The Center for Laser Applications (CLA) at the University of Tennessee Space Institute is pleased to present our annual report of the research projects funded by the Center and external sources for fiscal year 2014-2015. The Center for Laser Applications supports the research efforts of ten 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.

Productivity among Center faculty has been outstanding and diverse. Over thirty peer-reviewed articles were published in journals: an all-time high for the Center. Many of these articles are in high impact journals ensuring the wide dissemination of the research output of the Center for Laser Applications. The faculty has been successful in finding direct awards for research. The Tennessee Higher Education Commission (THEC) funding has proven the key to the advancement of innovation and the creation of intellectual property. THEC 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. Without this discretionary funding, advancement of new ideas would be limited. THEC resources allow faculty and students to pursue innovations. This year the awards from faculty research proposals was 2 ½ times the seed funding supplied by THEC.

In 2016 the Center will implement a new strategy of funding and accountability. Short, focused proposals will be accepted from the faculty and awarded by a committee comprised of three CLA faculty members; Trevor Moeller, Jacqueline Johnson, and Lino Costa. It is hoped that this process will help foster research ideas to the stage where efforts can be supported by external funding.

A special congratulations is due to Christian Parigger for a successful 22nd International Conference on Spectral Line Shapes which he organized at UTSI with the support of the Center for Laser Applications. Spectroscopists from around the world were able to visit our beautiful location and share new ideas in the science of spectroscopy.

We are enthusiastic about our opportunities for the future and proud of the past accomplishments.

William Hofmeister
Director, Center for Laser Applications
Research Professor of Materials Science and Engineering
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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, energy/ power 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
- Christian Parigger - photo-acoustic imaging, diagnostics and applications
- Feng-Yuan Zhang - MEMS/ NEMS, micro/ nano fluidics
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

- 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
- Feng-Yuan Zhang - micro/ nano manufacturing multifunctional materials

Spectroscopy

- Charles Johnson - Mössbauer spectroscopy
- Christian Parigger - ultrasensitive spectroscopy and combustion diagnostics
- Lloyd Davis - single molecule spectroscopy
- Ying-Ling Chen - combustion diagnostics
- George Murray - Raman and electrochemical spectroscopy
- Feng-Yuan Zhang - Tomography, Diode-laser absorption spectroscopy, thermography

Non-Equilibrium Fluid Physics

- Trevor Moeller - plasma physics and combustion
- Christian Parigger - laser-plasma physics, combustion and fluid phenomena and computational modeling
- Feng-Yuan Zhang - hypersonic flow and reaction
PERSONNEL

Dr. Brian Canfield, Research Scientist I

Research Scientist Dr. Brian Canfield (Ph.D. Physics, Washington State University) contributes to a wide range of CLA’s research projects in applied and non-linear optics, especially femtosecond laser materials processing, including fabrication of microfluidic and nanofluidic systems, and the development of experimental systems for ultrasensitive fluorescence detection, including single-nanoparticle trapping and tracking for biotechnology applications. Recently, Dr. Canfield designed and built optical systems for femtosecond machining with adjustable aberration correction, and for forming a very-high aspect “Bessel beam” focus for rapid machining of columnar electrodes within synthetic diamonds, to study their use in radiation-hardened detectors for next-generation high-energy particle physics experiments.

Kate Lansford, Research Coordinator II

Ms. Kathleen Lansford (B.S. in Engineering, University of Tennessee, 1998), provides UTSI Faculty and Students with training and support on the operation of various advanced characterization instruments, including optical and scanning electron microscopes, EDAX, and optical profilometry. In addition, she routinely carries out or supervises work on testing the fatigue, wear, erosion, and corrosion resistance of materials, as well as metallographic preparation and characterization of samples. Ms. Lansford also has experience in several electrochemical techniques and in Laser Induced Surface Improvement (LISI) processing.

Dr. Lee Leonard, Research Associate I

Dr. Lee Leonard obtained a B.S. in Mechanical Engineering from Tennessee Technological University in 1995. He then went on to work as an Engineer at Walker Die Casting Company in Lewisburg, Tennessee before returning to education at UTSI to pursue a Master’s and PhD. Lee graduated with an M.S. in Materials Science and Engineering in 2010 and a PhD in Biomedical Engineering in 2015, both from UTSI. He is now embarking on his own academic career.

Robert Rhodes, Research Scientist

Bob has a M.S. in Chemical Engineering. Prior to coming to the University of Tennessee Space Institute he worked in research and technology development at the Arnold Engineering Development Center (AEDC) for almost 30 years. Here he was involved in rocket plume research, including plume mixing, afterburning, and radiation. He was also involved in some of the first studies of supersonic combustion made at AEDC. For the past 22 years he has worked at UTSI on a variety of problems including arcjet and pulsed plasma thrusters, inductively coupled RF plasma devices, railguns, cableguns, and plasma opening switches. In conjunction with this work, he has developed an expertise in the thermodynamic and transport properties of non-ideal plasmas. In both the work at UTSI and AEDC he has also developed extensive experience in modeling chemically reacting flows using finite rate chemical kinetics. Most recently he has been working with on the analysis of a magnetohydrodynamic generator and on the thermal analysis of probes for high enthalpy flows.
Alexander Terekhov, Research Associate III

Alexander has a M.S in Physics from Moscow State University, M.S. in Materials Science from the University of Illinois Urbana-Champaign. Mr. Terekhov is responsible for maintaining the Laser Systems, Laser Safety and other technical hardware at CLA. Alexander is a co-author on many scientific papers in a variety of fields and is the most cited author of all the staff at UTSI.

Doug Warnberg, Research Specialist III

Doug is a United States Air Force veteran and has an Associate’s degree in Applied Science from Motlow State Community College and the Community College of the Air Force. He also has a diploma from the Tennessee College of Applied Technology -Shelbyville in Industrial Maintenance. Doug takes care of the physical plant of CLA and is an expert in HVAC and facilities operation. The many vacuum systems, Class 1000 clean room, and Phillips x-ray machine are all maintained by Mr. Warnberg. If you need a hand with any task Doug is always there to help.

