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TECHNICAL DOCUMENT 92

ANNUAL REPORT
FISCAL YEAR 1970

Independent Research and Exploratory Development

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FOREWORD

During the past year the Congress has initiated a requirement that all military research be directly relevant to identifiable military applications. In the same period the Department of Defense has stressed the necessity for minimum purchase cost, complexity, and maintenance of fleet equipment. These forces coupled with the decline in research and development funds have changed the environment in which the science and engineering programs are conceived and prosecuted at the Naval Electronics Laboratory Center. Within NELC, a new Commanding Officer and Technical Director have revised the Center structure to respond to the new environment and embarked on new programs under a modified philosophy. The new structure represents a strong unifying force to achieve a true Center approach to problem solution by making the resources and capabilities of all organizational elements available through a matrix organization. On a technical level, there is strong emphasis on completely engineered hardware, ready for fleet use, based on low-maintenance, reliable, and compatible equipment which requires minimally trained personnel to operate and maintain.

The current IR/IED program has responded as well to the external and internal changes in guidance. Long-term high-risk research has been replaced in many cases by shorter-term, lower-risk programs which would feed directly into established hardware requirements. The higher risk elements remaining in the program have been judged to be necessary for the introduction of sorely needed technology improvements.

A primarily IED-funded, centerwide approach to improved hardware was instituted. This program is based on the realizations that Naval Communications and Command Control functions will be using digital techniques wherever possible and that the state-of-the-art microelectronics offer the features of low cost, reliability, and maintainability. If one looks at the detailed functions that these equipments are asked to perform, there should be sufficient commonality that a set of standard building blocks will emerge which can be used in various combinations with minor modification to perform a wide variety of operations. This program which has been given the acronym BAMS (Benchmarks in the Application of Microelectronics to Systems) absorbs one-third of the IR/IED funding.

Another departure from prior experience involves the electro-optics program. Where in the past the primary emphasis of this effort was in phenomenological. basic research, the current program includes two engineering efforts to construct optical communication-system prototypes. one aimed at exterior ship communication and the other primarily at interior communications.

The electronic materials program of the Infrared Division added from the Corona Laboratory, Naval Weapons Center, has been continued at a slightly reduced level without material changes in content.

In summary, the IR/IED program at NELC has been integrated as much as possible with established Center and Navy programs and long-term technical objectives.

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HIGHLIGHTS OF FY 1970

DEVELOPMENT OF IMPROVED DISPLAY TECHNIQUES FOR ADVANCED SHIPBOARD DISPLAY SYSTEMS

W. E. Milroy

Electronic recording technique provides for the real-time, time-compressed display of sensor images. Tests with both trained and untrained radar operators show sharp rise in ability to detect, track, and identify air targets when using time-compressed format.

INTRODUCTION

The value of time-compression techniques in video displays has been enhanced by the development of an electronic recording process which overcomes the inherent limitations of film techniques. The experimental Time-Compressed Display System (TICODS) provides real-time analog storage and time-compressed recall and display of sensors, providing the operator with a dynamic display of the current sensor image and a selectable number of prior images. Desired returns (targets) are thus detectable as a coherent process imbedded in a noncoherent process (noise, interference, etc.). The abstract physiological processes of the operator can thus be brought to bear on detecting and tracking objects normally obscured by noise. The all-electronic equipment used to implement the system is relatively simple and inexpensive in comparison with alternative approaches which involve digitization of sensor signals and the subsequent automatic processing of the digitized data in large-scale digital computers. Film and development time are eliminated; the displayed picture is current; and the system has much more flexibility than the film system.

The experimental system was designed and constructed as of the end of FY 1969. Since the early part of FY 1970, tests have been conducted with both trained and untrained radar operators to determine their ability to detect, track, and identify air targets with a standard PPI format and with a time-compressed format. In all cases, the operators were significantly more efficient using the time-compressed display.

It should be stressed that the applications of TICODS are not limited to radar operation. At the time the test program was initiated, radar equipment, and operators for test subjects, were available and provided valuable information for study and comparison. Accordingly, the discussion here is in that context. However, the electronic recording process is equally useful in sonar, ECM, or in fact in any high-speed visual presentation of sequential images where playback and analysis are desirable.

Details of TICODS operation and description of the test program are furnished in reference 1 (see p. 9). They may be summarized as follows.

DESCRIPTION OF SYSTEM

The electronic recording process is implemented by a television camera (or, alternatively, a scan converter) which interfaces with the radar PPI display and "photographs" the PPI each antenna scan (fig. 1). These data are recorded as a television frame on one channel of a multichannel video disc; each antenna scan is recorded on a separate channel on the disc. The resulting electronic "pictures" appear rapidly on the time-compression display, up to 30 frames per second.

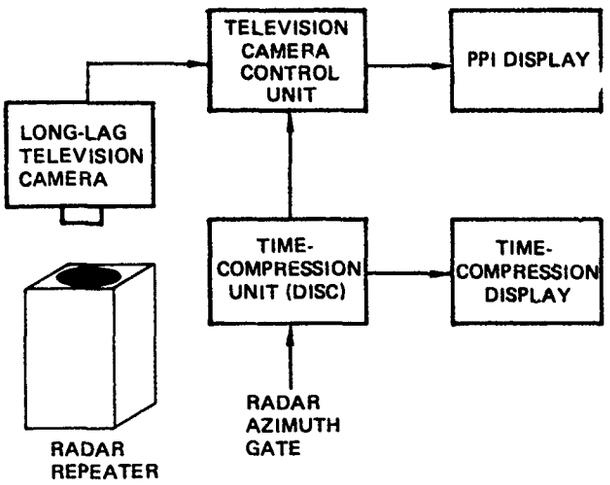


Figure 1. Electronic time-compression display system.

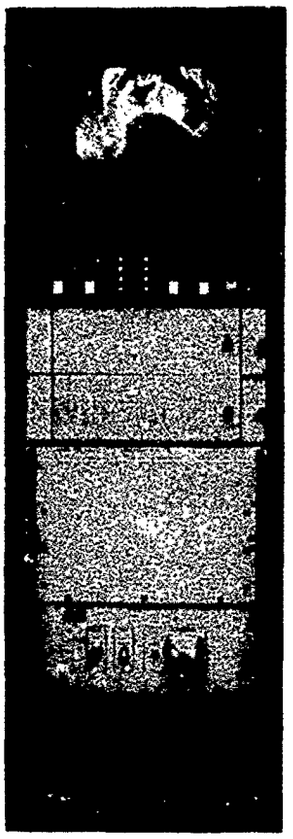


Figure 2. TICODS rack.

The 6-foot cabinet containing the TICODS equipment (fig. 2) provides all signal conditioning, processing, and controls for storage and retrieval of images in the form of television signals. The signals are stored on a magnetic disc recorder which has a capacity of 36 separate tracks of one television frame per track. The equipment accepts standard 525-line TV signals consisting of two interlaced fields per frame at 60 fields per second. Manual controls allow operator selection of the manual mode or several different modes of automatic read-write operation. The present system uses a closed-circuit television camera as the input. The camera is positioned over the CRT of a SPA-25 radar indicator so that the output is the PPI image in television format. The camera uses a long-lag vidicon to provide storage so the image does not fade immediately as the PPI sweep moves.

OPERATIONAL FEATURES

Figure 3 shows the basic block diagram of the TICODS equipment. Television signals are fed to a modulator section whose output is a period-modulated carrier signal with modulation proportional to input signal amplitude. The output of the modulator is fed to the inputs of the (write) section of the read-write amplifiers. Each track of the disc recorder has a read-write amplifier; the write function can be controlled from an external source. Thus, each track can be stored in a predetermined sequence by generation of control (write) signals. One group of 32 tracks makes up the main video storage section. These 32 tracks are controlled sequentially by the logic section. The remaining four tracks, available as auxiliary video images, are controlled manually.

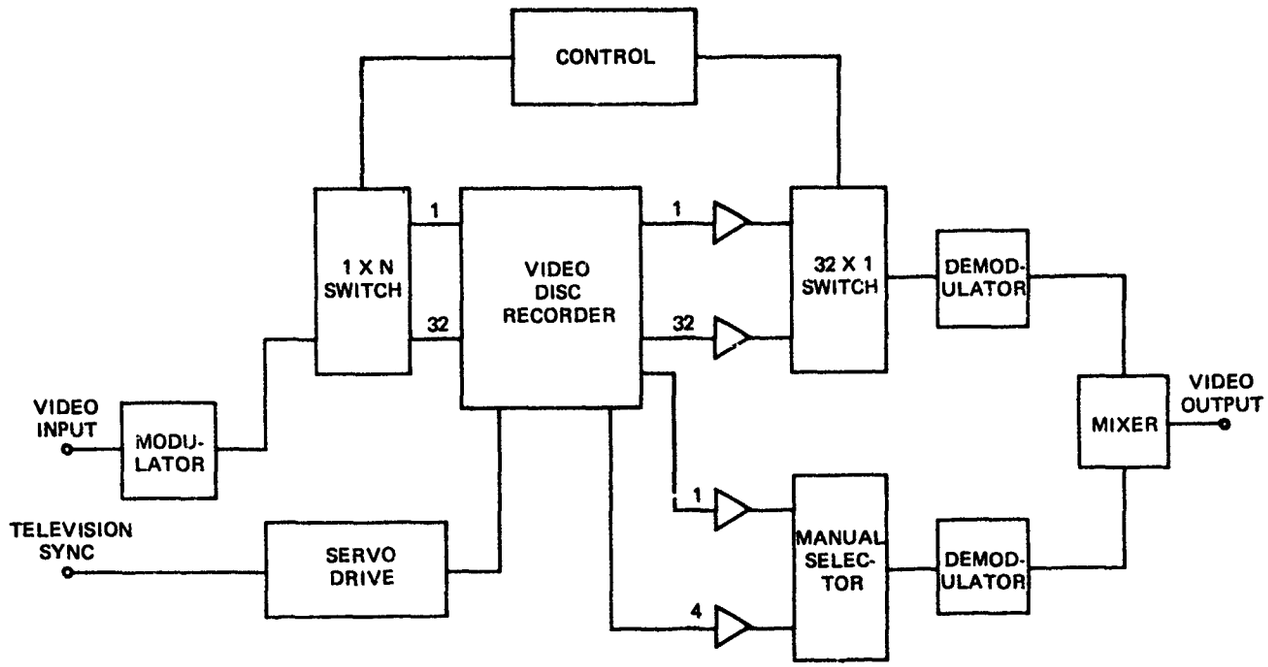


Figure 3. TICODS basic block diagram.

One of the auxiliary tracks may be used to store the last track written. This track is demodulated in a separate demodulator and mixed with the sequenced tracks as they are read. This gives a constant display of current PPI plus the time-compressed display of previous antenna scans. The remaining three tracks are available for use in investigating area moving-target indication (MTI) by scan-to-scan cancellation of fixed returns. They may also be used for providing an overlay, such as a map or chart, superimposed on the sensor images.

TEST PROGRAM

Early in FY 1970, a series of tests was performed to establish the optimum parameters (number of prior image frames, time-compression ratio, etc.) to set into the system control panel when working with radar returns. A short-range, surface-search radar and a mid-range, air-search radar were used to supply the signals.

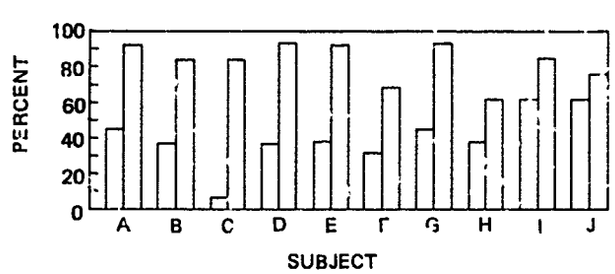
A second set of tests was then conducted to determine the improvement in operator capability in detection, tracking, and identification of air targets on a time-compressed display. In preparation for the tests, one-hour video tape recordings were made from each radar. From each of these tapes a segment was selected having sufficient air targets without too much traffic in any one area. Then another recording was made of the same segment, this time after the TV image had been processed through TICODS. Thus two tapes of each radar were produced, one a standard PPI display and the other a time-compressed display.

