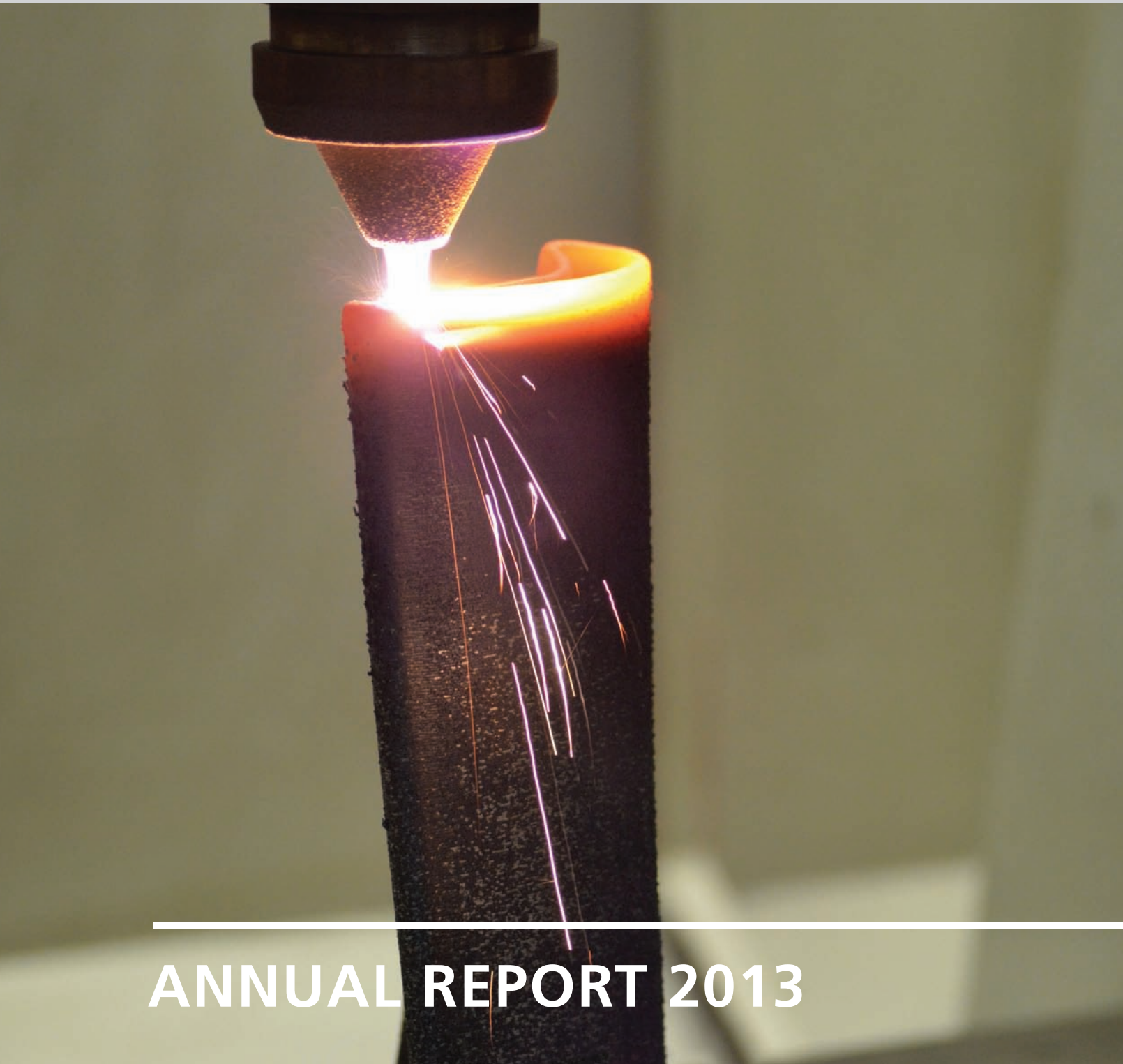
Fraunhofer
USA



ANNUAL REPORT 2013

Cover photo: Turbine blade demonstrator component built at Fraunhofer Center for Coatings and Laser Applications. *See page 11.*

The background photo appearing on this page and next: Custom tailored boron-doped diamond electrodes developed by Fraunhofer Center for Coatings and Laser Applications. *See page 9.*

About Fraunhofer

Fraunhofer USA is a non-profit research and development organization that performs applied research under contract to government and industry with customers such as federal and state governments, multinational corporations, as well as small to medium-sized companies.

Fraunhofer USA is a subsidiary of Fraunhofer-Gesellschaft, a world leading applied R&D organization with 67 institutes and research units.

Fraunhofer USA is comprised of seven research centers:

- Fraunhofer Center for Coatings and Laser Applications (CCL) at Michigan State University
- Fraunhofer Center for Energy Innovation (CEI) at the University of Connecticut
- Fraunhofer Center for Experimental Software Engineering (CESE) affiliated with the University of Maryland
- Fraunhofer Center for Laser Technology (CLT) affiliated with the University of Michigan
- Fraunhofer Center for Molecular Biotechnology (CMB) affiliated with the University of Delaware
- Fraunhofer Center for Manufacturing Innovation (CMI) at Boston University
- Fraunhofer Center for Sustainable Energy Systems (CSE), affiliated with Massachusetts Institute of Technology

These partnerships serve as a bridge between academic research and industrial needs.

The Fraunhofer USA Digital Media Technologies office and the Fraunhofer Heinrich Hertz Institute, USA office promote and support the products of their respective parent institutes from Germany, namely the Fraunhofer Institute for Integrated Circuits IIS, and the Fraunhofer Heinrich Hertz Institute HHI.

To learn more about Fraunhofer USA: **www.fraunhofer.org**
To learn more about Fraunhofer Gesellschaft: **www.fraunhofer.de**

ANNUAL REPORT 2013

MESSAGE FROM THE CHAIRMAN

Prof. Reimund Neugebauer

Prof. Reimund Neugebauer
President of the Fraunhofer-Gesellschaft and
Chairman of Fraunhofer USA, Inc.
with United States Secretary of Commerce Penny Pritzker.

The agenda for new manufacturing technologies in developed, high wage countries is set by the need for sustainable profit - through maximum value creation with minimal use of resources. This paradigm shift will require smart, intelligent and resource-efficient production technologies and processes. At Fraunhofer, we work for the vision of the E3-fab – the Efficient, Emission-neutral, and Ergonomic Factory. On a larger scale, cyber-physical production systems which literally integrate the factory floor with the internet, are expected to pave the way for a new industrial revolution and will open opportunities for new markets, products and jobs. Fraunhofer in the US and in Germany is committed to support this development through partnerships with industry, academia and government.

These issues were discussed on November 22, 2013, when I had the honor to welcome the United States Secretary of Commerce Penny Pritzker at Fraunhofer headquarters in Munich. The visit was arranged by the National Institute of Standards and Technology, after Mrs. Pritzker had expressed a particular interest in the way Fraunhofer operates. I was able to describe to her the essence of the successful Fraunhofer model of applied research and reminded her that the Department of Commerce was an instrumental political partner when we founded Fraunhofer USA in 1994. In the context of the U.S. President's manufacturing initiative, the National Network for Manufacturing Innovation, both Fraunhofer USA and Fraunhofer are offering to cooperate through local and transatlantic strategic partnerships.

In 2013, Fraunhofer USA staff have continued to excel in their fields of expertise winning prestigious awards and projects and serving the needs of an increasing number of industrial customers. I am grateful to all of our staff for their hard work and dedication, and to all of our customers and partners for their trust and support.

Reimund Neugebauer

MESSAGE FROM OUR LEADERSHIP

Dr. Georg Rosenfeld, President

Dr. William Hartman, Executive Vice President

Dr. Georg Rosenfeld
President

Dr. William Hartman
Executive Vice President

We are pleased that the U.S. government has recognized the Fraunhofer Model as a guide for establishing research institutes in the U.S. Fraunhofer research centers enhance innovation, provide benefit to industry, and create jobs for researchers, scientists, engineers and support personnel.

Awards

The Joseph von Fraunhofer Prize has been awarded by the Fraunhofer-Gesellschaft every year since 1978, in recognition of outstanding scientific work by members of its staff leading to the solution of application-oriented problems. In 2013, a prize of 50,000 euros was awarded to Dr. Andre Sharon, Director of the Fraunhofer Center for Manufacturing Innovation and to Dr. Vidadi Yusibov, Director of the Fraunhofer Center for Molecular Biotechnology. Together, they created a fully integrated, automated, GMP facility – a fundamental prerequisite for the production of biopharmaceuticals. "Our teams of biologists and engineers succeeded in building up our automated plant-based vaccine production factory. Now we have plants that consistently grow and make proteins to the same predictable quality, time after time whenever and wherever we like," said Dr. Andre Sharon.

The plants grow in trays with hydroponic cultures of mineral wool as opposed to soil, in specially designed growth modules. Light, water, and nutrients are precisely dosed and distributed. Specially developed robots bring the plants from station to station to carry out the various steps – from inserting the tiny seeds and vacuum infiltration, to harvesting and extraction.

The Fraunhofer Center for Experimental Software Engineering received a **NASA Group Achievement Award** for their work on software assurance research and tech transfer. These prestigious Honor Awards are presented to those "who have distinguished themselves by making outstanding contributions to the Agency's mission."

In April, the Fraunhofer Center for Sustainable Energy Systems (CSE) moved into its new facility in the South Boston Innovation District. A few weeks later, CSE was selected by Mayor Tom Menino as a **2013 Greenovate Boston Award** recipient at a ceremony held at Boston University. CSE was recognized in particular for its completed retrofit project, the Building Technology Showcase – an energy-efficient renovation of its 50,000 square foot historic building.

The Fraunhofer Center for Coatings and Laser Applications (CCL) and its parent institute the Fraunhofer Institute for Material and Beam Technology, IWS were selected for the **Fraunhofer Elevator Pitch Award**. In collaboration with Fraunhofer IWS in Dresden, Germany, CCL scientists participated at the 2013 Netzwert Symposium at Fraunhofer Gesellschaft in Munich. The team submitted a proposal to the competitive "Elevator Pitch" session, which awards seed

money to start new projects in promising areas. The proposed project QuelleSmart – Mobile Drinking Water Safety was selected for funding. The project is based on CCL's boron-doped diamond electrode technology and makes use of IWS developed spectroscopy expertise to develop a detector for heavy metal analysis in water.

The Department of Energy's **Advanced Research Projects Agency** awarded researchers at Fraunhofer CCL's Coatings Technology Division along with their university partner, Michigan State University (MSU), a grant in the field of diamond electronics to develop a diamond-based diode. The project will use the joint capabilities and expertise gained through the collaborative efforts of Fraunhofer CCL and MSU on diamond material synthesis and fabrication over the last 10 years.

The Fraunhofer Center for Molecular Biotechnology was awarded a contract from the National Institute of Allergy and Infectious Diseases, part of the **National Institutes of Health**, for developing vaccine technologies to advance the next generation Anthrax vaccine.

Milestones

The Fraunhofer Center for Coatings and Laser Applications celebrated ten years of partnership with Michigan State University at an Open House. MSU President Lou Anna Simon addressed employees, faculty, and customers attending the event.

A new Fraunhofer Center was created in July, 2013. The inaugural ceremony for the new **Fraunhofer Center for Energy Innovation** (CEI) was held at the University of Connecticut in Storrs. Speakers at the event included Connecticut Governor Daniel Malloy, UConn President Susan Herbst, and Fraunhofer USA President Georg Rosenfeld. The center is partnered with the Fraunhofer Institute for Ceramic Technologies and Systems (IKTS) in Dresden. Base funding for CEI is provided by Fraunhofer, the state of Connecticut, and UConn.

A change in leadership at the Fraunhofer Center for Sustainable Energy Systems (CSE) occurred in November. Dr. Christian Hoepfner was appointed Center Director. Previously CSE's Scientific Director, he is very familiar with CSE's research groups, namely, the Photovoltaic Technologies, Building Energy Technology, and Distributed Electrical Energy Systems.

A Sampling of New Technologies

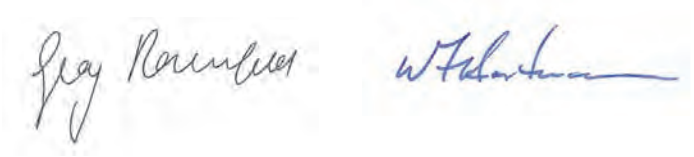
The Fraunhofer Center for Manufacturing Innovation (CMI) acquired a new project from the U.S. Treasury Department's Mint to develop alternative laser-based technologies for making coins (money). CMI is also developing a novel microfluidic platform for antibiotic susceptibility testing.

The Fraunhofer Center for Sustainable Energy Systems is developing the Plug and Play PV Systems for American Homes.

The Fraunhofer Center for Molecular Biotechnology is adapting technology to develop a cost-effective, lung tissue-based system for evaluating vaccine safety.

Partners

The relationships with our partnering universities and the institutes in Germany provide unique resources for our scientists, engineers, technicians and administrators. We are proud of the technological achievements resulting from these synergistic teams.



FRAUNHOFER CENTER FOR COATINGS AND LASER APPLICATIONS

Center for Coatings and Laser Applications

Fraunhofer USA's Center for Coatings and Laser Applications (CCL) has two separately located divisions. The Coatings Technology Division in East Lansing, Michigan, collaborates with Michigan State University. CCL's Laser Applications Division operates a laboratory in Plymouth, Michigan. CCL offers access to advanced technology solutions in thin film coatings, diamond technologies and laser applications. CCL's quality management system is certified according to the ISO9001:2008 standard ensuring efficient, documented and traceable project performance and high quality customer interactions.

Coatings Technology Division

Improving Powertrain Efficiency with Diamor® Coatings

Friction is a major cause for powertrain inefficiencies, reducing vehicle gas mileage and increasing total carbon dioxide emissions. Traditional oil lubrication may prove insufficient under high loads where the lubricious protective film can disappear leading to substantial friction and potentially critical wear. An example is the oscillating motion between piston rings and cylinder liners in combustion engines. Emerging fuel saving technologies such as start-stop automatics may aggravate friction and wear increasing circumstances even more. Low friction and wear resistant coatings aim to address some of the deficiencies of traditional liquid lubricants. Fraunhofer's Diamor® coatings offer excellent friction reduction and wear protection for powertrain components that experience highly loaded contact situations.