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 STUDENTS

Please congratulate our recent degree recipients listed below...

- **Aerospace Engineering**
  MS: Richard S. Kirkpatrick, Elizabeth Lara Lash, Jorge Damian Parrar Martinez

- **Bio Medical Engineering**
  MS: Julie Elizabeth Swafford

- **Mechanical Engineering**
  MS: Joshua A. Hartman, Reginald S. Floyd, Jr., Brent Phillip Rodgers

- **Physics**
  PhD: Alexander Charles Woods
  MS: David Michael Surmick, Michael Jonathan Witte
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.

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.
What goes around comes around! Summer Intern Program

For the last three years CLA and UTSI have jointly funded a summer intern program, led by Dr. Jacqueline Johnson of Biomedical Engineering and CLA. The program is multifaceted in that it aims to provide a real research experience to prospective graduate students, promote diversity, educate and market. In year one the group was comprised of seven students, five females and two minorities, year two, three males and year three, three males and one female. The students range in educational level from high school to seniors in college. The interns undergo a lecture course, laboratory instruction and training in literature searches before being assigned to a research project. During the course of the summer the students write a paper, prepare a proposal, give a presentation, obtain career advice as well as participate in a full social program.

Summer internships have been found to be a valuable recruiting tool. Two of the students attending the first intern program are now in graduate school at UTSI and two more applied. CLA showcases its spacious laboratories, friendly faculty and staff and dedication to the involvement of students in research.

Each year feed results from a survey done verbally at the midpoint of the internship and a written survey at the end.

The photographs show two students hard at work in the laboratory and the 2013 interns with their supervisors at the ultimate departure bonfire.
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 2011 through 2015, Center faculty published 103 peer-reviewed articles, 10 books and presented at 221 regional, national, and international meetings.

COMPARATIVE SUMMARY OF ACCOMPLISHMENTS

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Publications</td>
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<tr>
<td>Peer-reviewed articles</td>
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<td>15</td>
<td>17</td>
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<td>National</td>
<td>193</td>
<td>28</td>
<td>54</td>
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<td>Research Awards</td>
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<td>Research expenditures</td>
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<td>$1,205,258</td>
<td>$896,901</td>
<td>$666,070</td>
<td>$529,716</td>
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</table>

Despite the current funding environment, we have managed to maintain research expenditures. The decrease in funding in FY2013 is due to the commercialization of the Raptor Detection Technologies project and the shift from Raptor’s research resources to the new start up. Details of current faculty research are provided in the Faculty Reports section (pp. 22-31).
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.

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. We will also improve our flow and combustion measurement capabilities to be in line with UTSI's research in hypersonics. CLA's space and infrastructure will contribute to the success of that program.
## CLA Budget
### Centers of Excellence Actual, Proposed, and Requested Budget

**Institution:** UT Space Institute  
**Center:** Center of Laser Applications

<table>
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<tr>
<th>Expenditures</th>
<th>FY 2014-15 Actuals</th>
<th>FY 2015-16 Proposed</th>
<th>FY 2016-17 Requested</th>
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<tr>
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<td>Matching</td>
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<tr>
<td><strong>Salaries</strong></td>
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<tr>
<td>Faculty</td>
<td>$100,036</td>
<td>$184,377</td>
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<td>Other Professional</td>
<td>$27,762</td>
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<td>Clerical/Supporting</td>
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<td>Assistantships</td>
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<td><strong>Total Salaries</strong></td>
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<td><strong>Longevity</strong></td>
<td>$2,940</td>
<td>$2,927</td>
<td>$5,867</td>
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<td><strong>Fringe Benefits</strong></td>
<td>$63,752</td>
<td>$135,600</td>
<td>$199,352</td>
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<td><strong>Total Personnel</strong></td>
<td>$250,487</td>
<td>$560,606</td>
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<td><strong>Non-Personnel</strong></td>
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<td>Software</td>
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<td>Books &amp; Journals</td>
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<td>Other Supplies</td>
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<td>Equipment</td>
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<td>Maintenance</td>
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<td>Scholarships</td>
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<td>Consultants</td>
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<tr>
<td>Renovation</td>
<td>$0</td>
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</tr>
<tr>
<td>Other (Specify:)</td>
<td>$0</td>
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<td>Prof Services and Memberships</td>
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<td>$2,689</td>
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<td><strong>Total Non-Personnel</strong></td>
<td>$176,278</td>
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<td><strong>Total Non-Personnel</strong></td>
<td>$246,237</td>
<td>$676,619</td>
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### Revenue

<table>
<thead>
<tr>
<th></th>
<th>FY 2014-15 Actuals</th>
<th>FY 2015-16 Proposed</th>
<th>FY 2016-17 Requested</th>
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</thead>
<tbody>
<tr>
<td>New State Appropriation</td>
<td>$833,564</td>
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<td>$816,564</td>
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<td>Carryover State Appropriation</td>
<td>$10,322</td>
<td>$10,322</td>
<td>$167,267</td>
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<tr>
<td>New Matching Funds</td>
<td>$326,765</td>
<td>$426,765</td>
<td>$491,916</td>
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<tr>
<td>Carryover from Previous Matching Funds</td>
<td>$0</td>
<td>$0</td>
<td>$428,696</td>
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<td><strong>Total Revenue</strong></td>
<td>$426,765</td>
<td>$843,866</td>
<td>$1,270,651</td>
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</table>
**CENTERS OF EXCELLENCE**  
**ACTUAL 2014-2015 PERSONNEL**