The test tapes were displayed on a TV monitor for analysis, with the face of the CRT covered with a plastic overlay on which the operators (both trained and untrained) marked the tracks of the targets. In both detection-time and detect-and-track tests, all operators were significantly more efficient when the time-compressed format was used. Table 1 and figures 4 and 5 show the comparative performances.

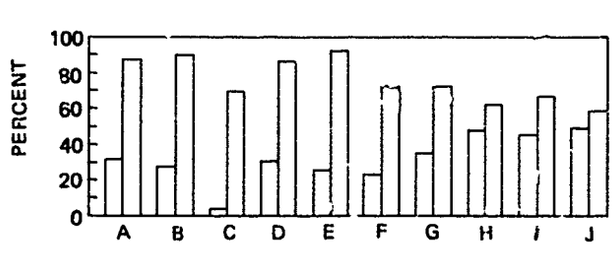
TABLE 1. DETECT-AND-TRACK TEST RESULTS

Subject†	Radar A PPI*		Radar A Time Compressed*		Radar B PPI**		Radar B Time Compressed**	
	Detect, percent	Track, percent	Detect, percent	Track, percent	Detect, percent	Track, percent	Detect, percent	Track percent
A	47	73	71	88	46	31	92	89
B	47	58	77	89	39	28	85	90
C	47	32	65	74	8	3	85	70
D	41	60	65	88	39	30	93	87
E	47	51	76	84	39	25	92	92
F	35	62	65	79	31	22	69	72
G	35	60	77	88	46	35	93	71
H	35	58	59	83	39	48	62	61
I	41	46	47	81	62	45	85	67
J	35	54	47	76	62	49	77	59
Average	41	55	62	83	41	32	83	76

*Short-range, surface search
**Medium-range, air-search
†A-G untrained operators; H, I, J, trained operators

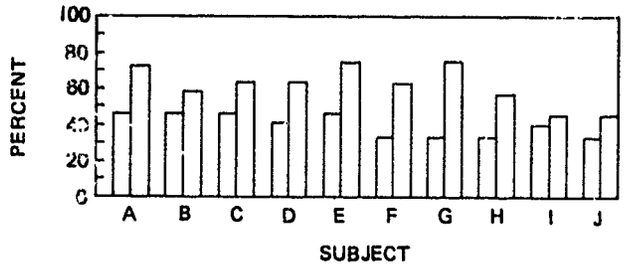


A. AIR TARGETS DETECTED ON RADAR. FIRST BAR INDICATES STANDARD PPI RADAR, AND SECOND IS TIME-COMPRESSED RADAR.

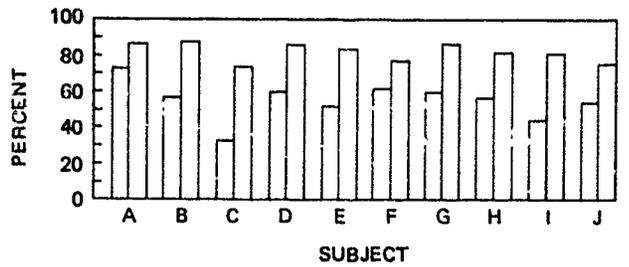


B. AIR TARGETS TRACKED ON RADAR. FIRST BAR INDICATES STANDARD PPI RADAR, AND SECOND IS TIME-COMPRESSED RADAR.

Figure 4. Detect-and-track results, short-range, surface-search radar



A. AIR TARGETS DETECTED ON RADAR. FIRST BAR INDICATES STANDARD PPI RADAR, AND SECOND IS TIME-COMPRESSED RADAR.



B. AIR TARGETS TRACKED ON RADAR. FIRST BAR INDICATES STANDARD PPI RADAR, AND SECOND IS TIME-COMPRESSED RADAR.

Figure 5. Detect-and-track results, medium-range, air-search radar.

SUMMARY

The electronic recording process represents an important advance in the application of time-compression techniques to the display of sensor images. Study on the process is continuing. Feasibility has been established for development of economical sensor-image processor/display systems in which analog images may be stored, processed, and accessed for real-time display in a manner analogous to the processing of digital words in a computer.

IN-HOUSE PUBLICATIONS

Chandler, G. F. and Harris, L. G., *Exploratory Development of a Real-Time, Time-Compressed Processor and Display System*, Naval Electronics Laboratory Center TR 1710, CONFIDENTIAL, 26 May 1970

ZFXX-212-001
(NELC Z214)

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APPLICATION OF SIGNAL PROCESSING THEORY TO NAVAL COMMUNICATION

B. LOW DETECTABILITY*

R. A. Dillard

Mathematical methods of determining interceptor detection probabilities were developed for several types of detection systems which employ energy detection. The procedures are adaptable to a variety of types of secure communications involving large time-bandwidth product signals in white gaussian noise.

Of the varying degrees of security requirements that can be imposed on a communication system, the requirement of low detectability is the most stringent. If an adversary is unable even to detect the existence of a radio transmission, he is certainly unable to learn from the radiation the location or character of the emitter or to determine the message content. By employing low-detectability communication systems, mobile units can reduce the chance of being observed by the enemy. Low detectability is especially important to subsurface Fleet strategic weapons. Low-detectability communications can be used to prevent the adversary from measuring traffic patterns of Fleet tactical communication nets to learn of attack preparations.

The probability of detection by a hostile interceptor can be reduced by spreading the radiated energy over a greater time-bandwidth area. For example, a communicator can distribute the signal energy in time and frequency in a way prearranged with the intended receiver. The intended receiver uses his "key" to extract and reassemble the signal. His processing gain is then sufficient for determining the message content. An interceptor, however, knows neither the signal structure nor the signal positions in time and frequency, and he utilizes energy detection methods to determine the presence of a transmission. The amount of noise energy that the interceptor has to integrate increases with the time-bandwidth area over which the transmission is spread.

The designer of a secure communication system meeting low-detectability criteria must be able to estimate interceptor detection probabilities for a variety of candidate signal structures and parameters and for different levels of intercept system complexity. During FY 1970, mathematical methods of determining interceptor detection probabilities were developed for several types of detection systems which employ energy detection. The analysis and computational procedures developed are adaptable to a variety of types of secure communications involving large time-bandwidth product signals in white gaussian noise. With simple parameter changes, the formulas are applicable for detection cases involving varying degrees of interceptor knowledge about the signals (knowledge of position in frequency and time, bandwidth, duration, number of transmitted pulses, etc.). Rules were found and graphical procedures developed for comparing systems which energy-detect individual pulses with systems which energy-integrate over entire transmissions. Special attention was given to the various types of false-alarm rate definitions appropriate in different detection situations.

Several of the detection procedures studied apply in particular to transmissions consisting of a number of distinct (and similar) parts. Each part could be a spread-spectrum pulse, a group of pulses, or any type of large time-bandwidth product signal. (For convenience, the individual parts are referred to as pulses.) Of major interest were

*Subtask A of this problem, "Feedback Communication," is covered under "Signal and Information Processing," page 48.

intercept strategies for detecting a transmission consisting of a number of frequency-hopped, time-dodged pulses.

One such detection system investigated is as follows. The interceptor knows that the pulses will lie within a particular band of frequencies and covers that band with a number of bandpass filters, each filter followed by an energy detector and a thresholder. The filter bandwidth and the detector integration-time are matched to the dimensions of the pulses. At the end of each integration interval, the output of each thresholder is a "1" or a "0," corresponding to a pulse-present decision or a noise-only decision. If, at any decision time, one or more filter-detector units has a pulse-present decision, the input to a binary moving-window detector is a "1." The window length corresponds to the transmission time or message duration. Effectively, then, the system integrates individual pulse decisions over the message duration. The moving-window detector alarms if its output reaches a specified threshold.

For this binary moving-window system, formulas for false-alarm rate and detection probability were found. These were programmed to examine relationships between false-alarm rate, detection probability, signal strength, optimum moving-window threshold value, number of pulses, etc.

Procedures were derived for calculating detection probabilities for interceptors employing conventional frequency scanning and energy detection against large time-bandwidth product pulses. The assumption was made that the energy of each pulse is spread uniformly over its time-bandwidth area and that the interceptor's receiver has a rectangular shaped i-f passband. The analysis is applicable mainly to situations where the interceptor's signal-to-noise ratio is so small that he has to sweep over a large portion of a pulse in order to have an acceptable probability of energy-detecting it. Two different models of message structure were considered, and thus two different sets of formulas for computing message-detection probabilities were developed, one set for each model. One model assumes that the pulses are equally spaced in time and are all centered at the same frequency. The other model assumes that the pulses occur randomly in frequency and time.

An NELC Research and Development Report covering the above material is almost complete. The report will also include many graphs relating detection probability, time-bandwidth area of integration, required signal energy, and false-alarm rate, for a large number of parameter values.

ZFXX-212-001
(NELC Z222)

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ELF AND VLF PROPAGATION ENVIRONMENT (COMMUNICATION SUPPORT)

A. LOWER IONOSPHERIC PHYSICS*

W. F. Moler

Improved forecasts of vlf broadcast coverage for operational fleet commanders and for emergency communication system design are achieved through numerical modeling of earth/ionosphere waveguide.

BACKGROUND

The Navy has an enormous investment in the vlf radio Fleet Broadcast communication system and the Omega navigation system. Other vlf and elf systems are being developed to provide emergency communications to the FBM submarines in the event of nuclear warfare. Accurate forecasts of broadcast coverage are needed for operational fleet commanders and for determining emergency network design parameters.

Precise numerical methods have been developed which are capable of providing the needed coverage forecasts. The computer codes require the height distribution of electron density and electron collision frequency within the D-region of the ionosphere. Unfortunately the D-region is the least understood region of the atmosphere.

The rocket sounding and hf radio ionosonde systems, which provide good measures of the ionization above 100-km altitude, are ineffective in the D-region because of the relatively low electron density and high neutral particle density. Improvements in knowledge of the D-region structure, and subsequent improvements in vlf broadcast coverage forecasts, require new methods for probing the lower ionosphere.

In FY 1968 a technique was conceived for obtaining the needed D-region ionization profiles from vlf reflection data measured with the NELC sounder at Sentinel, Arizona. The sounder consists of a broadband horizontal dipole transmitting antenna, a phase-stable, multiple-frequency transmitter operated in a pulsed mode, and a number of phase and amplitude sensing receivers located near the transmitter. The measurables are elements of the reflection coefficient matrix for waves once-reflected from the ionosphere for each transmitted radio frequency.

The central idea of the technique is the assumption that there exists a unique pair of electron-density and electron-collision-frequency profiles which yield calculated reflection matrices (using full wave methods of computation) which approach agreement with the ground-based measurements. The measure of agreement is the rms value for the differences between computed matrix elements and the corresponding measurements. The best-fit profile is found when the rms value approaches zero. The profile search uses function-minimization techniques. It has been automated by expressing the electron-density profile in parametric form; thus the rms deviation is a function of a discrete set of parameters. The parameters describing the profile are systematically adjusted until the rms deviation has reached some minimal preset value.

PROGRESS DURING FY 70

In earlier work, several parametric forms for the electron-density profiles have been tried including fifth-order polynomials, exponentials, and combinations of parabolic and exponential segments.

*Subtask B of this problem, "Elf Electromagnetic Wave Propagation Research," is covered under "Electromagnetic Propagation and Environment Studies," page 19.

The most useful form has been found to be a series of exponential segments in which the logs of the electron densities at the heights where the segments join are the unknown coefficients to be found. Figure 1 is an example of a profile consisting of exponential segments which best fits nighttime reflection data acquired at 13.2, 21.6, and 33.5 kHz by the NELC sounder.

