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Physics Department Research (archived)

Monterey, California, Naval Postgraduate School

PHYSICS DEPARTMENT RESEARCH

During FY 1994, 19 Physics Department faculty members participated in approximately 37 different research projects. Although the scope of these projects is quite broad, the research in the Physics Department can be grouped, for the purposes of this summary, into five general areas:

- **Electromagnetic propagation and remote sensing**
- **Acoustics and wave dynamics, including air-ocean interactions**
- **Electromagnetic radiation and particle beam technology**
- **Weapons and combat systems technology**
- **Free Electron Lasers**

An overview of research activities in each of these areas follows.

Electromagnetic Propagation and Remote Sensing

Research activities in this category can be subdivided into four areas:

- Optical propagation through turbulence
- Infrared multispectral imaging
- Infrared technology development

Professor Donald Walter is involved in understanding optical propagation through a turbulent atmopshere. The goal of Professor Walter's project is to develop and collect balloon measurements of the stratospheric microthermal fluctuations critical to resolving optical propagation limits imposed on the USAF Airborne Laser Program. To date, two successful balloon launches have occurred, and two more development, test launches are scheduled before the actual ABEL- ACE mission tests.

Professor Scott Davis is continuing a project which has as its primary goal the development of a prototype instrument capable of recording fully multiplexed images and multispectral images at long infrared wavelengths, where efficient focal plane array technology is not available. The major activity to which the year was devoted was the detailed design of unique reflecting and transmitting spatial encoding mask systems based upon orthogonal Walsh function patterns mapped into Cartesian and non-Cartesian coordinate systems.

Professor Alf Cooper is working in a number of areas related to the application of infrared technology to the Navy. One project is to evaluate experimentally techniques of passive ranging and target discrimination against background and to obtain horizontally and vertically polarized images of small boats in the littoral environment. In addition, Professor Cooper is trying to improve the prediction of detection range for infrared signatures through: evaluation of environmentally modified ship signatures; and experimental evaluation of criteria for detection and recognition. Another project involves the development of instrumentation and techniques for measurement of environmental factors needed for prediction, analysis and modeling of infrared sensor performance in the marine boundary layer. Professor Cooper is also involved with a project to evaluate the performance improvement to be gained by incorporation of IRST in the AEGIS combat system and to provide support to the AEGIS program office in the area of Cost and Operational Effectiveness Analysis.

Professor David Cleary is working in the area of remote sensing of the ionosphere. The objective of his research is to develop a passive technique for remote sensing the ionospheric electron density profile on a global basis. Specifically, he wants to determine if the electron density can be inferred from the ultraviolet signature of the positive ions in the ionosphere. In March 1994, his group conducted a sounding rocket experiment. During this experiment two ultraviolet spectrographs measured the UV spectrum of the Earth's ionosphere between 100 and 320 km. This experiment was conducted over the Poker Flat Missile Range in Alaska during and intense geomagnetic storm. The purpose of this experiment to investigate the effects of auroral electron precipitation on the UV spectrum of the ionosphere. Analysis of the data obtained from this experiment is ongoing. In addition, Professor Cleary and his coworkers made significant progress on the development of a new instrument for ionospheric remote sensing. This instrument is an All-Reflection Michelson interferometer. During FY 1994, they successfully demonstrated the operation of this instrument in the UV using the Mercury 2537- C5 emission.

Professor Chris Olsen is also working in the area of remote sensing. His research addresses the application of multispectral and hyperspectral imaging to Naval needs. The objectives are to identify target signatures, and other features of interest in land and littoral scenes. He is also involved with a project to determine the effectiveness of existing algorithms for the determination of wind speed from the DMSP microwave sensor, SSM/I. Professor Olsen also supported the PMG-Delta flight experiment, working with ground radar observations.

Acoustics and Wave Dynamics

Research activities in this area include:

- Thermoacoustics
- Sonar
- Array performance prediction
- Wave turbulence and soliton dynamics

The largest effort in acoustics is devoted to thermoacoustic heat engine research. Professors Atchley, Garrett, Hofler, and Keolian are working in this area. The objectives of Professor Anthony Atchley's work is to investigate mechanisms that place fundamental limitations on the high amplitude performance of thermoacoustic engines. Previous work has aimed their efforts to look for velocity effects at other than acoustic time scales, to study the possible effects of acoustic streaming and turbulence on heat transport in thermoacoustic heat engines. Since this heat transport effect is generated by acoustic fields with high acoustic pressure amplitudes, the influence of streaming and resulting turbulence may be important. Specific objectives include investigation of velocity fields in thermoacoustic engines using Laser Doppler Anemometry and investigation of heat exchanger performance in thermoacoustic prime movers.

Professor Steven Garrett's research is directed at the fabrication and testing of a thermoacoustic cooling engine which is capable of providing cooling for a CV-2095 Radar Azimuth Converter on surface ship radar system. A computerized instrumentation system was developed which was capable of accurately measuring electrical, thermal, and acoustical power flows and acoustical parameters within the engine and the associated internal and external heat exchanger components. Adaptation of the thermoacoustic cooler and measurement system for use on a navy surface ship was begun with the goal of testing the chiller at sea in April, 1995, as a cooler for an essential radar system component.