**INSTITUTION:** The University of Tennessee  
**CENTER:** Center for Laser Applications

1. List faculty whose actual Center effort was at least 25% of full effort.

<table>
<thead>
<tr>
<th>Name and Faculty Rank</th>
<th>Departmental Affiliation</th>
<th>Actual Center Effort in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr. Ying Ling Chen</td>
<td>Research Assistant Professor</td>
<td>70</td>
</tr>
<tr>
<td>Dr. Jose Lino Vasconcelos da Costa</td>
<td>Research Assistant Professor</td>
<td>70</td>
</tr>
<tr>
<td>Dr. Lloyd Davis</td>
<td>Professor</td>
<td>50</td>
</tr>
<tr>
<td>Dr. William Hofmeister</td>
<td>Research Professor</td>
<td>100</td>
</tr>
<tr>
<td>Dr. Jacqueline Johnson</td>
<td>Associate Professor</td>
<td>50</td>
</tr>
<tr>
<td>Dr. Trevor Moeller</td>
<td>Assistant Professor</td>
<td>50</td>
</tr>
<tr>
<td>Dr. Christian Parigger</td>
<td>Associate Professor</td>
<td>50</td>
</tr>
<tr>
<td>Dr. Feng Yuan Zhang</td>
<td>Associate Professor</td>
<td>50</td>
</tr>
</tbody>
</table>

2. List the total number and aggregate FTE Center effort of those faculty whose actual Center effort was less than 25%.

   Number  | FTE  
   ------- | ----- 
   0      | 0.00  

For each of the personnel categories other than faculty, list the total number of staff and aggregate FTE Center effort.

<table>
<thead>
<tr>
<th>Number</th>
<th>FTE</th>
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<tbody>
<tr>
<td>B.</td>
<td>5</td>
</tr>
<tr>
<td>C.</td>
<td>2</td>
</tr>
<tr>
<td>D.</td>
<td>1</td>
</tr>
</tbody>
</table>
1. List faculty whose actual Center effort was at least 25% of full effort.

<table>
<thead>
<tr>
<th>Name and Faculty Rank</th>
<th>Departmental Affiliation</th>
<th>Actual Center Effort in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr. Ying Ling Chen</td>
<td>Research Assistant Professor</td>
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<tr>
<td>Dr. Jose Lino Vasconcelos da Costa</td>
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</tr>
<tr>
<td>Dr. Lloyd Davis</td>
<td>Professor</td>
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<tr>
<td>Dr. William Hofmeister</td>
<td>Research Professor</td>
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</tr>
<tr>
<td>Dr. Jacqueline Johnson</td>
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<tr>
<td>Dr. Trevor Moeller</td>
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<tr>
<td>Dr. Christian Parigger</td>
<td>Associate Professor</td>
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<tr>
<td>Dr. Feng Yuan Zhang</td>
<td>Associate Professor</td>
<td>50</td>
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</table>

2. List the total number and aggregate FTE Center effort of those faculty whose actual Center effort was less than 25%.

   Number 0  FTE 0.00

   For each of the personnel categories other than faculty, list the total number of staff and aggregate FTE Center effort.

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<td>C. Clerical/Supporting</td>
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<td>D. Assistantships</td>
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</tbody>
</table>
1. List faculty whose actual Center effort was at least 25% of full effort.

<table>
<thead>
<tr>
<th>Name and Faculty Rank</th>
<th>Departmental Affiliation</th>
<th>Actual Center Effort in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr. Ying Ling Chen</td>
<td>Research Assistant Professor</td>
<td>Physics</td>
</tr>
<tr>
<td>Dr. Jose Lino Vasconcelos da Costa</td>
<td>Research Assistant Professor</td>
<td>Materials Science and Engineering</td>
</tr>
<tr>
<td>Dr. Lloyd Davis</td>
<td>Professor</td>
<td>Physics</td>
</tr>
<tr>
<td>Dr. William Hofmeister</td>
<td>Research Professor</td>
<td>Materials Science and Engineering</td>
</tr>
<tr>
<td>Dr. Jacqueline Johnson</td>
<td>Associate Professor</td>
<td>Mechanical, Aerospace and Biomedical Engineering</td>
</tr>
<tr>
<td>Dr. Trevor Moeller</td>
<td>Assistant Professor</td>
<td>Mechanical, Aerospace and Biomedical Engineering</td>
</tr>
<tr>
<td>Dr. Christian Parigger</td>
<td>Associate Professor</td>
<td>Physics</td>
</tr>
<tr>
<td>Dr. Feng Yuan Zhang</td>
<td>Associate Professor</td>
<td>Mechanical, Aerospace and Biomedical Engineering</td>
</tr>
</tbody>
</table>

2. List the total number and aggregate FTE Center effort of those faculty whose actual Center effort was less than 25%.

   Number 0   FTE 0.00

For each of the personnel categories other than faculty, list the total number of staff and aggregate FTE Center effort.

<table>
<thead>
<tr>
<th>Category</th>
<th>Number</th>
<th>FTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>B. Other Professional</td>
<td>5</td>
<td>4.25</td>
</tr>
<tr>
<td>C. Clerical/Supporting</td>
<td>2.5</td>
<td>2.50</td>
</tr>
<tr>
<td>D. Assistantships</td>
<td>0</td>
<td>0.00</td>
</tr>
</tbody>
</table>
## SCHEDULE 9A

**CENTERS OF EXCELLENCE**  
**ACTUAL EQUIPMENT, 2014-2015**

**INSTITUTION:** The University of Tennessee  
**CENTER:** Center for Laser Applications

<table>
<thead>
<tr>
<th>Description</th>
<th>Number</th>
<th>Unit Cost</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>APPROPRIATION</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labstar Pro Glovebox</td>
<td>1</td>
<td>20,000</td>
<td>20,000</td>
</tr>
<tr>
<td><strong>MATCHING</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phantom V711 Monochrome High Speed Camera</td>
<td>1</td>
<td>79,986</td>
<td>79,986</td>
</tr>
<tr>
<td>Electrochemical Test Station</td>
<td>1</td>
<td>27,971</td>
<td>27,971</td>
</tr>
<tr>
<td><strong>GRAND TOTAL</strong></td>
<td></td>
<td></td>
<td>127,957</td>
</tr>
</tbody>
</table>

(Matching and Appropriation should add to Grand Total)

List restricted and unrestricted budget account numbers to be used for matching:

- E024040 MABE Program

**Budget Form 2016-2017**
### Program Report

**SCHEDULE 9B**

**CENTERS OF EXCELLENCE**

**PROPOSED EQUIPMENT, 2015-2016**

**INSTITUTION:** The University of Tennessee  
**CENTER:** Center for Laser Applications

<table>
<thead>
<tr>
<th>Description</th>
<th>Number</th>
<th>Unit Cost</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>APPROPRIATION</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modern Femtosecond Laser System</td>
<td>1</td>
<td>311,098</td>
<td>$311,098</td>
</tr>
<tr>
<td><strong>MATCHING</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capillary Flow Spectrometer</td>
<td>1</td>
<td>40,000</td>
<td>40,000</td>
</tr>
<tr>
<td>Large Vacuum Pump System</td>
<td>1</td>
<td>60,000</td>
<td>60,000</td>
</tr>
<tr>
<td>Digital Oscilloscope 4-6 channel 500 MHz</td>
<td>1</td>
<td>30,000</td>
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<tr>
<td><strong>GRAND TOTAL</strong></td>
<td>$441,098</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**(Matching and Appropriation should add to Grand Total)**

List restricted and unrestricted budget account numbers to be used for matching.

- E024040 MABE Program
- E024050 Materials Science Program
- E024060 Physics Program
## SCHEDULE 9C

### CENTERS OF EXCELLENCE
**REQUESTED EQUIPMENT, 2016-2017**

**INSTITUTION:** The University of Tennessee

**CENTER:** Center for Laser Applications

<table>
<thead>
<tr>
<th>Description</th>
<th>Number</th>
<th>Unit Cost</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>APPROPRIATION</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optical Microscope</td>
<td>1</td>
<td>150,000</td>
<td>$150,000</td>
</tr>
<tr>
<td><strong>MATCHING</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tunable Laser Detection System</td>
<td>1</td>
<td>58,000</td>
<td>$58,000</td>
</tr>
<tr>
<td><strong>GRAND TOTAL</strong></td>
<td></td>
<td></td>
<td>$208,000</td>
</tr>
</tbody>
</table>

(Matching and Appropriation should add to Grand Total)

List restricted and unrestricted budget account numbers to be used for matching:
- E024040 MABE Program
- E024050 Materials Science Program
- E024060 Physics Program

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18
SCHEDULE 10A

CENTERS OF EXCELLENCE
BASE SUPPORT AND NON-EQUIPMENT MATCHING
ACTUAL 2014-2015

INSTITUTION: The University of Tennessee
CENTER: Center for Laser Applications

<table>
<thead>
<tr>
<th>Base Support by Budget Account Number</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>E024040 Mechanical, Aerospace, and Biomedical Engineering</td>
<td>234,070</td>
</tr>
<tr>
<td>E024050 Materials Science and Engineering</td>
<td>85,345</td>
</tr>
<tr>
<td>E024060 Physics</td>
<td>107,350</td>
</tr>
</tbody>
</table>

Total Base Support $426,765

Non-Equipment Matching:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Restricted Accounts Subtotal</td>
<td>$</td>
</tr>
<tr>
<td>Unrestricted Accounts Subtotal</td>
<td>318,808</td>
</tr>
<tr>
<td>Total</td>
<td>$318,808</td>
</tr>
</tbody>
</table>

List unrestricted budget account numbers to be used for matching:

E024040 MABE Program
E024050 Materials Science Program
E024060 Physics Program
**Program Report**

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**SCHEDULE 10B**

**CENTERS OF EXCELLENCE**

**BASE SUPPORT AND NON-EQUIPMENT MATCHING**

**PROPOSED 2015-2016**

**INSTITUTION:** The University of Tennessee  
**CENTER:** Center for Laser Applications

<table>
<thead>
<tr>
<th>Base Support by Budget Account Number</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>E024040 Mechanical, Aerospace, and Biomedical Engineering</td>
<td>270,554</td>
</tr>
<tr>
<td>E024050 Materials Science and Engineering</td>
<td>98,383</td>
</tr>
<tr>
<td>E024060 Physics</td>
<td>122,979</td>
</tr>
</tbody>
</table>

Total Base Support: **$491,916**

Non-Equipment Matching:

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restricted Accounts Subtotal</td>
<td></td>
</tr>
<tr>
<td>Unrestricted Accounts Subtotal</td>
<td>361,916</td>
</tr>
<tr>
<td>Total</td>
<td>$361,916</td>
</tr>
</tbody>
</table>

List unrestricted budget account numbers to be used for matching:

- E024040 MABE Program
- E024050 Materials Science Program
- E024060 Physics Program
### INSTITUTION:
The University of Tennessee

### CENTER:
Center for Laser Applications

#### Base Support by Budget Account Number

<table>
<thead>
<tr>
<th>Budget Account</th>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>E024040</td>
<td>Mechanical, Aerospace, and Biomedical Engineering</td>
<td>235,783</td>
</tr>
<tr>
<td>E024050</td>
<td>Materials Science and Engineering</td>
<td>85,739</td>
</tr>
<tr>
<td>E024060</td>
<td>Physics</td>
<td>107,174</td>
</tr>
</tbody>
</table>

Total Base Support = 428,696

#### Non-Equipment Matching:

- Restricted Accounts Subtotal
- Unrestricted Accounts Subtotal = 370,696

Total = $370,696

List unrestricted budget account numbers to be used for matching:

E024040 MABE Program
Professor Chen’s biophysics vision research utilizes her background in laser- and optical-physics to the study of the complex system of the human eye. Her research interests are illustrated in the two figures:

The first is the computational endeavor to develop analytical models of the imperfect eye. The models then serve as the basis for the design and deployment of expert system-based diagnostics of large populations. For example, she recently received a new contract to investigate the feasibility of combining the use of sub-micron particulate spectroscopy with age- and population-corrected eye modeling to produce cataract eye models that can be used for early cataract detection. This project will determine the feasibility of using a comparatively simple optical method to detect the formation of cataract, which is needed to respond to emerging treatment non-surgical options for this disease. This simulation capability will guide the optimal design of a low-cost device to approach the high-sensitivity detection.

