AIR FORCE OFFICE of SCIENTIFIC RESEARCH [AFOSR]
Manager of the Basic Research Investment for the Air Force

Research HIGHLIGHTS

JAN FEB MAR 04

Coronagraph Used in Exoplanet Hunting

Are there Earth-like planets beyond the solar system? For centuries, the world's greatest minds have been unable to definitively answer this question.

...Until now.

Armed with the support of the Air Force Office of Scientific Research's (AFOSR) Mathematics and Space Sciences directorate, a powerful telescope and a state-of-the-art astronomical camera known as a coronagraph, astronomers are on the cusp of a new world.

According to Dr. Ben R. Oppenheimer, a member of the American Museum of Natural History's astrophysics department in New York, his team began looking years ago into the possibility of seeing planets orbiting stars other than the Sun (called extrasolar planets or exoplanets). Their interest was peaked after a landmark 1994 finding by Dr. Roger Angel proved, for the first time, that obtaining images of exoplanets was feasible.

"Our effort involves the development of an extremely precise and unique sort of camera, called the coronagraph," Oppenheimer explained. "It is designed to address the technical issues that have so far prevented people from making images of the exoplanets." Coronographs were invented in the 1920s to create artificial eclipses of the Sun to allow scientists to study the Sun's corona in detail.

Prior to this endeavor, Oppenheimer had spent the better part of a decade trying to unravel this mystery. He was part of the discovery team who found the first brown dwarf orbiting a nearby star. Brown dwarfs are objects intermediate in size between stars and planets.

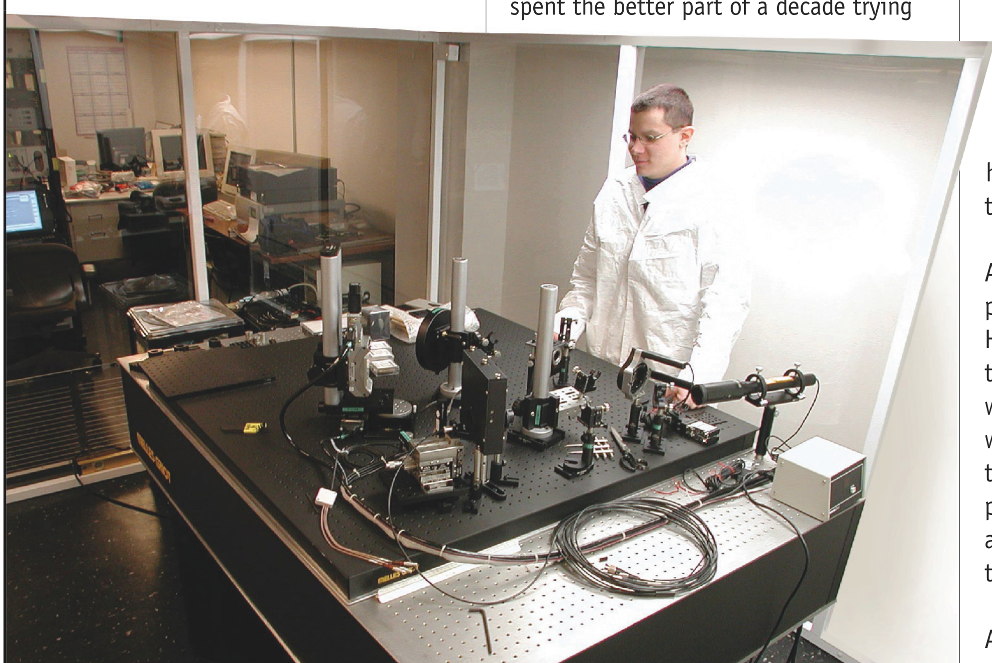
Planet hunters, as Oppenheimer explains, would be envious of those charged with finding the proverbial needle in the haystack. Those in his business must locate new planets only faintly lit by starlight reflected off their surfaces. Compounding the problem, such planets typically sit only a very small distance away from stars that are between a million and a few billion times brighter.