In collaboration with an industrial partner in Ohio, Fraunhofer engineers performed experiments comparing the performance of actual engines with and without Diamor® coated components. The engines were first tested as delivered using standard oil lubrication. Then the engines were disassembled and parts relevant to friction reduction were coated with Diamor®. Finally the reassembled engines were tested again under conditions identical to the first test. The results proved reduced friction, which led to more than 3% increase in peak horsepower and more than 2% power increase across the usable speed range of the engine with Diamor® coated parts. These results demonstrate the tremendous potential to conserve fuel and reduce carbon dioxide emissions for Diamor® with coated powertrains.

Tripling the Tool Life Reduces Manufacturing Costs

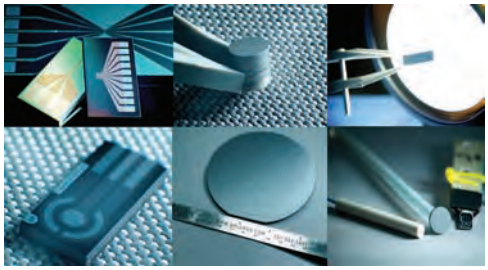
Meritor Inc., a leader in providing advanced drivetrain, mobility, braking and aftermarket solutions for commercial vehicle and industrial markets, collaborated with CCL engineers to test new high performance ceramic coatings for high temperature forming processes. Several spindle punches were coated using a physical vapor deposition process developed with the Fraunhofer Institute for Materials and Beam Technology (IWS) in Dresden, Germany.

Fraunhofer coated 15" long spindle punch for high temperature forming process (end mills in front are for size reference)

The coated tools were tested under manufacturing conditions using a hydraulic press at a Meritor plant in Morristown, TN. They are used for hot forging of steel parts at an operating temperature of 1950 F (1065°C). The results are very encouraging. Compared to uncoated spindle punches, coated tools lasted three times as long while enabling tool changes once a day rather than every shift.

Boron-Doped Diamond Electrodes – Tailored to Customer Requirements

Boron-doped diamond is a new electrode material for electrochemical applications. Due to the fabrication from methane and hydrogen gases, boron-doped diamond electrodes are less expensive than platinum electrodes. Yet boron-doped diamond by far exceeds the electrochemical performance of metal-based electrodes. Especially the wide electrochemical potential window, the low background currents and the low adsorption tendency make boron doped diamond electrodes particularly interesting for electrochemical trace analysis and neurochemistry. CCL researchers developed fabrication processes to reliably fabricate custom tailored boron-doped diamond electrodes. The material can be applied to a variety of substrates and shapes made from silicon, quartz, metals and diamond.



Custom tailored boron-doped diamond electrodes for electrochemical applications

CCL/IWS selected for "Fraunhofer Elevator Pitch Award"

In collaboration with IWS in Dresden, CCL scientists submitted a winning proposal to the 2013 Netzwert Symposium at Fraunhofer Gesellschaft in Munich. The team's "QuelleSmart – Mobile Drinking Water Safety" project was selected for funding and is based on CCL's boron-doped diamond electrode technology using IWS' spectroscopy expertise to develop a detector for heavy metal analysis in water.

CCL/MSU Collaboration Wins ARPA-E Research Grant in Diamond Electronics

The Department of Energy's Advanced Research Projects Agency (ARPA-E) awarded researchers at CCL's Coatings Technology Division and Michigan State University (MSU) a grant to develop a diamond-based diode operating at a breakdown voltage of 1200 V and a forward current of 100 A. The field of diamond synthesis and applications is undergoing a spectacular period of transformation as the ability to deposit high-quality monocrystalline diamond materials advances. Diamond is a unique material with multiple superlative properties, including unmatched thermal conductivity, high charge carrier mobilities, and high electric field breakdown strength. The exceptional semiconductor properties of diamond have enormous potential for high-power electronics technology with applications in transportation, manufacturing, and energy sectors. For power electronics applications, the achievable possibilities with diamond substantially exceed those of other wide bandgap semiconductor materials.

CCL/MSU Collaboration - 10 Year Anniversary

On September 13, 2013, the CCL – MSU collaboration celebrated its 10 Year Anniversary with an Open House Event. Guests from industry, academia and Fraunhofer attended the event and listened to presentations, toured the laboratories and enjoyed a German style dinner.

Staff members and students at Fraunhofer CCL Coatings Technology Division in East Lansing, Michigan

Prof. Neugebauer (center) with Ms. Bettina Wehring representing CCL and IWS at the "Elevator Pitch" session during the Netzwert Symposium 2013

For more information on these technologies, please visit us at www.ccl-coatings.fraunhofer.org

Fraunhofer Center for Coatings and Laser Applications

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Laser Applications Division

The division currently provides contract research and development services to its North American customers in the field of high power laser applications.

Overview of Activities:

CCL's Laser Applications Division has extensive know-how and expertise in the field of high power laser applications technology and works in partnership with its German parent institute, Fraunhofer IWS in Dresden.

The laser division's applications facility in Plymouth, Michigan features over 8 state of the art high power lasers from laser manufacturers such as IPG, Laserline, Rofin Sinar and TRUMPF. The center provides technical support and research and development for these companies in the US market, as well as for a variety of industrial end users of laser technology.

The main technology focus is on high power laser applications research and development in technology areas such as laser welding, heat treatment and cladding (including additive manufacturing) for a wide range of industrial customers and government organizations.

New Developments in 2013

The Laser Applications Division has successfully continued its growth, building on its core competence in high power laser applications resulting in a significant expansion of its facilities.

CCL has installed a state of the art robotic linear track, facilitating robotic laser welding and additive manufacturing with a potential work envelope now exceeding 4m (13.1ft) x 2.5m (8.2ft).

In addition, CCL commissioned a new state of the art CNC laser processing machine which features new dual core fiber technology, facilitating rapid process changeovers for different applications. This machine opens up the potential for work on larger scale applications development projects and allows high precision laser processing at extremely high speeds. This work cell also has a large work envelope of 4m (13.1ft) x 1.5m (4.9ft). High speed laser cutting, laser welding and laser additive manufacturing applications projects are planned for this machine.

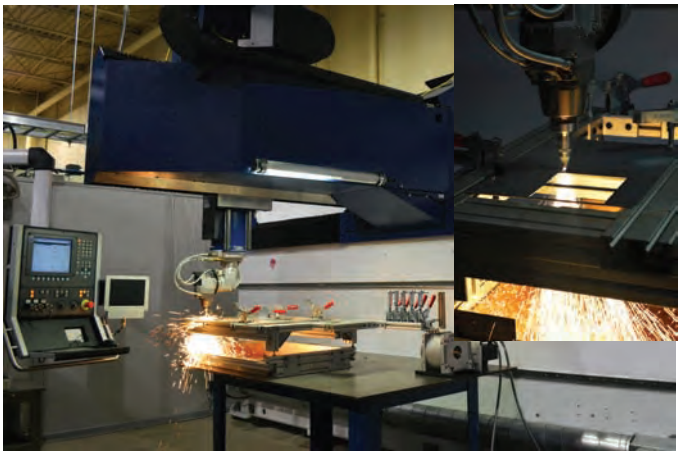
New robotic work cell with 3m linear track

Approximately 90% of the laser division's revenue is from industrial funding. Industrial clients view CCL as the premier laser applications development facility in North America.

The Laser Applications Division continued its growth with 100 industrial projects completed by year end for its customer portfolio of leading blue chip companies in North America.

CCL focuses its successful strategy of developing laser applications technology for markets such as oil and gas, alternative energy, automotive and aerospace. CCL-L plans to expand its facilities and operations further in 2014.

The laser division works closely with a large number of automotive companies in the Detroit area, developing new



New TRUMPF Trulaser cell 7040 high speed / high precision laser processing machine

laser technologies and applications for advanced light-weight vehicle structures and for electric vehicle applications.

CCL continues to see interest in its laser technology expertise as major automotive manufacturers increase their fuel efficiency by reducing vehicle mass and using advanced manufacturing technology, in order to meet future government CAFE regulations. These regulations require average vehicle fuel efficiency of 54.5 miles per gallon by 2025.

The Laser division also expanded into the aerospace industry working on laser process development for aluminum, titanium, and nickel-based super alloy materials for both laser welding and laser metal deposition processes.

Lithium-Ion battery technology has been a core competence of CCL over the last 5 years. CCL has developed laser welding technology for several major industrial customers in the lithium-Ion battery sector resulting in the successful transfer of this technology into industrial production for two different customers. Projects are continuing in this field for 2013/14.

CCL expanded its range of ID laser processing tools by developing new processing equipment for ID Cutting and ID Hardening, in addition to its already established range of ID cladding heads. The new heads have been tested on new development projects for industrial customers.

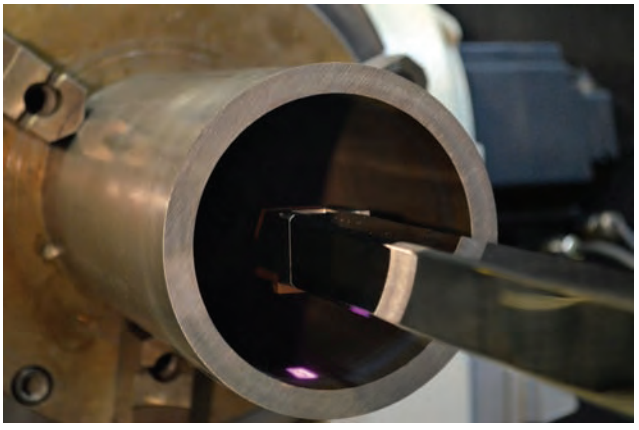
Outlook for 2014

The laser division plans to install a new state of the art 6kW IPG Fiber laser in 2014, which will have 50 micron diameter fiber beam delivery and a new state of the art 3D laser scanner which will improve its technology offering and capabilities for the upcoming year.

With the recent expansion of its facility and introduction of new state of the art equipment, CCL is the premier laser applications research facility in North America. It plans to add additional resources in 2014 in order to meet the objectives for the coming year.

CCL is confident that 2014 will provide further growth opportunities with expansion plans to the Plymouth, Michigan operations in order to meet the growing demand for its expertise and services in applied research and development for high power laser applications.

Turbine blade demonstrator component built at CCL-L using laser based additive manufacturing



New ID heat treatment head, developed by CCL-L in 2013

For more information: www.ccl-laser.fraunhofer.org

Fraunhofer Center for Coatings and Laser Applicatons

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FRAUNHOFER CENTER FOR EXPERIMENTAL SOFTWARE ENGINEERING

The Fraunhofer Center for Experimental Software Engineering, Maryland (CESE) is located in College Park, Maryland and conducts applied research in software engineering processes and technologies. It collaborates with private-sector organizations, government agencies, and academic and research institutions to develop innovative, practical approaches to software development and management issues.

CESE has affiliations with the University of Maryland at College Park and the Fraunhofer Institute for Experimental Software Engineering (IESE) in Kaiserslautern, Germany.

The Center's project portfolio includes a mixture of research efforts into new software technologies and empirical evaluations of existing tools and processes, and service-provision contracts to assist clients with software development and acquisition needs. Customers include government agencies such as NASA and the US Food and Drug Administration; large multi-national companies such as Johnson & Johnson, Agilent and Robert Bosch; and small and medium-sized companies with software needs in the Washington, D.C.– Baltimore, Maryland corridor.

Competencies
- Measurement and Knowledge Management
- Software Management and Process Improvement
- Software Architecture and Embedded Software
- Software Verification and Validation

Business Areas
- Aerospace / Defense
- Automotive
- Medical

PROJECTS IN PROGRESS

NASA Space Network Ground Segment Sustainment
Competencies: Measurement, Project Management

The NASA Space Network (SN) is a communication signal relay system that provides tracking and data-transfer services between user platforms and user Mission Operations Centers (MOCs). The SN was established in the early 1980s to re-place NASA's worldwide network of ground tracking stations and consists of a constellation of data relay and tracking satellites and associated ground systems. This space-based relay system can provide essentially unlimited communication services for altitudes ranging from 73 km to 9000 km, a capability that is unique within the civilian and commercial space industry. In addition, limited communication services can also be provided for customer platforms located on the ground and ocean/sea surfaces (e.g. ships) as well as airborne platforms (e.g. atmospheric balloons). The fleet of Tracking and Data Relay Satellites (TDRS) in geosynchronous orbit serves as a data relay system between SN ground system and user platforms. The SGSS project replaces a majority of the existing SN Ground Segment with modern technology in order to fulfill the following objectives.

1. Monitor and Control the SN Flight and Ground Segments; including management of the configuration, health and safety of the TDRS spacecraft fleet and SN Ground Segment elements.
2. Provide SN user service planning and scheduling.
3. Relay user signals in forward and return directions between the ground and user platforms.
4. Distribute user data on the ground using NASA Integrated Services Network (NISN) services, user-provided networks, and local interfaces (LIs).
5. Provide tracking services for TDRS and user spacecraft.

The heart of CESE's SGSS research is the collection and analysis of software progress and quality metrics from the SGSS development contractors. Software progress metrics include measures such as requirements decomposed; requirements volatility; components designed, coded and tested; etc. Software quality measures include defects found, defects corrected, etc. The analysis of these metrics permits CESE to identify areas of risk and opportunities for improvement of contractor outputs delivered to NASA. CESE also uses the metrics analysis to research new technologies and to infuse those that demonstrate risk reduction, better cost/schedule adherence or software technology improvement into both the NASA Project Team and the SGSS development contractors. Specific technologies that CESE is researching include software cost and schedule estimation and tracking, software defect detection and Reliability Growth Models, Service Oriented Architectures (SOA), and software metrics presentation techniques.

CESE performed critical design reviews for the SGSS project, and was instrumental in using metrics-based performance research to provide feedback and insight to NASA on the performance of the main software subcontractor.