The second figure illustrates the binocular instrumentation work followed by Dr. Chen’s three UTRF patents. The purpose of this technology is to assess ocular information automatically while the examinee views a short animation in his/her natural condition. Currently Professor Chen is developing collaborations with research groups in the Brain Institute and Eye Institute of Vanderbilt University to investigate the DOES application of detecting mental problems such as post-traumatic stress disorder, dyslexia, and physical/emotional abuse through the ocular response and the hand-eye-stimulus interaction.
Dr. Lino Costa joined UTSI during the fall of 2005 as a research associate and became a research assistant professor during the fall of 2010. He holds a Ph.D. degree in Materials Engineering from Instituto Superior Tecnico, in Lisbon Portugal, with a dissertation on finite element modeling of laser powder deposition of tool steels. Dr. Costa has contributed to the advancement of various laser materials processing techniques, including Laser Powder Deposition applied to Additive Manufacturing, Laser Induced Surface Improvement (LISI™) for development of wear and corrosion resistant surface coatings, and Femtosecond Laser Micromachining for fabrication of microfluidic lab-on-a-chip devices for biomedical research applications.

Femtosecond Laser Micromachining is uniquely capable of producing millions of deep and closely packed nanopores, rapidly, on the surface of transparent dielectric materials like fused silica. These surface nanopores are ideally suited for use in forming arrays of polymer nanowires. The individual nanowires have an average outer diameter of a few hundred nanometers and, depending on the material, can exhibit lengths ranging from a few micrometers up to 75 micrometers. Dr. Costa continues to develop various methods of forming such nanowire arrays from various polymer materials and for several different applications.
The research of Professor Davis and his group spans a range of activities in laser applications, mostly for chemical analysis and biotechnology. Much of this work is built on the group’s prior experience in ultrasensitive fluorescence detection, beginning with the first experiments to successfully demonstrate detection of a single fluorophore in solution in the late 1980’s, and including the first single-molecule detection in a “lab-on-a-chip” device in the 1990’s, early experiments on single-molecule imaging for 3rd generation DNA sequencing in the early 2000’s, and novel single-molecule detection and trapping in nano-fluidic channels around 2008-2010. In the past few years, our work has included development of experimental capabilities for tracking and trapping a single fluorescent nanoparticle in three dimensions (3-D) using a custom-built ultrasensitive confocal fluorescence microscope. Our ongoing work aims to improve and extend these capabilities for applications in biotechnology. Our experiments apply real-time control of solution flow or sample position to counteract Brownian diffusion. We are also carrying out computational and experimental studies of single-molecule recycling in a nanochannel by alternating the fluid motion using real-time control. This provides a further advantage of reducing a molecule’s exposure and photobleaching and hence prolonging the duration over which it may be observed.

Over the past year, several external collaborations have continued, including a project with JILA, at UC Boulder, in which aspects of our research on real-time control for trapping have been applied in a microfluidic device, which sorts cells in response to their fluorescence properties. In a Technical Innovation paper published in the November issue of Integrative Biology, we applied the device for research on genetically engineering improved fluorescent proteins to develop a mutant of the red fluorescent protein mCherry with 4-fold higher photostability under confocal imaging conditions. The mutant has been named Kriek, after the Belgian beer fermented from cherries. In a March paper in Analytical Chemistry, we demonstrated an improved version of the microfluidic device for high-speed multi-parameter photophysical analyses of fluorophore libraries. Another external collaboration that grew from our 3-D trapping research is an NSF-sponsored project with Vanderbilt University on ultrasensitive spectroscopy of nanoparticles for energy conversion applications. In an especially exciting result, published in the American Chemical Society journal ACS Nano, we combined ultrasensitive fluorescence measurements with atomic number contrast scanning transmission electron microscopy to show how the atomic arrangements of individual quantum dots impact their fluorescence emission properties, including brightness and suppressed blinking. This will facilitate rapid synthetic enhancement of desired quantum dot properties.

We are also enthusiastically continuing our research on femtosecond laser machining (originally initiated for fabricating fluidic devices for single-molecule experiments). Over the past few years, we have combined novel optical design of special focusing conditions to fabricate very high aspect ratio features, including deep holes and long channels. A new application under study over the last year (in collaboration with Prof. Spanier of UTK physics), illustrated in the figure at left, is the fabrication of electrodes within diamonds for developing next-generation detectors for use in high-energy particle physics experiments.
Faculty Reports

LASER MATERIALS PROCESSING

William Hofmeister

Research Professor of Materials Science and Engineering
PhD, Vanderbilt University
Adjoint Professor of Electrical Engineering, Vanderbilt University
University of Canterbury Visiting Erskine Fellow, 2011
Fellow of ASM International

Professor Hofmeister came to UTSI ten 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 additive fabrication. 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 is working with NASA, the US Air Force and Sciaky, Inc. to develop sensors and control strategies for additive manufacture using electron beam technologies. Two patents have been awarded to NASA for his innovations in control of electron beam additive manufacture.

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 four axis 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 has developed a unique 3D model for cell culture and is exploring the use of these models in several laboratories to study cancer mutagenesis, lymphocytes and tissue regeneration.

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. He has served as Board 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, Ace Pump, and Jarden Zinc, with materials related problem solving.
Dr. Charles Johnson studies materials using Mössbauer spectroscopy, which uses gamma-rays to probe the magnetic and electric fields at nuclei in atoms in solids.

A series of Metal Organic Frameworks (MOFs) has been measured. These are novel structures of metal ions or clusters with voids that can contain gases or organic molecules. They have important applications to catalysis, storing of hydrogen and other gases, gas purification and sensors. In collaboration with Rutgers University we have measured MOFs containing iron in porphyrins, where it is surrounded by four nitrogen atoms in a plane, similar to the structure of hemoglobin. The oxidation and spin state of the iron has been determined and compared with that in the bulk compounds. The results give information on the intermolecular interactions in these structures.

