WELCOMING REMARKS

The Center for Laser Applications (CLA) at the University of Tennessee Knoxville Space Institute at Tullahoma is pleased to present our annual report of research projects funded by the Center.

This has been a transformative year for CLA. The CLA has established capabilities, both in Faculty and equipment, that are unique for both the state and the nation. The strengths and interest in the applications of lasers for diagnostics and materials processing represent a unique university-based combination that is critical for many industrial, defense, and basic science application areas. Our capabilities now include combustion systems and jet engine/space propulsion systems development, laser materials processing, ground-based (simulated) aerospace testing, electro-optics, non-linear optics, quantum optics, molecular spectroscopy, and laser induced assisted chemical reactions. All of these areas fit with CLA’s original and current Mission. They have obvious relevance to the future competitiveness of technological industries and institutions of the state, region, and nation.

We have moved our strategic plan forward by bringing faculty and researchers from different disciplines to work together, each bringing a different expertise to the table. These include Bio/Nano-photonics, Material Science, Laser Material Interaction, Laser Spectroscopy, Laser based Measurement/Diagnostics, and Non-Equilibrium Fluid Physics. Our multidisciplinary collaborations with the MABE faculty have the potential to open many new opportunities. The process has already expanded our capabilities by allowing budgetary carry over that is being used to purchase new and up to date equipment, with more to come.

James L. Simonton Ph.D.

Acting Director, Center for Laser Applications
Associate Executive Director UTSI
University of Tennessee Space Institute
411 B.H. Goethert Parkway
Tullahoma, TN 37388
jsimonto@utsi.edu
931-393-7213
CENTER FOR LASER APPLICATIONS
ANNUAL REPORT 2019-2020

Table of Contents

Program Report

Introduction.................................................................................................................. Page 1
Mission Statement....................................................................................................... Page 1
Focus Areas................................................................................................................ Page 2
Personnel.................................................................................................................... Page 3
Collaborations............................................................................................................ Page 4
Graduate Students..................................................................................................... Page 4
Appreciation Spotlight............................................................................................... Page 4
Outreach and Enrichment Programs......................................................................... Page 5
Executive Summary.................................................................................................... Page 6
Research Accomplishments and Five-year Benchmark........................................ Page 8
Future Directions...................................................................................................... Page 8
Center for Laser Applications Budget....................................................................... Page 10
A europium-doped oxyhalide glass luminesces when excited by a green diode laser. These materials have applications in medical imaging. For more information, see the faculty report of Dr. Lee Leonard on page 17.
INTRODUCTION

CLA has established capabilities that are unique for both the state and the nation. The strengths and interest in the applications of lasers for diagnostics and materials processing represent a unique university-based combination that is critical for many industrial, defense, and basic science application areas. Examples of the strengths and interests include combustion systems and jet engine/space propulsion systems development, laser materials processing, ground-based (simulated) aerospace testing, electro-optics, non-linear optics, quantum optics, molecular spectroscopy, and laser-induced assisted chemical reactions. All these areas fit with CLA’s original and current Mission. They have obvious relevance to the future competitiveness of technological industries and institutions of the state, region, and nation.

One of the strengths CLA possesses is the ability of faculty from different disciplines to work together, each bringing a different expertise to the table. These include: Bio/Nano-photonics, Material Science, Laser Material Interaction, Laser Spectroscopy, and Non-Equilibrium Fluid Physics. These multidisciplinary collaborations have the potential to open many new opportunities for CLA.

MISSION STATEMENT

The original purpose and mission of CLA remains relevant as described in the original 1984 proposal. It has evolved to stay abreast and ahead of science and technological needs. This evolutionary process was the exact intent of the original proposers and better serves the needs of Tennessee by adding goals and objectives to an existing solid foundation.

Education

- Attract nationally recognized faculty and student scholars
- Produce well-trained graduates for employment in Tennessee
- Disseminate state-of-the-art information on laser application technology to the industrial and scientific communities
- Provide quality educational experiences for multidisciplinary students
- Generate opportunities for undergraduate and high school student research
- Assist businesses in development and implementation of technology
- Increase interest in STEM areas, i.e., support science education for students and teachers

Research

- Develop state-of-the-art experimental facilities for research on a variety of laser application problems.
- Develop a world class reputation for research and innovation to meet the needs of science and industry
- Utilize center funds for the exploration and development of new research areas
- Enhance the amount of research support from industrial and governmental organizations
- Transfer new laser application technology to state and regional industry and scientific organizations
- Enhance the research capability of other UTSI research groups through development of advanced laser-based measurement techniques
FOCUS AREAS

The focus of the mission-related research programs of the Center if the application of lasers and associated technology to bio/nanophotonic, materials science, laser materials interaction, laser spectroscopy, and non-equilibrium fluid physics. 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 detection, spectroscopy, and control; micro/nanofluids
- Lino Costa – devices for cellular chemotaxis
- Jacqueline Johnson – storage phosphor materials for dental imaging
- Christian Parigger – photo-acoustic imaging, diagnostics, and applications
- Feng-Yuan Zhang – MEMS/NEMS, micro/nanofluids

Materials Science

- Lino Costa – phase transformations, laser cladding and modeling of direct metal deposition
- Lloyd Davis – quantum dots, micro, and nanofabrication of amorphous and crystalline materials
- Christian Parigger – laser-induced materials physics
- Jacqueline Johnson – nanoparticles for medical theranosts
- Charles Johnson – Mössbauer spectroscopy
- Lee Leonard – glasses and glass ceramics for radiographic imaging and dosimetry
- Feng-Yuan Zhang – micro/nanomanufacturing multifunctional materials

Laser Materials Interaction

- Lino Costa – laser cladding and femtosecond laser machining
- Trevor Moeller – laser-ablation dynamics and modeling of laser ablation for space propulsion
- Lloyd Davis – femtosecond laser processing of diamonds and glass devices
- Christian Parigger – laser-induced ablation physics
- Feng-Yuan Zhang – micro/nanomanufacturing multifunctional materials
- Phillip Kreth – laser-based heating of material samples for high-enthalpy flows

Laser Spectroscopy

- Christian Parigger – ultrasensitive spectroscopy and combustion diagnostics
- Lloyd Davis – single-molecule and ultrafast spectroscopy, Raman and fluorescence spectroscopy
- Feng-Yuan Zhang – tomography, diode-laser absorption spectroscopy, thermography

Non-Equilibrium Fluid Physics

- Lloyd Davis – physics of non-equilibrium femtosecond laser-induced plasmas
- Trevor Moeller – plasma dynamics and combustion
- Christian Parigger – laser-plasma physics, combustion, and fluid physics and computational physics
- Feng-Yuan Zhang – hypersonic flow and reaction, electrochemical reaction
- Phillip Kreth - diagnostics development for hypersonic flows
PERSONNEL

Dr. Brian Canfield, Research Scientist I

Dr. Brian Canfield (Ph.D. in Physics, Washington State University) contributes to a wide range of CLA’s research projects in applied and nonlinear optics, in particular, ultrafast laser materials processing. Technologies relying on these processes include machining of microfluidic/nanofluidic systems, large-scale roll-to-roll replication template fabrication, custom foil mesh drilling for energy production and storage, surface modification for improved physical environmental interaction, and thrust and charge dissipation schemes for orbiting satellites. He has also been instrumental to the development of experimental systems for ultrasensitive fluorescence detection and single-nanoparticle trapping and tracking for biotechnology applications. Recently, Dr. Canfield has implemented turret-mounted Bessel beam optical systems for laser-machining very high aspect ratio holes and channels through various transparent substrates including polymers, glasses, and crystalline materials like diamond and sapphire. His current research highlights determining how these materials respond to laser pulses to determine the optimal laser pulse conditions (such as length, energy, and number needed) for both conventional Gaussian-focus and Bessel-beam machining in each material. Towards this goal, a newly acquired spatial light modulator in the ultrafast laser machining system will allow much greater flexibility in beam-shaping for future laser materials processing.