Keymind Process Improvement

Competencies: Measurement, Process Improvement

A long-time CESE process improvement customer, Keymind, a division of Luminpoint, Inc., has worked closely with Center staff since 2004 to improve its software processes. CESE provides support for Keymind's improvement initiative, which includes defining and implementing high-maturity, quantitatively-based processes, sustaining their maturity ratings as defined by the CMMI for Development (CMMI-DEV) framework, and performing other process-related work focused on achieving positive impacts to Keymind's business goals and project objectives. Keymind achieved a CMMI Maturity Level 5 rating with help from the Center's innovative application of empirical methods and tools.

Central to any process-improvement initiative is the idea that the selection and application of appropriate processes using empirical methods produces good products. This empirical mindset provides a basis for choosing the appropriate processes, analyzing the effects, and packaging the results which drives an effective process improvement initiative. The work at Keymind exemplifies some of the important factors that differentiate the CESE approach, including:

1. Tying the measurement of technical processes specifically back to the organizational and strategic goals, to give both technical leads and managers a "top-to-bottom view," helping them understand how their specific projects further the overall goals of the organization.
2. Eliciting context-specific quality indicators that can be applied to projects to identify potential risk areas, and which can be refined by capturing feedback from the teams and objective measures of impact.
3. Creating automated approaches to data collection, reporting, and analysis that can greatly reduce the time and effort required for the organization to gain insight about their projects.
4. Using innovative visualization tools that allow organizations to intuitively gain an understanding of the important points, including tools such as the CodeVizard application that CESE has helped develop. CodeVizard automatically analyzes and provides an interactive visualization of the whole history of a software project, allowing developers to explore how often quality indicators have been fulfilled and what corrective actions have been taken.

In accomplishing all of those goals with Keymind, CESE is applying technologies that resulted from several NSF-funded research projects as well as internal research undertaken in partnership with its sister institute, IESE. Through their application in the context of a highly-mature customer with a commitment to software quality, this work provided peer-reviewed results that add to the state of the art in the area.

Modeling and Analysis of Cyber-Physical Systems

Competencies: Software Architecture, Embedded Systems

With the University of Maryland and a team of universities around the US, researchers at CESE have been working on techniques for modeling cyber-physical systems (CPS). CPS consist of a physical components and computing infrastructure; examples include control system in automobiles and airplanes. Major research efforts in the US and Europe are devoted to the development of better mechanisms for designing, implementing and validating such systems. The consortium that includes CESE has been funded by the National Science Foundation to develop novel modeling strategies, and verification, techniques, for CPS.

At CESE, efforts have focused on the use of software-architecture concepts to simplify and standardize modeling of hybrid systems; the development of machine-learning-based methods for reconstructing requirements specifications for such models; and the use of formal-methods verification techniques, such as model checking, to verify the safety of medical-device controllers.

The Fraunhofer Approach to Software Testing (FAST)

Competencies: Software Architecture, Verification and Validation

Since 2011, CESE researchers have been developing FAST, which is a method for testing software from different domains such as aerospace, medical-device, and web software. FAST is based on two fundamental technical principles. The first is Design for Testability. Based on extensive experience in working on large-scale software systems, CESE staff members have collected an informal corpus of knowledge encompassing principles that are used by the best software engineers at NASA and JHU/APL to enhance the ease of testing software. These best practices dramatically improve the testability of the final product.

The second technical foundation for the FAST is Model-based Testing (MBT). MBT is a new technology developed in the research community that has attracted attention among practitioners. In MBT, tests are specified as abstract, programming-language-independent models. A translator maps abstract test specifications to concrete tests. The advantages of this approach are as follows.

1. Such test models are insulated from changes in the source code, thus reducing maintenance costs.
2. One creates a test-specification only once in terms of a model and executable test cases are automatically generated without programmer intervention.
3. Models are much easier to understand than code for humans and allow all stakeholders to understand how the software is being tested.
4. Tests automatically generated from behavioral models cover aspects of system behavior in a much more complete manner compared to manually written tests.

The FAST approach currently relies on models developed as state machines, or as Simulink® diagrams, and used tools such as JUMBL, GraphWalker and Reactis® to generate model-level tests that the FAST framework then translates into code-level test scripts. The technology has been used in several projects to date, including:

1. Center researchers continued to uncover previously unknown critical issues in NASA ground systems and flight-software systems. While the detected defects were reported to NASA, these testing projects were also documented and used as tutorials for demonstrating the technology's capabilities.
2. CESE also continued to use the FAST to test several commercial software systems, resulting in different types of detected software errors. Using the FAST, software may be improved for testability and then systematically tested, because its structured approach.

Measuring and Monitoring Technical Debt

Competencies: Measurement, Project Management, Process Improvement

In collaboration with the University of Maryland-Baltimore County (UMBC), a CESE research group has been engaging with a number of different organizations on questions related to technical debt. This term refers to the tradeoff that occurs when developers focus on achieving short-term gains (like delivering an increment of the software on time) at the expense of long-term benefits (like keeping software code maintainable and well-structured). Project researchers have been working with a number of different teams to look at what strategies can be effective for them, with respect to identifying and deciding what to do about technical debt. It should not be a surprise to anyone that what constitutes technical debt can vary greatly from one project to another; as do the tradeoffs that teams are willing to make regarding it. The common thread that has been found across all of this work is that projects should devote some time to understanding what kinds of technical debt are of interest and how the accumulation of the debt can be measured. Some examples:

1. CESE researchers worked with a team at a multinational company which provides document-related business solutions, products and services. The team was working on device drivers for the company's high-end products, and due to the size and variety of the customer base, maintainability and portability were a must. To find areas where the code had decayed, the CESE staff investigated computer-assisted support for detecting "code smells," anti-patterns formulated by Kent Beck as a way to help identify areas where good design principles were breaking down. Although some tailoring of the heuristics was necessary, these "smells" turned out to be a useful way of identifying areas the team agreed were accumulating technical debt.
2. With a mid-sized, local software development company that focuses on database-driven web applications, CESE researchers found that they highly value the use of a reference architecture. In this case, instances where developers design their own solutions and avoid reuse represent technical debt, since redesigning the system to be in compliance is expected to lead to greater understandability and maintainability over time. In this same context, CESE also had some promising results with finding potential code smells and out-of-date documentation as indicators of technical debt.
3. With a team developing high-performance code for supercomputers, CESE scientists noticed that they solve the difficulty involved in making optimal use of the parallel processors by strongly separating calls to the parallelization libraries from the code doing scientific

simulation - thereby allowing both the computer scientists and the domain experts to focus on what they know best. Instances where this separation of concerns breaks down should be treated as technical debt - that is, by detecting and fixing where the planned architecture of the system is not followed, CESE can help the developers create a more maintainable, more flexible system.

In all cases, the research team has developed a process that is bearing fruit: find some initial examples of what constitutes technical debt for the development team; show those examples and have a group discussion about whether it would be useful to take some time to "pay down that debt"; then either find additional examples that seem to fit the same mold or update relevant definitions of debt in this environment.

GQM+Strategies

Competencies: Measurement, Project Management

Scientists from CESE and IESE have continued applying the GQM+Strategies® methodology, which was jointly developed by the two organizations to provide a framework for connecting business-level goals with software-project-specific technical metrics and management artifacts. CESE and IESE collaborated on delivering GQM+ Strategies services to EcoPetrol, a Colombian oil company. CESE has also used the approach on projects with NASA, MITRE and Axiom, the parent of the Keymind company referred to above.

Fraunhofer CESE continues to collaborate with Fraunhofer IESE to refine the GQM+Strategies® methodology, and to package the technology so that it can be used to improve staff efficiency in the measurement-related project work that is a core capability for both organizations. The collaboration continues to build a unique and marketable Fraunhofer capability, which will address one of their business areas and facilitate projects at both entities. Both CESE and IESE have developed a set of assets that are reusable for both centers, including: a training course for use with customers and collaborators, process description, tool for visualizing the GQM+Strategies® outputs, and case studies – all of which stem from the knowledge, experience, and expertise resulting from the various engagements involving CESE and IESE with customers.

New Project

Important new project wins in 2013 included a major five-year, $7.5m NASA project; various efforts in the medical-device sector, both industrial and governmental; research projects through NASA's Software Assurance Research Program; and new work with a major private-sector company in the testing and measurement industry.

University Partners

- University of Maryland at College Park
- University of Maryland at Baltimore County
- Technical University of Kaiserslautern

Other Partners

- NASA Goddard Space Flight Center
- NASA IV&V Center
- Battelle

For more information: **http://www.fc-md.umd.edu**

Fraunhofer Center for Experimental Software Engineering

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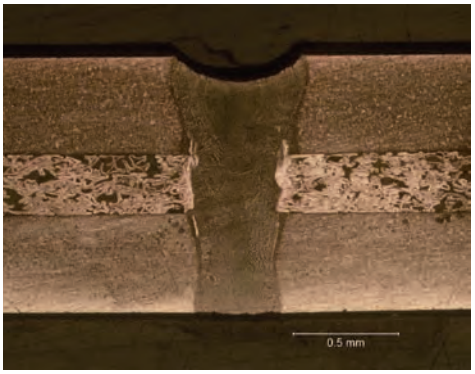
The Fraunhofer Center for Laser Technology (CLT), focuses on research and manufacturing solutions with light comprising the core expertise of processing, special components and lasers. It mainly serves the markets of alternative energy, automotive, medical and homeland security. The application of diode lasers for industrial manufacturing with high power and brightness, laser processing of batteries and solar cells enabling higher performance and cost effective manufacturing and micromachining application development for drilling and ablation are the main focus. Solutions spanning from optimized processes and real time quality control to customized workstations are provided.

Supercapacitors: Laser Joining

CLT is developing new packaging technology tailored to the specific requirements of advanced supercapacitors in a strategic partnership with Inmatech Inc., Ann Arbor. The development of laser based, cost effective manufacturing processes was previously focused on the sizing of electrodes, which were successfully tested. In addition, laser tab welding was developed to join a stack of electrodes based on infiltrated metal foam. CLT has also designed and manufactured prototype packages for supercapacitor cells. Single-cell and 3-cell prototypes were produced and tested. High peak power and good energy storage could be demonstrated and further work will optimize the performance and manufacturing processes.

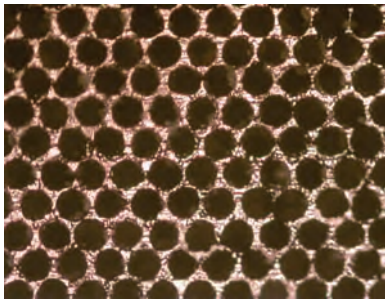


Laser welding of nickel foam electrode tabs

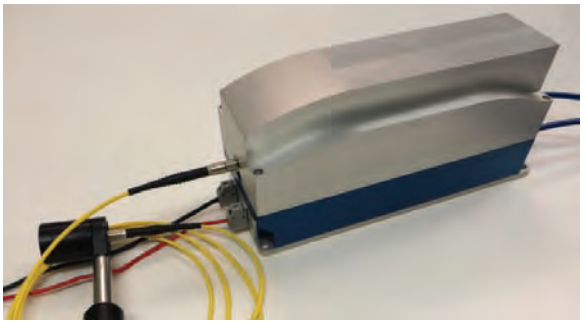
PV Solar Cells: Laser Drilling and Doping

Within the framework of the US DoE funded FPACE project and in partnership with solar cell manufacturer SolarWorld, CLT has used laser processing to achieve several advancements to the PERC cell concept. CLT has optimized the drilling process for metal wrap through (MWT) cells for a range of hole sizes and wafer thicknesses. Very high accuracy of hole size was achieved with standard deviation well within the required precision of +/- 5 µm. Furthermore, the results showed that the pitch error along each row was very low (+/- 2 µm) which ensured that the hole pattern matched with the metallization technique. Besides MWT design, a very high drill rate of 15,000 holes per second in 120 µm wafer was achieved for emitter wrap through (EWT) cell design.

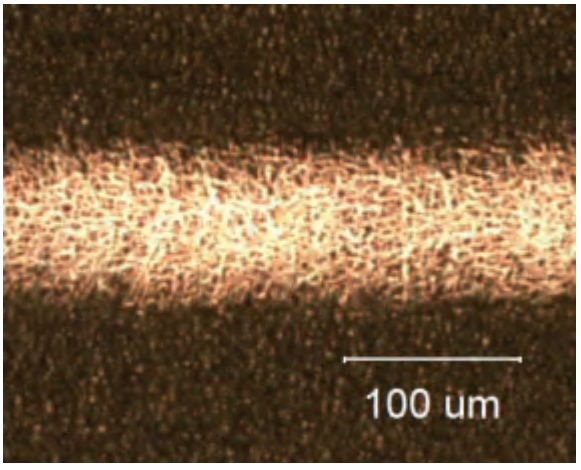
Selective laser diffusion pattern for PV solar cells



Laser drilling of very high aspect-ratio holes in Tantalum



20W 450 nm (blue wavelength) laser



Laser processing of silicon

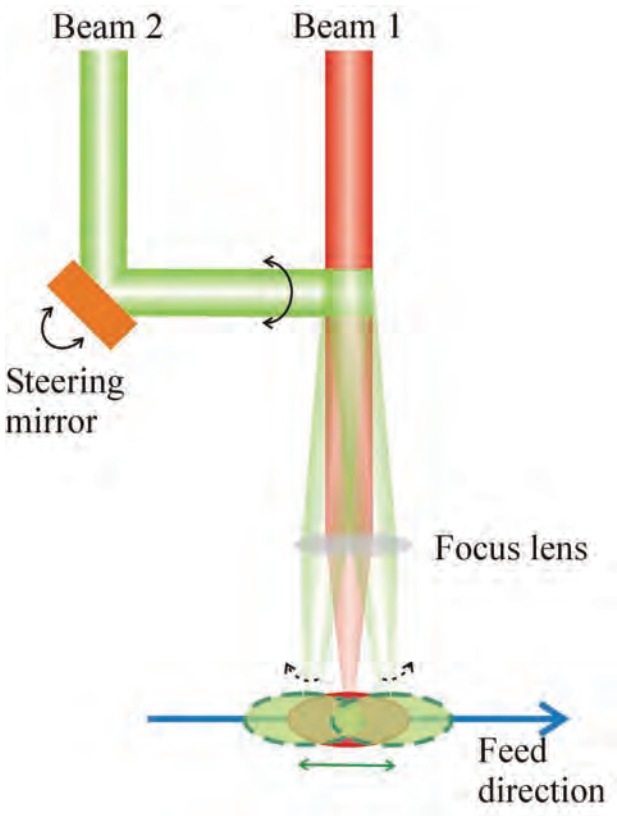
Selective laser diffusion was the second focus of the program. The goal was to locally increase the dopant concentration underneath the metallization lines to reduce the resistance and enable a more efficient charge collection. Using a pulsed 532 nm laser, CLT has demonstrated clear advantages in cell efficiency by achieving shallower doping profiles with higher surface concentrations and reduced surface damage.