Enter the coronagraph, an optical instrument that filters out the light so that faint objects can be seen next to the star.

"If you were looking up to the sky to see a plane and brought your hand up to shield the sunlight, you would be able to see a plane better," Oppenheimer explained. "The coronagraph works like your hand, shielding the light and allowing you to see the object better."

Now enter the U.S. Air Force-operated Advanced Electro Optical System (AEOS) perched on Mount Haleakela, located on the Hawaiian island of Maui. Haleakala is home to the Maui observatory and one of the world's most powerful telescopes. Armed with the coronograph, which sits behind the telescope and in front of an infrared camera, planet hunters can now see objects around a star, such as planets, or disks of dust that suggest the formation of new planets.

Using adaptive optics built into the AEOS telescope, astronomers are able to track imperfections in the wave front of



Dr. Ben Oppenheimer assembling the coronagraph in New York prior to shipping to the Maui observatory.

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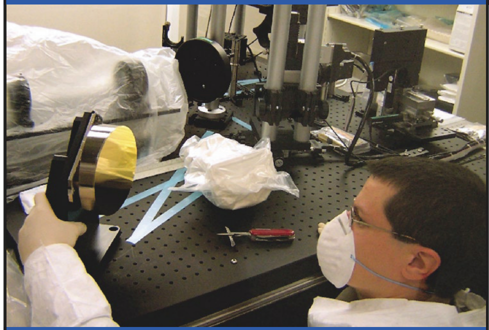

Dr. Oppenheimer inspecting the customized optics after its arrival in the laboratory.

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light from the star as it passes through the telescope. AEOS then corrects any sensed imperfections with a small, adjustable, motorized mirror. It allows the AEOS telescope to produce images at about 85 percent of theoretical perfection. Prior to that, scientists were only able to produce images at about 50-60 percent of theoretical perfection. Add to the mix the coronagraph, which removes 98.5 percent of the light from the star, and astronomers are seeing more than ever.

"As a result," Oppenheimer observed, "the small point source directly above the star is clearly visible."

With extrasolar planet hunting in its infancy, those in Oppenheimer's business are reluctant to announce to the world any definitive answers regarding life beyond our Earth. However, as Oppenheimer suggests, the exoplanetary revolution is within their grasp.

"Our calculations show that the instrument will be sensitive to objects orbiting these stars as close as the Earth is to the Sun, and as massive as several times the mass of Jupiter."

This research is important to the Air Force because it can lead to the understanding of planetary formation, the detection of unknown planets and signs of life on other planets. It also plays a key role in enhancing on high-resolution images of stars taken by NASA's Spitzer Space Telescope.

Along with AFOSR, the National Science Foundation and the American Museum of Natural History funded this research.

Maj. Paul Bellaire, AFOSR/NM 703-696-8411

Compact Pulses Powering Future

High power microwave (HPM) military systems will soon become a reality if scientists like Dr. Edl Schamiloglu and others in the field of pulsed power have their way.

Schamiloglu, the Gardner-Zemke Professor of Electrical and Computer Engineering at the University of New Mexico, who is funded by the Air Force Office of Scientific Research, recently received a five year, $5 million grant through the Department of Defense's Multidisciplinary University Research Initiative (MURI). As the principal investigator for the grant, Schamiloglu will conduct basic research that one day may lead to the development of compact, portable pulsed power technology that satisfies the stringent size and weight constraints for systems to be mounted on combat aircraft and land vehicles. UNM is one of 48 universities serving as a lead institution in the nation receiving the MURI grants.

His UNM group is teamed with Dr. Karl Schoenbach of Old Dominion University (ODU) and Dr. Robert Vidmar of the University of Nevada at Reno. The university also intends to educate and train graduate students and publish results to advance the field of pulsed power and applied electromagnetics.

Schamiloglu said that a major goal of the project is to research pulsed electrical properties of dielectrics (both liquid and solid) and to incorporate a new generation of high dielectric constant ceramics in the pulse forming line of pulsed power systems.