Alexander Terekhov, Research Specialist III and Manager of CLA Research Engineering and Operations

Mr. Alexander Terekhov (M.S. in Physics, Moscow State University; M.S. in Materials Science, University of Illinois Urbana-Champaign) has the responsibility of maintaining the Laser Systems, Laser Safety, and other technical hardware at CLA. Mr. Terekhov 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 Technologies-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 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, 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 as follows:

- **Aerospace Engineering**
  - Woritphon Overacker, MS  Dr. Trevor Moeller
  - Joshua Little, MS  Dr. Trevor Moeller
  - Cameron Craig, MS  Dr. Trevor Moeller

- **Mechanical Engineering**
  - Yifan Li, Ph.D.  Dr. Feng-Yuan Zhang
  - Derrick Talley, MS  Dr. Feng-Yuan Zhang
  - Vincent Boyd, MS  Dr. Trevor Moeller
  - Justin Jones, MS  Dr. Trevor Moeller

APPRECIATION SPOTLIGHT

Alexander Terekhov

Research Associate III and Manager of Research Engineering and Operations for the Center for Laser Applications. Alexander Terekhov, has over 40 years of experience in research and development in science and technology. Alexander exemplifies our core values remarkably. He consistently strives for excellence when supporting graduate students and faculty in their research projects and contracts. He approaches every new project and experiment with genuine curiosity and enthusiasm and is always committed to getting the work completed on time. His knowledge of the CLA, vast experience with different technologies including optics, lasers and laser materials processing, vacuum systems, and materials and materials characterization, combined with his superb problem-solving skills and gritty nature, make him the go-to person in many situations. Always eager to understand and explore the physics and chemistry behind a particular experiment, Alexander has made significant contributions to science and technology, as attested by the over 50 scholarly works that he has co-authored.
OUTREACH AND ENRICHMENT PROGRAMS

STEM PROJECTS

- Substantial STEM outreach using the UTSI Observatory occurred. Student led efforts resulted in 53 Facebook posts during this reporting period. Of these posts, 15 were celestial in nature (sun, moon, planets) and the rest were deep-sky objects.

- UTSI also hosted a public Star Party on November 1 with "over 150 in attendance" which had a large K-12 presence. Graduate students conducted STEM activities, such as straw rockets, with school-age children during this event.

- GRA student, Adam Croft, wrote a STEM script on conservation laws on mass, momentum, and energy, for the Hands-On Science Center, a hands-on, interactive STEM center, located in Tullahoma, TN.

- GRA student, Samuel Smith and his squadron commander, led a monthly Civil Air Patrol meeting, with 10-20 children, ages 12-18, to discuss and teach aviation or space-related topics. Prior to COVID the student also helped the children worked together on STEM kits - quadcopters, model rocketry, and RC aircraft.

Pictures link: https://drive.google.com/drive/folders/1qkteEnWUQ02YtNnCOnBUwx8lCV2FFxbG?usp=sharing
EXECUTIVE SUMMARY

Foreword

CLA has established capabilities that are unique for both the state and the nation. The strengths and interest in the applications of lasers for diagnostics and materials processing represent a unique university-based combination that is critical for many industrial, defense, and basic science application areas. Examples of the strengths and interests include combustion systems and jet engine/space propulsion systems development, laser materials processing, ground-based (simulated) aerospace testing, electro-optics, non-linear optics, quantum optics, molecular spectroscopy, and laser-induced assisted chemical reactions. All these areas fit with CLA’s original and current Mission. They have obvious relevance to the future competitiveness of technological industries and institutions of the state, region, and nation.

CLA Leadership

Dr. James Simonton is acting as Interim Director.

New Faculty Alliances

An important part of the original mission of CLA was the formation of alliances that would foster multidisciplinary work. Dr. Trevor Moeller and Dr. Phillip Kreth of the Mechanical, Aerospace, and Biomedical Engineering Department (MABE) are now using lab space in CLA. They are utilizing lasers to develop research related to measurements and diagnostics of hypersonic flow and combustion characteristics. Both of these areas are of high interest to the DoD, NASA, and private industry.

New Equipment Purchased

I am pleased to say that all major equipment in CLA are operational again. We have added new pieces of equipment, such as a 1-MHz Burst Mode Laser, that greatly improves our measurement and diagnostic capabilities. This was purchased with a DURIP award to the Horizon group from the Office of Naval Research ($825k).

With the $193k carryover from FY 18/19, CLA will purchase: an intensifier that can attach to any of our Photron high-speed cameras, and it will enable several additional laser diagnostic techniques utilizing the new pulse-burst laser. Without the intensifier, we are limited to particle image velocimetry (PIV). Other techniques like Krypton tagging velocimetry and laser-induced fluorescence require a high-speed intensifier, since the signal is directly proportional to the flow density (which is inversely related to Mach number to the fifth power) ($75k).

With the $517k carryover from FY 19/20, CLA will purchase: a new X-Ray Diffraction (XRD) machine, replacing our antiquated one, that will improve our capabilities not only in testing time but also greatly improve our test data fidelity. It is expected that our average testing time will be reduced from approximately four hours to approximately four minutes. The cost of the XDR is expected to reach $320k once features are added that will keep us current and expandable for many years to come.

CLA will also invest the remaining carry-over in test equipment that is related to our expanding needs and capabilities.
Activities

In FY 2020 CLA associated staff and faculty had 44 peer reviewed articles published and/or accepted into press, 2 book chapters, and 17 national/international presentations.

Percent Allocation of CLA Total Expenditures ($531,265)

- Salaries and benefits 48%
- Equipment related expenditures (repair, supplies, and new) 33.8%
- Travel 2.8%
- Student Fees 2.9%
- Assistantships 3%
- Maintenance 1%
- Supplies 8.5%

Ended the year with a carryover of $ 517,729.

This carryover will be utilized toward major equipment purchases as described in the New Equipment Purchased section.

Contact Information:

www.utsi.edu/center-for-laser-applications-cla/
jsimonto@utsi.edu
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 2016 through 2020, Center faculty published 135 peer-reviewed articles, 8 books and presented at 102 regional, national, and international meetings.

COMPARATIVE SUMMARY OF ACCOMPLISHMENTS

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Publications</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peer-Reviewed Articles</td>
<td>135</td>
<td>13</td>
<td>31</td>
<td>29</td>
<td>18</td>
<td>44</td>
</tr>
<tr>
<td>Book or Book Chapters</td>
<td>8</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Presentations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>International</td>
<td>36</td>
<td>13</td>
<td>6</td>
<td>3</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>National</td>
<td>66</td>
<td>37</td>
<td>9</td>
<td>7</td>
<td>1</td>
<td>12</td>
</tr>
</tbody>
</table>

FUTURE DIRECTIONS

Hypersonics research has grown tremendously over the past two years and from all projections, it will continue this growth. CLA is strategically placed to benefit from the funding associated with this work. CLA’s current involvement, through laser measurement and diagnostics, will continue to grow, and we will benefit from this growth. This alliance will spur growth related to our material science area in the form of thermal protection materials and bonding of those materials. The alliances we have formed, with the hypersonics group at UTSI, have the potential for introducing CLA capabilities to a much wider audience in the Aerospace and Defense sectors.

