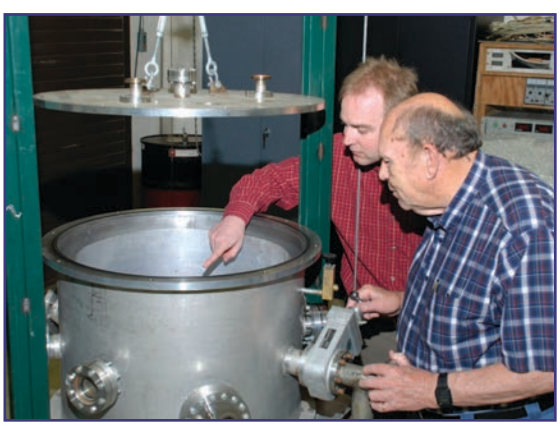
Trevor Moeller

Associate Professor
PhD, University of Tennessee
UTSI Program Coordinator for Mechanical, Aerospace, and Biomedical Engineering (MABE)

Dr. Trevor Moeller's research focuses primarily on high temperature gases and plasmas, including both modeling and experimentation. He has successfully completed projects involving technology development for a portable MHD generator, design and testing of a thermal storage and management system for the U.S. Air Force, and development of a unique, ultrasensitive thrust stand that can resolve µN-level thrust levels produced by efficient electric propulsion thrusters used for in-space propulsion. His current research activities for the U.S. Air Force include modeling and analysis of probes for high-temperature, high-velocity flows in rockets and gas turbine engines and investigations of cryodeposit contamination in cryopumped vacuum chambers. The sensitive nature of these programs precludes the presentation of further details. Dr. Moeller also is conducting research in the development of tools for the modeling of coupled electromagnetic / fluid systems and the modeling and analysis of a micro laser ablation thruster system, an advanced space propulsion system, for use in micro- and nano-satellites.

Current research with UTSI's private sensitive network has included simulation and modeling of plasma actuator technology and flow fields, investigations of strong conservative numerical formulations of the plasma / fluid equations for both wave and diffusion electromagnetic phenomena, and particle-in-cell / direct-simulation Monte Carlo models of low-density plasmas. We are presently capable of constructing substantial magnetohydrodynamic models of laboratory and propulsion plasmas and flows, particularly with the MACH2 code, and we are establishing the GEMS code as well at UTSI. Several other codes and capabilities exist to serve our needs for combustion, heat transfer and nozzle flows.

Satellite design has recently seen a trend of reducing satellite size for cost-effectiveness. One of the foremost challenges identified in this reduction of size is the development of a new, efficient and cost-effective propulsion system to accommodate mass and power restrictions. At UTSI, for the micro laser ablation thruster we have implemented the MACH2 magnetohydrodynamic code to develop significant computational models to simulate the ablation process of the microthruster. These models have allowed for a deeper insight of the ablation mechanism of the thruster, and they have led to investigations of the performance enhancement realized by the use of different exothermic fuels instead of passive solid propellants. Furthermore, modeling has also allowed for investigations of the improvement seen by the addition of nozzle geometries on the thruster.



Trevor Moeller and Newt Wright inspecting a new vacuum chamber

Molecular Recognition

George M. Murray

Research Associate Professor

Materials Science and Engineering

PhD, University of Tennessee

Professor George Milton Murray is a Research Associate Professor of Materials Science and Engineering at the University of Tennessee Space Institute. He came to UTSI in 2007 from Johns Hopkins University Applied Physics Laboratory. He specializes in chemical analysis, sensors and molecularly imprinted polymers. One of Professor Murray's areas of expertise is the preparation of luminescent sensors for toxic compounds. The techniques of molecular imprinting and sensitized lanthanide luminescence have been combined to create the basis for a sensor that can selectively measure a specific organophosphorous compound. A complex of polymerizable sensitizing ligand europium (III) and an organophosphorous compound are copolymerized in a cross-linked polymer matrix. The best coordinators are trifluoromethyl-substituted b-diketones. The best polymerization mechanism is by Reversible Addition Fragmentation Transfer polymerization. This approach is allowing the production of soluble processable imprinted materials.