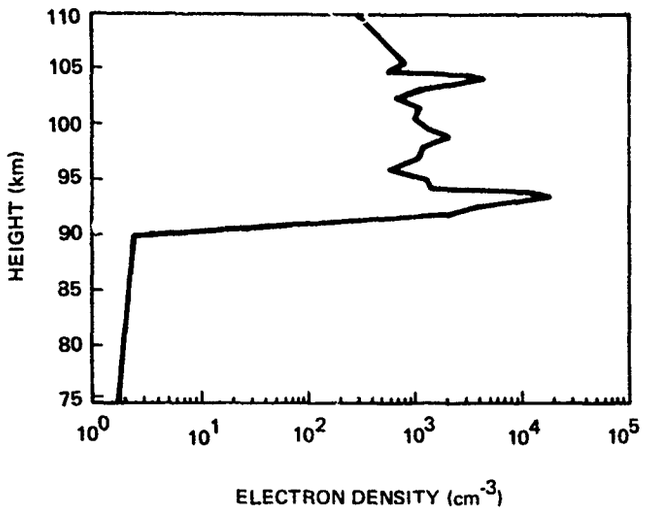

Figure 1. Best-fit electron-density distribution for data taken 16 September 1969, 2223 MST. $|_{\perp}R_{\parallel}/_{\perp}R_{\perp}|$, $_{\perp}\phi_{\parallel} - {}_{\perp}\phi_{\perp}$, and $|_{\perp}R_{\perp}|$ at 13.2, 21.6, and 33.5 kHz.

Until recently the set of predictors did not include the absolute phase of the normal wave reflection coefficient. Although the general shape of the profiles appeared physically plausible it was recognized that the absolute heights of the profiles could be in error. The feasibility of measuring this component was determined by a theoretical analysis of the transmitting antenna radiation characteristics and verified experimentally. With the inclusion of this element the height resolution has been greatly improved.

The most important addition to the computational procedure is an optional routine which determines the error limits of the electron-density or collision-frequency profiles from the standard errors in the sounder data introduced by noise or by calibration uncertainties. The error limits take the form of error bands about the derived curve.

The error bands are defined such that if the form of the real electron-density distribution were approximated by a series of exponential segments, that approximation to the real ionosphere should be within the error band with the same probability that the reflection parameters are within their respective standard error limits.

The error analysis is useful in determining the regions of the ionosphere which are most important for controlling the vlf reflection characteristics. If more resolution is called for than can be determined from the data, the error band widens. Thus the regions where the error band is narrow are the regions where the ionospheric control is greatest. For example, the error bands in figure 2 would indicate that all significant ionospheric effects are confined below 70 km and that the data contained little information about the ionosphere above 70 km.

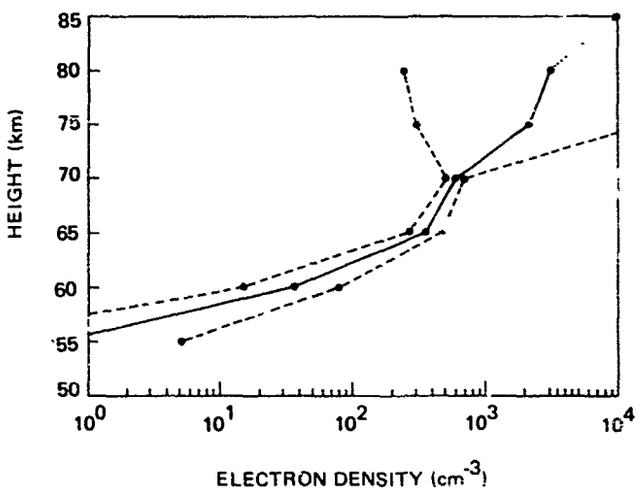

Figure 2. Best-fit electron-density distirbution and error band for data taken 30 January 1968, 1330 MST, 15 minutes after commencement of solar flare. Data at 8.3, 17.3, and 33.5 kHz.

In the error analysis, each of the measured elements of the reflection matrices has a standard error assigned. If a large sample of reflection data (e.g., portions of a diurnal cycle by season) is obtained, each element will have an average value and some measured standard deviation from the mean.

The electron-density and collision-frequency profiles derived will then be for the average values and the error limits will define the standard deviation of the profiles. This approach will save a tremendous amount of computer time over the usual methods. Normally one would be forced to calculate a large number of electron density profiles, at a large cost in computer time, and then perform statistics on the profiles. With this approach the statistics may be performed on the raw data and only one profile calculation need be made. For example, the electron-density profile in figure 1 shows a large spike-like maximum near the 92-km level. A large sample of nightime data will be analyzed to determine if this is a persistent feature and, if so, the limits of its variability in height and intensity. These data should make it possible to predict the variability of phase and amplitude of vlf transmissions over long propagation paths at night.

PUBLICATIONS

Scientific Journals

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In-house Publications

Sheddy, C. H., *Determination of Electron Density Distributions From VLF/LF Reflection Data.* Naval Electronics Laboratory Center Report 1639, 7 August 1969

Shellman, C. H., *Absolute Phase, $\perp \phi \perp$, of the Normally Reflected Skywave Radiated From a Horizontal Dipole at VLF,* Naval Electronics Laboratory Center Technical Note 1627, 16 February 1970

Shellman, C. H., *Determination of Error Limits on Electron-Density Distributions Derived From VLF/LF Sounder Data,* Naval Electronics Laboratory Center Report 1676, 12 December 1969

Shellman, C. H., *Least-Squares Method For Evaluating the First and Second Derivatives of a Function in N-Dimensional Space,* Naval Electronics Laboratory Center Technical Note 1636, 10 March 1970

ZR-011-01 01
(NELC Z135)

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RELATIONSHIP OF PROGRAMS TO NAVY NEEDS

Investigations of	Increase our Basic Understanding of	Which Leads to Improvements in
ELECTROMAGNETIC PROPAGATION AND ENVIRONMENT STUDIES (p. 12, 19, 37)		
Vlf propagation; electron-density distribution in the ionosphere	Formation and maintenance of the ionosphere; radio propagation predictions	Communication and navigation in normal and nuclear environments
Elf propagation	Prediction of propagation of extra-low-frequency electromagnetic waves	Communication with submarines
Microwave satellite-to-earth propagation	Limitations on millimeter wave communications due to environmental effects on propagation	Satellite communication systems
MATHEMATICS AND APPLICATIONS (p. 21, 39, 41)		
Research in numerical analysis and symbol manipulation	Realistic estimates of errors introduced by computers and numerical determinations of derivatives by computers	Effective and efficient applications of computers to engineering problems
Mathematical programming for optimization	Formulation and solution of problems involving feedback control under constraints	Quicker and better solutions of problems in engineering design and in allocation of resources
Distribution-free procedures for reliability analysis	Actual failure rates without assumption of an exponential failure distribution	Reliability and failure prediction
Walsh functions	Digital analysis and design	Communications and computing equipment
MAN-MACHINE EFFECTIVENESS (p. 22)		
Visually evoked cortical potentials	Information-handling characteristics of man under conditions of stress and vigilance	Improved model of human operator and improved use of men in military environment
OPTICAL TECHNOLOGY AND APPLICATIONS (p. 24,26,27,42,44,45,47)		
Holographic techniques and optical analog processing	Complex filtering, information storage, and display techniques	Communications, surveillance, and electronic warfare systems

Investigations of	Increase our Basic Understanding of	Which Leads to Improvements in
Nonaqueous chemistry of inorganic solutions for lasers	Stable, nontoxic, noncorrosive solutions for recirculating liquid lasers	Improved pulse illuminators for laser surveillance and ranging systems
Growing thin films of CdSe, CdS, and $CdSe_xS_{1-x}$; multilayer coatings	Thin-film lasers and laser amplifiers	Small-volume laser amplifiers and preamplifiers for electro-optical circuit elements, enhanced mirrors and optical systems
Refractive index of amplifying media in far infrared lasers	Sources of stable monochromatic radiation	Far infrared communications
Two-photon absorption in alkali halides	Color center production in the body of a crystal	Three-dimensional display devices; increased capacity computer storage elements
Spectra of dyes	Fluorescence and triplet-triplet absorption	Dye lasers which are continuously tunable for secure communication and surveillance
Infrared measurements of naval ships	Infrared emission by ships	Infrared countermeasures
MATERIALS RESEARCH AND DEVELOPMENT (p. 29, 30, 32, 34)		
Photoemission of electrons from solids	The band structure of solids	Microelectronic materials and devices
Optical absorption in heavily doped semiconductors	Photoelectronic characteristics and free carrier effects	Electroluminescent diodes
Excitation, absorption, and fluorescence spectra of rare earth-doped compounds	Quantum electronic materials	Lasers, quantum detectors, and display devices
Synthesis and growth of intermetallic semiconducting alloy films	Intermetallic semiconducting compound films	Gunn effect and LSA oscillators, solid-state lasers, and fast infrared detectors
MICROELECTRONICS TECHNOLOGY AND APPLICATIONS (p. 49)		
Defects in microelectronic circuits	Causes of failure of microelectronic devices and means of eliminating them	Reliability of microelectronic devices

Investigations of	Increase our Basic Understanding of	Which Leads to Improvements in
SIGNAL AND INFORMATION PROCESSING (p. 5, 10, 48)		
Electronic time compression	Image storage and retrieval in real time	Target detection and tracking
Communications signal processing	Information representation, transfer, recovery, and interference effects	Error control, spectrum utilization, and resistance to interference

SUMMARIES OF INDEPENDENT RESEARCH PROJECTS

ELECTROMAGNETIC PROPAGATION AND ENVIRONMENT STUDIES

ELF AND VLF PROPAGATION ENVIRONMENT (COMMUNICATION SUPPORT)

B. EXTREMELY-LOW-FREQUENCY ELECTROMAGNETIC WAVE PROPAGATION RESEARCH*

H. G. Hughes

The extremely-low-frequency (elf, 30 Hz - 3 kHz) band of radio waves is of particular interest to the Navy because the associated electromagnetic fields penetrate seawater to appreciable depths and can be received by submerged vehicles. Because of the long radio wavelengths it would be extremely expensive to build structures to radiate elf waves effectively. Consequently, researchers investigating elf propagation characteristics must depend on naturally occurring lightning flashes as sources of elf waves.

To evaluate the potential of elf for future Navy communication systems it is necessary to know how the elf attenuation depends on such factors as ionospheric structure, and the bearing of the propagation path relative to the geomagnetic field. To study the propagation of elf waves, NELC has employed a technique which utilizes the simultaneous recording of the vertical and horizontal electric-field components of elf atmospherics at two widely separated stations. The vertical electric fields are measured using a vertical monopole antenna 5 meters long. The horizontal electric fields are measured by amplification of the voltage developed by the wave between two metal rods (earth-probes) driven into the ground and separated by 150 meters. A line of bearing to the source of the disturbance is derived from a comparison of measurements obtained from two orthogonal sets of earth-probes and the vertical monopole. The waveform's source location can then be determined by its bearing relative to each station. Using the source distance from each station and the ratio of the spectral amplitudes of the vertical electric field received at each station, the wave-attenuation rate can be determined. The two-station recording technique, however, is limited to the fixing of sources that lie off a great-circle path through the two stations. If the propagation parameters are different along the two paths, apparent attenuation rates are obtained.

During October 1969, simultaneous recordings of the vertical and horizontal electric-field components of elf atmospherics were made at two widely separated stations. The source area was far from the great circle through the two stations, one of which was located on the Island of Hawaii and the other near Sentinel, Arizona.

*Subtask A of this problem is covered under "Highlights of FY 1970", page 12.

From several day and night waveforms recorded simultaneously at both stations, the differences between the day and night apparent attenuation rates were determined. The measurements showed the day apparent attenuation rate to be greater than for night by 1.5 dB/Mm at 50 Hz and 2.3 dB/Mm at 300 Hz.

Paralleling the analysis of the experimental data, theoretical investigations of elf propagation under realistic ionospheres was carried out by means of the NELC waveguide program for the full-wave solution of elf propagation in arbitrary waveguides. The theoretical calculations failed to show a significant path dependence on either the day or night attenuation rates for frequencies below 100 Hz, and they showed the night attenuation rates to be the greater for all magnetic-field dip angles. It must be concluded from the experimental measurements that the diurnal variation in the wave-attenuation rate may depend on the propagation paths and cannot be explained by accepted models of ionospheric conductivity.