Dr. Phil Kreth is a recent addition to the CLA faculty, his research is primarily focused on the development of advanced optical diagnostic techniques and their application to measurements in high-speed and hypersonic flows. In the Flow Diagnostics Laboratory, the HORIZON group works with optical diagnostic techniques such as shadowgraph and schlieren, laser-induced fluorescence (LIF), particle image velocimetry (PIV), krypton tagging velocimetry (KTV), and focused laser differential interferometry (FLDI). Using these measurement techniques in a controlled optics laboratory allows the group to explore the feasibility, resolution, and accuracy of these systems on small-scale experimental configurations prior to their deployment in the high-speed wind tunnel facilities at UTSI. With a recent DURIP award from Office of Naval Research a burst-mode laser with 1-MHz burst rates and a custom optical parametric oscillator (OPO) was purchased that permits tunable access to UV wavelengths.
Nuclear Space Propulsion is another area where CLA is positioned to benefit from interest in the space community. Our material science and engineering capabilities could hold the key to major hurdles in manufacturing nuclear space propulsion units that are safe and reliable. On the public side, NASA is interested and BWX Technologies on the private side.

Micro Scalable Thrusters for Adaptive Mission Profiles in Space, or μSTAMPS, is the low-thrust, high-specific impulse electric micro-propulsion technology being developed and tested by CLA associated personnel and faculty. Dr. Trevor Moeller and Dr. Lino Costa have developed this technology for use in Cubesats and other micro- and nano-satellites. μSTAMPS uses a revolutionary design that is structurally more robust and far easier to fabricate than current state-of-the-art designs. Recent tests have validated the thruster’s functionality.
## CLA Budget - Schedule 7

### CENTERS OF EXCELLENCE ACTUAL, PROPOSED, AND REQUESTED BUDGET

**Institution:** The University of Tennessee Space Institute  
**Center:** Laser Applications

<table>
<thead>
<tr>
<th>Expenditures</th>
<th>FY 2019-20 Actual</th>
<th>FY 2020-21 Proposed</th>
<th>FY 2021-22 Requested</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Salaries</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Faculty</td>
<td>$25,000</td>
<td>$88,858</td>
<td>$113,858</td>
</tr>
<tr>
<td>Other Professional</td>
<td>$28,000</td>
<td>$44,613</td>
<td>$72,613</td>
</tr>
<tr>
<td>Clerical/Supporting</td>
<td>$15,000</td>
<td>$34,418</td>
<td>$40,000</td>
</tr>
<tr>
<td>Assistantships</td>
<td>$35,108</td>
<td>$72,613</td>
<td>$100,000</td>
</tr>
<tr>
<td><strong>Total Salaries</strong></td>
<td>$103,108</td>
<td>$185,443</td>
<td>$288,551</td>
</tr>
<tr>
<td>Longevity (Excluded from Salaries)</td>
<td>$2,550</td>
<td>$2,849</td>
<td>$5,399</td>
</tr>
<tr>
<td><strong>Total Personnel</strong></td>
<td>$141,746</td>
<td>$255,731</td>
<td>$397,477</td>
</tr>
<tr>
<td><strong>Non-Personnel</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Travel</td>
<td>$4,000</td>
<td>$19,134</td>
<td>$2,000</td>
</tr>
<tr>
<td>Software</td>
<td>$9,650</td>
<td>$18,000</td>
<td>$43,000</td>
</tr>
<tr>
<td>Books &amp; Journals</td>
<td>$13</td>
<td>$25</td>
<td>$50</td>
</tr>
<tr>
<td><strong>Other Supplies</strong></td>
<td>$7,000</td>
<td>$55,000</td>
<td>$75,534</td>
</tr>
<tr>
<td>Equipment</td>
<td>$80,887</td>
<td>$600,000</td>
<td>$685,000</td>
</tr>
<tr>
<td>Maintenance</td>
<td>$7,825</td>
<td>$93,397</td>
<td>$96,125</td>
</tr>
<tr>
<td>Scholarships</td>
<td>$13</td>
<td>$2,000</td>
<td>$3,000</td>
</tr>
<tr>
<td>Consultants</td>
<td>$-</td>
<td>$-</td>
<td>$-</td>
</tr>
<tr>
<td><strong>Total Non-Personnel</strong></td>
<td>$123,887</td>
<td>$275,534</td>
<td>$399,421</td>
</tr>
<tr>
<td><strong>Revenue</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New State Appropriation</td>
<td>$855,317</td>
<td>$856,977</td>
<td>$856,977</td>
</tr>
<tr>
<td>Carryover State Appropriation</td>
<td>$193,677</td>
<td>$517,729</td>
<td>$517,729</td>
</tr>
<tr>
<td>New Matching Funds</td>
<td>$265,633</td>
<td>$687,353</td>
<td>$687,353</td>
</tr>
<tr>
<td>Carryover from Previous Matching Funds</td>
<td>$265,633</td>
<td>$687,353</td>
<td>$687,353</td>
</tr>
<tr>
<td><strong>Total Revenue</strong></td>
<td>$265,633</td>
<td>$1,048,994</td>
<td>$1,314,627</td>
</tr>
</tbody>
</table>

**Total**

- **Grand Total:** $2,062,059
- **Non-Personnel Deductions:** $147,918
- **Total Revenue:** $2,209,977

---

**Revenue**

- **New State Appropriation:** $855,317
- **Carryover State Appropriation:** $193,677
- **New Matching Funds:** $265,633
- **Total Revenue:** $2,062,059
Cubesats are increasingly used as a low-cost deployment solution to develop, test, demonstrate, and explore new space technologies, and to realize numerous scientific, research, defense, and commercial functions. In fact, Cubesats are seen as the key enabling technology to carry out many future missions, including missions to Mars. However, the vast majority of the over twelve hundred Cubesats launched so far lack a propulsion system and cannot perform basic maneuvers like rendezvous, orbit-keeping, and attitude control, which severely limits the type and duration of the missions they carry out. While several prototype micro-propulsion systems have been successfully demonstrated in orbit in recent years, significant work remains before off-the-shelf micro-propulsion systems become available. In recent years, electrospray of ionic liquid (IL) propellants has emerged as one of the most promising electric micro-propulsion technologies for micro- and nano-satellites. Electrospray thrusters accelerate ions through an applied electric field, and ejecting the resulting stream of high-velocity ions generates thrust. Dr. Costa is developing a revolutionary concept design for a micro-electric electrospray thruster that takes advantage of the unique microfabrication capabilities of ultrafast-lasers. The design, fabrication and testing of this miniaturized electrospray micro-propulsion technology, called Micro Scalable Thrusters for Adaptive Mission Profiles in Space (µSTAMPS), with hundreds of emitters per square centimeter and operating at sub-kilovolt electric potentials, is being done in partnership with Dr. Moeller. Alternative IL propellants were developed in collaboration with Dr. Eric Fox, of NASA-MSFC, under a CAN agreement. A proprietary IL propellant, developed by Streamline Automation, LLC, is currently being tested as part of a phase I STTR program. The µSTAMPS technology will provide affordable, scalable, and modular micro-electric propulsion to enable both station keeping and precision autonomous control of swarms for a host of new missions involving telecommunications, space exploration, and national security.

In addition to the micro-propulsion work, Dr. Costa continues to support the research activities of several local companies. In the past year, Dr. Costa received additional funds from International FemtoScience, Inc., to continue research on the processing and characterization of nanodiamond dispersions, in collaboration with Tennessee Tech University. Additionally, International FemtoScience, Inc., awarded Dr. Costa with funds to characterize the performance of diamond-based diodes. Ultra Small Fibers, LLC, continued to award Dr. Costa with grants for development of a proprietary nanoimprinting process. Virgin Orbit, LLC, provided funds for metallographic inspection of welds. In the past year, Gloyer-Taylor Laboratories, LLC, provided Dr. Costa and Dr. Moeller with funds to develop novel spacecraft coatings, and to prepare stainless steel surfaces with enhanced properties for cryogenic fluid transfer, using ultrafast-laser surface modification techniques. An additional award, from Streamline Automation, LLC, is currently pending.
Single-Molecule Spectroscopy, Quantum & Nonlinear Optics, and Femtosecond Laser Materials Processing

Dr. Lloyd M. Davis

BH Goethert Professor of Physics
Ph.D., University of Auckland, New Zealand

Lloyd Davis conducts research in single-molecule spectroscopy, quantum and nonlinear optics, and femtosecond laser materials interactions. He teaches various courses on optics and lasers to graduate students at UTSI and at UT Knoxville. He engages in external research collaborations with professors in the UT Knoxville Department of Physics, the UT Knoxville Department of Nuclear Engineering, and JILA (a joint institute between U Colorado Boulder and National Institute of Standards and Technology).

