Center for Manufacturing Innovation

The Fraunhofer Center for Manufacturing Innovation (CMI), together with its partner Boston University, 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 the development of medical devices and instruments as well as next-generation high-precision automation systems.

During 2010, CMI increased its focus on biotech/biomedical systems and was successful in acquiring a number of contracts in this area from government, foundations, and industrial sources. Most notably, CMI was successful in winning a very competitive, large R01 Grant from the National Institutes of Health (NIH), on Bacterial Drug Susceptibility Identification by Surface Enhanced Raman Spectroscopy. Also in this area, CMI developed a shock wave generator for the study of brain damage from Improvised Explosive Devices (IEDs) and contact sport impacts. Additionally in 2010, CMI acquired several industrial automation contracts from a number of well-known large manufacturing companies.

Renewable Energy

In the area of renewable energy, CMI has been developing a mobile wave energy harvesting system that alleviates the common problems that have hindered wide-spread deployment of ocean energy harvesting.

Mobile Wave Energy Harvesting System

Conventional approaches to harvesting energy from ocean waves and currents suffer from at least three major drawbacks:

1) expensive underwater power transmission cables,

2) storm damage susceptibility, and

3) energy output is not delivered at times of peak load.

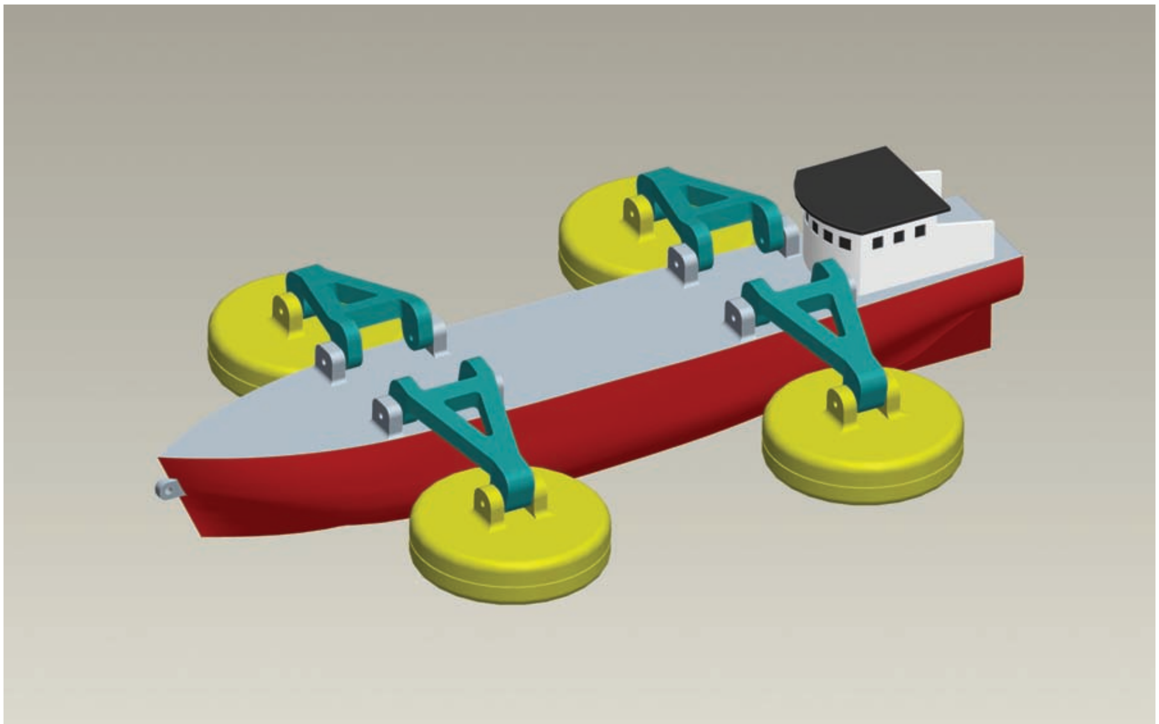
These factors translate into high electricity cost/KWH. Consequently, market economics do not drive the deployment and use of ocean energy, and the technology is only moving forward through government incentives.