PUBLICATIONS

Scientific Journals

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NELC Z135b

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METHODS FOR NAVAL EQUIPMENT AND SYSTEM RELIABILITY ANALYSIS AND PREDICTION

R. A. Shorack

Current reliability theory relies to a large degree on imperfect and unrealistic assumptions about the statistical nature of the systems and components involved. To investigate the development of methods which would utilize and develop distribution-free procedures for reliability analysis, and which would provide meaningful estimates or bounds on actual failure rates or system degradation using data obtained by accelerated testing, a focusing study was conducted during FY 1970. Distribution-free procedures derive their name from the property that they remain valid regardless of the probability distribution the underlying variables follow.

The focusing study was completed. Contact with reliability work in industry disclosed a strongly specific-task orientation. A "comparative" testing procedure similar in format to MIL STD 781B, without the assumption of an exponential failure distribution, was investigated and a class of such procedures was devised.

When the principal investigator returns from duty in Viet Nam, results of the work on comparative test programs will be submitted for publication.

NELC Z154

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BIOELECTRIC TECHNIQUES FOR SCREENING AND SURVEILLANCE OF MILITARY PERSONNEL

C. T. White

In the immediate future, the main application of the results of the studies of visually evoked cortical responses will be in the medical and paramedical fields; but since such fields play such an important role in the overall military picture, it is rather artificial to differentiate too strictly.

The work on sensory inputs could be utilized in the large-scale screening of applicants or recruits by relatively untrained personnel, thus saving the trained optometrist, ophthalmologist, or audiologist for more important tasks. Since the techniques in question do not depend upon the verbal responses of the person being tested, it is obvious that malingerers could be identified. This could be of value both in the testing of recruits and in the testing of men claiming service-connected sensory impairment.

The other aspect of the problem, dealing with telemetered indicants of the physiological and psychological state of an individual, has direct potential for military use. It would give a person in charge of certain individuals in critical positions an indication of those individuals' state of readiness to perform critical tasks or make decisions. Other applications of a classified nature could also be discussed in this regard.

A major part of the work this year was a continuing concern with binocular interaction effects. A paper was published on the relationship between such effects and the quality of the visual image presented to the two eyes. The promising results of this work led to further studies in which images differing in quality (focus or sharpness) were presented to the two eyes. These studies were carried out in an effort to get a better understanding of the processes involved when a person's eyes are markedly different in their visual characteristics (such as in *amblyopia*). Preliminary studies were also carried out on the effect that attending to a stimulus presented to one eye has on the brain's response to visual patterns presented to the other eye.

Another group of workers has reported that the stimulation of the upper and the lower visual fields results in markedly different response patterns. Our group carried out a parametric study in which a series of checkerboard patterns consisting of various sizes of checks were presented to the upper, lower, and central visual fields. The earlier findings were verified, and in addition it was found that the upper and lower visual fields reacted differentially to the size of the checks used – the lower field giving the greatest responses to relatively large patterns, while the upper field appears to be more sensitive to smaller patterns. These findings suggest that there are as yet unsuspected functional differences between the upper and lower visual fields which need to be investigated.

During this period I have continued to serve as a consultant to other groups who have decided to use our techniques for their own purposes. Of special interest is the work going on in the San Francisco area, under the general direction of the Brain-Behavior Research Group at Sonoma State Hospital. Their main interest is concerned with the development of visual perception processes in normal and abnormal infants and children. At the present time laboratories have been set up at Sonoma, San Francisco Children's Hospital, and at the Kaiser Foundation Hospital. The last named alone plans to test at least 3,600 infants a year for both research and diagnostic purposes.

PUBLICATIONS

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OPTICAL PROCESSING OF SIGNALS FOR MILITARY INFORMATION TRANSFER

A. HOLOGRAPHY

J. F. Bryant

Development has continued on the holographic subtraction technique, which allows the comparison of old and new reconnaissance data to detect changes that might have occurred in the time intervening between them.

The initial study was based on the image hologram. Recent work has been extended to include the two other kinds – the Fresnel and the Fourier-transform holograms. Each method invokes the principles of interferometry but different arrangements of the optical components are involved. In the image case, a projection lens is used to image the input transparency onto the film plane; in the Fresnel case, the film plane is in the near field of the coherently illuminated input transparency and no lens need be used; and in the Fourier-transform case, the film plane is in the focal plane of the projecting lens. During exposure, a coherent reference beam oblique to the input beam is used to create the hologram, and during reconstruction, the reference beam illuminates the hologram to recall the stored information.

The image hologram system is the best to use because the interference between a uniphase image and an oblique collimated reference beam results in straight-line hologram fringes. Degradations caused by temperature change, emulsion shrinkage, and stress relieving, etc., can be compensated for by a slight adjustment of the reference beam angle.

The Fresnel hologram has an advantage over the others in that artifacts in the hologram plane do not degrade the output imagery. There is, however, an undesirable limitation in that the information content of the system does not use the full space-bandwidth product of the recording film.

The Fourier-transform case has the disadvantage that its dynamic range cannot be linearly recorded by the photographic film. Recording the low-frequency information linearly results in underexposure and consequent loss of higher-spatial-frequency information.

Other work areas investigated by this group include searching for ways to apply optical data-processing techniques to high-resolution radar signal analysis, theoretical and experimental study of motion-degraded images, theoretical and experimental analysis of lens systems for optical data processing, and development of digital computer programs to perform fast Fourier-transform analysis for optical signal-processing systems.

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NELC Z136a

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OPTICAL PROCESSING OF SIGNALS FOR MILITARY INFORMATION TRANSFER

B. OPTICAL COMPUTER STORAGE DEVICE

M. Geller

Three-dimensional writing with an optical beam was first demonstrated at NELC in 1967, when F-centers were produced in alkali halides by a pulsed N_2 laser. The technique not only has practical applications in high-density binary storage, but could have important ramifications in the field of solid-state physics. The mechanism of the formation of crystal defects in solids by intense optical radiation is extremely important. One type of such defect, an F-center, is normally produced by ultraviolet radiation, X-rays, or other means. The process has been studied since the 1920's and extensive work has been done, but there is still a considerable lack of understanding of the exact nature of the photochemical reactions involved. Two-photon absorption offers another technique of examining this problem. The nonlinear experiments which have been conducted at NELC may shed valuable insight into the photochemistry and photophysics of interaction of high-intensity radiation with matter.

A theoretical analysis based on experimental results was made of the feasibility of obtaining an electro-optical, high-density computer storage element. Since color centers can be produced in alkali halide crystals by two-photon absorption, a colored spot can be produced anywhere in the crystal by a sharply focused ultraviolet beam. This provides a means of storing binary information, which can be read by measuring the interaction of a focused beam (of another wavelength) with the color centers. A storage capacity of 5×10^{10} bits/cm^3 and reading and writing rates of 40 MHz are estimated for KBr. This analysis has been documented and the report submitted for publication.

PUBLICATIONS

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NELC Z136b

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FAR INFRARED LASER FOR NAVAL SURVEILLANCE AND COMMUNICATION SYSTEMS

W. Schade

Advances in optical communications technology will make increasing demands for detectors having wide spectral bandwidth and fast response in coherent receivers. Evaluation of heterodyne detectors requires sources of stable or controllable monochromatic electromagnetic radiation such as that from lasers. Since the oscillation frequency and amplitude of a laser depend on the index of refraction of the amplifying medium in the optical resonator, knowledge of this dependence is necessary for evaluating the signal and noise components of heterodyne detectors.

Studies during FY 1970 were directed to development of a technique for making accurate measurements of resonant wavelengths within the amplifying media of far infrared lasers in the spectral range of 10 to 400 μm. Such measurements may be used to compute the refractive indices of the amplifying media at the resonant wavelengths.

Two resonant wavelengths of the H_2O laser at 27.9 μm and 78.4 μm were measured to a precision of $1/10^6$ with a Michelson interferometer for calibrating the change in length of a scanning optical resonator. These preliminary measurements indicated the role of electrons in the water-vapor discharge because the index of refraction was less than unity. Modifications in the technique for scanning the optical resonator have improved the *accuracy* of the measurements to about $1/10^6$. These improvements make it possible to analyze the dependence of the resonant wavelength on the electron density in the laser discharge.

During the first quarter of FY 1970, a Michelson interferometer was assembled and installed on the tunable far infrared gas laser which was constructed during the preceding year. Preliminary scanning of the interferometer indicated the need for a more stable source of monochromatic radiation to calibrate the change of length of the far infrared optical resonator. The problem was solved by installing a Spectra-Physics Model 119 He-Ne laser which has a long-term instability of ± 75 MHz/day from the center of the Ne^{20} emission band at 6328Å. A patent disclosure of this laser interferometer for measuring optical properties of amplifying media was made.

The passive instabilities of the far infrared laser and the calibration interferometer were examined to determine the background variations in optical paths which would cause experimental errors. The far infrared laser and calibration interferometer were operated simultaneously and continuously in a free-running mode at a fixed resonator length. The H_2O laser transition at 78.4 μm changed by $\pm 10^{-6}$/hr and the calibration interferogram changed by $(\lambda_c/4)hr^{-1}$, where λ_c is the calibration wavelength. These instabilities indicated the required improvements for more accurate measurements.

The first precise measurements of resonant wavelengths in a laser were made on the 78.4 μm and 27.9 μm transitions of H_2O. Reported vacuum wavelengths for these transitions were used to compute the index of refraction, $n = \lambda_o/\lambda_r$, where λ_o is the wavelength in vacuum and λ_r is the resonant wavelength in the laser discharge. The results indicate that $n \sim 0.999$ which is consistent with the electron density of the H_2O discharge.

Higher accuracy can be achieved with the improvements that were made during the last quarter. The optical resonator is scanned through several hundred longitudinal modes in about one minute while the calibration interferogram is recorded with an electronic counter. This technique reduces the experimental errors caused by optical instabilities to about $1/10^6$. Measurements using the recent modifications are in process.

PUBLICATIONS

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NELC Z157

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MICROELECTRONICS TECHNIQUES FOR MILITARY APPLICATIONS

C. R. Zeisse

There is certain to be an increased need for microelectronic devices in Naval communication systems. A creative response to this need requires not only the application of existing microelectronic techniques, but also research in the physics of solid-state devices. Work on this problem has therefore been concentrated on developing a photoemission apparatus for studying the band structure, surface properties, and charge transport in various metals, semiconductors, and solid-state devices. Preliminary work on the band structure of tungsten metal is in progress for the purpose of testing the apparatus. When these measurements are completed the apparatus will be used to investigate some of the following mechanisms: radiation damage and charge transport in metal-oxide-semiconductor (MOS) devices, integrated circuit failure due to electromigration, and sodium ion contamination of integrated circuit devices. This research can also have an impact on other areas of interest to the Navy, such as the development of very efficient infrared detectors to be used to increase night vision.

During FY 1970, preliminary results on the 5d electron structure of tungsten were obtained and presented in November at a National Bureau of Standards Symposium.

With the intention of improving these data, the apparatus was experimented with and a number of changes were made to reduce the amount of spurious current caused by scattered light, increase the total signal-to-noise ratio, and improve the accuracy of the measurements.

The improved apparatus was then used to obtain final data on tungsten. These investigations were supported by X-ray work on the samples and by a computer study on the effect of instrumental broadening.

PUBLICATIONS

Scientific Journals

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NELC Z145

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SPECTRAL RADIOMETRIC STUDIES OF PHOTOELECTRONIC SOLIDS CHARACTERISTICS FOR DEVICES WITH APPLICATION IN NAVAL SURVEILLANCE AND COMMUNICATION SYSTEMS

D. L. Stierwalt

The design and development of both passive and active optical components for military and defense applications require a detailed knowledge of the optical properties of the materials under a wide variety of conditions. To increase the knowledge and understanding of these optical properties, a continuing program of study of materials being used or showing promise of potential application in the infrared region of the spectrum has been conducted.

