MASTER OF SCIENCE
IN
APPLIED PHYSICS

THE USE OF RIGID POLYURETHANE FOAM AS A LANDMINE BREACHING TECHNIQUE

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The results of a feasibility test using Rigid Polyurethane Foam (RPF) as an operational anti-personnel mine counter-mine technique are presented. RPF, at a given density and thickness, can withstand the explosive effects of anti-personnel blast mines and mitigate or neutralize the effects of surface laid anti-vehicular mines. A 12-inch thick, 4 pound per cubic foot foam block completely contained a 10-gram explosive charge of PETN while a 30-inch foam block with the same density contained a 30-gram charge. A 24-inch thick pad supported 50 passes of an M88A2 Recovery Vehicle, crushing the foam no more than 2-3 inches throughout the length of a 56-foot foam roadway. Underneath this roadway, simulated land mines set at 14 psi were not triggered by the passage of an M88A2 and a HMMWV. Our experiments indicate that RPF can provide additional traction in muddy conditions and set-off explosives connected to trip wires. The pressure and trafficability experiments were conducted at the Waterways Experiment Station, Vicksburg, MS, in July-August 1997, and the explosive experiments were conducted at the Energetic Materials Research and Testing Center (EMRTC) of the New Mexico Institute of Mining and Technology, Socorro, NM, in August and October 1997.

KEYWORDS: Explosives, Landmines, Rigid Polyurethane Foam, Countermine

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures, Conventional Weapons

DEVELOPMENT OF HIGH POWER MICROWAVE (HPM) ADVANCED CONCEPT TECHNOLOGY DEMONSTRATION (ACTD) FOR ASCM DEFENSE OF THE ARG (U)

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CLASSIFIED ABSTRACT

KEYWORDS: High Power Microwaves (HPM), Directed Energy Weapon, Anti-Ship Cruise Missile Defense, Microwave Coupling

DoD KEY TECHNOLOGY AREAS: Electronic Warfare, Directed Energy Weapons

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THE MACH-ZEHNDER COUPLER

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This thesis is the second in a series which investigates the possibility of creating a code-shift-keying (CSK) optical receiver using single-mode 2x2 couplers and fiber optical delay lines to construct Mach-Zehnder couplers which comprise the main building block of the CSK receiver. There were two main goals of this thesis research. The first was to investigate design and construction modifications which would lower the system loss of a previously designed Mach-Zehnder coupler. As a result of this research, the system loss was reduced from 10.5 dB to 3.3 dB by changing the design to eliminate an unnecessary stage and by replacing several mechanical connections with fusion splices. The second goal was to find a method to measure the inherent phase shift of a 2x2 fiber optical coupler. Two separate methods were developed and implemented, and a third previously developed method was used to verify the results. All three methods provided experimental values between 145° and 149°. This thesis develops the theory that explains the discrepancy between the measured values and the ideal value of 180° for the inherent phase shift

KEYWORDS: Fiber Optic Receiver, Mach-Zehnder Coupler, Interferometry

DoD KEY TECHNOLOGY AREAS: Electronics, Sensors, Command, Control, and Communications

CHARACTERIZATION AND MAGNETIC AUGMENTATION OF A LOW VOLTAGE ELECTROMAGNETIC RAILGUN

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In the near future armored vehicles will be fielded with reactive armor which cannot be defeated by today's chemically propelled munitions. Today's munitions are limited to muzzle velocities less than the speed of sound in the chemical propellant which is about 1.8 km/s. Electromagnetic launch technologies have the ability to launch projectiles at velocities in excess of 2 km/s and may be able to defeat the reactive armor. Not only can electromagnetic launch technologies be used as an anti-tank weapon, but also it can be used as anti-missile defense.

To investigate electromagnetic launch technologies and the effects of augmentation a 44 cm railgun was constructed and tested. The railgun was powered by a capacitor bank of fourteen 330 V, 600 μF capacitors. The velocity of the projectile, the voltage across the capacitors and the current through the rails were measured. The augmentation of the gun with a permanent magnetic field increased the velocity of the projectile by 85% while air injection augmentation had no effect.