X-Ray Space Collimator: Laser Drilling

CLT worked with the Navy Research Lab on the drilling of up to a 3 mm thick tantalum sheet. The application was an x-ray collimator optic which required drilled holes with a diameter of less than 50 µm and a depth to diameter ratio of 60:1 and an open area fraction rate of 70%. CLT used a pulsed disc laser to drill 2 mm tantalum sheet and used chemical etching to remove the melt debris and further increase the hole diameter.

Novel Blue Laser

High brightness diode lasers have been a main research field of CLT for the past decade. CLT developed and patented a novel packaging technique allowing 3x higher brightness than in commercial products. The technology was licensed to Direct Photonics Industries (DPI), which focuses on the >$1billion market for cutting and welding. CLT used its in-depth expertise in intelligent diode laser packaging and combined multiple diodes into a single beam to develop a 20 W prototype laser in the visible (blue) range with a wavelength of 450



Schematic of Multi-Beam LAM

nm. The laser was successfully designed, built, assembled and tested. A number of applications were developed using this laser system including cutting of copper, surface marking of metals and processing of silicon for solar wafers.

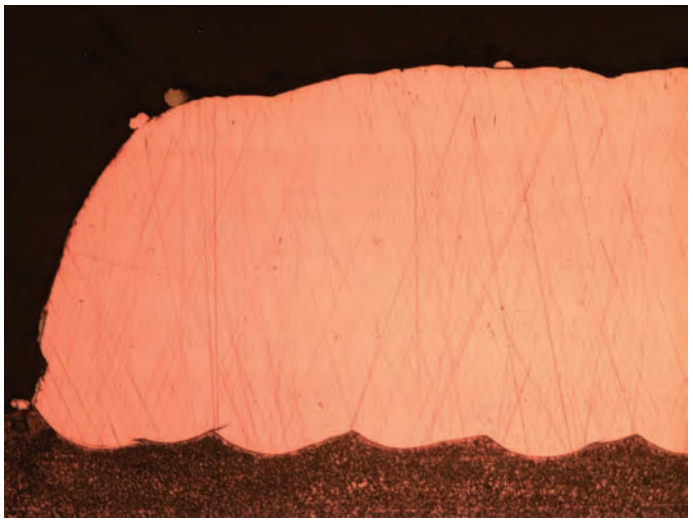
Laser Additive Manufacturing

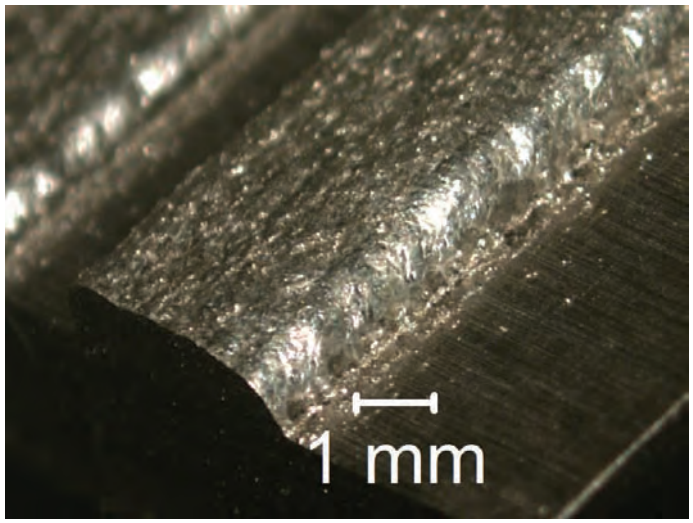
To support its maintenance and repair efforts, the Department of Defense (DoD) depots require new and proven technologies that can ensure high equipment readiness. Additive manufacturing technologies are currently used at DoD depots including laser additive manufacturing (LAM). LAM is typically performed using a single beam with power up to multiple-kilowatts. The associated high heat input and limited process control restricts tight manufacturing tolerances and the applicable material spectrum.

National Center of Manufacturing Science

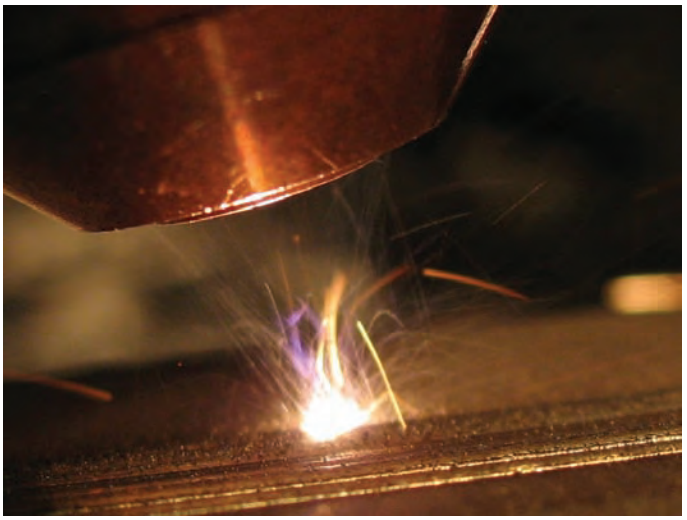
The National Center of Manufacturing Science (NCMS) through its Commercial Technologies for Maintenance Activities (CTMA) initiative, awarded a project to CLT and its collaborating partner University of Michigan to develop a novel approach for laser additive manufacturing using multiple beams. This program is aimed at the development of Multi-beam LAM technology to address the shortfalls of today's technology and to broaden the applicability to many industries. CLT completed the development of the MB-LAM process by deploying several low power laser beams simultaneously. The single beams either work in parallel to scale productivity without sacrificing precision or in close proximity creating desired heat profiles. This new approach is scalable in productivity through multiplication.

The Multi-beam laser additive manufacturing (LAM) system is a complete integrated processing unit. It's compact size and light weight makes it very adaptable to robotic motion systems. The MB-LAM system was applied for laser additive manufacturing using Inconel 738 powder. The results showed that the clad profile could be precisely controlled by varying the oscillation parameters. Subsequently, area deposition was conducted which showed good overlapping tracks without defects. Multi-layer deposition with 2 and 3 layers resulted in up to 1mm thick layers and exhibited a high quality deposition.





Inconel 738 deposited on steel using MBLAM



Multi-Beam LAM process

For more information: www.clt.fraunhofer.com
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FRAUNHOFER CENTER FOR MANUFACTURING INNOVATION

The Fraunhofer Center for Manufacturing Innovation (CMI), together with its partners, Boston University and the Fraunhofer Institute for Production Technology in Aachen, Germany, conducts advanced research and development leading to engineering solutions for a broad range of industries, including biotech/biomedical, photonics, and renewable energy. Fraunhofer engineers, faculty and students scale up basic research into advanced technologies for client companies in the U.S. and abroad. CMI's primary focus is on next-generation, high-precision automation systems as well as medical devices and instruments that lie at the intersection of engineering and biology.

In the life-sciences area, during 2013, CMI won another highly competitive research grant from NIH on "Rapid Antibiotic Susceptibility Testing." In conjunction with its other NIH grants, including "Bacterial Drug Susceptibility Identification by Surface Enhanced Raman Microscopy," its participation in the "NIH Center for the Future Technologies of Cancer Care," in which it will serve as the engineering arm for this multi-organization, multi-year program, and its grant from NSF on "Charge-Assisted Protein Sensing," CMI is establishing itself as a key player in the biotech/biomedical areas with the U.S. government funding agencies.

On the industrial front, CMI has acquired repeat business from industry leaders, as well as new key accounts from major U.S. Corporations. CMI also acquired a new a project from the US Treasury Department's Mint to develop alternative laser-based technologies for making coins (money). In fact, CMI was selected as a "preferred vendor" by the US Mint.

Also, in 2013, Prof. Andre Sharon, CMI's Executive Director, was awarded the prestigious Joseph von Fraunhofer Prize for Science and Innovation, for the development of a fully automated factory for the production of plant-based pharmaceuticals. Prof. Sharon shared this prize with his colleague Dr. Vidadi Yusibov, Executive Director of the Fraunhofer Center for Molecular Biotechnology (CMB). The Joseph von Fraunhofer prize is awarded annually in recognition of outstanding scientific work by Fraunhofer scientists that provide solutions to real-life problems. Jointly, Prof. Sharon and Dr. Yusivov were able to harness the natural protein production machinery of plants in a commercially-viable automated process. With the assistance of talented engineers and scientists at CMI and CMB, they were able to build a fully automated, first-of-a-kind, GMP-compliant manufacturing facility capable

Dr. Andre Sharon (foreground) with Dr. Vidadi Yusibov inspecting plants in the automated factory for plant-based pharmaceuticals.

of producing proteins for use in a variety of applications, including vaccines, therapeutics and diagnostics.

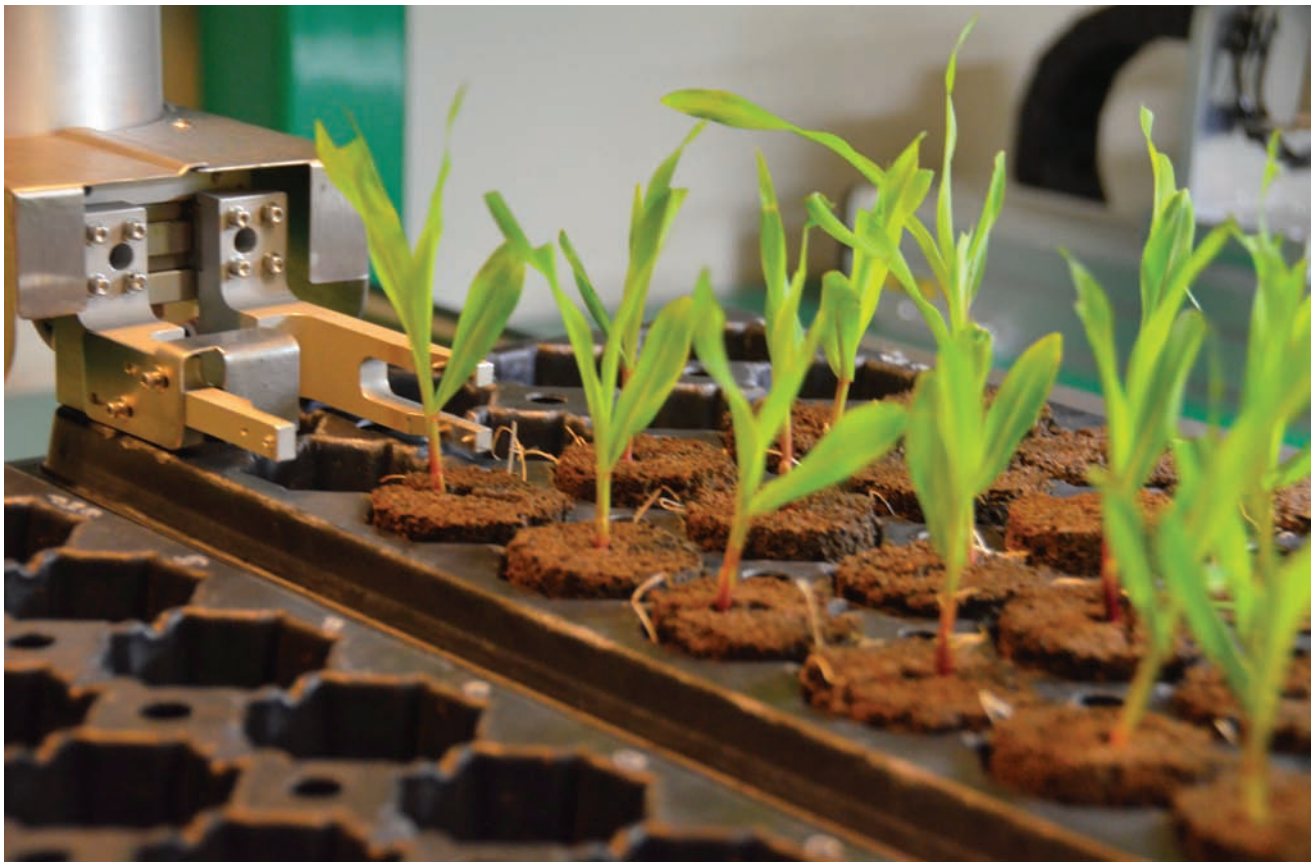
Finally, CMI has further enhanced its reputation in the scientific community with several new journal publications in 2013.

Representative systems under development at CMI during 2013 include:

Sampling of Plant Tissue

Fraunhofer CMI has designed and fabricated a system to automatically take tissue samples from live corn plants for genetic testing. The young plants, which are grown in hydroponic plugs, are automatically removed from plant trays and transported to the sampling location. An optimized algorithm ensures the leaf material to be spread out on a vacuum chuck. This presents the leaves to a sophisticated vision system which determines if there is sufficient leaf material to take a defined sized sample. The sample shape is optimized based on the width of the largest available leaf.

A CO2 laser, combined with an X-Y scan head, is used to then cut the sample at the optimal location. The separated samples are robotically picked up and placed in micro titer plates for bulk DNA testing. Integration into a central sample



Live corn plants ready for genetic testing

database ensures the traceability of each sample back to the corresponding plant.