Analogous methodologies are currently being applied to the production of sensors for the detection and determination of drugs of abuse, explosives and meat spoilage. Drugs are measured in an analogous manner to the nerve agents while the explosives are being detected by the production of charge-transfer complexes between the explosives molecules, (acceptor) and immobilized amines (donor).

Meat spoilage sensing is obtained using luminescence from a transition metal macrocyclic complex. The materials are also capable of providing highly selective binding sites to other transducers such as quartz crystal microbalance and surface plasmon resonance sensors.

Dr. Murray has published over 50 peer-reviewed papers in scientific journals as well as articles in the popular science press. He holds eighteen U.S. patents and was named as one of the eighteen Master Inventors of the Johns Hopkins University Applied Physics Laboratory. Dr. Murray's research interests are centered on developing methods for the sequestration and ultra-trace determination of toxic or useful substances in real samples. The means to this goal involves the production of molecularly imprinted materials for sequestration and as specific polymer sensors. Laser spectroscopy is used for sensor transduction and verification. Laser processing is used to obtain specific form factors. Materials are also prepared for direct electronic or electrochemical transduction using electro-active polymers with imprinted polymer receptors.

Ultrasensitive Spectroscopy

Christian Parigger

Associate Professor of Physics

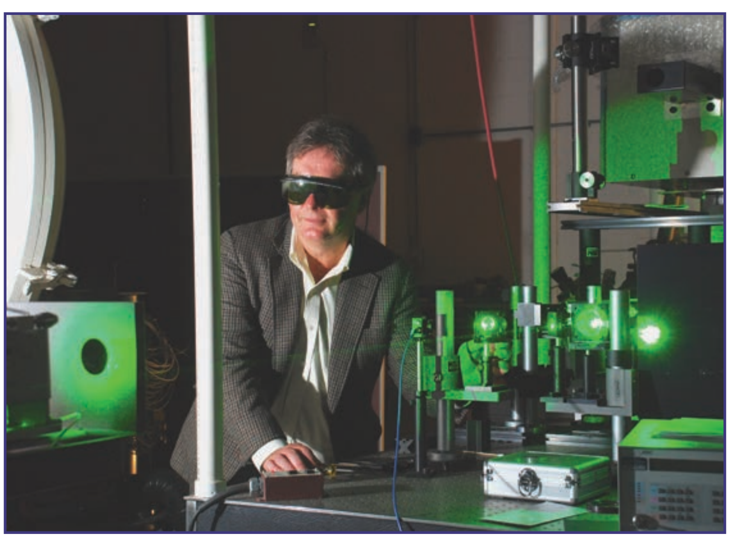
PhD, University of Otago, Dunedin, New Zealand

Dr. rer.nat. in Physics, University of Innsbruck, Innsbruck, Austria

Professor Parigger joined the Center for Laser Applications (CLA) in 1987. His research interests include experimental and theoretical and computational physics, particularly electromagnetic interactions, fundamental and applied spectroscopy, nonlinear optics, quantum optics, ultrafast phenomena, lasers, combustion and plasma physics, optical diagnostics, applied optics, biomedical applications, and in general atomic and molecular and optical (AMO) physics. His Academic service activities include President of Faculty Assembly at UTSI, Research Committee Chair at UTSI, Graduate Curriculum Committee in Physics, Graduate Council of The University of Tennessee, Graduate Council Policy Committee of The University of Tennessee, and Faculty Senate of The University of Tennessee. Professor Parigger has been strongly engaged in postgraduate teaching, primarily doctoral research related courses. He usually engages actively in peer review and other publication related activities.