CMI has been working on an economically viable, alternative method of harvesting ocean wave energy, comprised of a boat with an on-board wave energy harvesting system, and on-board energy storage capacity. A typical system consists of 50 meter boat with 1 MW capacity wave energy harvesting equipment and 20 MWH of energy storage capability. Operationally, the boat cruises to a favorable location off-shore, harvests energy for approximately 20 hours, cruises back to shore, connects to the electricity grid, and releases the stored energy during high demand periods. Preliminary calculations promise electricity cost of 15 cents per KWh. The proposed concept is a modular, distributed energy system in which numerous such small boats harvest wave energy off the entire coast-line. This means that the energy is produced near the point of use, eliminating the need for a new infrastructure, like such as high power transmission lines typically needed for wind energy, or special docking facilities, as conventional marinas will suffice.

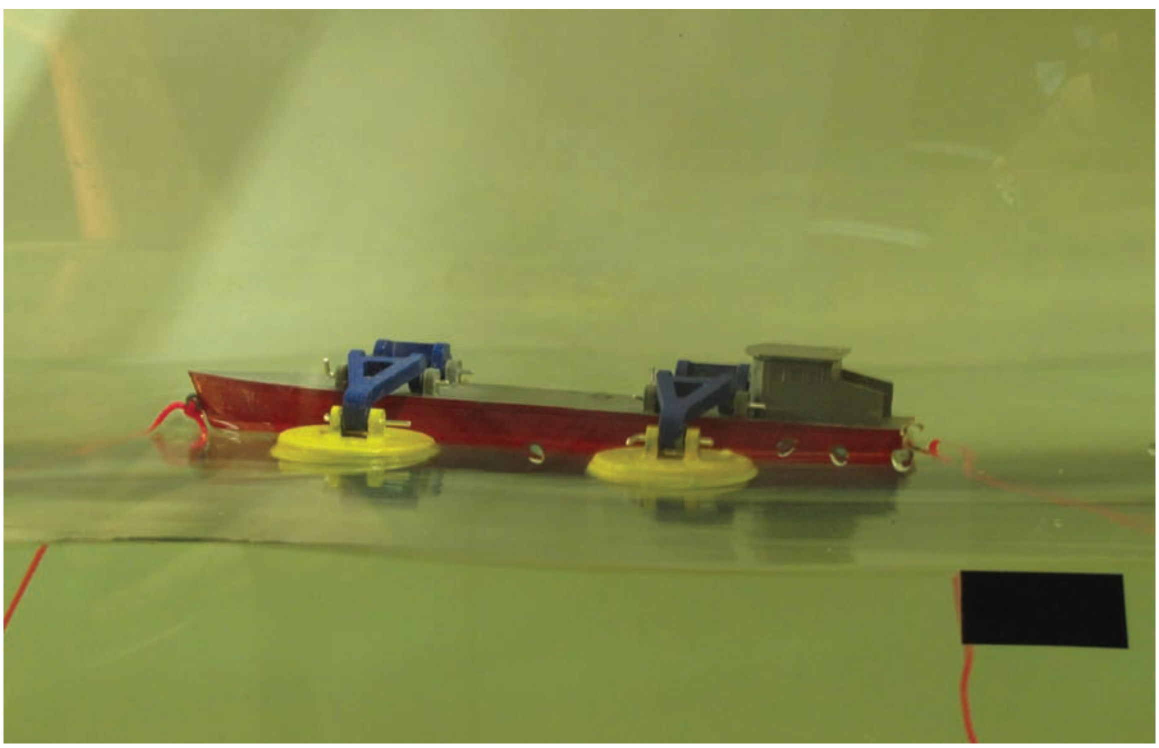
The technical and economic feasibility of mobile wave energy harvesting and storage was investigated using dynamic modeling as well as small-scale wave pool experimentation. A myriad of energy storage technologies, including flywheels, ultracapacitors, compressed gas, thermal storage, gravity, osmosis, in addition to a range of battery technologies, are evaluated in terms of energy density, weight, space, and overall system cost. Additionally, a number of different wave harvesting technologies were dynamically evaluated, including heaving point absorbers, pitching/surging converters, and articulated concepts, in order to optimize relative motion between the boat and the harvesters for different wave length conditions. This is a new concept for economically viable ocean energy harvesting system that does not suffer from the typical drawbacks associated with ocean energy, namely:

a. No need to lay down expensive underwater transmission cables

b. No need for major infrastructure development, as this is distributed energy



Mobile Wave Energy Harvesting Concept



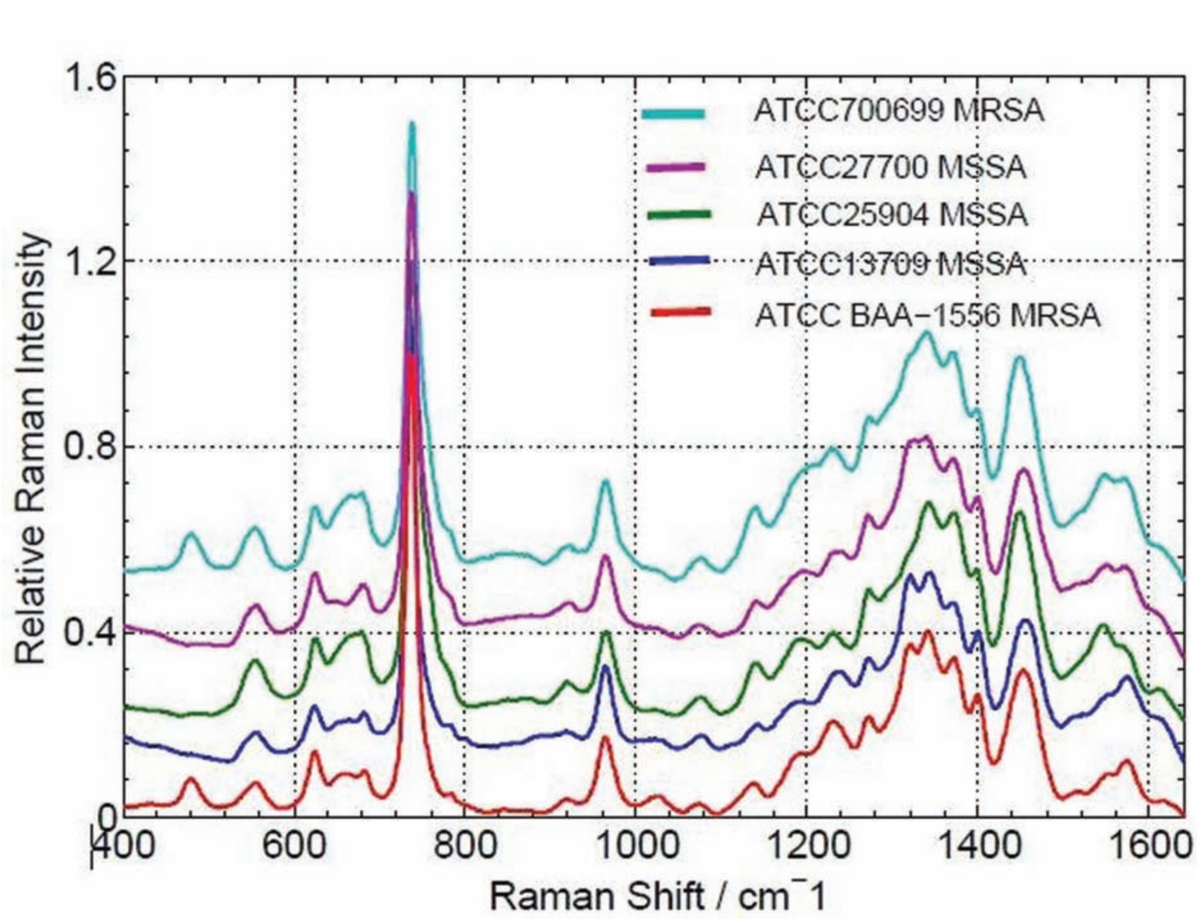
Mobile Wave Energy Concept testing in wave tank at 1:200 scale

c. Stored energy is available on demand during peak times
d. No permanent effect on the marine environment
e. Harvester remains at port during storms avoiding damage
f. Increased capacity through modular replication
g. No political hurdles to overcome

Bacterial Drug Susceptibility Identification by Surface Enhanced Raman Spectroscopy

Fraunhofer CMI, in conjunction with Boston University and Brigham and Women's Hospital, has won a competitive NIH R01 Grant to develop a novel rapid-detection device for of bacteria. Our interdisciplinary team, covering the fields of clinical microbiology, chemistry, optics, biophysics, bioengineering and infectious diseases, has joined together in this project to demonstrate that the technology can be developed into a system for point-of-care diagnostics. The technology is based on Surface Enhanced Raman Spectroscopy (SERS), which has been shown in our collaborator's labs to have exquisite analytical sensitivity (down to one bacterium) and specificity (being able to distinguish bacteria to the strain-level). Moreover, the acquisition and processing of the Raman spectrum takes less than ~20 seconds.