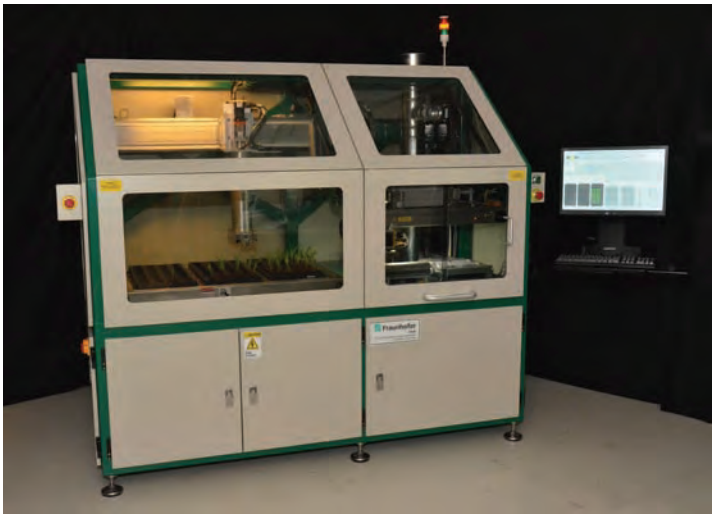
The plants that were successfully sampled are placed in outgoing trays while those which are too small to be sampled are placed on a separate tray that is then returned to the green house to be re-sampled at a later date.

Using this system, Fraunhofer CMI was able to significantly improve the sampling throughput of the client's sampling process over the previously-used manual operations. More importantly, the automatic process produces a significantly more repeatable sample size than the manual sampling process. This allows for better quantification during DNA testing. The use of bar code readers which automatically identify both plant trays and sample titer plates, along with the database integration, ensure global traceability of each sample and plant throughout the whole process.

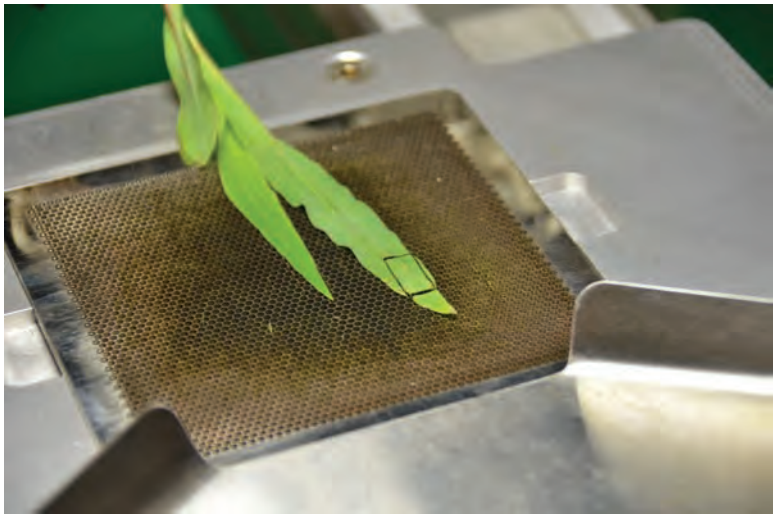
Eccentric Positioning System for I.D. Grinding

Precision internal grinding is a process used in the manufacture of round or cylindrical internal surfaces on hardened materials. It is often used in the production of gears and bearings, and can account for 30% of their cost of manufacture. A new internal diameter (I.D.) grinding system which reduces grinding costs while maintaining or improving part quality would have broad market appeal. Fraunhofer CMI is developing, jointly with its sponsor, a new three axis positioning system capable of linear and angular motions for I.D. grinding. This system has a novel and unique implementation, using eccentric rotary bearing spindles, that allows arbitrary trajectory motion within the X, Y, and θ coordinate space.

This new approach provides several advantages to I.D. grinding machines. The use of rolling element bearings in the spindles will reduce the cost and complexity by eliminating



Automated Plant Sampling Machine



Plant Leaf Being Imaged and Laser-cut for Sampling

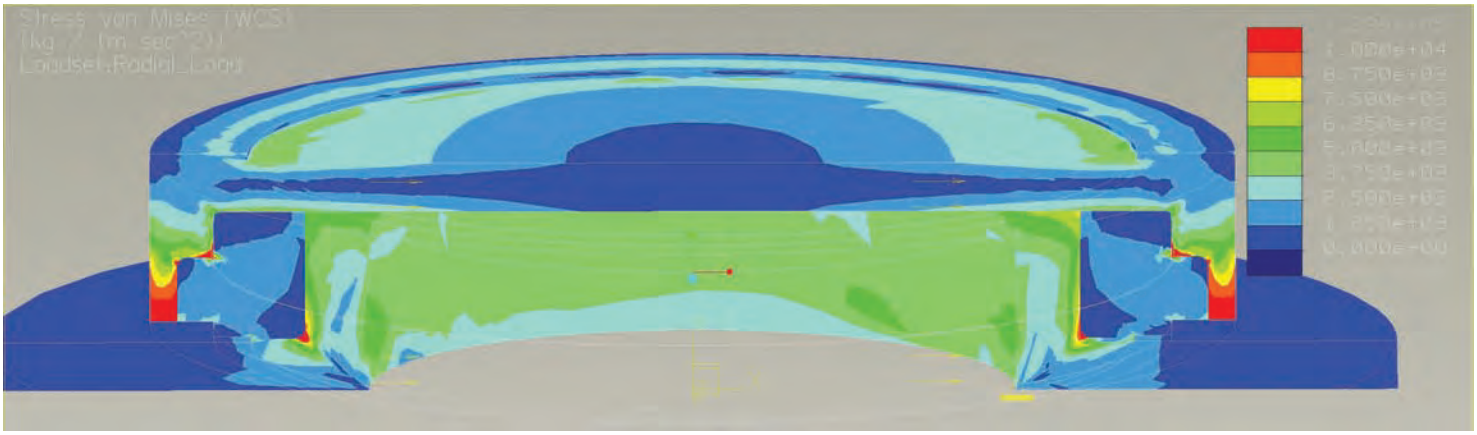
hydraulic systems for hydrostatic bearings, as well reduce energy consumption. The performance of the equipment will also improve, as the integrated linear and angular positioning would allow real time measurement of forces and grinding spindle deflection. This allows grinding wheels to be compensated in order to run true to the workpiece, improving part accuracy. It also allows instant transition between "rate-feed" and "controlled force" grinding to reduce production time.

Detailed mechanical design of the eccentric positioning system is underway. Finite Element Analysis is used to optimize the stiffness of the system and placement of the fluid dampers. The system is being engineered for retrofit onto a commercial I.D. grinder base for workholding and test purposes.

Microfluidic Platform for Rapid Antibiotic Susceptibility Testing

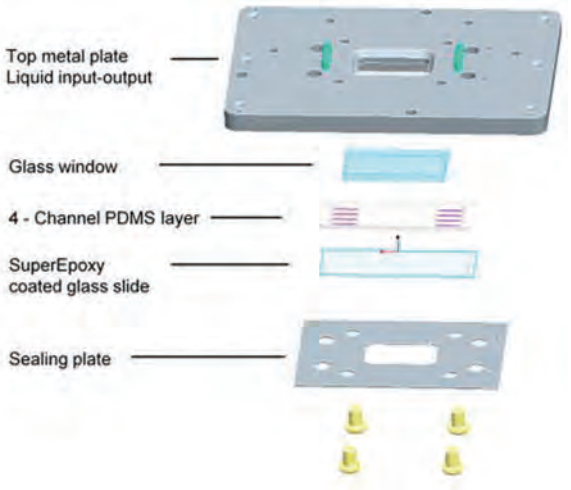
The emergence and spread of bacterial resistance to ever increasing classes of antibiotics intensifies the need for fast phenotype-based clinical tests for determining antibiotic susceptibility. Standard susceptibility testing relies on the passive observation of bacterial growth inhibition in the presence of antibiotics. Fraunhfoer CMI is developing a novel microfluidic platform for antibiotic susceptibility testing based on stress-activation of biosynthetic pathways that are primary targets of antibiotics. We chose Staphylococcus aureus as a model system due to its clinical importance, and selected bacterial cell wall biosynthesis as the primary target of both stress and antibiotic.

Enzymatic and mechanical stresses are used to damage the bacterial cell wall, and a β-lactam antibiotic interfers with the repair process, resulting in rapid cell death of strains that harbor no resistance mechanism. Bacteria, covalently-bound to the bottom of a microfluidic channel, are subjected to mechanical shear stress created by flowing culture media through the microfluidic channel and to enzymatic stress with sub-inhibitory concentrations of the bactericidal agent lysostaphin. Bacterial cell death is monitored via fluorescence using the Sytox Green dead cell stain, and rates of killing are measured for the bacterial samples in the presence and absence of oxacillin. Using model susceptible (Sanger 476) and resistant (MW2) S. aureus strains, a metric is established to separate susceptible and resistant staphylococci based on normalized fluorescence values after 60 minutes of exposure to stress and antibiotic. Because this groundbreaking approach is not based on standard methodology, it circumvents the need for MIC measurements and long wait times. Using this system, CMI was able to correctly designate the phenotypes of 16 clinically relevant S. aureus strains. In addition



Finite Element Analysis of Eccentric Positioning System for I.D. Grinding

to future clinical utility, this method has great potential for studying the effects of various stresses on bacteria and their antibiotic susceptibility.



Microfluidic Platform for Rapid Antibiotic Susceptibility Testing

CMI Internship Program

CMI's internship program continues to thrive, providing a global experience to 12 European interns per year. Since its inception, the program has hosted over 150 interns, mostly from Europe. Interns are provided with housing and a stipend, and are encouraged to experience not only the American workplace, but the American culture as well. The program has been tremendously successful, receiving rave reviews from all involved. These students are subsequently highly recruited in Europe, as they bring a global perspective to the job.

For more information: www.fhcmi.org

Fraunhofer Center for Manufacturing Innovation

Dr. Andre Sharon, Executive Director
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asharon@fraunhofer.org

Fraunhofer CMB's Plant-Based Product Development Continues

In 2013, the Fraunhofer Center for Molecular Biotechnology (CMB) continued its research and development in recombinant subunit vaccines against Anthrax, Yellow Fever and Malaria. These projects are funded through the United States Defense Threat Reduction Agency (DTRA), the Brazilian Ministry of Health through BioManguinhos and the Malaria Vaccine Initiative (MVI), respectively.

Investigational New Drug (IND) applications were filed with the U.S. Federal Drug Administarion (FDA) for both a recombinant protective antigen-based vaccine against Anthrax and a transmission-blocking vaccine (TBV) against malaria, and clinical trial is underway for malaria.

Anthrax Vaccine

CMB was awarded a contract from the National Institute of Allergy and Infectious Diseases, part of the National Institutes of Health, for developing vaccine technologies to advance the next generation Anthrax vaccine. The contract will support the advanced development of candidate vaccine components and technologies that accelerate the immune response against vaccine. Most disciplines within Fraunhofer will play a part in successfully completing the deliverables, from biomass generation, to agro infiltration and protein purification, formulation development and stability, pre-clinical activities, pre-IND activities and IND submission, and ending with the option to conduct a Phase 1 clinical trial.

Malaria Vaccine

Malaria is a mosquito-borne, life-threatening, infectious disease devastating developing countries in Africa and South-East Asia. The disease is caused by Plasmodium parasites, of which Plasmodium falciparum is responsible for the majority of deaths. No licensed vaccine is currently available, whereas effective vaccines for the control and prevention of malaria are urgently needed. Malaria transmission blocking vaccines (TBVs) directed against proteins found on sexual stages of P. falciparum present in the mosquito midgut are considered an effective means to reduce malaria transmission.

To produce a safe and immunogenic TBV against malaria, CMB developed Virus-like particles (VLPs) comprising Alfalfa mosaic virus coat protein (CP) fused to the Pfs25 antigen from P. falciparum (Pfs25-CP VLP) and produced non-enveloped hybrid VLPs in Nicotiana benthamiana plants using a Tobacco mosaic virus-based vector. Purified Pfs25-CP VLPs were highly consistent in size (20-25 nm) with an estimated 10-20% incorporation of Pfs25 onto the VLP surface.

Immunization of mice produced results supporting the potential of the Pfs25-CP VLP as a TBV candidate and the feasibility of the vector technology for the production of VLP-based recombinant vaccines against infectious diseases.

L to R: Dr. William Hartman, Executive V. P. Fraunhofer USA, Dr. Hans-Jorg Bullinger, Former President of Fraunhofer Gesellschaft, Dr. Georg Rosenfeld, President of Fraunhofer USA, Dr. Patrick Harker, President, University of Delaware, Dr. Vidadi Yusibov, Exec. Dir., CMB, Douglas Muzyka, Senior V. P. and Chief Science and Technology Officer, DuPont, Delaware Governor Jack Markell, Dr. Karl Steiner, Associate Provost, Research and Development, Univ. of Delaware.

Collaborations and Partnerships

University of Delaware – Fraunhofer CMB - State of Delaware
Inaugural Technology Summit

In March, academic scientists and engineers came together with CEOs and entrepreneurs at the inaugural Fraunhofer–Delaware Technology Summit to discuss energy and life sciences challenges in a rapidly changing global environment.

The "Solutions for Sustainability," event was held at the University of Delaware where Delaware Governor Jack Markell and Univ. of Delaware President Dr. Patrick Harker welcomed

L to R: Maria Stössel, Carolin Hartwig, Peter Worthington, Elisabeth Bludau, Erin Crowgey and Robert Kaspar. Photo by Lane McLaughlin

nearly 150 participants. The summit was organized and chaired by Dr. Vidadi Yusibov, Executive Dir. of CMB and Dr. Karl Steiner, Senior Associate Provost for Research and Development at the University of Delaware.

Lee Davis, Senior Vice President of NRG, gave the keynote for the meeting's energy track: "From Fossil to Photons: An Energy Company's Transformation." Douglas Muzyka, Senior Vice President and Chief Science and Technology Officer at DuPont, gave the keynote for the life sciences track: "Life Sciences: Addressing Global Challenges."

New Fraunhofer – University of Delaware Graduate Student Exchange Program

In conjunction with the Technology Summit, a new graduate student exchange program was launched. It is designed for selected German and UD students to participate in research placements in energy and biotechnology, at the University of Delaware or Fraunhofer in Germany. The first Fraunhofer exchange cohort included German students Carolin Hartwig, Elisabeth Bludau and Maria Stössel, and University of Delaware students Robert Kaspar, Erin Crowgey and Peter Worthington.