Research has continued in characterizing materials for biomedical applications. The stoichiometry of superparamagnetic iron oxide nanoparticles has been determined for use as an agent for enhancing magnetic resonance images. The recycling of anodes for rechargeable sodium-ion batteries has been tested for use in portable devices such as pacemakers and blood-pressure meters.

In another application, measurements have been made in collaboration with Dr. Feng-Yuan Zhang to analyze the corrosion products in a reverse fuel cell (polymer electrolyte membrane electrolyzer cell or PEMEC). It was found that iron had diffused from the anode and had been deposited on the carbon paper cathode in the form of $\gamma$-Fe$_2$O$_3$ and $\gamma$-FeOOH.

A metal organic framework: the sphere shows the void which can be filled with a gas or an organic molecule.
The Johnson group continued its research into luminescent glass ceramics, including neutron and high energy (MeV) scintillators and storage phosphors. In addition, they collaborated with South Westphalia University of Applied Sciences, Soest, Germany, on the investigation of temperature-dependent luminescence of Tb$^{3+}$ and Eu$^{3+}$ doped glasses for LED applications. In such applications, the color appearance is one of the most important features. Figure 1 indicates the chromaticity coordinates of Tb$^{3+}$ and Eu$^{3+}$ in the CIE (Commission internationale de l’clairage) color space chromaticity diagram for both ZBLAN and borate glasses. The Tb$^{3+}$ doped glasses showed high color stability over the entire temperature range investigated, whereas the Eu$^{3+}$ doped glasses changed their color appearance with increasing temperature [Temperature-dependent luminescence of Tb$^{3+}$ and Eu$^{3+}$ doped glasses for LED applications, Loos et al. (2015)]. This system is particularly interesting as a frequency down converter for LEDs.

H$_2$O$_2$ has gained considerable attention due to its antiseptic properties, specifically for its use in swimming pools for disinfection as it is less of an irritant than chlorination. The Johnson group joined with MTSU to characterize zinc oxide nanoparticles tethered to carbon nanotubes as a sensor of hydrogen peroxide (H$_2$O$_2$) levels. Monitoring of H$_2$O$_2$ was performed as shown in Figure 2. The sensor had excellent reproducibility, exhibited stability and selectivity, and was able to measure concentrations in a dynamic environment as they varied [A zinc carbon nanotube based sensor for in situ monitoring of hydrogen peroxide in swimming pools, Wayu et al. (2015)].

Dr. Johnson continues to be a reviewer for the National Institutes of Health (NIH), is on the Advisory Board for Neutron Sciences at Oak Ridge National Laboratory and currently organizing the conference: Physics of Non-Crystalline Solids (PNCS) XIV, to be held in Niagara Falls, USA in 2015.

Dr. Johnson is grateful for the hard work by graduate students Lee Leonard, Jason Hah, Julie Swafford and Adam Evans.
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 an ultrasensitive electric propulsion thrust stand. 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, precise measurement of convective heat transfer coefficients for unique probe geometries, investigations of cryodeposit contamination in cryopumped vacuum chambers, and diagnostics for space environment simulation chambers. The sensitive nature of these programs precludes the presentation of further details. Dr. Moeller also is conducting basic research in high speed flows and the development of tools for the modeling of coupled electromagnetic/ fluid systems.

Key future engineering technologies such as advanced propulsion and hypersonic flight require both experimental test capabilities and advanced modeling. To accommodate the former, Dr. Moeller’s is developing a Mach 3 Scramjet Flowpath Facility (wind tunnel) that will be used to study internal flow characteristics in hypersonic vehicle propulsion systems. For the latter, both commercial and in-house CFD tools are used. One example is the ongoing development of 3D, CFD models to further investigate the effects of pulsation of various fuels (e.g. hydrogen and ethylene) into supersonic crossflows (Fig. 1).

Figure 1. Contour plots from the 2-D steady and pulsed injection study

Dr. Moeller’s group is continuing to develop our in-house CFD tool, TEM PEST (Tennessee electromagnetics/ fluids/ plasmas equation solver toolchain), to facilitates accurate quantitative modeling of plasma dynamics in complex-geometry, multidimensional problems, which permits us to resolve the complete multi-species, multiscale dynamics occurring within a plasma device both efficiently and accurately. We have successfully applied this new tool to a wide range of relevant physical problems, including low-electrical-conductivity effects, magnetic field wave and diffusion behavior in the same computational domain, and magnetohydrodynamic turbulence.
MOLECULAR RECOGNITION

George M. Murray
Adjunct Professor
Mechanical, Aerospace and Biomedical Engineering (MABE)
PhD, University of Tennessee

Professor George M. Murray is an Adjunct Professor of Mechanical Aerospace and Biomedical 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 specific sensors for toxic compounds. In one embodiment, 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 polymerization mechanism used is Reversible Addition Fragmentation Transfer (RAFT) polymerization. This living radical polymerization method allows the preparation of specifically engineered block copolymer stars with nanoscale dimensions. The stars are soluble and processable imprinted materials. The stars are also end functionalized for binding to specific substrates such as glass or gold. Analogous methodologies are currently being applied to the production of sensors for the detection and determination of toxins, drugs of abuse, explosives and meat spoilage. Toxins are measured using piezo-electric transducers. Drugs are measured in an analogous manner to the nerve agents, while 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. All of 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 twenty-one U.S. patents and was named as one of the twenty-two Master Inventors of the Johns Hopkins University Applied Physics Laboratory. Dr. Murray's research interests are centered on developing methods for the sequestration and the 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.
ATOMIC AND MOLECULAR LASER SPECTROSCOPY

Christian Parigger
Associate Professor of Physics and Astronomy
PhD, University of Otago, Dunedin, New Zealand
Dr. rer. nat. in Physics, University of Innsbruck, Austria