KEYWORDS: Electromagnetic Railgun, Electromagnetic Launch Technology, Railgun Augmentation

DoD KEY TECHNOLOGY AREAS: Conventional Weapons, Electronics, Ground Vehicles

DESIGN, CONSTRUCTION, AND OPERATION OF THE NAVAL POSTGRADUATE SCHOOL'S ULTRAVIOLET IMAGING SPECTROMETER

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Hyperspectral imaging spectrometers produce an image comprised of the standard two-dimensional spatial scene and the corresponding spectra of each scene. Hyperspectral imaging is a relatively new and fast growing field with both commercial and military applications. Commercial applications vary from vegetation identification and mapping, surface geological identification and mapping to atmospheric composition and mapping. Military applications include target identification and classification, airborne chemical identification and mapping, and rocket plume identification.

This thesis describes the design and operation of the NPS Ultraviolet Imaging Spectrometer (NUVIS). NUVIS is a hyperspectral imaging spectrometer designed to investigate the ultraviolet region of the spectrum. NUVIS is comprised of a scanning mirror, telescope assembly using an off-axis parabolic mirror, a slit, a flat field imaging diffraction grating, an image intensified camera assembly, and the support/controlling electric and electronic hardware and software. This is part of a continuing project to build, test and use this sensor in support of military and government agencies.

KEYWORDS: Hyperspectral Imaging, Ultraviolet, Imaging Spectrometers, NUVIS, Support to Military Operations, Support to Government Agencies

DoD KEY TECHNOLOGY AREA: Sensors

THE MIE SCATTERING SERIES AND CONVERGENCE ACCELERATION

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This thesis research presents an algorithm for the precise determination of the Mie extinction efficiency parameter. The mathematical representation of the Mie parameters is in the form of an infinite series, and any technique that could be found to accelerate the convergence of the Mie series would have great commercial and military application. Results are presented that show the comparison of the rate of convergence obtained by directly summing the individual terms of the extinction efficiency parameter and the rate obtained using an existing series acceleration technique. It was found that the acceleration method employed, known as the Levin method of series transformation, proved unsuccessful in accelerating the convergence of the Mie series. However, other acceleration techniques exist and should be explored.

KEYWORDS: Mie Scattering, Levin Method, Series Acceleration

DoD KEY TECHNOLOGY AREAS: Environmental Quality, Sensors

SIMULATIONS OF THE LOS ALAMOS NATIONAL LABORATORY (LANL) 1 KW REGENERATIVE AMPLIFIER FREE ELECTRON LASER (FEL)

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The development of a high average power FEL for military applications would represent a significant improvement in missile defense, especially shipboard self-defense. The LANL regenerative amplifier FEL (RAFEL) is designed to produce an average output power of 1 kW. This FEL represents a significant increase in average power demonstrated in an FEL provides a test of the concept of combining the FEL oscillator and amplifier designs. Simulations were performed to better understand the physics behind the LANL RAFEL operation.

Simulations study the transverse effects due to optical guiding by the intense electron beam and feedback. These simulations are applied to optimizing the undulator taper rate, feedback optimization, and initial phase velocity. Additional simulations study the longitudinal effects due to short electron pulses and optical pulse development over multiple passes. Finally, simulations of the RAFEL design using an ideal beam expand on understanding of the design's basic characteristics and limitations.

KEYWORDS: Free Electron Laser, FEL, LANL, RAFEL, Missile Defense, Simulations

DoD KEY TECHNOLOGY AREAS: Directed Energy Weapons, Surface/Under Surface Vehicles - Ships and Watercraft, Manufacturing Science and Technology (MS&T)

IMPLEMENTATION AND EVALUATION OF AN INERTIAL NAVIGATION SYSTEM (INS) FOR THE SHEPHERD ROTARY VEHICLE

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An autonomous vehicle must be able to determine its global position even in the absence of external information input. To obtain reliable position information, this would require the integration of multiple navigation sensors and the optimal fusion of the navigation data provided by them.

The approach taken in this thesis was to implement two navigation sensors for a four-wheel drive and steer autonomous vehicle: An inertial measurement unit providing linear acceleration in three dimensions and angular velocity for the vehicle's global motion and shaft encoders providing local motion parameters. An inertial measurement unit is integrated with the Shepherd mobile robot and data acquisition and processing software is developed. Position estimation based on shaft encoder readings is implemented. The framework for future analysis including most general motion profiles have been laid.

The sensor's system performance was evaluated using three different linear motion profiles. Test results indicate that the shaft encoder provide a positioning accuracy better than 99% (typ. 7.5 mm for 1 m motion) under no slip conditions for pure translational motion. The IMU still requires further improvement to allow for both sensors to be combined to an integrated system.