Worthington, a UD doctoral student in biomedical engineering, worked with a lab group at the Fraunhofer Institute for Cell Therapy and Immunology in Leipzig, Germany, and focused on using magnetic particles and microfluidics to create devices that can quickly display if a patient has a disease without requiring sample processing in a dedicated lab.

Elisabeth Bludau, doctoral student in pharmaceutical biotechnology at the Fraunhofer Institute for Toxicology and Experimental Medicine hosted at the Technical University of Braunschweig, worked with UD's Babatunde Ogunnaike.

Fraunhofer CMB – Fraunhofer ITEM Precision-Cut Lung Slices as an Alternative System for Evaluating Vaccine Safety

Working with technology that was originally developed by Fraunhofer Institute for Toxicology and Experimental Medicine (ITEM) in Hannover, Germany; Fraunhofer CMB is adapting the technology specifically for vaccine development. The objective is to develop and establish a cost-effective, high throughput, ex-vivo, lung tissue- based system for evaluating vaccine safety and immunogenicity directly in human tissue.

PCLS (Precision Cut Lung Slices) could potentially be an alternative to animal models for evaluating product safety. This undertaking enhances and accelerates CMB's ability to characterize vaccines and therapeutics in humans as well as reduces the time and cost of developing products. CMB received funding for the project from the Defense Threat Reduction Agency to move forward on research and development efforts and will be subcontracting to Fraunhofer ITEM. The three year contract will address one of the largest obstacles in the current system of evaluating vaccine safety and immunogenicity; the lengthy testing in animal models that precedes clinical drug development. By some estimates, 30% of potential new drugs never move on to clinical trials because results of animal testing are not predictive of human response.

The development of a high-throughput ex vivo human system that is predictive of the human system for measuring potential toxicological and allergenic reactions will be instrumental in enhancing our ability to predict product safety as well as reduce the cost of developing new products. Human precision-cut lung slices (PCLS) represent a promising ex vivo model that offers intact structural integrity and cell composition of normal lung tissue. Another advantage is the high numbers of PCLS that can be obtained from one lobe of a lung.

Fraunhofer CMB and Fraunhofer IME -- Plant Produced Immunotoxin Demonstrates Toxic Activity

Many cancer cells express specific markers on their surface

that distinguishes them from normal cells. To target and destroy cancer cells, it was suggested to use immunotoxins. Immunotoxins are proteins composed of a marker binding portion linked to a toxin. The immunotoxin binds to a surface marker on a cancer cell, enters the cell by endocytosis, and kills it. In this collaboration, an immunotoxin developed by Fraunhofer IME with potential of treating a variety of chronic inflammatory diseases such as rheumatoid arthritis and atopic dermatitis, was provided to CMB to determine if the target could be successfully expressed in plants. The immunotoxin was successfully expressed, purified and tested in vitro. Plant produced immunotoxin demonstrated toxic activity against targeted cells. In conclusion, it was demonstrated that CMB's plant-based production platform could be successfully used for production of immunotoxins in active form.

Fraunhofer CMB - University of Delaware
Enhancement of TMV-based Vaccine Expression

The goal of this collaborative project between CMB and the University of Delaware (UD) is to generate transgenic Nicotiana benthamina plants which will be more susceptible to viral infection. This work may help to improve viral cell-to-cell movement, which may in turn increase expression levels of target proteins, one of the major goals of the technology developed by CMB. CMB's labs developed transgenic Nicotiana benthamina lines which were tested by UD lab members. In certain of these new lines, the speed of viral spread increased three times compared to wild type. Significantly increased numbers of initial infected host cells were found, which is important for increasing the yield of vaccine candidates. These early results will be followed up through continuous collaboration between the two groups including testing of current vaccine candidates being developed at CMB.

Vaccine Manufacturing Innovators Awarded Fraunhofer Prize

Dr. Vidadi Yusibov, Executive Director of Fraunhofer CMB, and Dr. Andre Sharon, Executive Director of the Fraunhofer Center for Manufacturing Innovation (CMI) and Professor of Mechanical Engineering at Boston University, were awarded the Joseph von Fraunhofer prize in recognition of outstanding scientific work by Fraunhofer scientists in providing solutions to real-life problems.

The practical problem tackled by CMB was the need to produce proteins more safely, economically and faster than through traditional manufacturing methods. Researchers at CMB developed the methodology to harness the natural protein production machinery of plants and then made the production process commercially viable. With the assistance of engineers at CMI, CMB built a fully automated, GMP compliant manufacturing facility capable of producing proteins for use in a variety of applications, including vaccines, therapeutics and diagnostics. The innovative plant-based production facility is successfully producing bulk drug substances for use in FDA approved human clinical trials.

Education and Research Outreach - *German Interns*

During 2013, CMB provided internships for three German students. Ms. Nazgul Kydyraliyeva is a Master's candidate from the University of Aachen in molecular biotechnology. She was a member of CMB's Protein Biochemistry group. Her Master's thesis was titled: "Expression and in-vitro characterization of mono and bi-valent recombinant SNAP-fusion proteins for targeting of Rhabodomyosarcomas."

Mr. Soriba Letzian is pursuing his Master's degree in Biotechnology at the RWTH Aachen University. He worked in CMB's Molecular Design and Engineering group where he contributed to efforts aimed at improving target gene expression.

Ms. Carmen Heitler graduated from the German University of Applied Sciences in Munich, with a degree in Bioengineering. She also interned at a German company and brought practical experience to her internship at CMB in the Protein Biochemistry Group, where she contributed to the development of a transmission blocking vaccine approach for malaria.

Delaware Governor's Bioscience Fellowship

Initiated by CMB in 2006, as a scholarship support for young scientists pursuing studies in the life sciences and biotechnology at Delaware institutions of higher education, the program has provided awards to 24 young scientists. In 2013, the program was revised to specifically support innovative research by students from Delaware institutions of higher learning. The 2013 Fellowship winners were Ms. Deaetta Grinnage of Delaware State University, Ms. Julia Yu, from the University of Delaware and Mr. Stephen Krasucki from Delaware Technical and Community College.

Lt. Governor Matthew Denn, (left) receives a check in support of Delaware Governor's Bioscience Fellowship Fund presented by (l-r) Vidadi Yusibov, CMB, Ben Hsu, QPS Inc. and Ty Jones, Astra Zeneca

Dr. Stefan Barth of IME and Dr. Mark Jones, CMB at New Cells, New Vaccines meeting

Ms. Grinnage researched the regulation of genes by a cell receptor found in a form of breast cancer. Ms. Yu's project included studying antibiotic resistance of bacteria found in bee pollen and Mr. Krasucki's research took him from caves to the lab as he characterized protein and bacteria from fungus found on bat wings. His work could eventually lead to more effective vaccines to combat bioterrorism and prevent life-threatening infectious disease epidemics.

CMB leads fundraising efforts to support the Fellowship program and organizes an annual awards luncheon recognizing the academic accomplishments of the Fellowship winners.

New Cells, New Vaccines VII: From Protein to Product

New technologies to produce vaccines more safely, quickly and economically than traditional approaches were featured at the *New Cells, New Vaccines VII: From Protein to Product*.

Due to the global demand for vaccines and other biologics, development of new, alternative production technologies is critical. The latest advancements in protein production include the use of stem cell, insect cell and plant systems.

With a focus on getting to market, topics discussed during the conference included progress through clinical trials, technology transfer, and regulatory considerations for new technologies. Leading scientists, business leaders and regulatory agency representatives from around the world gathered for the scientific conference to exchange information on bringing life-saving vaccines and antibodies to market more quickly through innovative manufacturing processes. At the conference, world-leading scientists discussed how these advances significantly impact responsiveness to life-threatening infectious disease epidemics and bioterrorism threats.

Keynote Speaker Dr. Robin Robinson, Deputy Assistant Secretary and Director Biomedical Advanced Research and Development Authority, Office of the Assistant Secretary for Preparedness and Response in the U.S. Department of Health and Human Services, keynoted the three day conference with a presentation entitled "*Flexible Manufacturing & Synthetic Biology Converge towards New Defense against Threats.*"

The event was organized by CMB in cooperation with the International Association for Biological Standardization (IABS), headquartered in Geneva, Switzerland.

For more information: http://www.fhcmb.org

Fraunhofer Center for Molecular Biotechnology

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FRAUNHOFER CENTER FOR SUSTAINABLE ENERGY SYSTEMS

The new headquarters of CSE at 5 Channel Center Street, Boston, MA. It's more than meets the eye; while preserving the historic façade of the 100-year-old port warehouse, the inside of the building is a "living laboratory" featuring state-of-the-art insulation, lighting, heating and cooling systems.

The Fraunhofer Center for Sustainable Energy Systems (CSE), located in Boston, Massachusetts, provides collaborative technology research and development for the solar photovoltaics (PV), building technology, and distributed electrical energy systems industries, as well as offering start-up and technology commercialization expertise for promising early-stage companies through its TechBridge program. In 2013, the combined expertise and resources of Fraunhofer CSE's Boston and Albuquerque labs and test fields have attracted new research partners and laid the groundwork for new projects.

New Building, New Home

CSE's retrofit of a 100-year-old Boston warehouse was completed in early 2013. In April, the Center's staff moved into this new "living laboratory," which serves as a research platform for innovative building energy technologies. Over 40 companies contributed materials and systems for the building, which features state-of-the-art radiant heat flooring, an elevator that regenerates electrical energy and feeds it back to the building, efficient heating and cooling distribution systems, and advanced insulation systems, such as vacuum insulation. The building houses CSE's research laboratories, which include a full set of equipment to fabricate solar PV modules; to characterize them with state-of-the-art precision, and to subject them to different climate conditions. Other laboratories support the thermal and hygro thermal characterization of advanced building materials.

High Efficiency, Low Cost Photovoltaics

Fraunhofer CSE's PV Technologies group aims to improve performance, cost, and durability of PV components and systems, with the goal to accelerate the widespread adoption of this important renewable energy generation technology. In 2013, the focus was on cost reduction for the installation of residential PV systems, and the improvement of durability assessment methods for PV modules.

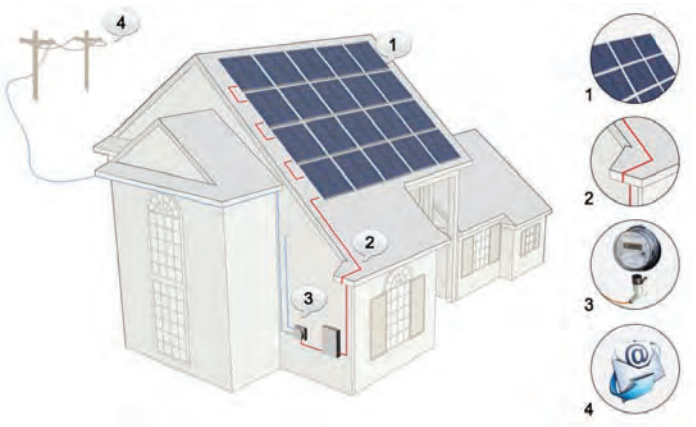


Diagram of the Plug and Play PV System

Plug and Play Photovoltaic for American Homes

The development of Plug and Play PV Systems for American Homes project is funded by the Department of Energy's SunShot Initiative to make solar energy cost-competitive with other forms of energy by the end of the decade. The project aims to eliminate and automate the permitting, inspection, and interconnection processes for residential PV systems through the use of advanced technologies. The vision for Plug and Play PV systems is that the homeowner will be able to install a home PV system in 10 hours or less.

Fraunhofer CSE's researchers are working with a wide range of partners to achieve this goal, including partners from the PV module and power electronics industry who are developing advanced hardware, and researchers who are working to find ways to address the codes, standards, and regulatory barriers for these systems. The new technologies will address weight and attachment concerns for the roofs – which means developing lightweight PV modules that do not exceed roof load limits and advanced adhesive applications to eliminate the need for penetrating a roof's surface. In addition, the researchers are finding other ways to make installation accessible to the homeowner; from the development of prefabricated wiring harnesses, which eliminate the need for handling bare electrical wires, to a system that can "self-test" for ground and arc faults, as well as a safe plug that connects the system to the home's existing wiring.

In late 2013, the first complete Plug and Play PV system was installed in CSE's test center in Albuquerque to demonstrate the integration of the various technologies that were developed during the first project year. Part of the demonstration was the successful installation of 3kW of PV modules in 40 minutes on a compound asphalt shingle rooftop with adhesives. Also demonstrated was a wiring harness that can detect if all PV modules have been properly connected.

The Plug and Play PV project will continue in 2014 with the aim to demonstrate a more sophisticated version, which can lead to a commercialization in the following year.

Photovoltaic Durability Initiative

Not all PV solar modules are the same, and cost and risk uncertainties related to photovoltaic module technologies remain a major hurdle in financing solar projects. The Photovoltaics Durability Initiative (PVDI), a joint effort by Fraunhofer ISE in Freiburg, Germany and CSE in Boston, was created in 2011 to develop test protocols that will be able to predict the durability of solar modules. At the same time, the initiative generates valuable data that allow a comparison of different PV modules on the market to examine the likelihood that they will reach their intended service life of 25 years. In their Boston, Albuquerque and Freiburg laboratories, the CSE and ISE researchers are trying to find just the right degree of stress in terms of temperature, temperature excursions, humidity and UV exposure to study the contrast in their modules' degradation. The PVDI team keeps improving the stress parameters to reach a reliable assessment of the tested solar modules. In 2013, the first publication with test results comparing modules from 5 major manufacturers was published, creating significant interest in the industry. In the meantime, two more rounds of testing have started, which will bring the total of tested modules to 10 by the end of 2014. This will be the largest publicly available comparison for PV module durability.

Outdoor Testing in Albuquerque, New Mexico

The Outdoor Test Field located in Albuquerque, New Mexico, is now at full capacity due to new customer projects. Fraunhofer CSE is planning to expand its outdoor test fields, which complement the existing testing and certification capabilities offered through CFV Solar Test Laboratory, a joint venture between Fraunhofer CSE, Fraunhofer ISE, CSA International, and the VDE Testing and Certification Institute.