During 2018-9, one significant accomplishment has been the realization of a new experimental technique for trapping a single molecule freely diffusing in solution in three dimensions. Single-molecule measurements by laser-induced fluorescence have enabled many breakthrough discoveries, particularly in the biosciences, but the observation time of each molecule is limited because it diffuses out of the focused laser beam. Most trapping methods, such as optical tweezers, are ineffective on nanoscopic objects such as single molecules, but feedback-driven trapping, in which Brownian motion is measured and counteracted in real time by electric-field driven motion, is possible. One and two-dimensional anti-Brownian electrokinetic traps have already been developed, but the trapped molecule is confined in a nanochannel, or between two closely spaced surfaces and hence is perturbed by surface interactions. We used CLA’s femtosecond laser machining and clean room facility to fabricate a two-layer crossed-channel microfluidic device with four inlets, which we used to successfully trap single fluorescent nanoparticles and molecules in three dimensions in the center of the crossing region. For real-time control, a custom-made field programmable gate array (FPGA) circuit, programmed to time-gate and count detected photons, estimates the molecule’s displacement from the center due to Brownian diffusion and rapidly controls voltages that manipulate the microfluidic flows to return the molecule to the center. Contributors to this project include CLA staff member Dr. Brian Canfield and CLA graduate student Kapila Dissanayaka (pictured), who graduated in May 2019 with his Ph.D. in physics.

Another core activity continuing throughout the year has been research on femtosecond laser materials processing, where a tightly focused energetic laser pulse creates a plasma which explodes to leave a void, or recondenses to modify the material. Applications of interest include improved methods for fabricating microfluidics (such as those used in the single-molecule trap) and the formation of arrays of high aspect nanoscale holes, which may be used as templates for nanoimprint lithography (in support of research of Dr. Lino Costa), or permeable membranes for use in electrolyzer cells (in support of research of Dr. Feng Zhang), or nanoscale templates for use in reactive ion etching (in a collaboration with UTK and ORNL). Also, we are researching the use of femtosecond laser Bessel beams to rapidly write arrays of graphitic electrodes in synthetic diamonds. Due to the unique material properties of diamond, this will enable scalable fabrication of pixelated high-energy-particle detectors that can withstand high-flux radiation conditions, such as those in the high-luminosity upgrade of the large hadron collider for upcoming high-energy particle physics experiments. Graphitized regions of the diamond are also selectively etched to form diamond microfluidic devices, which uniquely address alpha-particle diagnostic needs in molten salt reactors for nuclear power generation.
Mössbauer Spectroscopy

Dr. Charles Johnson

Adjunct Professor of Physics
M.A., Oxford University, England
D. Phil., Oxford University, England

Charles Johnson uses Mössbauer spectroscopy to study materials containing iron, europium, or antimony for basic chemistry studies and applications to biomedical science and magnetism.

The Mössbauer Effect provides a particularly powerful tool for (i) identifying the valency of elements which can exist in more than one oxidation state, (ii) getting information about amorphous materials since x-ray diffraction can only be used to determine structures in crystals, and (iii) measuring magnetic properties.

Spectra have been measured of $^{121}$Sb in soda-lime-glass (ordinary window glass) made by the float-glass process as shown in Figure 1. Antimony trioxide $\text{Sb}_2\text{O}_3$ is an important additive (known as a “fining” agent) in glass manufacture as $\text{Sb}^{3+}$ removes bubbles formed during melting without coloring the glass, and $\text{Sb}^{5+}$ decolorizes glasses containing iron by reducing $\text{Fe}^{2+}$ to $\text{Fe}^{3+}$ through mutual redox reactions. The Mössbauer spectra showed that antimony was present in these glasses mainly (90%) as $\text{Sb}^{3+}$ with a smaller amount (10%) of $\text{Sb}^{5+}$. The data were combined with Raman spectroscopy to show that the $\text{Sb}^{3+}$ is incorporated in the glass structure as trigonal pyramidal ($:\text{SbO}_3$) polyhedra.

Because of its ability to distinguish oxidation states non-destructively, there is a demand for Mössbauer spectra from industrial companies in order to analyze their samples. We are one of the few laboratories using this technique and have run spectra for several companies, including Akeso Biomedical (cancer immunology) (Figure 2). In addition we have run experiments for Apicore LLC (pharmaceuticals), 3M Manufacturing (Iron oxides), and Niron Magnetics (non-rare earth magnetic materials), Calgon Carbon (reaction of iron with activated carbon), and Johnson Matthey (industrial process catalysts).
Pulsed Laser Deposition of Robust Thin Films

Dr. Jacqueline Anne Johnson

Professor
Mechanical, Aerospace and Biomedical Engineering (MABE)
B.Sc., University of Liverpool, England
Ph.D., University of Liverpool, England
Fellow of American Ceramic Society
Fellow of the Institute of Physics

Professor Jackie Johnson’s research interests include functionalized nanoparticles, glasses and glass ceramics, thin films, dosimetry, and imaging techniques. She is a Fellow of both the American Ceramic Society and the Institute of Physics. Prior to joining UTSI in late 2007, Professor Johnson worked for twelve years as both a scientist and administrator at Argonne National Laboratory.

The Johnson BEAMS (Biomedical Engineering and Materials Science) group obtained a grant from the National Institute of Health to develop an antifog coating for medical instruments. Laprascopes and endoscopes are instruments used to examine internal tissue and consist of a long tube with a lens system (see Figure 1). The lens system has a tendency to fog. The work includes synthesizing diamond-like carbon films doped with silicon monoxide and other materials and characterizing them with respect to antifogging properties.

Many of the films synthesized thus far have displayed a low-enough water contact angle to be considered antifogging ($\leq 40^\circ$). Increasing the SiO dopant results in a marked decrease of contact angle, reaching an asymptote at approximately $33^\circ$ with 25% SiO doping and above as a percentage of total laser pulses (see Figure 2). As expected, surface energy also increases with SiO dopant, reaching greater than 80 mN m$^{-1}$ for the 30% SiO-doped sample, using water and ethylene glycol as probe liquids.

A commercial CellTiter-Glo assay was carried out to evaluate cell viability at the end of the culture period and the resulting luminescence was assessed via In vivo Imaging Systems (IVIS); while results are preliminary, they are encouraging, i.e., the materials are likely safe for insertion into the human body.

Dr. Johnson also manages projects in iron nanoparticles for enhanced magnetic resonance imaging, glass-ceramic thin films, and carbon-carbon composite materials. She continues to serve on federal review panels as well as multiple department planning and hiring committees. Dr. Johnson is grateful for the hard work of BEAMS group members, Lee Leonard, Charles Johnson, Saeed Kamali, Adam Evans, Chad Bond, Austin Thomas, Anna Bull, and Aleia Williams as well as interns Jackson Mayfield and Paige Bond.
Synchrotron-based techniques such as High Energy X-Ray Diffraction (HE-XRD), Magnetic Compton Scattering (MCS), and Extended X-ray Absorption Fine Structure (EXAFS), together with various laboratory-based techniques have been utilized to investigate structural and magnetic properties of nano-crystallites, nano-glasses, and low-dimensional compounds.