KEYWORDS: Robotics, Sensors, Navigation, NPS, Shepherd, Rotary Vehicle

DoD KEY TECHNOLOGY AREAS: Sensors, Ground Vehicles

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SIMULATION OF THE AUTONOMOUS COMBAT SYSTEMS ROBOT OPTICAL DETECTION SYSTEM

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NPS Combat Systems students learn systems engineering through a series of courses in design, development, implementation, and testing and evaluation. In the last of this series of courses, students design an autonomous robot capable of searching, acquiring, and tracking another autonomous robot having similar capabilities. The project culminates in the Robot Wars Competition, where groups of students have their robots battle each other.

This thesis is the second in a series designed to realistically simulate the robot wars battles. The end-to-end functionality of the optical detection system is modeled, and the necessary physics are implemented for effective simulation and depiction. The model uses a transfer function approach and includes all physical processes, from initial optical beacon emission to final digital control signal. Exercising the model over time using realistic robot inputs yields a simulation that closely replicates real behavior. A Virtual Reality Modeling Language (VRML) program uses data files of each Simbot's movement to generate a 3-dimensional animated scene of the detection sequence. This implemented optical model effectively simulates the SE 3015 robot optical detection system and can reproduce an actual detection and tracking sequence between two robots.

KEYWORDS: Optics, Models, Simulation, Robots

DoD KEY TECHNOLOGY AREAS: Computing and Software, Electronics, Modeling and Simulation

SIMULATIONS OF LOS ALAMOS NATIONAL LABORATORY (LANL) REGENERATIVE MEGAWATT FREE ELECTRON LASER AMPLIFIER

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The development of a speed-of-light hard-kill weapon system for military applications represents a significant advancement in technology over present conventional kinetic weapon systems. Over the past two decades, the U.S. Navy has successfully developed a megawatt-class chemical laser; however, under some maritime environments, the high power beam propagation was unable to delivery sufficient energy to kill a modern anti-ship missile (ASM) due to significant atmospheric absorption and the resulting thermal blooming process. A critical problem to resolve for the shipboard high-energy laser weapon systems is to develop a shipboard-compatible megawatt-class laser weapon at a wavelength where the atmospheric absorption is smallest. The megawatt-class Free Electron Laser (FEL) has significant advantages over conventional weapon systems and other chemical high-energy laser systems. Infinite magazine, rapid response, and wavelength tunability make the FEL a suitable and desirable shipboard weapon system.

This thesis divides into four chapters. Chapters I and II introduce the FEL and background theory of the FEL. Chapter III explores the analysis of the LANL Regenerative MW FEL Amplifier design and optimizes its efficiency. Lastly, Chapter IV summarizes the feasibility of achieving the desired efficiency.

KEYWORDS: Free Electron Laser, FEL, MW, LANL, RAFEL, Missile Defense

DoD KEY TECHNOLOGY AREA: Directed Energy Weapons

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HYPERSPECTRAL POLARIMETRY FOR SATELLITE REMOTE SENSING

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The study of polarization of reflected light and its angular dependence is well documented. However, most measurements have been panchromatic in nature, i.e., they were taken over a broad wavelength region. A few polarization measurements have examined polarization at several specific narrow wavelength bands. These measurements can be classified as multi-spectral. Thus, previous efforts to characterize an object using polarization have not investigated a hyperspectral polarization signature.

This thesis determines the hyperspectral polarization signature of several common materials that are significant to the military. A range of materials was examined including camouflage fabrics, military paints, rubber, plastic, taggant, and glass. It is shown that a hyperspectral polarization signature, when combined with a hyperspectral reflectance signature may enhance present capabilities to detect, classify, and identify objects of military significance. This technique appears especially promising for dark objects, shiny surfaces, synthetic fabrics, and unpainted metal.

This combined approach could be realized in a hyperspectral polarimetric imaging satellite. The utility of designing such a sensor and many key design considerations are examined. Preliminary analysis suggests sensor designs for low earth and geosynchronous orbiting spacecraft may be feasible. Sensor data rate and signal-to-noise ratio will be the limiting factors in these designs.

KEYWORDS: Hyperspectral Imagery, Polarization, Polarimetry, Satellite Remote Sensing

DoD KEY TECHNOLOGY AREA: Sensors

DESIGN, CONSTRUCTION AND TESTING OF AN AUTONOMOUS MINE HUNTER

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Landmine detection is an immense technological problem. A small, low power metal detector would find application in concert with other search technologies. A detection circuit was designed and constructed consisting of a search coil and a CMOS exclusive OR gate forming an oscillator. This was interfaced to a microprocessor which counted the pulses from the oscillator and decided whether a detection had been made. Detection range for an anti-personnel mine like object was 14 cm at the coil centerline. A robot platform to autonomously search for landmines was constructed.