Christian Parigger's current research in the area of laser-induced breakdown spectroscopy, plasma and combustion physics and diagnostics is ground breaking and comprises a pioneering effort, and is internationally and nationally well respected and recognized from a fundamental physics and laser applications point of view. His collaborations extend to international universities, to name a few, in Italy, Russia, Austria, Hungary, to several national universities, e.g., Auburn University, New Mexico State University, Denver University, University of Nebraska-Lincoln, University of Florida, and to National Laboratories including at Oak Ridge and at Albuquerque.

Christian Parigger's recent efforts comprise studies in femto- pico- and nanophysics and chemistry, nanoscale materials modifications, and nanoscale structures that impart novel functional properties to materials, partly through coating, surface and/or bulk modifications. Moreover, of interest are diagnostic applications that derive from AMO (atomic/molecular/optical) Physics that involve cold-temperature applications. These are primarily based on the use of appropriately shaped coherent radiation both in temporal and spatial domains. Additional areas of interest, in collaboration with members of the Engineering College, include the testing of particular hypotheses arising in the diagnostics of chemically reacting flows, turbulent swirling flows, and non-equilibrium fluid physics.



Christian Parigger conducting laser research

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C. Paßlick, B. Ahrens, B. Henke, J.A. Johnson and S. Schweizer, “Crystallization behavior of rare-earth doped fluorochlorozirconate glasses,” Journal of Non-Crystalline Solids, 357, 2450, 2011.

U. Skrzypczak, M. Miclea,, A. Stalmashonak, B. Ahrens, B. Henke, G. Seifert, J.A. Johnson, and S. Schweizer, “Time-resolved Investigations of Erbium Ions in ZBLAN Glasses and Glass Ceramics,” Phys. Status Solidi C, 1–4 (2011) / DOI 10.1002/pssc.201084131.

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R.J. Thompson, T.M. Moeller, "MACH2 Simulations of Exothermic Propellants in a Micro-laser Ablation Plasma Thruster," AIAA-2010-7021, 46th AIAA / ASME / SAE / ASEE Joint Propulsion Conference, Nashville, TN, 2010.

R. Rhodes and T. Moeller, "Modeling a Phase Change Thermal Storage Device," AIAA-2010-4768, 10th AIAA / ASME Joint Thermo Physics and Heat Transfer Conference in Chicago, IL, 2010.

Book Chapters:

J.O. Hornkohl, L. Nemes, and C. Parigger, "Spectroscopy of C_2 and CX, , Book Chapter in Spectroscopy, Dynamica and Molecular Theory of Carbon Plasmas and Vapors, Advances in the Understanding of the Most Complex High-Temperature Elemental System," eds. L. Nemes and S. Irle; World Scientific, 2010, pp.113-169, Accepted and in press.

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Y.L. Chen, L. Shi, J.W.L. Lewis, M. Wang, and R. Vida, "Keratoconus Eye Modeling," ARVO Meeting, Fort Lauderdale, FL, 2011.

J.W.L. Lewis, L. Shi, E.E. Hartmann, N. T. Naser, Y.L. Chen, and M. Wang, "Pilot Study of an Automatic Assessment of Ocular Alignment," ARVO Meeting, Fort Lauderdale, FL, 2011.

L. Shi, E.E. Hartmann, N. T. Naser, J.W.L. Lewis, Y.L. Chen, and M. Wang. "Pilot Study of a Dynamic Binocular Photoscreening Device," ARVO Meeting, Fort Lauderdale, FL, 2011.

J.L. Lubbeck, K.M. Dean, L.M. Davis, A.E. Palmer, R. Jimenez, "Directed Evolution of New Imaging Probes: A Microfluidic Cell Sorter Based on Dark-State Conversion and Photobleaching of Fluorescent Proteins," Janelia Conference: Multiphoton Imaging: The Next 6×1023 Femtoseconds; Janalia Farm, Chevy Chase, MD, 2011.