As part of this program, several lines of investigation were pursued during the past fiscal year: The optical constants of a partially transparent sample can be determined from measurements of spectral emittance and of emittance plus transmittance, by a method developed here. This year the method was expanded to enable us to calculate the optical constants of a thin film on a transparent substrate. This technique was applied to several samples of gallium antimonide grown epitaxially on gallium arsenide. The effect of plasmon-phonon coupling was studied in a series of bulk gallium antimonide samples having a range of carrier concentrations. Similar measurements were made on a series of lead-tin telluride films. These films exhibited a large shift of the plasma frequency with temperature.

The study of the spectral emittance of potentially useful optical materials was continued. A new program was initiated for measuring the infrared spectral transmittance of solids at cryogenic temperatures. These measurements are made down to transmittance values as low as 10^{-6}.

Cryogenic optical materials play a critical role in extra-low-photon detecting systems. ARPA has indicated a support level of 50K for precise measurements of infrared properties of windows and filters at very low temperatures.

The electronic band structures of several semiconductors were investigated by determining the spectral characteristics of the optical constants. A joint program with NWC China Lake was carried out for investigating amorphous germanium films. Details of the electronic density of states were determined by means of the pseudo-Brewster angle technique. These details were related to the state (or its lack) of crystallinity. The electronic states of the low-band gap semiconductor SnTe are being examined by the same technique as a function of specimen stoichiometry.

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NELC Z156

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QUANTUM ELECTRONIC MATERIALS FOR DEVICE APPLICATIONS IN NAVAL SURVEILLANCE AND COMMUNICATION SYSTEMS

H. H. Caspers

The application of quantum electronic materials and methods to detectors, lasers, frequency converters, optical communications systems, and display devices has been accelerating in recent years. The present program has been devoted to solid-state optical materials which have found applications for lasers and narrowband quantum counter detectors. The purpose of the program has been to examine in great detail those physical properties which characterize the special optical utility of the materials.

During the past fiscal year, the spectral properties of Ho^{3+} doped into single crystals of LaF_3 have been examined. The electronic energy level structure has been deduced out to 50,000 cm^{-1} from absorption and fluorescence experiments. The analysis has permitted calculation of empirical wave functions in intermediate coupling which should prove useful as a basis for more extensive calculations concerning fluorescence lifetimes, quantum efficiencies, line strengths, and the like.

In addition to the foregoing, a major problem is that of increasing the 'pumping" power so as to increase the fluorescence output. In the case of rare-earth optical materials, the 5d configuration serves as one of the ultraviolet pumping bands. The program has sought to shed some light on the structure of these 5d levels and their interactions with the 4f energy levels. The simplest case is that of Ce^{3+}; during the past year, instrumentation was developed to examine these levels in detail in the range 1400 to 3000Å. Films of pure CeF_3 and single crystals of LaF_3 doped with Ce^{3+} have been studied to obtain the location of the levels, and intensities of the $4f \rightarrow 5d$ transitions. Cerium has been extensively used as a sensitizer in many important phosphors and this work could possibly reveal the critical parameters involved.

Ions in crystals are not isolated, but interact with the host lattice. The degree of this interaction and its mechanism significantly modifies the optical properties. The present program has had to direct some attention to this question. Since the interaction is principally through the phonons, the lattice vibrations of laser-host crystals have been examined by Raman scattering experiments and infrared-emittance measurements. These measurements permit the deduction of the frequencies and symmetries of the phonons. The degree of interaction of the lattice with the electronic properties of the ions may be indicated by the appearance of vibrational-electronic (vibronic) lines in the optical spectra, reduced fluorescence, or effective energy transfer between electronic levels of ions.

A study of the infrared and Raman active phonons of $LiYF_4$ has been completed. This is a new optical material which has been shown to be a good host for the Nd^{3+} 1.06μ laser. Moreover, doped with Er^{3+}, the material is an excellent quantum counter detector.[1,2,3]

Work was initiated on Pr^{3+} doped into $LiYF_4$. Still in progress, this work will strive to obtain the energy levels fluorescence and excitation spectrum, and to derive the crystalline electric field effective at the site of the doped ion.

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NELC Z158

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INTERMETALLIC SEMICONDUCTING COMPOUND FILMS FOR DEVICE APPLICATION IN NAVAL SURVEILLANCE AND COMMUNICATION SYSTEMS

H. H. Wieder

The three intermetallic semiconducting compounds, indium antimonide, indium arsenide, and gallium arsenide, are of importance in a wide range of active and passive electromagnetic energy sensors, mechanical and acoustic transducers which include Hall generators, magnetoresistors, photoconductive and photovoltaic infrared detectors, acoustoelectric and praetersonic devices and transferred electron (Gunn effect and limited space charge accumulation (LSA)) oscillators. A NELC program of research and development is aimed at improving the technology of synthesis and growth of the intermetallic semiconducting alloys, InSb (indium antimonide) and InAs (indium arsenide), in the form of thin films, 0.1 to 20 μm in thickness. Work in progress is concerned with the characterization of such films by means of electrical and optical measurements for the purpose of determining their type, density, distribution, homogeneity, and galvanomagnetic and thermal transport properties as well as the electron and hole lifetimes, recombinations, and trapping rates.

During FY 1970, work on electron-beam zone crystallized film has continued with emphasis on electron-hole plasma oscillations generated in high electric fields above and below the threshold for impact ionization. Depending on the direction and magnitude of a steady, transverse magnetic field applied to a film, the current through it exhibits, above a threshold electric field, either a large increase with field or a very small value and a negligible change due to a difference in the electron-hole recombination rates on different film surfaces. This work will be continued and expanded to include coherent plasma oscillations in InSb and in epitaxial InAs films.

Infrared polarizers, for the 8-14 μm range, are needed for the construction of nonreciprocal optical analogs of microwave Faraday rotators, circulators, and phase shifters. Work on two-phase, semiconductor-semimetal (InSb + Sb) films carried out during the past year has led to the development of an infrared polarizer with lower absorption characteristics at lower cost than bulk materials. (See Davis *et al.*, below, and Authorized Invention Disclosure #50,225, p. 59). At present there is only one other polarizer available for this wavelength range.

PUBLICATIONS

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SUMMARIES OF INDEPENDENT EXPLORATORY DEVELOPMENT PROJECTS

ELECTROMAGNETIC PROPAGATION AND ENVIRONMENT STUDIES

SATELLITE COMMUNICATION MEASUREMENTS OF MILLIMETER WAVES

F. M. Tirpak

Investigations have continued to determine the possible usefulness to the Navy of a millimeter wave satellite under various weather conditions, using the existing NASA ATS-5 satellite. During FY 1970 the 60-foot parabolic dish antenna at the Microwave Space Research Facility, La Posta, was calibrated for gain and beamwidth at 15.3 GHz. The NASA millimeter wave receiver was then installed and used to record signals from the ATS-5 at 15.3 GHz.

Between October 1969 and June 1970 a total of 105 hours of data were recorded. An unusually dry winter limited the usefulness of the test results; measured rainfall rates of 6 or 7 hundredths of an inch per hour caused about 2 dB of attenuation in the 15.3-GHz signal. However, attenuation of this order was measured during cloudy weather when no rain was falling in the immediate area of the receiving antenna. It is difficult to draw firm conclusions about the feasibility and/or desirability of implementing a K_u-band SATCOM system without definitive experimental results on the effects of rain on electromagnetic propagation. Further experimentation appears warranted, to permit formulation of valid conclusions on such effects. At least one year's data should be collected and analyzed so that all seasons are taken into account.

Various computer programs for controlling the antenna and for tracking satellites were modified and improved, and recorded in Technical Notes. Technical Notes covering the antenna pointing accuracy and antenna gain were also completed and a TN on the ATS-5 millimeter wave data is forthcoming.

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In-house Publications

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ZFXX-212-001
(NELC Z308)

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MATHEMATICS OF COMPUTATION FOR NAVAL APPLICATIONS

B. F. Witte and J. C. Pigniolo

In the computation processes essential to scientific investigations at NELC, the most powerful mathematical procedures should be available. The large-scale digital machines involved in such computations must be used as efficiently as possible, or time and cost factors may become prohibitive. Toward that end, the program is directed at advancing computation methods in both numerical analysis and non-numeric techniques and at upgrading the utilization of large computers in many of the scientific programs of the Center. Two tasks are involved: (1) to develop solutions of realistic nonlinear systems of algebraic or differential equations with emphasis on the reliability and accuracy of the computed numerical results and their error estimates; and (2) to develop means for extending the scientist's access to the computing machine and for increasing the amount of meaningful, preevaluated information returned to him after machine processing.

Under Task 1, an error analysis of the triangular decomposition of matrices was nearly completed for application to linear systems of equations, and was incorporated into NELC's computer library. For single nonlinear equations, an efficient method was developed. For systems of simultaneous nonlinear equations many methods require low-order derivatives of analytically given functions. Derivatives of functions are also required in a variety of other contexts. The main effort during FY 1970 was directed toward the development of a method for evaluating derivatives. It resulted in a powerful algorithm which employs finite-difference approximations in combination with higher-order extrapolations to a zero difference. The algorithm was tested in over ten thousand cases involving derivatives of orders one through ten; it performed exceptionally well in regard to obtainable accuracy, sharpness and reliability of error estimates, and computer cost economy. No other finite-difference algorithm is known capable of matching its performance.

Associated with the above described development of numerical differentiation procedures was some work leading to analytic differentiation formulas for the probability density function and for the set of functions $x^t e^{i/x}$, $x^t \cos(1/x)$, $x^t \sin(1/x)$. These resulted in recurrence relations with simultaneous recursions on t and on the order of the

derivatives. Their stability against cancellation of significant digits was found excellent.

Less directly related to the specific problem of numerical differentiation was an effort which resulted in a proposal to create for NELC and other DOD laboratories a comprehensive mathematical problem-solving capability. All persons currently engaged in scientific computing are expected to benefit from the proposed question-and-answer type of interaction on standard computer terminals.

Work on Task 2 has been devoted to developing advanced computer software which will permit engineers to study complex circuits and system networks using algebraic models. The software capable of manipulating algebraic matrices was completed for the CDC-1604 computer.

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APPLICATION OF DESIGN AND OPTIMIZATION ALGORITHMS TO NAVY DESIGN PROBLEMS

D. C. McCall

The main objective of this effort is to provide analysis and synthesis of real-world Navy design problems either where no synthesis techniques exist or where the design problem has unique specifications. Additional goals which support this objective are: (1) to develop an in-house capability for handling mathematical optimization problems, (2) to develop techniques for expressing engineering design problems in a form suitable for the application of mathematical optimization methods, and (3) to spread the information acquired throughout the Center so that the practicing engineer may be able to use these methods.

An optimum design for a tunable bandpass filter was obtained using mathematical programming (MP) techniques. Existing methods for solving this type of design problem did not allow realizability constraints to be included in the problem. The advantages in using MP techniques are: (1) a realizable design can be guaranteed by the design equations at the outset, and (2) one is assured of obtaining the "best" possible design.

MP methods were used to obtain a straightforward method for solving a two-point boundary-value problem (TPBVP) which occurs frequently in engineering applications, typically control engineering and trajectory optimization. The TPBVP was first cast as a mathematical optimization problem, then solved using direct search methods.

Also, an experimental antenna-matching device was built from a design obtained by MP concepts. The device was fabricated out of pieces of inexpensive coaxial cable the lengths of which were chosen by an iterative optimization scheme.

The concepts and algorithms of iterative optimization were continuously reviewed and investigated for possible application to Navy engineering design problems. Those methods found pertinent were tested on a variety of problems, documented, and made available to the scientific community.