Modern day pulsed power, he noted, is an area of science and engineering that emerged in the 1960s, initially in the United Kingdom. It has since spread to the U.S. and former Soviet Union.

"As the name implies," Schamiloglu began, "the principle behind 'pulsed power' is to use prime power, such as the wall plug in a laboratory facility, to store electrical energy gradually over a relatively long period of time and then to release this electrical energy in a relatively short period of time – typically in tens of nanoseconds to about one microsecond.

"Since power is energy per unit time," he added, "by releasing a given amount of energy in very short time, one can generate very high output power pulses."

Schoenbach, his ODU colleague, believes it is imperative to find ways to store electrical energy more densely, thus reducing the size and weight of the entire system. It is why, he explained, those in his business are focusing on liquids.

"We're trying to build all liquid systems instead of all solid," he said. "It's a field that hasn't been looked at compared to solids and gases. We're looking into how liquids behave and operate in pulsed power systems.

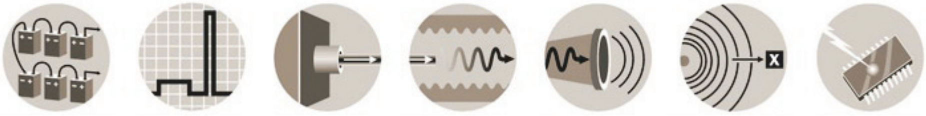
"Secondly," Schoenbach continued, "we're trying to build something that can be used by the Air Force, like a small, portable pulsed power system."

Pulsed power systems, Schamiloglu explained, are fairly large facilities typically

Dr. Schamiloglu in front of a compact pulsed power generator.

In Focus

Directed-energy weapons that use microwaves to disable electronic targets are an increasing focus of research. They harness large pulses of energy for conversion into microwaves that can be aimed at a target, scrambling the orderly function of its circuitry.



1. Packs of small, high-energy-density batteries are linked together to create a large charge at modest voltage.
2. The voltage is compressed in time, creating a much higher voltage and power pulse.
3. An electron gun, powered by this pulse, emits an intense beam of electrons.
4. The electron beam energy is converted to microwaves...
5. ...that are then radiated out through a high-power antenna.
6. The wave fronts expand and move forward toward the target...
7. ...where their energy overwhelms the circuitry of the target, incapacitating or destroying it.

Source: Ed Schamiloglu, University of New Mexico

found in universities, and in laboratories of the Department of Defense and Department of Energy.

"For future applications of pulsed power, both in the commercial and DoD sector," he said, "these pulsed power systems need to be placed on mobile platforms, whether on land, sea, or air. In this situation, the bulky laboratory facilities of today are not practical."

Prior to this grant, Schamiloglu explained, most scientists focused their attention on high power microwave sources; the front end of the system. Now armed with a better understanding of the front end, he said, it was time he and others exploited the possibilities of pulsed power.

One way to make pulsed power systems more compact, Schamiloglu noted, was through the use of new materials.

"Instead of traditional plastic-based dielectrics in pulsed forming lines," he said, "we can use novel, high dielectric constant ceramic that has a high breakdown strength, thus making the overall length of these transmission lines much smaller. This leads to compact systems."

There are other challenges he and his colleagues face – the old ways of doing things.

"The pulsed power community has been accustomed to working with certain materials," Schamiloglu began. "They are comfortable with liquid dielectrics, even though they may not understand the physics in detail. They also are comfortable with plastic dielectrics. They know how far they can stress these materials without them breaking down."

"However," he added, "this new generation of high dielectric constant materials, such as ceramics that are made with nanocrystalline materials, is an unknown area."

Alas, there is good news for those leary of the unknown, Schamiloglu insists, thanks to some groundbreaking work conducted by colleagues at the University of Missouri-Rolla.

"By conducting simple static testing of these materials," he reported, "they have found that these nanocrystalline-based materials have better performance characteristics than traditional plastic dielectrics. Now, rather than looking at these materials under static conditions, we can examine them under pulsed conditions."