J.L. Lubbeck, K.M. Dean, L.M. Davis, A.E. Palmer, R. Jimenez, "A microfluidic cell sorter for directed evolution of fluorescent proteins based on darkstate conversion and photobleaching," Biophysical Society 55th annual meeting, Baltimore, MD, Biophysical Journal 100, Abstracts Issue, 964-Plat, 2011.

W.N. Robinson and L.M. Davis, "Comparison of particle trapping in two dimensions using feedback from two illumination techniques," 14th Annual Southeast Ultrafast Conference (SEUFC), Oak Ridge, TN, 2011.

C. Parigger, J. Hornkohl, A.B. Donaldson, and T. Sanchez, "Molecular Spectroscopy Diagnostic: Aluminum Monoxide," FACSS2010 Conference, Raleigh, NC, 2010.

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J.K. King, B.K. Canfield and L.M. Davis, "Microfluidic device for use in single molecule trapping," 14th Annual Southeast Ultrafast Conference (SEUFC), Oak Ridge, TN, 2011.

J. Germann, L.M. Davis, B.K. Canfield and A. Terekhov, "Three-dimensional flow measurements using FCCS," 14th Annual Southeast Ultrafast Conference (SEUFC), Oak Ridge, TN, 2011.

B.K. Canfield, L.M. Davis, W.H. Hofmeister, and S.A. Soper, "Rapid, ultrasensitive fluorescence readout from multichannel microfluidic devices," 14th Annual Southeast Ultrafast Conference (SEUFC), Oak Ridge, TN, 2011.

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L.M. Davis, "Single-molecule fluorescence detection in sub-micron fluidic channels," JILA, University of Colorado, Boulder, CO, 2010.

L.M. Davis, "Development of a nanoparticle trap for student training and nano-spectroscopy," Vanderbilt University, Nashville, TN, 2010.

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"Closed-Loop Process Control for Electron Beam Freeform Fabrication and Deposition Processes," K.M. Taminger, R.A. Hafley, R.E. Martin, W.H. Hofmeister, NASA Langley Case LAR-17245-1. U.S. Patent Application no 20100260410, October 14, 2010.

Investigator	Contract Title	Funding Agency	Period of Performance	2007-2011 Awarded	2007-2011 Expended
Chen, Ying-Ling	Keratoconus Eye Model Bank for Virtual Clinical Trials and Medical Educations (R02-4313027)	National Institutes of Health	August 1, 2009 – August 31, 2011	$410,250	$203,878
	Optical Investigation on Early Keratoconus Detection (R02-4313026)	National Institutes of Health, American Recovery and Reinvestment Act (ARRA) Grant	August 1, 2009 – July 31, 2012	$404,731	$322,097
	Multiple Optical Access Rocket Chamber (MOARC) (R02-4313023)	United States Air Force / CFD Research Corporation subcontract	August 21, 2006 – February 28, 2009	$150,000	$150,000
	Pilot Clinical Test of Adaptive Photo Screening System (R02-4313025)	University of Tennessee Research Foundation	February 1, 2009 – January 31, 2010	$15,000	$14,830
Davis, Lloyd	High Throughput Microfluidic Systems for Drug Discovery / Development of Assays for High Throughput Drug Discovery (R02-4318031)	National Institutes of Health / Louisiana State University subcontract	August 1, 2007 – July 31, 2011	$494,606	$426,032
	Development of a Nanoparticle Trap for Student Training and Nano-Spectroscopy (R02-4318033)	National Science Foundation / Vanderbilt University subcontract	April 1, 2009 – August 31, 2010	$36,535	$36,535
	Nanostructures for Enhancing Energy Efficiency, Tennessee Solar Conversion and Storage using Outreach, Research and Education (TN-SCORE) (R02-4318034)	National Science Foundation	August 10, 2010 – July 31, 2011	$44,183	$18,612
	Single Protein Actuation by Real-time Transduction of Affinity in Nanospace (R02-4318030)	DARPA / Vanderbilt University subcontract	January 1, 2007 – December 31, 2008	$381,867	$381,867
	US Department of Health and Human Services (R02-4318032)	University of Memphis	March 25, 2008 – July 14, 2008	$5,000	$5,000
	Maximus-likelihood Multi-Channel Fluorescence Microscopy (R02-4318029)	National Institutes of Health	August 1, 2005 – July 31, 2008	$148,534	$148,534
Hofmeister, William	E-Band Traveling Wave Tube Amplifier with Innovative Carbon Nanotube Cathode (R02-4411038)	AFML / CFD Research Corporation subcontract	February 18, 2011 – February 20, 2012	$30,000	$6,009