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EXPLORATORY DEVELOPMENT OF THIN-FILM AND LIQUID-LASER DEVICES FOR NAVAL APPLICATIONS

A. LIQUID LASERS

E. J. Schimitschek

Present and future plans in the Navy call for surveillance systems which will allow identification of objects at a distance of several miles under very low light-level conditions (TDP's 36-60 and 36-41). Systems of this sort require active illumination sources which can provide very high-intensity light pulses of short duration and repetition rates of up to 30 pulses per second. The liquid-laser program at NELC is concerned with the investigation of liquid media to be applied as laser sources in such surveillance systems.

Liquid laser solutions of the type Nd^{3+}: $POCl_3$/$ZrCl_4$ were further improved and their properties measured. Values were determined for fluorescence decay times, quantum efficiency, cross section for stimulated emission, dynamic scattering losses, viscosity and index change with temperature. The following table lists some of the data measured on a 0.2 m Nd^{3+}, 0.4 m $ZrCl_4$ solution:

Decay time	300 μsec
Quantum efficiency	49%
Linewidth, Δf	$3.8 \times 10^{12} sec^{-1}$
Cross section	$\sim 10^{-19} cm^2$
Dynamic loss, α	~0.3%
Viscosity, η	2.676 cp
Index change, dn/dt	$\sim 6 \times 10^{-4}/°C$

Using this liquid solution, a liquid laser unit was built capable of delivering several pulses per second at a peak power (Q-switched) of about 5 megawatts. The liquid was constantly recirculated through the laser cell and an external nickel heat exchanger during operation. In a closed moisture-free system, there was no deterioration of the laser liquid whatsoever. The practicability of such a liquid laser system was thus successfully proved. Building advanced models with high flow speed cells for faster pulsing seems to be a relatively straightforward problem, although some careful engineering is required (circulating pump, flow pattern, and so on). This part of the project is now actively pursued under the LLL Electro-optical Surveillance Program (Sponsor NAVSHIPS 065).

Based on our original work at NELC, the liquid laser solution is now commercially available from Sylvania Metallurgical Division.

As a side product of the work with liquid laser, a new preparation method for Nd $(O_2PCl_2)_3$ and Nd $(O_2PBr_2)_3$ was discovered. That method seems to be applicable to other rare-earth metals beside neodymium and might find some interest in chemical research.

Infrared-, absorption-, fluorescence-, and excitation-spectra were taken of the solid neodymium phosphorusdichloridates, suggesting their molecular structure to be a coordination polymer consisting of eight-membered rings.

PUBLICATIONS

Scientific Journals

Schimitschek, E. J., Trias, J. A. and Liang, C. Y., "I. R. and Raman Spectra of Europium (III) β-Diketonates," *Journal of Inorganic and Nuclear Chemistry*, 32, 811-831, March 1970

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EXPLORATORY DEVELOPMENT OF THIN-FILM AND LIQUID-LASER DEVICES FOR NAVAL APPLICATIONS

B. THIN-FILM LASERS

V. N. Smiley

Thin-film laser work at NELC during the past year has not only advanced the state of the art in laser development, but has contributed to a newly emerging technological area. This new area is optical electronics, in which electrons are replaced by photons, information is carried on modulated light beams, and circuit elements are optical devices including signal sources, amplifiers, modulators, gates, and directional couplers.

A major accomplishment during FY 1970 was the thermal tuning of cadmium selenide (CdSe) thin-film lasers over a range greater than 200 Å at a central wavelength of 5950 Å. A detailed experimental study was made of the mode-hopping and tuning effects of the same lasers. Experimental measurements of near- and far-field laser emission were carried out.

In the continuing effort to improve semiconductor layer materials, a method was developed for growing platelets in a flowing vapor-transport system by adding a unique step-shaded substrate. In addition, a study was directed at finding a satisfactory way of growing crystal laser films of large area and of controllable thickness and configuration. Experiments were made on recrystallized CdSe films deposited in vacuum; fluorescence was successfully attained from some samples.

A thorough study was made of all reported work relating to the mechanisms for laser action in platelet lasers. Knowledge in this area is important to understand the problems in achieving efficient operation at room temperature. Preliminary calculations of a new mechanism for producing stimulated emission in II-VI compound lasers based on an exciton molecule have been carried out.

A diffusion experiment was started and will lead to large-area, thin-film lasers and optical circuit elements. In this experiment, sulfur (S) was diffused into cadmium selenide (CdSe) platelets forming mixed crystals of $CdSe_xS_{1-x}$. This technique is useful for producing lasers of desired operating frequency and for making miniature optical waveguides. Mixed crystals with various percentages of S have also been successfully grown using a vapor transport system.

An analysis was made of a two-cavity laser interferometer. In particular, its application as a hydrophone or microphone was investigated. Such a device would be extremely sensitive.

PUBLICATIONS

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ZFXX-512-001
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EXPLORATORY DEVELOPMENT OF THIN-FILM AND LIQUID-LASER DEVICES FOR NAVAL APPLICATIONS

C. LIQUID-DYE LASERS

T. G. Pavlopoulos

Dye lasers are a special class of liquid lasers and share the advantage of high repetition rate and high power output with the parent category. A major advantage of dye lasers is that they are continuously tunable over a wide wavelength range. This property opens up heretofore unavailable possibilities in target identification (and other surveillance areas) by applying reflectance spectroscopy. The dye laser shares with other lasers capabilities in secure communication and ranging.

The ground state S_0 and each higher excited electronic state of organic compounds (dyes) consist of a superposition of many vibrational levels. This gives rise to their broad absorption and emission (fluorescence spectra). Laser emission results from the stimulated transition from the lowest vibrational level of the S_1 band into one of the vibrational levels of the ground state S_0 The concentration of dye molecules in the excited singlet state S_1 must reach a certain value (critical inversion) before coherent emission will be produced. The magnitude of the critical inversion depends upon losses in the complete laser system. From the excited singlet state, the molecule can relax nonradiatively to the lowest triplet state T_1 (intersystem crossing). This relaxation route competes with the fluorescence in the deactivation of S_1 and presents the main source of losses in the dye laser system for the following reasons: The lifetime for decay of the triplet state to the ground state ($T_1 \rightarrow S_0$) is about 10^{-3} sec, but the fluorescence lifetime is 10^{-9} sec. Therefore, owing to the relatively long life time, the triplet state acts as a trap for the excited molecule in the S_1 state and quickly depletes the supply of molecules available for the laser process. Transitions from the lowest T_1 state to higher ones are spin-allowed (T-T absorption) and therefore strong. Unfortunately, this absorption very often overlaps with the singlet-state fluorescence spectrum, and consequently the accumulation of molecules in the T_1 state may produce a large loss at the wavelengths for which laser emission is most probable. T-T absorption may be strong enough to quench or even prevent laser action. Further, molecules excited into higher triplet levels are highly reactive chemically (photodecomposition).

To minimize the detrimental effects of the triplet state and improve the gain of dye lasers, a very sensitive spectroscopic arrangement has been built which allows one to measure even very weak T-T absorption spectra of dyes. The system employs a high-pressure mercury-arc lamp of very high brightness to produce a high concentration of triplet molecules in a very small area. Noise is reduced with the aid of a lock-in amplifier. This experimental setup will be useful for:

1. Dye selection. It would be advantageous to use as a lasing material a dye which has a window in its T-T absorption spectrum for its own fluorescence.
2. Reducing photodecomposition of the dye, by filtering out portions of the flash-lamp spectrum which coincide with strong T-T absorption bands.
3. Selection of quenchers for the triplet state. Molecules in the triplet state can be efficiently deactivated to the ground state S_0 by the presence of quenchers. One promising way uses the intermolecular $T_A \rightarrow T_B$ excitation transfer effect (sensitized phosphorescence).

Molecule A in proximity to molecule B may transfer its excitation energy to B in a radiationless mode. If molecule B contains heavy atoms, the transition $T_1 \rightarrow S_0$ in B is very fast. Experimentally, one focuses on a strong T-T absorption band of molecule A (the dye) and adds the quencher B. If the result is a considerable reduction of the intensity of the T-T absorption band, a usable quencher has been found.

All parts for a dye laser setup, such as power supply, capacitors, and flash lamps, have been ordered. A laser head is under construction.

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(NELC Z212c)

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INFRARED RADIATIONS FROM NAVAL SHIPS AND HYDROFOIL PATROL GUNBOATS

R. A. Eastley

Low-angle quantitative and qualitative harbor investigations were conducted during FY 68-69, to determine the infrared radiations from all areas of various types of naval vessels. Diurnal studies of ship signatures relative to water and sky backgrounds were also conducted.

In addition, during FY 69 an infrared noncontact radiometric temperature survey was made of the Navy's advanced surface craft, patrol gunboat hydrofoils PGH 1 and PGH 2, while they were operating off the coast of southern California. These measurements were supplemented by qualitative real-time pictures obtained from an infrared scanner.

During FY 70, comparative investigations of the hydrofoils were conducted. Real-time infrared pictures of the craft were obtained from the beam, bow, and stern aspects while they operated in formation. High-radiance areas were identified and compared between the craft.

A final report was prepared presenting the quantitative findings of the ship signature study and the information contained in the Technical Notes of the hydrofoil investigations.

The infrared measurements performed in this program have direct application to the NRL ship model program. The hydrofoil measurements are being used by DEPCOMOPTEVFORPAC to provide comparative IR radiation data for operational evaluation. This information will aid in defining mission applications and future designs.

Further operational evaluation work has been stimulated by this effort. A trials plan for signature studies of a new vessel undergoing test by OPTEVFOR is tentatively scheduled for FY 71.

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ZFXX-112-001
(NELC Z221)

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SIGNAL AND INFORMATION PROCESSING

APPLICATION OF SIGNAL PROCESSING THEORY TO NAVAL COMMUNICATION

A. FEEDBACK COMMUNICATION*

C. Nuese

Two classes of feedback communication - symmetric and unsymmetric – have been considered. Particular attention has been given to the use of binary error detection and correction codes. The constraints and restrictions inherent in the use of feedback have been examined, with emphasis on Navy needs.

Symmetric feedback communication involves two stations, each transmitting messages or other traffic along a communication link to the other. The links in each direction are essentially identical, and the amounts of traffic passed in each direction approximately equal. Economy in error control can be achieved by using signals along one link to request as much additional redundancy as is needed in the other link to confidently determine the message or other traffic received. Signals along one link can also be used to control the mode of operation on the other link in response to changing conditions.

Unsymmetric feedback communication involves one station which must transmit over a limited link to a second station, which can transmit much more easily back to the first station over a second link. An example is that of an aircraft or satellite with limited power transmitting to a ship or ground station, or that of a reconnaissance craft or vehicle which must transmit back the information it has gathered, but which wishes to minimize the likelihood of hostile interception. In either case the limited station can transmit a marginal signal, and the unlimited station can use essentially noiseless feedback to confirm its reception or to request additional signal. This case is particularly amenable to the techniques of sequential detection.

During FY 1970, algebraic and convolutional codes which can serve to detect errors at the receiver and to determine the need for repetition or additional redundancy have been examined. Some attention has been given to channels in which the noise statistics are not stationary, and in which errors tend to occur in bursts. The problem of identifying both feedback signals and the responses they are intended to produce has been examined. Study of the work of other investigators has continued.

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*Subtask B of this problem is covered under "Highlights of FY1970," page 10.

ZFXX-212-001 (NELC Z222a)

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MICROELECTRONICS EFFECTIVENESS

D. W. McQuitty

The objective of the NELC microelectronics effectiveness program is to assure that devices which are now in the design phases will meet the Naval requirement for reliability, interchangeability, producibility, and serviceability.