The detection technology comprises of a novel gold nanostructured substrate that amplifies the Raman signal to achieve excellent sensitivity, a well-developed Raman microscope that is now in a portable unit format, and detection algorithms that automatically process the Raman signals and compare the signature to a library for identification of the microorganism. As an example of the detection technology's specificity, we have used it to distinguish between methicillin-resistant and -susceptible Staphylococci. It is envisioned that this technology will provide the basis of a revolution in point-of-care diagnosis of bacteria. To that end, we have been developing a fast sample preparation system for the isolation and concentration of bacteria from human blood, followed by deposition of bacteria onto the SERS substrate. While the sensitivity of the SERS technology is extremely high, the



Typical SERS spectra of different MSSA strains
© Boston University, Larry Ziegler

remaining challenge is concentrating the blood sample to the point that an adequate number of bacteria is aggregated in a very small area on the SERS substrate. The sample preparation device under development, is separated in two different concentration stages: the first stage is a disposable, multi-stage centrifugation device; in the second stage, the sample is then further concentrated using evaporation. A first-generation 2-part system which can prepare the bacteria for identification by SERS within 20 minutes, is being developed.

The goal of this project is to:

- integrate the sample preparation system into a single, fully automated unit designed for the point-of-care setting,
- develop the SERS library to include a large number of bacteria,
- demonstrate the functionality of the entire system (sample preparation through bacterial identification) in a progression from simulated samples (healthy donor blood spiked with bacteria cultured in vitro) to clinical blood culture specimens, to blood from bacteremic rodents.

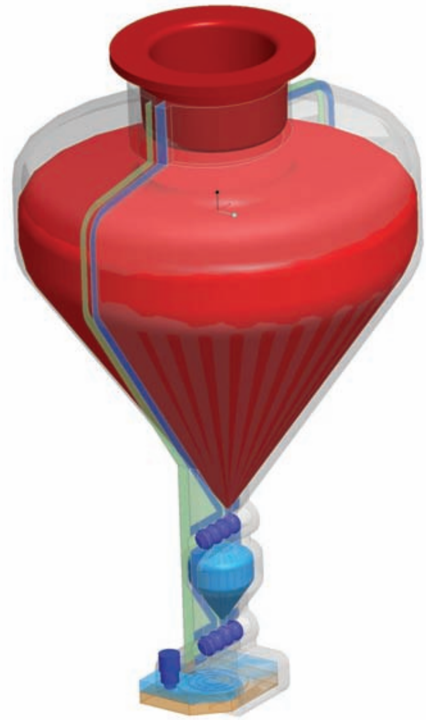
In this step-wise manner, we will be able to validate that the technology could be used as a point-of-care system for bacterial diagnostics and drug-susceptibility determination.

Collaborations with U.S. Partners

Our collaboration with our U.S. partner, Boston University, continues to strengthen as we closely collaborate in many of our life sciences activities. This has led to joint government and industry proposals, including the National Institutes of Health (NIH) SERS grant that we won. Additionally, we continue to closely collaborate with a number of Boston area hospitals, including Brigham and Women's, Beth Israel, and Boston Medical Center.

Collaboration with Partnering Institute (IPT)

The collaboration between CMI and the Fraunhofer Institute for Production Technology, IPT in Aachen, Germany, continues to thrive via the joint Life Sciences Engineering Group. This group pools our complementary strengths in the automation of biological and biomolecular processes and development of medical instruments and devices. This initiative has led to the submission of joint proposals to both NIH and the European Union, a joint project, and a great deal of interaction between our personnel.



Integrated macroscalemicroscale concentrator. Input: 10 mL of infected blood; output: 100 nL of purified bacteria.

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