Investigator	Contract Title	Funding Agency	Period of Performance	2007-2011 Awarded	2007-2011 Expended
Hofmeister, William	Determination of TiCN layer lattice parameter in tooling insert (R02-4411037)	ATI Engineering	January 1, 2011 – February 15, 2011	$7,500	$7,500
	Laser Induced Surface Improvement for Superior Wear Resistance in Extreme Conditions (R02-4411035)	AFOSR / CFD Research Corporation subcontract	June 1, 2010 – March 31, 2011	$50,000	$50,000
	ORNL IR&D Machining Trials (R02-4411034)	UT-Battelle, LLC-Oak Ridge National Laboratory	April 1, 2010 – April 30, 2010	$2,000	$2,000
	Rocket Technology Based Thermal Barrier Coatings for Hypersonic Wind Tunnels (R02-4411033)	Air Force Small Business Technology Transfer Research Program / Exquadrum subcontract	September 1, 2009 – December 31, 2009	$21,138	$20,852
	Investigate Laser Ablation Parameters (R02-4411029)	Korvis Automation, Inc.	April 1, 2008 – April 30, 2008	$5,000	$5,000
	Modeling of Electron Beam Freeform Fabrication for Zero Gravity (R02-4411025)	NASA - Langley Research Center	October 1, 2006 – December 31, 2007	$75,000	$75,000
	Monitoring and Feedback Control of Electron Beam Deposition Process (R02-4411030)	NASA / Lockheed Martin Aeronautics Company	May 22, 2008 – December 31, 2008	$99,997	$99,140
	Exploration LISI Coating of Transportation Rails (R02-4411032)	Transportation Technology Center, Inc.	October 5, 2009 – March 31, 2011	$35,845	$35,845
	Closed-Loop Process control for Electron Beam Direct Manufacturing Phase I and Phase II (R02-4411031 and 039)	Air Force / Sciaky, Inc. subcontract	April 20, 2009 – February 28, 2013	$173,030	$33,029
	SBIR Phase II – Electron Beam Direct Manufacturing of Titanium Alloys (R02-4411040)	Air Force / Sciaky, Inc. subcontract	May 10, 2011 – February 28, 2013	$39,980	$2,917
	High Speed Thermal Imaging of WC-Co LENS Deposits (R02-4411028)	NFS / University of California, Davis subcontract	December 15, 2007 – August 31, 2009	$5,000	$5,000
	Process Improvement for Hydroforming of Welded Stainless Steel Tubing (R02-4411027)	Center of Industrial Services / Fisher USA	April 1, 2007 – December 31, 2007	$30,000	$30,000
	Erosion Prevention in Crossover Tools (R02-4411026)	Baker Oil Tools	October 16, 2006 – June 7, 2007	$110,949	$110.949