Since the program was started, late in FY 1970, techniques have been perfected for determining the cause of failure of plastic and ceramic encapsulated integrated circuits. X-ray equipment for failure analysis has been selected and purchased. The equipment has been calibrated and is being used as the first step in the analysis of failed microcircuits. One hundred microcircuits, which failed electrical tests, have been subjected to X-ray analysis. Both plastic and ceramic packaged circuits were used. Whenever any deviant or questionable indications were observed, a photographic enlargement was made of the X-ray. Procedures were developed to remove the encapsulant to confirm or clarify the physical nature of the defect. Extraneous encapsulated materials, such as parts of the gold preform, were the most common form of defects found in the ceramic packaged circuits. Obviously, this could cause a potential short under vibration conditions. Failures in plastic packaged integrated circuits were found to be caused by defective thermocompression bonds and metallization failure. This study is still in progress and when it is completed, recommendations will be made to improve the effectiveness of microcircuits for use in Naval systems and a technical note will be prepared. In addition the X-ray system's versatility permitted it to be applied to a wide range of other electronic components. One example: By use of X-ray, defects were found in a high-contact-density relay. These defects could not have been detected by any other nondestructive method.

Approval was secured for lease of a scanning electron microscope which is being used for analysis of microcircuit failure. During the course of its installation, which was completed on 26 June 1970, the microscope was successful in determining the cause of two microcircuit failures that could not be determined with more conventional equipment. Work will continue during this year in the application of scanning electron microscopy to microelectronics effectiveness. Results will be reported in a technical note.

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Gabriel, C. J., "The Error in Faraday Rotation Measurements With Mirrors," p. 31-41 in Naval Weapons Center, China Lake TP 4868, *Foundation Research Projects; Final Report, October 1969 – March 1970*, May 1970

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Monahan, M. A., *Coherent Optical Processing of Motion-Degraded Images*, Naval Electronics Laboratory Center TR 1720, 26 August 1970

Monahan, M. A., Bromley, K., and Bryant, J. F. *Use of Holographic Subtraction in the Optical Processing of Reconnaissance Data*, Naval Electronics Laboratory Center Report 1665, 23 October 1969

Sheddy, C. H., *Determination of Electron Density Distributions from VLF/LF Reflection Data*, Naval Electronics Laboratory Center Report 1639, 7 August 1969

Shellman, C. H., *Determination of Error Limits on Electron-Density Distributions Derived From VLF/LF Sounder Data*, Naval Electronics Laboratory Center Report 1676, 12 December 1969

Shellman, C. H., *Least-Squares Method For Evaluating the First and Second Derivatives of a Function in N-Dimensional Space*, Naval Electronics Laboratory Center Technical Note 1636, 10 March 1970

Shellman, C. H., *Absolute Phase, $\perp \phi \perp$, of the Normally Reflected Skywave Radiated From a Horizontal Dipole at VLF*, Naval Electronics Laboratory Center Technical Note 1627, 16 February 1970

Spehn, R. W. and Schade, W. J., "Far Infrared Laser: A General Graphical Analysis of Wavelength and Gain as Functions of Optical Length in Gas Laser Resonators," p. 7-17 in Naval Weapons Center, Corona TP 899, *Foundational Research Projects; Quarterly Report July – September 1969*, December 1969

Voss, P. and Ortwein, N., *The La Posta Microwave Space Research Facility Installation*, Naval Electronics Laboratory Center TR 1716, 8 July 1970

INDEPENDENT EXPLORATORY DEVELOPMENT

Chandler, G. F. and Harris, L. G., *Exploratory Development of a Real-Time, Time-Compressed Processor and Display System (U)*, Naval Electronics Laboratory Center TR 1710, CONFIDENTIAL, 26 May 1970

Dejka, W. J., *Direct-Search Methods For The Solution of the Two-Point Boundary Value Problem (TPBVP)*, Naval Electronics Laboratory Center Technical Document 82, 30 January 1970

Dejka, W. J. and McCall, D. C., *Study in the Design of a Practical Tunable Bandpass Filter Using Mathematical Programming*, Naval Electronics Laboratory Center Technical Note 1641, 4 March 1970

Dillard, R. A., *Detection Probabilities For Frequency-Scanning Interceptors Vulnerability of a Secure Communication System Which Uses Spread-Spectrum Pulses*, Naval Electronics Laboratory Center Technical Note 1515, 30 July 1969

Eastley, R. A. and Putnam, W. H., *Infrared Radiation Investigation of the Hydrofoil Patrol Gunboats FLAGSTAFF, PGH 1 and TUCUMCARI, PGH 2*, Naval Electronics Laboratory Center Technical Note 1527, SECRET, 21 August 1969

Eastley, R. A. and Putnam, W. H., *Infrared Radiations From Naval Ships and Hydrofoil Patrol Gunboats (U)*, Naval Electronics Laboratory Center TR 1704, SECRET, 8 July 1970

Huston, T. O., *Large Screen Laser Display Study*, Naval Electronics Laboratory Center TR (in publication)

Kohne, J., *Digital Resolver Test Programs*, Naval Electronics Laboratory Center Technical Note 1585, 13 November 1969

Kohne, J. F., *Computer Algorithm For Solving Exponentials*, Naval Electronics Laboratory Center Technical Note 1613, 23 January 1970

Kohne, J. F., *Satellite Prediction Programs*, Naval Electronics Laboratory Center Technical Note 1681, 18 June 1970

Kohne, J. F., *A Quick Fourier Transform Algorithm*, Naval Electronics Laboratory Center TR 1723, 2 July 1970

McCall, D. C. and Ogata, C. T., *Two Direct Search Methods of Mathematical Programming*, Naval Electronics Laboratory Center Technical Note 1628, 26 January 1970

Niemi, R. O., *Input, Output and Utility Programs For the La Posta Microwave Space Research Facility*, Naval Electronics Laboratory Center Technical Note 1653, 21 April 1970

Niemi, R. O., *Peripheral Utility Package For Use on the DDP-24 Digital Computer*, Naval Electronics Laboratory Center Technical Note 1674, 11 June 1970

Niemi, R. O., *Drive Displays Diagnostic Program For Use on the DDP-24 Digital Computer/Interface*, Naval Electronics Laboratory Center Technical Note 1675, 11 June 1970

Niemi, R. O., *Update Program For the La Posta Microwave Space Research Facility*, Naval Electronics Laboratory Center Technical Note 1680, 18 June 1970

Niemi, R. O., *Real-Time Monitor and Command Generation Program For the La Posta Microwave Research Facility*, Naval Electronics Laboratory Center Technical Note 1703, 7 July 1970

Nuese, C., *Feedback Communication*, Naval Electronics Laboratory Center Technical Note 1516, 30 July 1969

Paulson, M. R., *La Posta Antenna Alignment and Calibration*, Naval Electronics Laboratory Center Technical Note 1642, 26 March 1970

Paulson, M. R., *Discussion of Near-Field Gain Measurements For Large Parabolic Dish Antennas With the Results of Antenna Gain and Pattern Measurements Made on the La Posta 60-Foot Antenna*, Naval Electronics Laboratory Center Technical Note 1664, 8 May 1970

Paulson, M. R., *ATS-5 Millimeter Wave Propagation Experiment Data Report For La Posta*, Naval Electronics Laboratory Center Technical Note 1707, 10 July 1970

Pigniolo, J. C., *POLYNELIAC: A Syntactic and Semantic Description*, Naval Electronics Laboratory Center Technical Note 1580, 27 October 1969

Taylor, H. F., *Physics of Stimulated Emission in II-VI Semiconducting Compounds*, Naval Electronics Laboratory Center TR 1713, 3 June 1970

PATENT ACTIVITY DURING FY 1970

PATENTS

M. Geller and D. E. Altman	Patent No.
Transmission Line Gas Laser. Describes a new design of a gas laser tube and its power supply which results in high peak power and short optical pulses. It may be used as a source of blue-green laser pulses for underwater communication, viewing, and antisubmarine surveillance systems.	3,458,830 (NC 42,644) Issued 29 July 1969

D. E. Altman and M. Geller	Patent No.
Laser Energy Pump which Employs an Extension of a Coaxial Transmission Line. Describes a method of exciting a liquid laser by radiation from electrically pumped gas in a coaxial flash tube. It may be used in communication or surveillance systems.	3,470,493 (NC 44,102) Issued 30 September 1969

CLAIMS ALLOWED, PENDING ISSUE

E. J. Schimitschek, E. R. Schumacher and R. B. Nehrich, Jr.	Patent Application Serial No.
Adjustable Recirculating Liquid Lens Laser Cell. A recirculating system for liquid lasers to maintain both the liquid lens material and the laser material at the same temperature. This system improves the performance of the liquid laser for building future laser devices.	656,628 (NC 43,895)

E. J. Schimitschek and E. R. Schumacher	Patent Application Serial No.
Liquid Lens Liquid Laser Cell. A liquid lens material of a selected index of refraction surrounds a capillary filled with the lasing material for improved energy transfer. A more efficient energy transfer to the lasing material by the selected liquid lens material will lead toward building better laser devices for the Navy.	656,631 (NC 42,976)

A. R. Clawson and H. H. Wieder	Patent Application Serial No.
Ohmic Low Resistance Contact to Gallium Arsenide. A simple, direct technique for producing complex shapes of low-resistance contact which are useful for microwave oscillators as well as field-effect transistors. Low resistance ohmic contacts to gallium arsenide are imperative for implementing vhf and microwave oscillators.	771,222 (NC 47,938)

J. F. Bryant and W. T. Hyde	Patent Application Serial No.
Character Identification System. An optical system for identifying characters, symbols, and alphanumerics. The system allows the serial reading of alphanumeric characters and symbols for input to computer logic editing and translation of foreign text material.	774,737 (NC 43,817)

AUTHORIZED INVENTION DISCLOSURES

E. R. Schumacher	Navy Case No.
Laser Stimulator (External). A tubular light source, closely coupled to an elliptical reflector working in conjunction with two spherical retroreflectors and two plane reflectors for the purpose of reflecting as much energy as possible into a laser cavity, externally connected to the cavity for greater laser output power. It is significant to the Navy's effort in finding ways to make more efficient laser devices.	49,219

D. C. Arrington, R. L. Bates, J. D. Merriam, W. L. Eisenman, and D. L. Stierwalt	Navy Case No.
Black Submillimeter Radiation Detector. This invention provides a sensitive spectral reference detector to establish spectral response performance criteria for the infrared detector industry. It has been approved for Navy use and provides the capability for a standard that has not heretofore been available.	50,224

A. R. Clawson, N. M. Davis, H. H. Wieder, and D. A. Collins	Navy Case No.
Lamellar Eutectic InSb+Sb Films as Infrared Polarizers. A process for making polarizers using eutectic indium antimonide-antimony films for the infrared portion of the spectrum, particularly for the atmospheric window of 8-14 μm. It can be used for both digital and analog information processing for CO_2 lasers, high-frequency phase modulators, rotators, and circulators.	50,225

V. N. Smiley	Navy Case No.
Laser Interferometer Acoustic Sensor. A two-cavity laser interferometer which is extremely sensitive to acoustic signals. It makes possible a very sensitive hydrophone for sonar or passive listening and an ultrasensitive microphone for intelligence gathering.	50,980

PATENT APPLICATIONS FILED

V. N. Smiley	Patent Application Serial No.
Wide-Range Continuously Tunable Thin-Film Laser. A thin-layer laser of mixed crystal composition with a gradient in composition along one direction in the plane of the layer so that varying the position of the pump energy varies the frequency over a range of 1000 Å. It will be valuable as a tunable, multichannel source for short-range optical communication systems.	842,914 (NC 47,273)

	Patent Application Serial No.
Method of Producing a Thin-Film Laser. A method of producing a laser material by depositing recrystallized material on an unoriented substrate. It is a more practicable method for producing thin-film lasers because thickness and lateral dimensions can be accurately controlled.	842,916 (NC 49,107)
Continuously Tunable Thin-Film Laser Employing the Electric Field Effect. A thin-film laser with attached electrodes	842,915 (NC 47,243)