CSE has two outdoor test fields in Albuquerque, New Mexico, to test the performance of solar PV and building technologies.

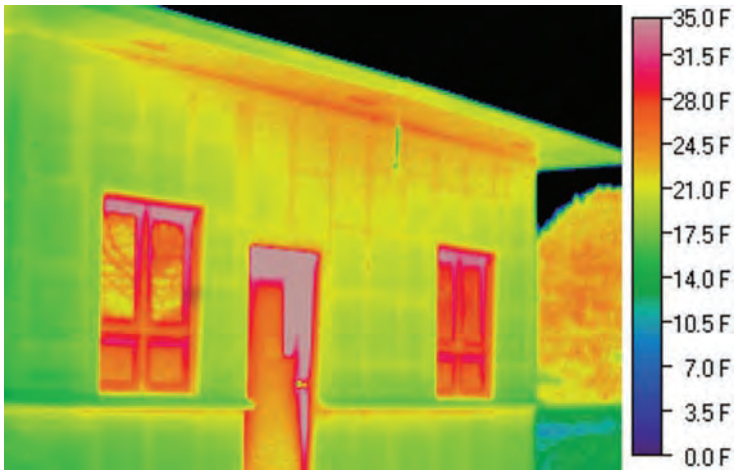
The facilities test the performance and durability of solar modules and support manufacturers by providing the data they need to meet product performance and lifetime expectations. The conditions for testing solar modules in Albuquerque are ideal. The location offers more than 310 days of direct sunshine and a local climate capable of inducing module temperature changes of over 60° Celsius over the course of a single day. To exploit these conditions, the site is equipped with both variable-angle mounting racks and dual-axis trackers.

CSE's photovoltaic research group monitors solar resources, including solar spectrum and meteorological conditions, and assesses the actual field performance and durability of commercial solar modules. The test facilities provide services such as analysis of individual modules and components, strings, or grid-tied systems; stabilization with continuous monitoring under open circuit, short circuit, and/or max power conditions; and inverter DC/AC power conversion analysis. The facilities also support long-term testing of modules and systems, and monitoring and characterization of a system that concentrates sunlight to increase the efficiency of solar modules (Concentrated PV System).

Making Buildings More (Energy Efficient) with Less

Fraunhofer CSE's Building Energy Technologies group researches the performance of home energy management technologies; how people interact with them, how to save energy by applying novel insulation materials and systems; and the consumers' behaviors affecting energy consumption. At the heart of these efforts is data. CSE assesses technologies and characterizes energy consumption to support energy

In September of 2013, Massachusetts Governor Deval Patrick formally unveiled the 2013 Clean Energy Industry Report at CSE's Building Technology Showcase. Following his presentation, Governor Patrick toured Fraunhofer CSE's solar research labs.



Thermal scan of a commercial building, retrofitted by Dow Corning, Dryvit and CSE using vacuum insulation panels (VIPs). The low surface temperature of the wall represents the thermal insulating capability of the new technology (blue and green representing lower, yellow and red representing higher, heat losses).

policy and business decisions. They work with industry and government to accelerate the development, commercialization, and deployment of energy-saving building technologies and practices.

CSE studied energy consumption and efficiency programs for manufacturers, industry associations, and the government. The CSE Building Energy Team worked on behalf of the Massachusetts Technical Advisory Committee (MTAC) to assess next-generation energy savings measures for utilities. They also studied major medical equipment power consumption and restaurant signage, and evaluated the energy-saving potential, durability, and cost of deep-energy retrofit of roofs for iconic New England "triple-deckers." Furthermore, the Building Enclosures Group had great success with its work on a computer simulation model enabling thermal and energy performance analysis of roofs and attics. Two studies that commenced in 2013 help illustrate the diversity of building energy technology research.

What Happens to the Grid in a Crisis?

What policies should be enacted to ensure the stability of the electric grid in the event of a crisis, such as an attack? And what kind of human intervention can help to stabilize the grid in such an event? The Department of Defense, the University of New Mexico, and researchers at Fraunhofer CSE are studying how behavioral factors affect the stability of electric grids. As part of this study, the University of New Mexico in Albuquerque is working to simulate the physical grid, and CSE is developing models on how grid operator stress and incomplete and inaccurate information can affect grid stability. The resulting behavioral model will be integrated with the physical grid model to generate a more realistic and complete picture of the impact of catastrophes on the grid stability. The study will be completed in December of 2015.

Is Your Cell Phone Consuming Too Much Energy?

In 2010, the Consumer Electronics Association (CEA) asked Fraunhofer CSE researchers to characterize the electricity consumption of residential consumer electronics ("CE") and to note major trends affecting energy consumption. However, the electricity consumption characteristics of CE can change rapidly and become dated as CE products change. This makes it more challenging to ensure that potential regulations and voluntary programs for product efficiency are based on up-to-date information. That is why, in 2013, CEA engaged Fraunhofer CSE to conduct a study to comprehensively evaluate the installed base, power draw, and usage of residential CE, taking into account the most important CE trends since 2010 – such as the rise of tablet-based computing. The study

will be completed in spring of 2014. One early result that may surprise many people: cell phones account for less than one percent of residential CE electricity consumption. In 2013, the Building Energy Technology group started another related study – this time on behalf of the government – to assess the savings potential for commercial computer and server power usage. The project is expected to conclude in mid-2014.

Giving New Technologies a Head Start

Since its inception in 2010, Fraunhofer CSE's TechBridge program has supported a large number of local startup companies in the New England area. Some of the largest challenges that start-up companies face are in product development and testing. Fraunhofer CSE provides a unique role in working with these companies to determine whether they have a viable product.

The TechBridge program was originally funded by the DOE Innovation Ecosystem program. In 2013, TechBridge landed its first contract with a large strategic industry partner, Shell, who provided funding out of its Game Changer program to create a "Challenge" for cleantech startup teams. This Challenge focused on identifying, vetting, and selecting a group of start-up teams with innovative microgrid solutions; both with regards to technology and business models. More than 40 qualified applications were submitted and evaluations of their technologies by Fraunhofer CSE researchers began in early 2014.

Fellowship Program

CSE's Fellowship Program continues to thrive: in 2013, 14 Fellows joined Fraunhofer CSE and contributed to our projects in diverse fields, such as building energy efficiency technologies, photovoltaic, smart grids, technology commercialization, and science communication. Designed to give young scientists valuable project experience, CSE's Fellowship Program has provided opportunities for more than 100 young scientists, engineers, and business professionals. Many of them have gone on to R&D positions in leading energy, science, and engineering firms, as well as government organizations.

Dr. Christian Hoepfner

New Leadership

In November 2013, Dr. Christian Hoepfner, who had been CSE's Scientific Director for four years, took on his new role as Fraunhofer CSE's Center Director.

Patents

Due to the creative and ambitious work of our researchers, CSE filed three patents on photovoltaic modules and systems in the second half of 2013.

Some Notable Partners and Clients of 2013

- Aspen Aerogels
- Consumer Electronics Association
- Department of Energy
- Dow Corning
- Dryvit
- Microsoft
- National Grid
- NSTAR
- Shell
- Soitec
- STO
- University of New Mexico

For more information: www.cse.fraunhofer.org

Fraunhofer Center for Sustainable Energy Systems

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FRAUNHOFER CENTER FOR ENERGY INNOVATION

The Center for Energy Innovation (CEI) at the University of Connecticut (UConn) was established in 2013 to promote, develop, test and implement advanced energy systems that foster efficient utilization of resources with environmental stewardship. The foundational knowledge at the Center, gained through multi-disciplinary research and systems engineering, will accelerate the global adoption and deployment of cost effective energy technologies for the common good of humanity.

CEI, a 4-year partnership between UCONN, Fraunhofer USA, and the Connecticut Department of Energy and Environmental Protection (DEEP), was officially launched by Governor Dannel Malloy on Thursday, July 25th. Fraunhofer USA, Inc. President Georg Rosenfeld, German Consul General Rolf Schutte, the Commissioner of Energy and Environmental Protection Daniel Esty, Fraunhofer USA Executive Vice-President William Hartman, and UCONN President Susan Herbst joined Governor Malloy for the launch. The event was attended by more than 170 researchers, government officials, community members, and UConn's faculty, staff, and students.

"This partnership between the state, UConn, and Fraunhofer USA is a welcome and important collaboration when it comes to finding solutions to some of the most pressing energy challenges we face," said Governor Malloy. "With the resources, talent and expertise of UConn and Fraunhofer, we expect to see technological breakthroughs that will help deliver a cheaper, cleaner, and more reliable energy future for Connecticut, the nation, and the world. I deeply appreciate the efforts of Presidents Rosenfeld and Herbst and their teams in establishing this partnership."

The Fraunhofer Center for Energy Innovation (CEI) located in Storrs, Connecticut focuses on developing advanced technologies related to energy storage, fuel cells, in-stream hydro, power management and distribution through contract research. With the combined expertise of the founding partners for the development and commercialization of new materials and technologies, the Center will develop highly efficient and cost-effective energy conversion and storage systems. Working with industry, the Center's research and development will concentrate on modern functional materials, such as metals, ceramics, micro- and nanostructures, as components for energy storage and conversion systems.

Upon its founding in July 2013, CEI became the seventh Fraunhofer USA research center. It plans to relocate to the new UConn Technology Park in 2015.

Fraunhofer President Georg Rosenfeld speaking at the inauguration of the new Fraunhofer Center for Energy Innovations

Governor Malloy speaks about the importance of collaborating with Fraunhofer and finding solutions for a cleaner environment

Partners

CT DEEP is charged with conserving, improving and protecting the natural resources and the environment of the State of Connecticut as well as making cheaper, cleaner and more reliable energy available for the people and businesses of the state.

UCONN has a rich history of excellence in energy innovation. UCONN's Center for Clean Energy Engineering, with support from regional, state and industrial entities, has a diverse portfolio of energy technologies addressing emerging global energy and environmental challenges.

CEI is partnered with the Fraunhofer Institut für Keramische Technologien und Systeme (IKTS) located in Dresden and Hermsdorf, Germany and covers the complete field of advanced ceramics, from basic research to application

Competencies

Batteries and Energy Storage: CEI applies its substantial expertise in next-generation functional materials development (metals and ceramics, nano and micro structures) toward the discovery and development of utility-scale and novel energy storage systems for integration in renewable and grid support systems. Core aims include the use of abundant (in the U.S.) raw materials and resources, device life and durability, operational safety, reduced environmental impacts and economic contributions.

Microgrid Engineering: This work involves the integration and validation of components and subsystems in flexible microgrid architectures for scalable and reliable electrical power distribution and management at the municipal/community level. Diverse subsystem technologies include fuel cells, electrolyzers, photovoltaics, small hydro and other renewable technologies along with integration of energy storage systems, building efficiency and power management.

Environmental Technology: The targeted research activities include new materials for gas and liquid separation, filtration and catalytic conversion; new methods for membranes and catalyst manufacturing; and process engineering of membrane separation and catalytic conversion, especially for the purpose of process integration, chemical processing and production of biofuels such as biogas, bioethanol and biomethane.

Fuel Cells and Electrolyzers: This work entails the development of advanced electrochemical energy conversion systems with a focus on enhanced electrical efficiency, minimal environmental impact and carbon footprint reduction, "cradle-to-grave" cost effectiveness, and global adaptation.

L. to R.: UConn Dean Kazem Kazerounian, Fraunhofer CEI Center Director, Dr. Prabhakar Singh, UConn Provost Mun Choi, Fraunhofer President Georg Rosenfeld, and Executive Vice President Dr. William Hartman signing of the 4-year partnership agreement.

Projects in Progress

The Center has five projects currently underway that include the formulation of new glass seals, development of methodologies to characterize the wettability of solid surfaces at high temperatures, characterization of a new class of adsorbents, high temperature stationary battery systems, and membrane reactions.

The glass sealing project was the first project started at the Center. Glass formulations are attractive as a sealing material for high temperature advanced energy systems due to compositional flexibility, long-term durability, and manufacturing ease for complex shapes. The objective of this proposed research is to develop glasses suitable as a reliable seal for high temperature batteries. The particular aim is to develop glass

compositions to overcome the shortcomings of the commonly used glass seals. The basic understanding and experimental knowledge gained through systematic research will be applied to various molten salt battery-systems.

The second project focuses on developing a methodology to accurately determine the wetting behavior of solid surfaces with liquid metals or molten salts and propose the best way to improve the wetting. Poor wettability has been identified as a major issue in cell performance. The wettability method identified through this project will enhance the cell performance in the application of large scale energy storage and in electric vehicles because of the high specific energy, power density, and long cyclic life.

The third project analyzes the synthesis, and characterization of the adsorptive properties of a new class of adsorbents. Some pollutants that are difficult to remove but are present in many different feeds and fuels are siloxanes and organic sulfides. Our primary goal in this work is to find new generations of adsorbents that have high adsorption capacity for siloxanes and for organic sulfides like CS2 and COS. The goal of this project is to generate novel adsorbents, file patent applications, and then create a new startup company to commercialize these materials.

The fourth project is advanced stationary battery research. This project focuses on the preparation of new high temperature stationary battery systems that are inexpensive and efficient. We plan to optimize the nickel component of these materials. Particle sizes and morphologies of nickel will be optimized and the surface areas of these systems will be modified. Minimization of temperature of use will be another objective of this research.

The fifth and most recent project is membrane studies. This project involves the synthesis, characterization and use of tailored and engineered materials in membrane reactions. Unique mesoporous materials developed by UCONN will be extensively examined. Membrane materials developed at Fraunhofer IKTS will also be studied. Some of the reactions to be studied include separation of hydrocarbons, catalytic reactions like natural gas reforming, and dye degradation. We plan to prepare novel membrane materials based on microporous manganese oxide materials as well as new mesoporous materials. Optimization of pore sizes will be a key goal of these syntheses.

Goal of the Center

The goal of CEI is to develop and commercialize new materials and technologies which will improve and lead to advances in widespread use in energy production and storage. The Center will develop highly efficient and cost-effective energy conversion and storage systems aimed at accelerating the global deployment of clean and efficient engineered energy systems.