Professor Thomas Hofler is performing basic research on thermoacoustic cooling processes for applications requiring high cooling power and a small temperature span. Such applications could include cooling onboard Navy ships. He is also involved with a project to construct third generation prototypes of thermoacoustic refrigerators (TARIII) suitable for use in spacecraft, for the purpose of cooling electronics and sensors to cryogenic temperatures. The goal of this research is to improve the refrigerator performance and design on a fundamental level, so as to increase the temperature span with acceptable efficiency.

The primary objective of Professor Robert Keolian's research is to construct and test "pin stacks," a new thermoacoustic stack geometry. It is expected that the pin stack will improve the efficiency of thermoacoustically based refrigerators, heat pumps, and acoustic sources. A conventional stack can be thought of as a stack of separated flat plates, with sound passing through a fluid in the gaps between the plates. In a pin stack, an array of thousands of wires aligned along the acoustic axis in the fluid is used instead. By removing essentially unnecessary material from the stack, viscous losses can be reduced while keeping optimal thermal contact between the stack and the fluid. Secondary objectives include the exploration of the desirability and practicality of fractal heat exchanger designs and of parametric sound sources.

Professor Steven Baker is working with Professors Canright and Scandrett from the NPS Mathematics Department to develop an efficient means to compute the performance of an arbitrarily densely packed, randomly distributed, three-dimensional array of sonar projectors. Present methods of analysis fail to include the effect on the distribution of the radiation of one source due to the presence of another, i.e. the distortion of the nearfield. For this application they are pursuing a combination of analytical and numerical methods. Professor Baker is also trying to experimentally validate a theory developed by scientists at the Naval Coastal Systems Station for the scattering of underwater sound from a porous solid sphere. The theory has potential application to the detection of mine-like objects buried in sediment.

Professors Andres Larraza and Robert Keolian are working on a project that deals with experimental and theoretical studies of nonlinear random surface waves driven far off equilibrium. Investigations of the self focusing mechanisms of nonlinear waves were also considered. Professor Larraza also conducted experimental and theoretical investigations of nonlinear dispersive waveguide modes in an acoustic duct. He made preliminary observations of a localized envelope that splits into two disturbances moving with two different velocities of propagation. As a consequence, he predicted that if a signal is amplitude modulated at the source it would become frequency modulated at periodic positions in space.

Professor Donald Spiel is working the role that bubble generated aerosols play in processes including air-sea dynamics, global climate, gas exchange, and ocean background acoustic noise. The purpose of this continuing work is to understand the physics of individual bursting bubbles as it relates to the oceanic aerosol source function. The work included the measurements of the number and size of jet drops produced by collapsing bubbles with radii from 350 to 1500 micrometers. In addition, the speeds of ejection, the times of ejection and the heights above the surface at which the droplets separate from the ascending jet, the so-called jet drop birth parameters, were also completed.

Electromagnetic Radiation and Particle Beam Technology

Professor Fred Schwirzke is working to understand the high voltage breakdown process and the process of plasma formation on the surfaces of electrodes of a vacuum diode. Electrical breakdown and formation of cathode spots are basic processes in many areas of high voltage engineering and pulsed power technology. A self-consistent physical model of the breakdown process has been developed. Experimental results obtained with the NPS Flash X-Ray and Electron Accelerator System confirm the new breakdown model.

Weapons and Combat Systems Technology

Professor Steven Baker is involved with a project to develop and validate through laboratory and field measurements a numerical computer model of the PHALANX gun which can be used to quantify of the effects of design changes and/or modifications on its performance. The PHALANX close-in weapon system (CIWS) provides close-in ship defense against incoming missiles. Reducing the PHALANX gun dispersion can significantly increase its ability to destroy targets at long range.

Professor Joseph Sternberg is working on a project is to develop and experiment with a unique wargame designed to assess the value of TRAP information to the mission success of a carrier battle group. The development of the software support system for handling the basic functions of the TRAP information flow, the background message traffic, the preparations for offensive and defensive operations, and the evaluations of the outcomes of those operations has been completed and extensively testsed. Since the prime objective of the wargame is to show how, or whether, the differences between the player's intelligence picture and "ground truth" affects mission success in a contingency scenario, the software has been designed to keep separate the player's perception of the status of enemy weapon systems and activity, used in decision making, and the corresponding "ground truth", which is used in evaluating engagement outcomes.

Professor Michael Melich is working Project Gusty Oriole. The goal of this research has been the understanding of the properties of complex sensor systems and their interactions with one another and the military units that make use of their measurements. This is a continuation of a multi-year, multi-person research effort.. This year they have investigated the operational characteristics of existing systems. The goal has been to determine how the information that these systems generate is complementary to that available from other sensor systems. He is also working on on SEALAR, HTSSE, STAR Space Technology. This year was the last year of a multi-year effort and was devoted to documenting a portion of the previously conducted research.

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