V. N. Smiley (Contd.)	Patent Application Serial No.
which can be tuned through 50 to 100 Å by applying a low voltage to the electrodes. It will provide a moderate-power, tunable source for communication or surveillance.	
Thin-Film Active Interference Filter. An optical filter with amplification (gain). It will be useful for enhancing detectivity and for eliminating background in optical surveillance and communication systems.	842,917 (NC 50,200)
Thin-Film Laser. A device consisting of a thin film or layer of active material, often with an auxiliary coating, such that laser action is produced perpendicular to the plane of the layer. It will be valuable as a moderate-power, coherent radiation source and amplifier for communication, surveillance, display, and underwater photography.	842,938 (NC 47,272)
Narrow Band Tunable Laser Oscillator Amplifier. A variable-gap Fabry-Perot thin-film laser which can be tuned through approximately 50 angstroms. It will be a moderate-power, tunable source for communication or surveillance.	843,939 (NC 47,057)

M. Geller, D. E. Altman, T. A. DeTemple, and H. F. Tayler	Patent Application Serial No.
High Density Binary Storage System. A laser beam produces distinct, colored spots inside a transparent crystal resulting in a high-capacity computer storage element. A fast, random-access, high-density storage element is needed for many Navy computers.	858,693 (NC 46,171)
H. H. Wieder	
Two-Layer Magnetoresistors. A method of increasing the change in resistance with magnetic field by more than a factor of two over presently available devices. Such magnetoresistors are used in linear and angular displacement sensors.	865,708 (NC 49,169)
D. E. Altman and M. Geller	
Selectively Controllable Radiant Energy Device. A magnetic field is used to selectively control the output wavelengths from a gas discharge. This technique has potential applications for obtaining higher efficiencies from lasers.	873,323 (NC 46,517)

N. M. Davis and A. R. Clawson	Patent Application Serial No.
Controlled Nucleation in Zone Recrystallized InSb Films. Improvement in the technique of electron-beam recrystallization of InSb films allows processing of more homogeneous and higher quality films. High quality (crystallographic and electrical) films of InSb make possible the construction of more reliable and cheaper infrared detectors.	885,923 (NC 49,351)

K. Bromley, J. F. Bryant, and M. A. Monahan	Patent Application Serial No.
A Complex Spatial Filtering Technique Employing Holographic Subtraction. A real-time holographic process (complex spatial filtering) for observing directly the difference between a reference and an input coherent light waveform. It allows the direct observation of differences between surveillance photographs taken of a given area at different times.	17,550 (NC 50,024)

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"ARDS AND HONORS, FY 1970

INVITED PRESENTATIONS AT PROFESSIONAL MEETINGS

CLAWSON, A. R.

"Preparation and Properties of InSb Films," University of Southern California, Los Angeles, California, June 1969

DAVIS, N. M.

"Electron Beam Microzone Crystallization of InSb Films," Conference on Crystal Growth, Washington, D.C., 13 August 1969

HOOD, JOHN M., JR.

"Phase Imaging," Meeting of San Diego Section, Optical Society of America, San Diego, California, 17 June 1970

POTTER, R. F.

"Optical Constants of Opaque Semiconductors," Thin Film Symposium, American Vacuum Society National Symposium, Seattle, Washington, 1969

SCHADE, W.

"Precise Measurement of Resonant Wavelengths in Far Infrared Gas Lasers," Seminar on Quantum Electronics, School of Engineering, University of California, Irvine, California

SCHIMITSCHEK, E. J.

"Liquid Lasers," Meeting of San Diego Chapter, American Optical Society, San Diego, California, 22 April 1970

"Properties of Liquid Laser Solution," Meeting of Sylvania Electro-Optics Group, Mountain View, California, 17 December 1969

STIERWALT, D. L. ZAESCHMAR, G., AND NEDOLUHA, A.

"Optical Constants of Semiconductor Thin Films from Combined Infrared Emittance and Transmittance Measurements," Meeting of American Vacuum Society, Anaheim, California, 15 June 1970

WHITE, C. T.

"Evoked Cortical Responses and Vision":

World Congress of Oto-Rhino-Laryngology, Mexico City, August 1969 (tutorial lecture)

Annual Meeting of Alumni of U.C. Berkeley School of Optometry, U.C. Irvine Campus, October 1969

Joint Psychology Department/Division of Optics Colloquium, University of Arizona, Tucson, Arizona, November 1969

Psychology Colloquium, University of Connecticut, Storrs, Connecticut, December 1969

Psychology Colloquium, Rockefeller University, New York City, December 1969

Psychology Colloquium, University of Illinois, Urbana, Illinois, December 1969

Panel member on Symposium on Computer Applications, Winter Prain Research Meeting, Aspen, Colorado, January 1970

Convocation address, Chapman College, Orange, California, October 1969

All-Campus Seminar, University of California at San Diego, La Jolla, California, April 1970

WHITE, C. T. (Continued)

"Cortical Responses Evoked by Visual Patterns," Lecture demonstration, International Congress of Electroencephalography, San Diego, California, September 1969

"Binocular Summation in the Evoked Potential as a Function of Image Quality," Annual Meeting of American Academy of Optometry, Philadelphia, Pennsylvania, December 1969

"Time-Compression of Radar Displays," Institute of Aviation Seminar, University of Illinois, Urbana, Illinois, December 1969

WIEDER, H. H.

"Transport Properties of InSb Films," David Sarnoff RCA Research Laboratories, Princeton, New Jersey, July 1969

CONTRIBUTED PRESENTATIONS AT PROFESSIONAL MEETINGS

BROMLEY, K.

"Vibration Measurement by Holographic and Conventional Interferometry," Instrument Society of America Symposium, Houston, Texas, 27-30 October 1969

BROMLEY, K. and MONAHAN, M. A.

"Vibration Measurement by Holographic and Conventional Interferometry," Fifth IMEKO (International Measurement Confederation) Congress, Versailles, France, 25-30 May 1970 (read by title)

CASPERS, H. H., RAST, H. E., and FRY, J. L.

"Optical Absorption and Fluorescence Spectrum of Ho^{3+} and LaF_3," Meeting of American Physical Society, Dallas, Texas, 1970

EASTLEY, R. A.

"Low-Angle Investigation of Infrared Radiations from Naval Ships," Fifteenth Annual Electronic Warfare Planning Conference, Eglin Air Force Base, Florida, 3 December 1969

HOOD, J. M., JR.

"A Recursive Method and Notation for Phase Grating Diffraction Analysis," Holography and Computer Conference, Houston, Texas, 10-12 December 1969

MILLER, S. A., RAST, H. E., and CASPERS, H. H.

"Raman Spectroscopic Study of Ferroelectric Triglycine Sulfate," Meeting of American Physical Society, Honolulu, Hawaii, September 1969

MONAHAN, M. A., BROMLEY, K., BRYANT, J. F., and THOMPSON, B. J.*

"The Use of Holographic Subtraction in the Optical Processing of Reconnaissance Data," Seventeenth AGARD Avionics Technical Symposium, Tonsberg, Norway, 29 September - 3 October 1969

*Of Institute of Optics, University of Rochester, Rochester, New York

POTTER, R. F., ROCKAR, E., and DONOVAN, T.

"Optical Constants of Amorphous Germanium," Meeting of American Physical Society, Dallas, Texas, March 1970

RAST, H. E., CASPERS, H. H., and MARLIN, H. R.

"Ultraviolet Absorption Spectrum of CeF_3 and LaF_3 (Ce^{3+})," Meeting of American Physical Society, Dallas, Texas, March 1970

SCHIMITSCHEK, E. J.

"Liquid Laser," Photochemistry meeting (ONR sponsored), University of California at Los Angeles, Los Angeles, California, February 1970

SCHIMITSCHEK, E. J. and TRIAS, J. A.

"Performance of a Nd^{3+}: $POCl_3$/ZrCl4 Liquid Laser," Sixth International Quantum Electronics Conference, Kyoto, Japan, 7-10 September 1970

SHELLMAN, C. H.

"Determination of Error Limits on Electron Density and Collision Frequency Distributions Derived from VLF/LF Sounder Data," 1970 Spring URSI Meeting, Washington, D.C., 16-18 April 1970

STIERWALT, D. L.

"Low Temperature Spectral Transmittance of Infrared Optical Materials," Advanced Ballistic Missile Defense Agency Meeting, Huntsville, Alabama, 7 April 1970

PROFESSIONAL HONORS

CASPERS, H. H.

Selected as Chairman of the Western Spectroscopy Association meeting in 1971

CASPERS, H. H., RAST, H. E., and MILLER, S. A.

Awarded Research Society of America (China Lake Chapter) award for best scientific paper of the year 1968 (awarded summer, 1969)

EASTLEY, R. A. and PUTNAM, W. H.

Received letter of "Appreciation for Assistance in Hydrofoil Gunboat Evaluation" from Deputy Commander Operational Test and Evaluation Force, Pacific, 23 September 1969

MILROY, W.

Active member of ODDR&E Advisory Group on Electron Devices

SCHIMITSCHEK, E. J.

Nominated for Arthur E. Fleming Award, 1970; one of 20 semifinalists

SMILEY, V. N.

Requested by Applied Physics Department, University of California at San Diego, to give series of lectures on Quantum Electronics for year 1970-71; asked to serve as advisor for doctoral candidate working on laser project.

WHITE, C. T.

Received San Diego Council on Creativity Award, 1969

Received Man of Distinction Award, Temple Bethel, 1969

INDEPENDENT RESEARCH PROGRAM FOR FY 1971

NELC Problem	Title	Principal Investigator	Autovon	NELC Mail Code	Funding	NARDIS Key
Z135	ELF and VLF Propagation Environment (Communications Support)	W. E. Moler	952-7677	2200	95	DN 848 016
Z136	Optical Processing of Signals for Military Information Transfer	J. F. Bryant	952-6421	2500	60	DN 848 017
Z155	Digital Systems: Walsh Functions, Theory and Applications to Design of Naval Equipment	R. E. Simmons	952-7172	3300	35	New
Z156	Spectral Radiometric Studies of Photo-Electronic Solids Characteristics for Devices with Application in Naval Surveillance and Communication Systems	Dr. D. L. Stierwalt	933-4316	2600	114	DN 848 220
Z157	Far Infrared Laser for Naval Surveillance and Communication Systems	Dr. W. Schade	933-4316	2600	26	New
Z158	Quantum Electronic Materials for Device Applications in Naval Surveillance and Communication Systems	Dr. H. H. Caspers	933-4316	2600	100	New
Z159	Intermetallic Semiconducting Compound Films for Device Application in Naval Surveillance and Communication Systems	H. H. Wieder	952-6877	2600	80	New
Z160	Liquid Dye Lasers for Naval Applications	Dr. M. Geller	952-7920	2500	110	New

INDEPENDENT EXPLORATORY DEVELOPMENT PROGRAM FOR FY 1971

NELC Problem	Title	Principal Investigator	Autovon	NELC Mail Code	ED Task Area	Funding	NARDIS Key
Z222	Application of Signal Processing Theory to Navy Communication	R. A. Dillard	952-7465	3300	ZFXX-212-001	68	DN 948 503
Z223	Application of Design and Optimization Algorithms to Navy Design Problems	D. C. McCall	952-6258	3300	ZFXX-512-001	50	DN 948 504
Z226	Total System Design of a Digital Demodulator	W. J. Dejka	952-6454	4300	ZFXX-512-001	35	New
Z227	Optical Communication Techniques for Naval Applications	W. E. Richards	952-6422	2500	ZFXX-212-001	85	New
Z231	High Speed Correlators Using Surface Wave Electronics	K. J. Kelley	952-6634	2400	ZFXX-512-001	70	New
Z235	Digital Fleet Broadcast	R. U. F. Hopkins	952-7767	2400	ZFXX-212-001	65	New
Z237	Optical Components for Information Transfer	Dr. V. N. Smiley	952-6422	2500	ZFXX-512-001	60	New
Z238	Command Control Display Module Study	F. C. Martin, Jr.	952-6541	3100	ZFXX-212-001	68	New
Z239	Control System Modules	D. W. Doherty	952-6258	3300	ZFXX-512-001	20	New
Z240	Digital Module Coordination	W. J. Dejka	952-6454	4300	ZFXX-512-001	35	New
Z241	New LSI Evaluation	O. H. Lindberg	952-6879	4800	ZFXX-512-001	50	New

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