"Through a better understanding of the electrical breakdown problem," Schamiloglu added, "one can push the limits and design a system that is more compact and robust."

Overheating could also become a problem. That's where the University of Nevada's Dr. Vidmar comes in. He has been charged with finding novel ways to use thermal management as a way to solve the puzzle. Working from the premise that tightly packed electrical components will inevitably get hot, Vidmar has patented a micro-channeled cooling technology. By using tiny capillaries combined with ultra-powerful pumps, he can introduce huge flows of cooling fluids into the tiniest of spaces. Such technology will ultimately be integrated into compact portable pulsed power systems as a means of removing heat. Just as a fan helps keep your computer cool, Vidmar is trying to discover ways of removing heat so these compact systems can operate at very high power densities.

Schamiloglu said pulsed power is a critical enabling technology for areas of science and engineering research such as high-power microwaves, controlled fusion, and high-power lasers. Schamiloglu added that the ability to develop more compact and lightweight sources of pulsed power will lead to the incorporation of advanced non-lethal weapons technology into the DoD arsenal.

"The Air Force is interested in high-powered microwave energy sources because of directed energy weapons, such as non-lethal anti-personnel and lower frequency microwave for an electronic attack on enemy communication and control," he explained. "Computers and microprocessor components are most vulnerable to this type of attack."

Schamiloglu said that he hopes the research conducted will lead to other projects.

"Advances in basic research sponsored by the DoD lead to spin-offs that one no longer connects with the DoD," Schamiloglu insisted.

Drs. Edl Schamiloglu and Christos Christodoulou, chair of the electrical and computer engineering department at the University of New Mexico.

"The microwave oven is one simple case in point," he continued. "Although it is unlikely that the consumer will have the requirements for compact pulsed power systems with the power levels we are concerned with, one can clearly envision applications that can arise in medicine and biotechnology."

The results of our program, he noted, will likely open the way for industry to manufacture compact pulsed power sources to supply the drivers for these new opportunities.

Many of the breakthroughs, Schamiloglu insisted, would not have been possible without the support of AFOSR.

"We owe a lot to Dr. Robert Barker, the AFOSR program manager, for supporting our research and enabling us to train the future generation of graduate students that will go on to work in several AFRL laboratories and industry," Schamiloglu said.

Dr. Robert Barker, AFOSR/NE 703-696-8574

AWARDS: Mr. Phil Gibber

AFOSR Analyst Receives Silver Cross of Honor of the Federal Armed Forces from the Federal Republic of Germany

The Federal Republic of Germany bestowed one of its highest military honors, the Silver Cross of Honor of the Federal Armed Forces, to Mr. Phil Gibber at a special ceremony held in Vienna, Va.

Mr. Gibber, a retired Navy captain who is an AFOSR senior international program analyst, earned the nomination for his personal commitment and dedication to the Engineer and Scientist Exchange Program (ESEP) between the U.S. and Germany.

The two countries have conducted the ESEP program since 1963. To date, more than 1,600 engineers, military officers and civil servants have taken advantage of the opportunity to participate in a one-year scientific or technical assignment in the other's country.

Instrumental in AFOSR's ESEP since 1993, Gibber has dedicated himself to working closely with Germany to place their scientist in positions around the U.S., enhancing scientific understanding and cooperation between both nations.

Gibber was instrumental in providing guidance to those looking to secure an exchange slot in the U.S. during a period of heightened security.

Phil Gibber, shown with his wife Erma, is recognized by the Federal Republic of Germany.

"It is important to maintain and foster relations," Gibber said. Creating the mold, he standardized the submittal packages to streamline the highly-competitive selection process and formulated the blueprint on how to place scientists in other countries – specifically mapping out the step-by-step process to work with the different state departments and ambassadors of the respective countries.

The Silver Cross of Honor of the Federal Armed Forces is rarely awarded to a non-German and is similar in stature to the U.S. Legion of Merit.

Research Highlights

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