In contrast to x-ray scattering of nanoparticles (NPs), which is much weaker than that of bulk materials due to their small volume and limited coherence, HE-XRD measurements combined with a Pair Distribution Function (PDF) analysis can yield valuable information on the short-range atomic ordering of nanocrystalline materials with some degree of structural coherence and periodicity. This is possible because of the advent of high-flux and high-energy synchrotron radiation sources. In recent work, we were able to infer that Mn atoms in MnO NPs, which can be used in Li-ion-batteries and biomedical systems, are octahedrally coordinated in the form of MnO$_6$ [Figures 1, 2]. In a new publication, our analysis shows that PbSe NPs, as a member of the important lead chalcogenides semiconductors, are arranged in an orthorhombic Pnma phase.

Mössbauer spectroscopy in combination with magnetization measurements was used to obtain insight into cation distributions for iron-oxide nano-crystallites. The magnetic properties of these nano-crystallites have been studied as functions of temperature and their size for spherical and cubic shaped ones. Furthermore, the vacancies in maghemite nano-crystallites result in interesting observations, reflected in Mössbauer spectra, explained with unique computer fits.

Maghemite-based core-shell nano-crystallites using different template groups, either methyl (TMOS) or ethyl (TEOS), with a porous shell suitable for drug delivery and other medical applications, were investigated to obtain insight into their magnetic and structural properties.

Low-dimensional transition metal chalcogenides are interesting compounds due to their large structural diversity, resulting in important superconducting and magnetic properties. In collaboration with the University of Iowa, we have studied the structural and magnetic property of (FeSe$_2$)$_4$(Fe(en)$_3$)$_3$Cl$_2$, where Mössbauer spectroscopy reveals its mixed-valent nature, with Fe$^{3+}$ centers in the [FeSe$_2$]$^-$ chains and Fe$^{2+}$ centers in the [Fe(en)$_3$]$^{2+}$ complexes [Figure 3].

In another project, we have investigated the magnetic and structural properties of magnetic carbon nanotube (CNT)/alumina (Al$_2$O$_3$) nanocomposites, which were synthesized by the direct growth of CNTs on alumina by chemical vapor deposition (CVD).
Development of Advanced Optical Diagnostics for High-Speed Flows

Dr. Phillip Kreth

Assistant Professor

Mechanical, Aerospace, and Biomedical Engineering
Ph.D., Florida State University

Dr. Phil Kreth’s research areas are in the development of advanced optical diagnostic techniques and novel flow control strategies for application in high-speed and hypersonic flows. Dr. Kreth is an assistant professor within the broader HORIZON research group (http://horizon.utsi.edu/), which focuses on hypersonic aerothermodynamics and other aerospace and defense research. In the Flow Diagnostics Laboratory, the HORIZON group works with optical diagnostic techniques such as shadowgraph and schlieren, pressure-sensitive paint (PSP), laser-induced fluorescence (LIF), particle image velocimetry (PIV), and focused laser differential interferometry (FLDI). Using these measurement techniques in a controlled optics laboratory allows the group to explore the feasibility, resolution, and accuracy of these systems on small-scale experimental configurations prior to their deployment in the various high-speed wind tunnel facilities located at UTSI, such as the Mach 4 Ludwieg tube in the TALon laboratory or the Mach 2 wind tunnel.

Recently, the group characterized a fast-responding, pressure-sensitive paint (Fast PSP) in the Flow Diagnostics Laboratory. The paint formulation can be applied to various wind tunnel models enabling the simultaneous measurement of surface pressures over larger regions and more complex aerodynamic shapes. With a luminophore whose fluorescence properties are dependent on the partial pressure of oxygen, the paint represents an optical diagnostic capability to measure localized static pressures in high-speed air flows such as those in our Mach 2 wind tunnel. An example of an application of the Fast PSP diagnostic technique is shown in Figure 1. Here, the paint was applied to the floor and sidewall of the Mach 2 tunnel, and a circular cylinder was installed from the ceiling to create a blockage and an associated shockwave. The unsteady pressure fluctuations over a substantial region of about 60 square inches were measured by a high-speed camera located outside of the tunnel.

The HORIZON group has also been developing new laser diagnostic techniques that utilize UTSI’s burst-mode laser that was recently acquired with a DURIP award from the Office of Naval Research. The pulse-burst laser system is capable of producing 10 millisecond bursts with inter-pulse rates up to 1-MHz, and with a custom optical parametric oscillator permitting tunable access to UV wavelengths, this system uniquely positions UTSI among a select few institutions with similar diagnostic capabilities for hypersonics. State-of-the-art laser diagnostic techniques that are minimally-intrusive, such as particle image velocimetry (PIV) and planar laser-induced fluorescence (PLIF), are required to study the critical phenomena present within high-speed flows and to provide high-resolution data for the development of computational models and their validation. Figure 2 shows typical measurements from a PLIF experiment with acetone seeding in a turbulent Mach 1.5 jet. With the CLA investment towards a high-speed intensifier that couples with our Photron high-speed cameras, we will soon be able to deploy more advanced laser diagnostic techniques such as Krypton tagging velocimetry. Further, the intensifier will help to increase the sensitivity of the PLIF system when it is installed in the Mach 4 Ludwieg tube.

Figure 1. Unsteady surface pressures were measured using an optical diagnostic called PSP inside the Mach 2 wind tunnel when a circular cylinder unstarts the flow.

Figure 2. Acetone PLIF of a turbulent jet acquired at 10 kHz using the pulse-burst laser.
Dr. Lee Leonard’s research interests include functionalized nanoparticles, glasses and glass ceramics, thin films, dosimetry, and imaging techniques. He is a member of the American Ceramic Society and has served as a reviewer for the National Science Foundation on multiple occasions. Prior to joining UTSI in early 2009, Dr. Leonard worked for twelve years as a project and tooling engineer in the high-pressure aluminum die casting industry.

Dr. Leonard is currently developing luminescent glass and glass-ceramic materials for radiographic imaging and dosimetry applications. The luminescent properties of these materials can be tuned by varying composition and processing conditions. For example, the addition of elements with a high atomic number may result in the materials being more responsive to gamma and x-ray radiation, while the incorporation of certain isotopes such as $^{10}$B or $^6$Li makes the materials more sensitive to neutron radiation. Dr. Leonard has developed both scintillators and storage phosphor materials. Scintillators spontaneously emit visible light upon exposure to ionizing radiation. In contrast, storage phosphors do not spontaneously luminesce during exposure and require optical or thermal stimulation to initiate emission.

Presently, Dr. Leonard and Dr. Jacqueline Johnson are participating in a collaborative study with researchers at Stony Brook University to improve the detective quantum efficiency (DQE) of indirect digital radiographic systems. The DQE describes the efficiency of information transfer through an imaging system and depends on x-ray exposure and energy, as well as spatial frequency. Improvement in DQE can be used to achieve improved image quality at similar dose, or to reduce dose without penalizing imaging performance, or a combination of the two.

Dr. Leonard is also participating in projects concerning high-temperature carbon-carbon composites, anti-fogging diamond-like carbon coatings, and thin-film ceramics for LED and radiography applications. These projects are in collaboration with Dr. Jaqueline Johnson.

Figure 1. Photographs of an unpolished glass scintillator sample: (a) in visible light and (b) in 254 nm UV light.
Nonequilibrium Fluid Physics

Dr. Trevor Moeller
Ph.D., University of Tennessee
UTSI Program Coordinator and Graduate Programs Director for the Department of Mechanical, Aerospace, and Biomedical Engineering

Dr. Trevor Moeller’s research focuses primarily on high temperature gases and plasmas and high-speed flows, including both modeling and experimentation. NASA is highly interested in LCH4/LOX rockets for exploration of Mars. Recently, Dr. Moeller completed a contract to develop a liquid methane (LCH4) liquid oxygen (LOX) rocket testbed for research involving these engines. Dr. Moeller is currently conducting research on tunable laser absorption spectroscopy (TLAS) in the mid-infrared for diagnostics in high-temperature flows for the Air Force. The sensitive nature of this program precludes the presentation of further details. He is also pursuing research in nuclear thermal propulsion and the development of micro-electric propulsion thrusters. Additionally, Dr. Moeller is conducting basic research in high-speed flows and the development of tools for the modeling of coupled electromagnetic/fluid systems in nonequilibrium. Additional details are provided below.