Professor Parigger has been a member of the Center for Laser Applications (CLA) since 1987, and during the coming year he will commence his 30th year of contributions to The University of Tennessee Space Institute (UTSI) and CLA in its research, education, and service missions. His research contributions encompass experimental, theoretical, and computational Physics, with focus in Atomic and Molecular and Optical (AMO) Physics. The work includes fundamental and applied spectroscopy, nonlinear optics, quantum optics, ultrafast phenomena, ultrasensitive diagnostics, lasers, combustion and plasma Physics, optical diagnostics, applied optics, biomedical applications. His academic activities include service on various Masters and PhD committees both in Engineering and in Physics. During the last year, he organized as Chair the 22nd International Conference on Spectral Line Shapes (ICSLS), and he worked as editor for the Journal of Physics: Conference Series peer-reviewed papers on subjects of interest to the spectral line shape community. He served as President-elect during 2014/2015, and will lead the UTSI caucus and Faculty Assembly as President in 2015/2016, and he served and will continue to concurrently serve as Senator of the Faculty Senate of The University of Tennessee. Professor Parigger has been strongly engaged in postgraduate education, primarily offering doctoral research related courses for students of Physics and Engineering, most of these courses included interactive video from the UTSI campus to the Knoxville Campus.

Christian Parigger’s research activities in atomic and molecular spectroscopy and non-equilibrium physics are very well received at international level, including for instance the laser-induced breakdown spectroscopy, plasma and/ or combustion Physics communities. Collaborations extend to faculty and researchers at international universities, to name a few, in Italy, Austria, Hungary, Russia, India, Egypt, to several national universities, e.g., Auburn University, Arkansas State University, New Mexico State University, Denver University, University of Nebraska at Lincoln, and to National Laboratories including at Oak Ridge and at Albuquerque.

Christian Parigger’s recent experimental research efforts include various diagnostic works in natural science, i.e., Physics, and in applied science, i.e., Engineering. The figure illustrates results of optical breakdown in humid air, taken at a time delay of 1 µs after laser-plasma generation with 170 mJoule, 13 ns NdYAG laser pulses. Of interest are laser induced plasma generation in gases and during laser ablation of various materials including solid propellants and nano materials. During the current reporting period, Alexander C. Woods and Michael J. Witte completed their doctoral PhD dissertation and Master’s thesis, respectively. The students Ghaneshwar Gautam and David Surmick continue to work on their doctoral research, both passed the so-called comprehensive examination in 2014/2015. Lauren Swafford showed major strides towards completion of her Master’s degree. Noteworthy, David Surmick received for the second year in a row in 2015 The University of Tennessee Chancellor’s Honors for “extraordinary professional promise,” an award that reflects continuing, extraordinary academic quality of ongoing work in Physics and at the Center for Laser Applications.
The research interests of Dr. Zhang's NanoHELP group lie in thermal-fluid sciences, nanotechnology, and advanced spectroscopies and diagnostics. The goal of his NanoHELP group is to take advantage of nanotechnology for developing high-efficiency, low-cost and sustainable energy, power and propulsion devices, such as fuel cells, electrolyzers, batteries, direct combustion engines, and electric thrusters. The NanoHELP research ranges from fundamental understanding to system optimization with a strong interdisciplinary program for the study of micro/nano-scale reaction, heat/mass transport, fluid mechanics, novel materials, corrosion, 3D printing/additive manufacturing, degradation, surface/mechanical/chemical properties and MEMS/NEMS. More details can be found at his group website at http://fzhang.utsi.edu/.

One of the research projects in Dr. Zhang's NanoHELP group is to develop an advanced polymer electrolyte membrane electrolyzer cell (PEMEC), which is a reverse PEM fuel cell (PEM FC). Figure 1 shows a module schematic of a PEM electrolyzer cell for space applications. In this simplified system, a PEM EC combines solar energy and water to produce oxygen at the anode and hydrogen at the cathode, respectively. As an oxygen generator, it has been successfully used in space to continuously provide breathing oxygen for the astronauts. Hydrogen fuel has been applied for propulsion power systems when needed and the water product may be electrolyzed in the next cycle. There are several challenges for promoting the PEMEC efficiency. The harsh environment in the PEMEC will cause material corrosion and consumption, leading to poor interfacial contacts and a reduction in its performance and efficiency. A set of liquid/gas diffusion layers (LGDLs), made of different materials, tested for better investigating corrosion mechanism and interfacial degradation in our group. Severe corrosions were discovered with both electropotential performance and electrochemical impedance measurements. Based on the discoveries, titanium was identified to be a promising material, and a matrix of Ti LGDLs with different thicknesses and a range of porosities from 30% to 80% are designed and examined for parameter optimization. The CLA nanofabrication facilities have been utilized for LGDL fabrications and surface modification. In addition, a high-speed and micro-scale visualization system (HMVS) with large working distance and speed rate of up to 1,400,000 fps, as shown in Figure 2, was developed in the group to capture the dynamics of micro-scale reaction and transport coupling with the development of transparent PEM ECs. A thermal infrared spectroscopy was also established for multiscale investigation of reaction mechanism and temperature profiles. Corrosion measurements have been made in collaboration with Dr Charles Johnson’s group, and the forms of corrosion elements have been identified.

Publications

Peer Reviewed:


Accepted and in Press:


Book Chapters:


Conference Proceedings:


Presentations

Invited Presentations:


Lino Costa, Eight lectures on Laser Materials Processing at the Northwestern Polytechnical University (NPU), located in Xi’an, Shaanxi Province, and People’s Republic of China. January 2015.

Christian G. Parigger, “Laser-Induced Plasma Dynamics: (1) Laser-Induced Plasma (LIP) Fundamentals; (2) LIP and Atomic Spectroscopy; (3) LIP and Molecular Spectroscopy,” invited Speaker for Guest – Lecture-Series, The University of Cairo, Giza, Egypt, January 10-12, 2015.

**Contributed Presentations:**


A. Shanker, S. Goodwin, L. Costa, A. Terekhov, M. Thounaojam, W. Hofmeister, R. Uzhachenko; “Cross-talk between CD8+ T and NK cells: Fine-tuning of anti-tumor immune response,” Immunology Summit 2014 - 3rd International Conference and Exhibition on Clinical & Cellular Immunology; Baltimore, Maryland, USA; 29 September to 01 October 2014; (oral presentation).