Investigator	Contract Title	Funding Agency	Period of Performance	2007-2011 Awarded	2007-2011 Expended
Hofmeister, William	Net Shape Rapid Manufacturing Using Nano Encapsulated Powders (R02-4411024)	NASA / Advanced Powder Solutions, Inc.	July 1, 2006 – June 30, 2009	$108,000	$108,000
Johnson, Jacqueline	Advanced High-Resolution Two-Dimensional X-Ray Detector for Mammography (R02-4417020)	National Institutes of Health	February 1, 2008 – November 30, 2011	$1,768,679	$1,419,675
	Study of the Evolution of Nanoparticle Crystallization and Optical Properties in Glass Ceramics (R02-4417022)	National Science Foundation	July 1, 2010 – June 30, 2013	$289,108	$35,130
	Environmental Benign High Rate Deposition of Alloy coatings for Electrolytic Hard Chrome Replacement (R02-4417023)	NSF / Ultool, LLC	July 1, 2010 – May 31, 2011	$12,000	$10,865
	Nanophase Glass Ceramic X-Ray Imaging Materials (R02-4417022 and 024)	National Institutes of Health / Materials Development, Inc. subcontract	October 2008 – September 30, 2012	$54,999	$27,078
Moeller, Trevor	Cryo Deposition Research, Experimentation, and Development of Early Warning and Mitigation Techniques (R02-4348026)	Air Force / AEDC	November 21, 2008 – November 20, 2011	$200,000	$143,473
	Combined Recover Factor Model (R02-4348028)	Air Force / AEDC	May 20, 2009 – May 20, 2012	$35,000	$31,256
	Integration & Technical Support to the 12V Vertical Thrust Integration (R02-4348033)	Air Force / AEDC	September 22, 2010 – September 30, 2012	$50,000	$8,894
	UCDS to Predict the Combustion Stability of Fast Response Liquid Rockets (R02-4348032)	Missile Defense Agency / Gloyer-Taylor Laboratories subcontract	June 1, 2010 – October 31, 2010	$39,992	$39,992
	Electric Propulsion Vertical Thrust Stand (R02-4348023)	Air Force / AEDC	July 31, 2006 – April 30, 2010	$310,000	$310,000
	Space Engineering and Planning Study (R02-43489039)	Air Force / Office of Naval Research	May 20, 2009 – May 20, 2010	$60,000	$60,000
	Support the Analysis of the Ares Solid Rocket Motor Thrust Oscillation (R02-4348027)	Gloyer-Taylor Laboratories	February 1, 2009 – March 2009	$19,831	$19,407
	Thermal Energy Storage IR&D (R02-4348030)	General Atomics	November 23, 2009 – May 31, 2010	$6,503	$6,403

Investigator	Contract Title	Funding Agency	Period of Performance	2007-2011 Awarded	2007-2011 Expended
Moeller, Trevor	Test-Plan: Cryogenic Composite Cylinder (R02-4348031 and 034)	NASA / Gloyer-Taylor Laboratories subcontract	January 22, 2010 – September 30, 2011	$10,913	$7,359
	Multimegawatt Electric Power System Thermal Management (R02-4348025)	General Atomics	November 21, 2006 – November 15, 2009	$760,153	$668,440
Murray, George	IMPACT (Imprinted Polymer Array for Counter Terrorism): A Simple, Low-power Approach to Explosives Detection (R02-4419020)	National Science Foundation / John Hopkins APL	November 4, 2008 – July 31, 2010	$150,000	$150,000
	Uranium Sensors for Y-12 Plant at Oak Ridge (R02-4419021)	B&W Technical ServicesY-12	March 2, 2009 – August 31, 2010	$125,000	$125,000
	Electro-active Polymers for Explosives Detection (R02-4419022)	Raptor Detection, Inc.	February 12, 2010 – February 17, 2012	$399,805	$225,693
	Soluble Molecularly Imprinted Polymers for Biomedical Applications (R02-4419023)	Ambiocore, Inc.	July 29, 2010 – July 28, 2011	$401,879	$111,084
Parigger, Christian	On Laser Ignition of Solid Propellants: Aluminum Particle Ignition (R02-4334020)	Sandia National Laboratory	July 21, 2009 – September 30, 2009	$44,945	$44,945