Microthruster Development: Dr. Moeller has experience in electric propulsion systems and has continued development of a micro-electrostatic thruster in a collaborative effort with Dr. Lino Costa. This effort utilizes femtosecond laser micromachining to reduce the scale of features by 10-fold over state-of-art thrusters, allowing for an increase in thrust density by 100 times. As a part of this effort, computer simulations have been performed to determine the trends in critical operating parameters with respect to changes in geometric design (Figure 1). This effort also includes examination of a newly proposed device design utilizing pores in a dielectric material. Drs. Moeller and Costa have a subcontract with a small business through a NASA STTR to further develop the microthruster.

Mid IR Absorption Spectroscopy Basic Research: UTSI currently uses a single-zone absorption cell to conduct spectral studies for common combustion products in the MID IR; however, typical absorption cells suffer from non-uniform temperature distributions that lead to instrument calibration with large uncertainties. As a part of Dr. Moeller’s TLAS research, a three-zone absorption cell was designed to achieve a uniform temperature distribution that exceeds 1000°C for the calibration of mid-infrared spectral lines. Development of the three-zone calibration device is underway through US government funding. This cell will allow for greatly improved accuracy in TLAS measurements, enabling improved characterization of high-temperature flows. Simulation results for the proposed three-zone absorption cell are shown in Figure 2.

Nonequilibrium Plasma Simulations: Dr. Moeller’s group continues to research computational plasma dynamics algorithms and develop in-house plasma dynamics simulation codes. Work with our recently developed SUPG finite element solver for the two-fluid plasma model has continued. Lately, this work has been focused on validating our implementation using a two-dimensional GEM test problem originally devised as the basis for an investigation of how accurately various plasma models and numerical algorithms can model fast magnetic reconnection, an important phenomenon in space plasmas, in particular. It provides a way to gauge the solver’s performance so that we can be more confident of its results when we use it to simulate scenarios where we don’t already know what’s supposed to happen. This investigation has revealed that the inclusion of “discontinuity capturing terms”, a common approach to stabilizing numerical schemes like SUPG in the presence of sharp, under-resolved features, can have a significant impact on the results obtained in this scenario. While these terms help to prevent numerical instabilities resulting from under-resolved features, they have a detrimental effect in well-resolved regions of the solution. Careful application is likely critical to obtaining efficient and accurate simulations of problems that involve phenomena like the thin current sheets seen in the GEM challenge problems using the SUPG method. Work related to better understanding the impact of these terms on the solution quality, and improving our ability to employ them precisely, only where necessary, is ongoing.

Figure 1. Microthruster design parameters.

Figure 2. Three-zone absorption cell simulation results. Temperature contours (left) and centerline temperature (right).

Figure 3. A plot of electron density about half way through the GEM challenge problem.
Professor Parigger’s active research continued in the current reporting period in 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, nonequilibrium fluid Physics, optical diagnostics, applied optics, and biomedical applications. Recently, Professor Parigger published a book together with posthumus Jim Hornkohl on fundamental spectroscopy of diatomic molecules with plenty of experimental research associated with plasma diagnosis in combustion, non-equilibrium fluid physics, and study of expansion phenomena that occur at well-above hypersonic and supersonic speeds.

Dr. Parigger’ research is well-received as evidenced by his book chapter in response to an invitation for discussing molecular laser-induced breakdown spectroscopy. The chapter is co-authored by former and current students David M. Surmick, Ghaneshwar Gautam, and Christopher M. Helstern, and with experts in the field Alexander A. Bolshakov and Richard E. Russo. Moreover, several communications were published in well-respected archived journals and communications of ongoing research. Professor Parigger continues to be strongly committed to postgraduate education, continued engagements with UTK campus Physics, including offering postgraduate-research related courses and Ph.D. program core courses, introducing students of Physics and Engineering to research projects of interest to CLA, and as Senator of the Faculty Senate and President of the UTSI Faculty Assembly,

Christian Parigger’s recent research currently focuses on molecular laser-induced breakdown spectroscopy (LIBS). Of interest are applications in diverse fields that include plasma diagnostics, combustion diagnostics, molecular plasma spectroscopy, and selected astrophysics spectra analyses. The analyses of diatomic emission spectra reveal molecular excitation temperatures up to 10,000 K following laser-induced optical breakdown. Cyanide (CN), aluminum monoxide (AlO), titanium monoxide, Swan bands of C₂, and hydroxyl molecules are frequently recorded in nanosecond LIBS investigations over and above the usual atomic emission spectra. The CN molecule occurs within the first few hundred nanoseconds after optical breakdown, and Abel inversion of CN line-of-sight data determines the spatial distributions of molecular signals. For nanosecond LIBS, expansion dynamics and shockwave phenomena explain the measured radial distributions for CN and, equally, for hydrogen. International collaborations continued during the reporting period, strongly affected by limitations due to world-wide health concerns in 2020. At UTSI, Christopher M. Helstern continued his doctoral studies with a projected graduation in fall 2020; notable is the addition of a new Physics student, full-time employee at the Arnold Engineering Complex, commencing his Physics studies fall 2020.
Nanodynamics and High-Efficiency Lab for Propulsion/Power/Energy (NanoHELP)

Dr. Feng-Yuan Zhang

Ph.D., Nagoya University
Associate Professor, Mechanical, Aerospace, and Biomedical Engineering Department

The research interests of Dr. Zhang’s NanoHELP group (http://fzhang.utsi.edu/) lie in thermal-fluid sciences, nanotechnology, and advanced spectroscopies and diagnostics. The goal of his NanoHELP group is to take advantage of nanotechnology and associated engineering 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 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.

One of the recent research studies is on high-efficiency hydrogen and oxygen productions and energy storages with PEM electrolyzer cells (PEMECs). Combining advanced manufacturing and novel material/component design fabrication, state-of-the-art characterization, system testing, and theoretical modeling/simulations, the NanoHELP has revealed a structure innovation to significantly reduce the PEMEC cost, weight and volume. Low electron/proton conductivities of electrochemical catalysts, especially earth-abundant non-precious metal catalysts, severely limit their ability to satisfy the triple-phase boundary (TPB) theory, resulting in extremely low catalyst utilization and insufficient efficiency in true energy devices. We proposed an innovative electrode design strategy to build electron/proton transport nano-highways to ensure that the whole electrode meets the TPB, therefore significantly promoting oxygen evolution reactions and catalyst utilizations. It is discovered that easily accessible/tunable mesoporous Au nanolayers (AuNLs) not only increase the electrode conductivity by more than 4000 times but also enable the proton transport through straight mesopores within the Debye length. The catalyst layer design with AuNLs and ultralow catalyst loading augments reaction sites from one dimension (1D) to 2D, resulting in a significant improvement in mass activities. Furthermore, using micro-scale visualization and unique coplanar-electrode electrolyzers, the relationship between the conductivity and the reaction site is revealed, allowing for the discovery of the conductivity-determining and Debye-length-determining regions for water-splitting. These findings and strategies provide a novel design of electrodes (catalyst layer + functional sublayer + ion exchange membrane) with a sufficient electron/proton transport path for high-efficiency electrochemical energy conversion devices.