R. Uzhachenko, J. Goodwin, L. Costa, A. Terekhov, M. Thounaojam, W. Hofmeister, A. Shanker; “Mitochondrial Ca2+ Transport Fine-Tunes Functional Cross-Talk Between Anti-Tumor CD8+T Lymphocytes and Natural Killer Cells,” Tumor Immunology and Immunotherapy: A New Chapter; Orlando, Florida, USA; 1-4 December 2014; American Association for Cancer Research (AACR). (Poster presentation)


Ghaneshwar Gautam, Christian G. Parigger, “Hydrogen Balmer Series Measurements in Laser-Induced Plasma,” Oral Presentation Wed #H5-6, 46th Annual Meeting of the APS, Division of Atomic Molecular & Optical Physics (DAMOP), Columbus, Ohio, June 8-12, 2015.


**Conference Organizing:**

Feng-Yuan Zhang, Track Co-Chair and Session Chair: Characterization of Interfaces and Interphases, 225th ECS Meeting, 2014.


Awards:

David M. Surmick, University of Tennessee Chancellor’s Honors Recipient for “Extraordinary Professional Promise,” April 2015.

Dr. Trevor Moeller received special award from the Tennessee Section of the AIAA; Citation: For being an exception mentor and advisor challenging students and young engineers to strive for technical excellence in their academic pursuit and professional development. May 2015.

Dr. Charles Johnson has received an award from the International Union of Pure and Applied Physics (IUPAP) and the German Physical Society for his research, and which will be presented at the International Conference on the Applications of the Mössbauer Effect in Hamburg in September 13-18, 2015. He will give an invited talk on Mössbauer measurements on Fe$_3$O$_4$ nanoparticles for medical applications”.


Patents, Patent Applications and Disclosures:


“Nanostructure used as e.g. nanowires that are used as cell culture substrated to study cell behavior in three dimensional microenvironement, comprises polymer where nanostructure is prepared from nanohole formed within transparent substrate,” W.H. Hofmeister, A.Y. Terekhov, J.L.V. de Costa, K.S. Lansford, D. Rajput, L.M. Davis, US Patent Application US2015093550-A1, filed 4 Dec 2014.

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<tr>
<th>Investigator</th>
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<td>Chen, Ying-Ling</td>
<td>A Quantitative Purkinje Technique for Early Cataract Detection (Phase 1: Feasibility Evaluation) SWIFT INFO (R02-4313029)</td>
<td>Swift Info Technology 8500045849</td>
<td>April 25, 2015 – April 30, 2016</td>
<td>$100,000</td>
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<td>Costa, Lino</td>
<td>Prototyping of Nanostructures (R02-4428020)</td>
<td>Ultra Small Fibers, LLC</td>
<td>June 1, 2015 – May 31- 2016</td>
<td>$50,564</td>
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<td>Optical Imaging of Residual Disease with Upconverting Nanocrystals (R024417026)</td>
<td>National Institutes of Health/ Materials Development, Inc. subcontract</td>
<td>September 16, 2013 – August 31, 2014</td>
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<td>Multielectron Cathode Materials with Capacities (R02-4417028)</td>
<td>Volkswagen</td>
<td>October 1, 2014 – September 30, 2015</td>
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<td>Moeller, Trevor</td>
<td>Cryo Deposition Research, Experimentation, and Development of Early Warning and Mitigation Technologies (R02-4348026)</td>
<td>Air Force/AEDC</td>
<td>November 21, 2008 – December 31, 2014</td>
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<td>Continued Participation by The University of Tennessee Space Institute (R02-432026)</td>
<td>Vanderbilt University</td>
<td>June 14, 2010 – June 30, 2016</td>
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<td>Heat Transfer Coefficient Characterization for Stag (R02-4348042)</td>
<td>DOD-Department of Air Force</td>
<td>April 19, 2013 – March 31, 2015</td>
<td>$50,000</td>
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<td>Support of Plasma Effects, Diagnostics, and Analysis in STAT (R02-4348044)</td>
<td>AEDC/ FMF</td>
<td>February 24, 2014 – September 30, 2015</td>
<td>$55,000</td>
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<td>Radiation Uncertainty Characterization for Stagnation Probe (R02-4348045)</td>
<td>Air Force/ AEDC</td>
<td>April 11, 2014 – May 8, 2015</td>
<td>$50,000</td>
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<td>A Cryo-Vacuum Compatible Positioning System (R02-4348046)</td>
<td>Square One Systems Design, Inc.</td>
<td>July 1, 2014 – June 30, 2016</td>
<td>$10,000</td>
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<td>Solar-Lunar Exclusion Projection System (R02-4348048)</td>
<td>Physical Optics Corporation</td>
<td>October 1, 2014 – August 31, 2015</td>
<td>$79,191 Cont.</td>
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<td>Development of an Innovative Sys For Cryodep (R02-4348049)</td>
<td>Physical Sciences Inc.</td>
<td>October 1, 2014 – August 31, 2016</td>
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<td>Medium-Scale Cryotank Testing Support (R02-4348050)</td>
<td>Gloyer-Taylor Laboratories, LLC</td>
<td>March 26, 2015 – August 31, 2015</td>
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<td>Ace Booster PH II (R02-4348051)</td>
<td>Gloyer-Taylor Laboratories, LLC</td>
<td>June 8, 2015 – May 20, 2017</td>
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<td>Zhang, Feng-Yuan</td>
<td>Developing Novel Multifunctional Materials for High-Efficiency Electrical Energy Storage (R02-4421020)</td>
<td>Department of Energy</td>
<td>September 1, 2013 – August 31, 2016</td>
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<td>Development of Next-Generation Lubricant Additive for High-Efficiency Engines (R02-4421022)</td>
<td>DOE-ORNL</td>
<td>August 20, 2014 – December 31, 2015</td>
<td>$40,825</td>
<td>$32,630</td>
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