KEYWORDS: Landmine, Induction, Robot, Microprocessor

DoD KEY TECHNOLOGY AREA: Sensors

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APPLICATIONS AND LIMITATIONS OF TWO IMPORTANT NUMERICAL METHODS FOR THE COMPUTATION OF TRANSMISSION COEFFICIENTS

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As a consequence of the ever-shrinking sizes of nanoelectronic devices, hitherto neglected quantum effects, such as tunneling, are becoming important for device characterization. The study of electron reflection and transmission probabilities at potential barriers is one of the important areas of active research in this field.

Analytic solutions for the quantum-mechanical transmission coefficient through a potential energy profile of arbitrary shape do not exist. One conceivable method for finding the transmission coefficient through such a potential involves transfer matrices. This technique is numerically limited, unfortunately, and fails to provide adequate results for potentials of interest in the development of practical nanoelectronic devices. However, within its capabilities, the transfer matrix method is a useful reference to which other results may be compared. Another method, utilizing backward recurrence, has been proposed as a numerically stable alternative for calculating the transmission coefficient through such potentials. This second method has yet to be widely applied.

This thesis investigates the capabilities and limitations of each method, with an emphasis on their scope of applicability. Extensive programming, in the C language, has been done to examine the two methods. Output from these programs has been analyzed, and the backward-recurrence method has been shown to have wider applicability, and to be faster and much more numerically stable.

KEYWORDS: Nanoelectronics, Device Modeling, Numerical Methods, Numerical Instability, Quantum Physics, Quantum Transmission Coefficient

DoD KEY TECHNOLOGY AREAS: Electronics, Modeling and Simulation, Other (Quantum Physics, Quantum Transmission Coefficient)

ANALYSIS OF ACOUSTIC PLANE-WAVE VARIABILITY IN THE REGION OF THE MID-ATLANTIC BIGHT SHELF BREAK

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From the summer cruise of the Mid-Atlantic Bight Experiment, conducted jointly by the Naval Postgraduate School, University of Rhode Island, and Woods Hole Oceanographic Institution, a study of acoustic plane-wave variability in the region of Mid-Atlantic Bight shelf break was conducted. The period of the experiment was from 19 July to 09 August 1996. The experiment consisted of a suite of acoustic and oceanographic sensors including three 400 Hz (100 Hz bandwidth) transceivers, one 224 Hz (16 Hz bandwidth) transceiver and two vertical line arrays (VLAs). This study involved the signal processing of data collected by a telemetry buoy, an analysis of the spatial and temporal coherence of the phones and beams of the vertical array, and the tidal and seasonal variabilities of plane-wave arrivals at the vertical array. Results of the changes in arrival time of the beams, the horizontal displacement of the front, the changes in the speed of propagation of the wave, and the change in the water temperature are discussed.

KEYWORDS: Mid-Atlantic Bight, Ocean Acoustics, Plane-Wave Beamforming, Temporal Coherence, Spatial Signal Processing, Shelf Front Tidal Response

DoD KEY TECHNOLOGY AREA: Other (Ocean Acoustics)

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ESTIMATE OF MAXIMUM DETECTION RANGE FOR FORWARD LOOKING INFRARED (FLIR) FROM EOMET95 MEASUREMENT DATA

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FLIR sensor maximum range predictions for operational use may be based on the intersection of apparent target contrast temperature difference (ΔT_{app}) and sensor minimum resolvable (MRTD) or minimum detectable temperature difference (MDTD), each expressed as a function of range. Ranges obtained using the SEARAD code (MODTRAN modified for sea surface radiance) are compared with those based on Beer's Law with constant extinction coefficient. Physical and meteorological parameters for the common scenario were taken from the database of the EOMET95 measurements in Monterey Bay, with the research vessel *Point Sur* as instrumented target and measurement platform. MRTD and MDTD functions were developed as functions of range for a generic Common Module FLIR using the Johnson Criterion for resolution with a parallelepiped geometry model of the *Point Sur*. The Beer's Law results underestimate the SEARAD-based ranges by approximately 50% for detection but less for classification and identification. Replacement of Beer's Law with MODTRAN-computed transmittance reduces this discrepancy. SEARAD-based modeled sea radiance and short range contrast temperature show unexpected variation with range.

KEYWORDS: Atmospheric Optics, Infrared Sensors, FLIR

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Modeling and Simulation