Provisional Disclosures

Structured Glass-Ceramic Scintillators”
R. Lee Leonard, Lino Costa, Jacqueline Johnson, Brian Canfield, Alexander Terekhov, A. Richard Lubinsky, Adrian Howansky
University Tennessee of Research Foundation Number: 20199-07

“Transparent, Antimicrobial Glass”
R. Lee Leonard and Jacqueline Johnson
University Tennessee of Research Foundation Number: 20191-07

“Laser Processing Waveguides in Scintillator Glasses for Indirect Digital Radiography Applications”
R. Lee Leonard, Lino Costa, Jacqueline Johnson, Brian Canfield, Alexander Terekhov, A. Richard Lubinsky
University Tennessee of Research Foundation Number: 20080-07

“Laser Processing Waveguides in Optical Filter Glasses for Computed Radiography Applications”
R. Lee Leonard, Lino Costa, Jacqueline Johnson, Brian Canfield, Alexander Terekhov, A. Richard Lubinsky
University Tennessee of Research Foundation Number: 20077-07

Provisional Patents

“Scintillating Substrate Coating Composition and Method for Dual-Screen Flat-Panel Detectors”
R. Lee Leonard, Jacqueline Johnson, Charles Bond, A. Richard Lubinsky, Adrian Howansky

“Light-Scattering Glass-Ceramic Scintillators as Substrates for Dual-Screen Flat-Panel Detectors”
R. Lee Leonard, Jacqueline Johnson, Brooke Beckert, A. Richard Lubinsky, Adrian Howansky
Publications

Peer reviewed:


- K. D. Dissanayaka, B. K. Canfield, and L. M. Davis, “Three-dimensional feedback-driven trapping of a single nanoparticle or molecule in aqueous solution with a confocal fluorescence microscope,” *Opt. Express* 27, 29759–69 (2019); https://doi.org/10.1364/OE.27.029759


https://doi.org/10.1016/j.jnoncrysol.2020.120184


• Gamage, Eranga; Greenfield, Joshua; Unger, Colin; Kamali, Saeed; Clark, Judith; Harmer, Colin; Luo, Liang; Wang, Jigang; Shatruk, Michael; Kovnir, Kirill. *Inorganic Chemistry.* Tuning Fe-Se tetrahedral frameworks by a combination of [Fe(en)3]2+ cations and Cl– anions. 59 (18) 13353-13363 (2020).


• Frank Zoladz, Steven Rhodes, Dwight Patterson, Warner Cribb, Puskar Chapagain, Dereje Seifu, Valentin Taufour, Saeed Kamali, Suman Neupane *Journal of Nanoparticle Research,* 22 157-1:157-9


**Publications, accepted and in press:**


  https://www.preprints.org/manuscript/201906.0134/v1

  https://www.preprints.org/manuscript/201910.0013/v1

  https://www.preprints.org/manuscript/201906.0264/v1

  https://www.preprints.org/manuscript/201905.0364/v1


**Book Chapters**


Conference Proceedings:

• C.G. Parigger, “Laboratory hydrogen laser-plasma and white-dwarf stars line shapes,” 12th Serbian Conference on Spectral Line Shapes in Astrophysics, June 3-7, 2019, Vrdnik, Serbia, published invited presentation October 2019:
  http://www.scslsa.matf.bg.ac.rs/press12/day1/Parigger.pdf


PRESENTATIONS

Invited Presentations:

• C.G. Parigger, “Optical spectroscopy of laboratory and astrophysical plasma,” invied Keynote speaker. Presented at the three-day international webinar at the Ewing Christian College, Prayagraj, Uttar

28


- P. Kreth & J. Schmisser, Briefing on UT's Hypersonics Research Program for Adjutant General Jeff Holmes, Knoxville, TN, 2019

**Contributed Presentations:**


**Conference Organizing:**

• Christian G. Parigger, International committee for the International Conferences on Spectral Line Shapes (ICSLS), 25th ICSLS Caserta, Italy, June 22-26, 2020, deferred to June 2021 due to pandemic in 2020.