Outlook for 2014

In 2014, CEI will focus on the development of advanced technologies related to energy storage, fuel cells, in-stream hydro, and power management and distribution. Through collaboration with industry, federal, state and local agencies, CEI will continue to expand its research areas and portfolio in materials characterization and ceramic technologies and identify new potential applications on larger scale projects.

The CEI Executive Advisory Board will meet periodically to provide guidance and recommend business and scientific strategies for the Center. In addition, an Industry Advisory Board will advise on industry trends, network leveraging, and business strategies for the development of new materials to help generate clean and efficient power systems and reveal novel methods and applications for energy storage. A well-defined growth strategy based on input from the Executive Advisory Board and industrial clients, independent market analysis and technology forecasts will serve as a guide to develop continued and sustainable growth.

With the growth of renewable energy and the imperative to reduce carbon emissions, the need for clean and efficient energy systems deployment and storage has never been greater. CEI will continue to draw upon Fraunhofer Germany, energy industries and UConn's real-world expertise to develop cost effective solutions which are a success from early project evaluation and design to system commissioning and life cycle maintenance.

The team at Fraunhofer CEI:
Back Row: Ugur Pasaogullari, Terry Barber-Tournaud, Venkat Manthina, Manoj Mahapatra, Pete Menard, Amy Smith, Raelene Phillips, Stefan Kaeding, Sheila Ciccone
Front Row: Steve Suib, Prabhakar Singh, Len Bonville.

For more information: www.cei.fraunhofer.org

Fraunhofer Center for Energy Innovation

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The Fraunhofer USA Digital Media Technologies Office located in San Jose, California, promotes and supports the products of their parent institute, the Fraunhofer Institute for Integrated Circuits, IIS in Erlangen, Germany.

The HE-AAC Audio Codec – Global Standard for Radio Broadcasting and Streaming

It's hard to believe that the first Internet radio broadcast took place just 20 years ago. Today, tens of millions of people stream Internet radio to their smartphones, tablets and other connected devices. Nearly every terrestrial radio station as well as Internet-only broadcasters offers streaming services to reach listeners. Thanks to changes in consumer listening behaviors, users are embracing Internet radio on a massive range of devices and the Internet radio audience is expected to continue growing over the next years. During 2013, the number of US Internet radio listeners grew to approximately 147 million, up 11% from 2012.

HE-AAC and other audio codecs are developed and tested in Fraunhofer's advanced sound lab that allows for critical listening and flexible loud speaker arrangement.

Streaming services face significant monetization challenges as Internet services pay higher content royalties than cable and satellite radio, while AM/FM radio services are not required to pay any fees.There are several audio codecs in use for streaming but they vary significantly in their ability to provide and maintain reliable audio quality at low bit rates. Yet one codec stands out from the others—the ISO MPEG standard High Efficiency AAC (HE-AAC), which has become the audio codec of choice among leading broadcasters, including BBC, NPR and Cienradios as well as music service providers such as Pandora and iTunes Radio.

In their search for the best audio codecs, U.S. public radio broadcaster NPR conducted a test of the six codecs, including HE-AAC, LAME MP3, AAC-LC, AMR-WB+, and xHE-AAC ("Extended HE-AAC"). NPR tested each codec over a wide range of bit rates and programming formats, and found that HE-AAC was the top performer, citing its high-quality audio, low bit rates and broad compatibility with target device platforms such as Android, Apple iOS, Windows, Mac as well as Adobe Flash and leading HTML5 browsers. The report also noted that HE-AAC does not require any content distribution fees, and that it provides support for audio-specific metadata for loudness normalization.

Co-developed by Fraunhofer IIS, the HE-AAC audio codec provides the same quality audio at one-half or one-third the bit rate of other audio codecs. Thanks to audio bit rates down to 96 kbit/s for 5.1 surround, HE-AAC also allows broadcasters to stream in surround sound without switching to stereo when bandwidth becomes constrained. This can avoid a simulcast of stereo and surround programs.

NPR's study also tested xHE-AAC, the latest member of the AAC codec family co-developed by Fraunhofer IIS. Researchers found that xHE-AAC performed very well at low bit rates for mixed content containing both, audio and speech signals. Previously, providers of low bit rate streaming and digital radio broadcast services had been forced to select and prioritize either an audio or speech codec. This resulted in poor quality for some signals. xHE-AAC eliminates this dilemma by providing one unified codec suitably for all content types. Because of these impressive results, NPR considers to adopt xHE-AAC as it becomes more widely deployed on consumer devices.

This recent NPR study is not the first time HE-AAC has been rated the best performing audio codec for internet radio. A 2007 study by the European Broadcast Union (EBU) evaluated a variety of open-standard and proprietary audio codecs, and found that "HE-AAC has proven, in several independent tests, to be the most efficient audio compression scheme available worldwide." The codec provided remarkable results for bit rates equal and higher than 160 kbit/s for 5.1 surround sound, marking it the favorable choice for broadcast-

ers and service providers. Google is a prominent example of a service provider that is using HE-AAC 5.1 to sell movies with surround sound on Android and Chromecast devices.

Another sign for HE-AAC's role as the de-facto standard for Internet radio streaming, was its selection by one of the largest Internet radio broadcasters in Latin America, Cienradios, that recently licensed HE-AAC from Fraunhofer IIS for its growing digital platform. Cienradios brings users the experience of listening, enjoying and choosing their favorite entertainment within a specific genre, offering listeners more than 500 stations to select from. Transitioning from broadcaster to "anycaster", Cienradios seeks to deliver content anytime, anywhere to listeners in as many formats as possible. The site receives approximately 1 million page views per day and its adoption of HE-AAC as the only audio codec for all of their Internet radio stations is key to the company's goal to become Latin America's premier 24-hour internet streaming service.

Cienradios is just the latest streaming service adopting HE-AAC. Thanks to the availability of HE-AAC in the complete broadcast and streaming ecosystem, many more broadcast systems and Internet audio services such as CBS and Clear Channel have been on air with HE-AAC for a long time. With the introduction of HE-AAC as the mandatory stereo and optional surround audio codec in the DASH-AVC/264 Implementation Guidelines for dynamic adaptive streaming over HTTP and its native support in HTML5 browsers, HE-AAC will further expand its position as the number one broadcast and streaming audio codec worldwide.

Fraunhofer booth at the NAB Broadcast Show in Las Vegas

Fraunhofer at Industry Events and Tradeshows

In 2013, the Audio and Multimedia Branch of Fraunhofer USA Digital Media Technologies (DMT) continued its promotional and market development efforts around the latest audio technologies. In close collaboration with Fraunhofer IIS in Erlangen, one of the key objectives of 2013 was to support customers such as Google with the launch of services using the HE-AAC 5.1 audio codec. With the initiation of U.S. business deals, Fraunhofer USA helped create increased awareness of Fraunhofer's offerings. During the course of the year, Fraunhofer exhibited at a number of industry events in the U.S. The employees of Fraunhofer USA DMT supported their colleagues from Fraunhofer IIS at a number of occasions including the Audio Engineering Society (AES) Convention and the Streaming Media East Conference in New York, the NAB Broadcast and CEA Consumer Electronics Shows in Las Vegas and the Uplinq Developers Conference in San Diego. Fraunhofer USA through its employees of the San Jose office also introduced Fraunhofer's audio codecs in various industry specifications such as the DECE UltraViolet Common File Format for Online Video distribution.

For more information:
www.fraunhofer.org/DigitalMediaTechnologies

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FRAUNHOFER HEINRICH HERTZ INSTITUTE HHI, USA

The Fraunhofer Heinrich Hertz Institute – Infrastructure for the future Gigabit Society

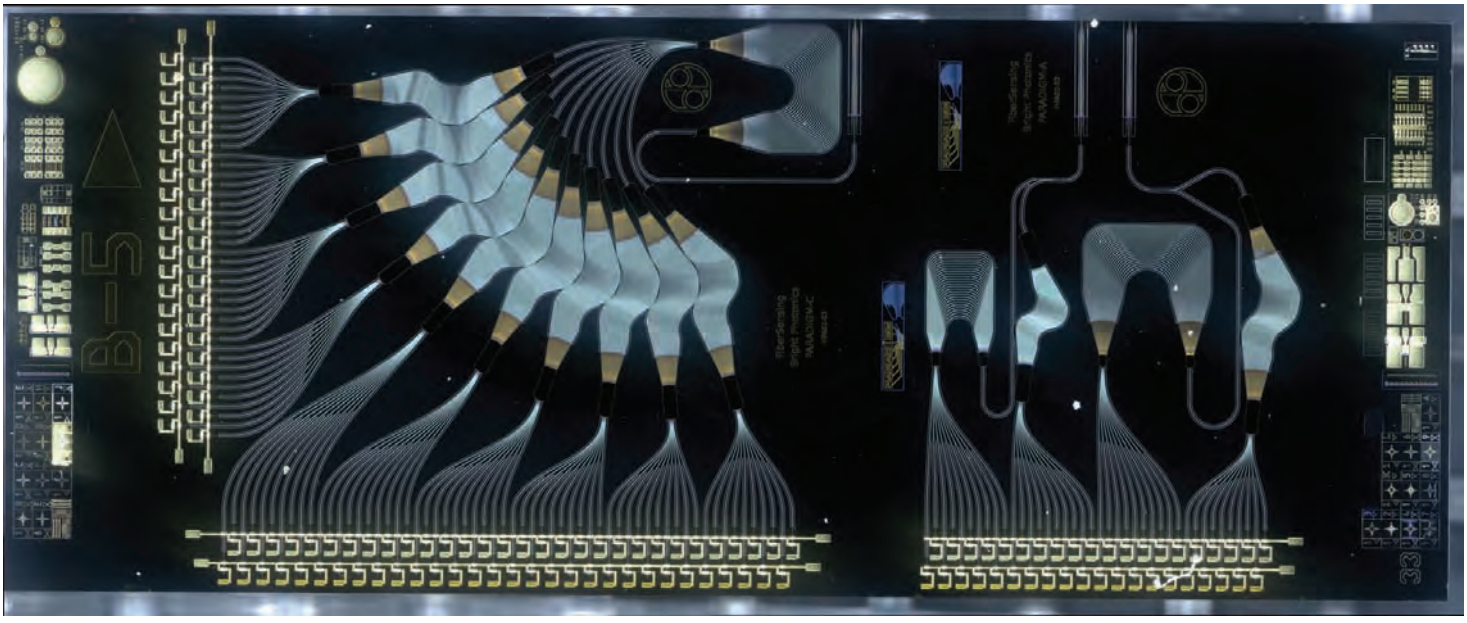
The U.S. Office of the Fraunhofer Heinrich Hertz Institute (HHI), located in California, promotes and supports the products of its parent institute, the Fraunhofer HHI in Berlin, Germany. HHI is a world leader in the development of mobile and fixed broadband communication networks and multimedia systems. From photonic components and systems to fiber optic sensors and high-speed hardware architectures, the Heinrich Hertz Institute works together with its international partners from research and industry on building the infrastructure for the future Gigabit Society.

Platform Technology for Application oriented PICS – PARADIGM

The photo below shows an example of a result from the PARADIGM project at the Heinrich Hertz Institute. The main objective of the PARADIGM program is to enable a "fabless" model for the design and fabrication of Indium Phosphide based photonic devices and components. The goal is to offer a suite of design tools and access to InP fabrication facilities. Further this "fabless" model for Indium Phosphide devices enables a lower barrier to entry for entrepreneurs and small companies. A partner or customer may purchase only a portion of the wafer and share the rest of the wafer with parts for other customers. Further, several manufacturing partners and institutions are involved in this effort. Ultimately the target is to facilitate designing and manufacturing Photonic Integrated Circuits or PICs. The PARADIGM program helps effect a fundamental change in the way photonic integrated circuits (PICs) based on indium phosphide (InP) are created, with the aim of reducing the costs of design, development and manufacture while enabling companies to make more complex and capable designs possible than ever before. The key step is to develop a generic platform technology for application-specific PICs. This will be achieved by adopting a similar methodology in the field of photonics to the one that has been so successful in microelectronics. This new approach will be indispensable in creating a sustainable business sector with potential for significant future growth. PARADIGM addresses the whole product development chain from concept, through design and manufacturing to application. The Fraunhofer Heinrich Hertz Institute is a leading partner in PARADIGM.

Beyond 100 G – New Solutions for Greater Data Capacity

Over the past ten years global demand for broadband in telecommunications networks has been steadily rising by 50-100 percent a year. The current challenge in core networking is to



raise transmission capacity per wavelength channel in optical fiber and free-space transmission systems over the 100 Gbit/s mark – beyond 100 G. At the same time, the costs, energy consumption and footprint of each transmitted bit must also be reduced.

Optimal Trimming – Smart Sails for Setting New Records

New fiber optical sensors enable boats to sail safely at the outer limits of endurance. These sensors compute real-time measurements of the forces the sails, masts and hull are exposed to as the boat races forward. They are based on fiber Bragg grating (FBG) sensors or sensors inscribed in optical fibers. These sensors are integrated in an optical fiber cable attached to the boat's sails, hull or mast.

New Impetus for Machine-to-Machine Communication

Machine-to-machine communication deals with the automated exchange of information between technical systems like machines, robots and road vehicles. Development of highly optimized network stacks and PCI express connectivity is a major driving force for innovation on the machine-to-machine market. Application of FPGA-based hardware solutions (Xilinx Altera FPGAs) can drastically reduce key performance parameters like latency while also significantly raising net bandwidth. Special boards support ultra-rapid communication at forthcoming speeds of 40-100 Gbit/s.

Cross-border Research and Development for the Gigabit Society

For more information: **www.hhi.fraunhofer.de**

Fraunhofer Heinrich Hertz Institute, USA

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Fraunhofer USA Board of Directors Meeting

March 7, 2013, Fort Lauderdale, Florida

Mr. Frank Treppe and Mr. Mark Eby at the board dinner.

At the board dinner, Prof. Bullinger was honored for his 10 years of service to Fraunhofer USA as Chairman of the Board. Seated to his right is Mrs. Margarita Bullinger.

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Back cover photo:
Live corn plants ready for genetic testing.
For more information, please see page 20.