**Appointments:**


• Christian G. Parigger, Robert Splinter, Guest editors, Molecules/MDPI – Special Issue “Practical Applications of Molecular Spectroscopy,” manuscript submission February 2019 to July 2020, [https://www.mdpi.com/journal/molecules/special_issues/Molecular_Spectroscopy](https://www.mdpi.com/journal/molecules/special_issues/Molecular_Spectroscopy)
<table>
<thead>
<tr>
<th>Investigator</th>
<th>Contract Title</th>
<th>Funding Agency</th>
<th>Period of Performance</th>
<th>Awarded</th>
<th>2019-2020 Expended</th>
</tr>
</thead>
<tbody>
<tr>
<td>Costa, Lino</td>
<td>Pattern Templates Using USF Laser Engraver System Project No. A19-0789 (R024428029)</td>
<td>Ultra Small Fibers, LLC</td>
<td>February 7, 2019 – May 31, 2020</td>
<td>$30,000.00</td>
<td>$17,865</td>
</tr>
<tr>
<td>Costa, Lino</td>
<td>Flats Coupons Macro Examination Project No. A19-1098 (R024428030)</td>
<td>Virgin Orbit, LLC</td>
<td>May 13, 2019 – July 31, 2019</td>
<td>$4,365.00</td>
<td>$0</td>
</tr>
<tr>
<td>Costa, Lino</td>
<td>Low Boiloff Transfer Lines Project No. A20-0364 (R024428031)</td>
<td>Gloyer-Taylor Laboratories LLC</td>
<td>August 26, 2019 – February 18, 2020</td>
<td>$12,250.00</td>
<td>$12,250.00</td>
</tr>
<tr>
<td>Costa, Lino</td>
<td>Preparation of Tissue Culture Dishes Project No. A20-0969 (R024428032)</td>
<td>Ultra Small Fibers, LLC</td>
<td>February 15, 2020 – May 15, 2020</td>
<td>$5,000.00</td>
<td>$4903.52</td>
</tr>
<tr>
<td>Costa, Lino</td>
<td>SEM Imaging of Electronic Device Samples Project No. A20-0970 (R024428033)</td>
<td>International FemtoScience, Inc.</td>
<td>March 1, 2020 – February 28, 2021</td>
<td>$20,000.00</td>
<td>$2729.77</td>
</tr>
<tr>
<td>Costa, Lino and Moeller, Trevor</td>
<td>Passive Spacecraft Coating Project No. A19-1043 (R024348068)</td>
<td>Gloyer-Taylor Laboratories, LLC</td>
<td>February 4, 2019 – February 3, 2020</td>
<td>$14,500.00</td>
<td>$13,245.18</td>
</tr>
<tr>
<td>Costa, Lino and Moeller, Trevor</td>
<td>Demonstration of Dual Mode Ionic Liquid Propulsion Project No. A20-0334 (R024348071)</td>
<td>Streamline Automation, LLC</td>
<td>August 19, 2019 – September 18, 2020</td>
<td>$20,594.00</td>
<td>$9,152.00</td>
</tr>
<tr>
<td>Johnson, Charles</td>
<td>Analysis of steels and other materials by Mössbauer spectroscopy</td>
<td>Johnson Matthey Calgon Carbon Corp Iowa State Material</td>
<td>October 9, 2019 – July 31, 2020</td>
<td>$13,500.00</td>
<td>$13,500.00</td>
</tr>
<tr>
<td>Johnson, Jacqueline</td>
<td>Designer Glass Ceramics Project No. A16-0943 (R024417029)</td>
<td>National Science Foundation</td>
<td>July 1, 2016 – December 31, 2020</td>
<td>$319,842.00</td>
<td>$74,203.35</td>
</tr>
<tr>
<td>Johnson, Jacqueline and Leonard, Lee</td>
<td>Diamond-like Carbon Thin Films for Anti-fog Lens Coating in Laparoscopy Project No. A20-0251 (R024417032)</td>
<td>HHS – NIH – National Institutes of Health</td>
<td>September 1, 2019 – August 31, 2021</td>
<td>$422,057.00</td>
<td>$147,069.51</td>
</tr>
<tr>
<td>Johnson, Jacqueline</td>
<td>Gas Flow Hollow Electrode Depaint Technology Project No. A20-0737 (R024417033)</td>
<td>UL Tool, LLC</td>
<td>December 15, 2019 – March 15, 2020</td>
<td>$10,045.00</td>
<td>$10,045.00</td>
</tr>
<tr>
<td>Researcher, Project Title</td>
<td>Funders, Project No.</td>
<td>Start Date - End Date</td>
<td>Total Costs</td>
<td>Direct Costs</td>
<td></td>
</tr>
<tr>
<td>-----------------------------------------------------------------------------------------</td>
<td>----------------------</td>
<td>------------------------</td>
<td>-------------</td>
<td>--------------</td>
<td></td>
</tr>
<tr>
<td>Johnson, Jacqueline, Materials Maturation for Hypersonics - BAA No. FA8650-18-S-5010</td>
<td>University of Dayton Research Institute</td>
<td>January 12, 2020 – January 31, 2023</td>
<td>$379,575.00</td>
<td>$30,421.62</td>
<td></td>
</tr>
<tr>
<td>Leonard, Lee Johnson, REACH: High-Efficiency Flat Panel X-ray Imager with Scintillating Glass Substrate</td>
<td>National Institutes of Health, under subcontract of Stony Brook University</td>
<td>December 5, 2019</td>
<td>$33,800.00</td>
<td>$33,800.00</td>
<td></td>
</tr>
<tr>
<td>Kreth, Phillip, AFRL.RQHX Corner Flow Experimental Support Project No. A17-0982</td>
<td>DOD – Air Force Research Laboratory</td>
<td>May 1, 2017 – September 30, 2020</td>
<td>$390,000.00</td>
<td>$41,857.73</td>
<td></td>
</tr>
<tr>
<td>Kreth, Phillip, Materials Maturation for Hypersonics Project No.20-0085</td>
<td>DOD - UDRI</td>
<td>January 12, 2020 – January 31, 2023</td>
<td>$379,575.00</td>
<td>$30,421.62</td>
<td></td>
</tr>
<tr>
<td>Kreth, Phillip, Plenoptic Camera Density Measurement Project No. A18-0629</td>
<td>DOD – AEDC/FMP</td>
<td>January 1, 2018 – August 31, 2019</td>
<td>$68,785.00</td>
<td>$6,826.59</td>
<td></td>
</tr>
<tr>
<td>Kreth, Phillip, Excellence in Research: Co-Axial Flow Mixing and Control Using Ultra-High Frequency Actuators Project No. A20-0567</td>
<td>Tuskegee University</td>
<td>August 1, 2019 – July 31, 2022</td>
<td>$39,998.00</td>
<td>$9,582.90</td>
<td></td>
</tr>
<tr>
<td>Kreth, Phillip, Advanced Measurement Capability of Turbine Engine Exhaust and Jet Flows Through Non-Intrusive Methods Project No. A20-0793</td>
<td>Non-Contact Technologies, LLC</td>
<td>December 12, 2019 – March 11, 2020</td>
<td>$11,750.00</td>
<td>$11,750.00</td>
<td></td>
</tr>
<tr>
<td>Kreth, Phillip, Coupled Simulation Tool for Modeling Structural Profile Disruption of Aerovehicles Project No. 20190091</td>
<td>CFD Research Corporation</td>
<td>January 1, 2019 – December 31, 2020</td>
<td>$49,835.00</td>
<td>$4,393.81</td>
<td></td>
</tr>
<tr>
<td>Moeller, Trevor, Low Boiloff Transfer Lines Project No. A20-0364</td>
<td>Gloyer-Taylor Laboratories LLC</td>
<td>August 26, 2019 – February 18, 2020</td>
<td>$12,250.00</td>
<td>$12,250.00</td>
<td></td>
</tr>
<tr>
<td>Moeller, Trevor, Tennessee Space Grant Consortium Fellowship Support Project No. A16-0535</td>
<td>Vanderbilt University</td>
<td>August 4, 2015 – June 3, 2020</td>
<td>$204,944.00</td>
<td>$34,640.11</td>
<td></td>
</tr>
<tr>
<td>Moeller, Trevor, BHL Cryotank Validation and Enhancement Project No. A17-1318</td>
<td>Gloyer-Taylor Laboratories, LLC</td>
<td>August 15, 2017 – August 14, 2020</td>
<td>$15,000.00</td>
<td>$2,480.53</td>
<td></td>
</tr>
<tr>
<td>Moeller, Trevor</td>
<td>Passive Spacecraft Coating Project No. A19-1043 (R024348068)</td>
<td>Gloyer-Taylor Laboratories, LLC</td>
<td>February 4, 2019 – February 3, 2020</td>
<td>$14,500.00</td>
<td>$14,500.00</td>
</tr>
<tr>
<td>Moeller, Trevor</td>
<td>High Pressure Spherical Tank – NASA Topic #Z10.01 Project No. A20-0301 (R024348070)</td>
<td>Gloyer-Taylor Laboratories LLC</td>
<td>August 28, 2019 – February 18, 2020</td>
<td>$5,031.00</td>
<td>$5,031.00</td>
</tr>
<tr>
<td>Moeller, Trevor</td>
<td>Demonstration of Dual Mode Ionic Liquid Propulsion Project No. A20-0334 (R024348071)</td>
<td>Streamline Automation, LLC</td>
<td>August 19, 2019 – September 18, 2020</td>
<td>$20,594.00</td>
<td>$9,152.00</td>
</tr>
<tr>
<td>Moeller, Trevor</td>
<td>ACE Booster 2 Project No. A20-0368 (R024348072)</td>
<td>Gloyer-Taylor Laboratories LLC</td>
<td>September 3, 2019 – August 27, 2021</td>
<td>$155,439.00</td>
<td>$26,146.64</td>
</tr>
<tr>
<td>Moeller, Trevor</td>
<td>Development of Three Zone Absorption Cell for Spectral Measurement Verification Project No. A20-0376 (R024348073)</td>
<td>DOD – Air Force – AFRL – Air Force Research Laboratory</td>
<td>September 1, 2019 – August 31, 2021</td>
<td>$70,000.00</td>
<td>$56,231.05</td>
</tr>
<tr>
<td>Moeller, Trevor</td>
<td>Modeling of Laser Induced Plasma Process Project No. A20-1046 (R024348074)</td>
<td>DOD – AEDC/FMF</td>
<td>December 13, 2019 – December 12, 2020</td>
<td>$50,000.00</td>
<td>$3,941.60</td>
</tr>
<tr>
<td>Moeller, Trevor and Kreth, Phillip</td>
<td>Plenoptic Camera Density Measurement Project No. A18-0629 (R024432022)</td>
<td>DOD – AEDC/FMP</td>
<td>January 1, 2018 – August 31, 2019</td>
<td>$34,392.50</td>
<td>$4,246.66</td>
</tr>
<tr>
<td>Moeller, Trevor</td>
<td>Aerostructural Analysis Supporting the Development of Reusable Hypersonic Vehicle Structures Project No. A18-0123 (R024427031)</td>
<td>UDRI - University of Dayton Research Institute</td>
<td>November 16, 2017 – October 20, 2020</td>
<td>$314,626.65</td>
<td>$124,754.88</td>
</tr>
<tr>
<td>Researcher</td>
<td>Project Title</td>
<td>Department</td>
<td>Start Date</td>
<td>End Date</td>
<td>Total Funding</td>
</tr>
<tr>
<td>------------</td>
<td>---------------</td>
<td>-------------</td>
<td>------------</td>
<td>-----------</td>
<td>---------------</td>
</tr>
<tr>
<td>Zhang, Feng-Yuan</td>
<td>Electolyzer Integrated Modular - Project No. A19-0713 (R024421027)</td>
<td>Skyre, Inc./DOE – EERE – The Office of Energy Efficiency and Renewable Energy</td>
<td>October 1, 2018 – December 31, 2021</td>
<td>$300,000.00</td>
<td>$102,505.77</td>
</tr>
</tbody>
</table>