
Advanced Energy Projects FY 1984 Research Summaries

October 1984



U.S. Department of Energy
Division of Advanced Energy Projects
Office of Basic Energy Sciences
Office of Energy Research

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OFFICE OF BASIC ENERGY SCIENCES

DIVISION OF ADVANCED ENERGY PROJECTS (AEP)

Program Description

What projects are supported?

This Division supports exploratory research on novel concepts related to energy. The research is usually aimed at establishing the scientific feasibility of a concept and, where appropriate, also at estimating its economic viability. Because projects supported inevitably involve a high degree of risk, an indication of a high potential payoff is required. An immediate, specific application of the concept is not an absolute prerequisite for consideration; thus, for example, proposers of schemes leading to the development of x-ray lasers are not required to justify their proposals by discussing potential applications of such lasers.

The concepts supported are typically at too early a stage of scientific verification to qualify for funding by DOE programs responsible for technology development. Where doubt exists, such programs are consulted, prior to proposal consideration by AEP, in order to establish their possible interest in the project.

Projects not supported

The AEP Division does not support ongoing, evolutionary research. Neither does it support large scale demonstration projects.

Period of support

By design the period of support is finite, generally not exceeding three years. It is expected that, following such a period, the concept will either be at a stage where it can be supported by a technologically appropriate organization or branch of DOE, or else it will be dropped.

Funding levels

The size of a contract in FY '84 varied between \$48,000 and \$390,000 per annum.

Who can propose?

Unsolicited proposals can be submitted by universities, industrial organizations, nonprofit research institutions or private individuals. Consideration is also given to ideas submitted by scientists working at national laboratories.

Proposal evaluation

Awards are based on the results of an evaluation process which usually involves a review by external reviewers. Regardless of the outcome of the evaluation, proposers receive copies of reviewers' reports.

Questions asked of the reviewers depend on the subject of the proposal. Some typical questions are listed below:

1. Is the proposed concept new? How does it compare with other work in the field?
2. Are there basic flaws in the scientific (technical) arguments underlying the concept?
3. Are the technological requirements of the proposed concept, including material requirements, within the realm of either present or near term future capabilities?
4. Is there anything about the concept which makes its economics manifestly untenable, even under reasonably optimistic assumptions?
5. Is the anticipated benefit to the public high enough to warrant the Government's involvement in the R&D effort?

Preproposals desired

It is suggested that before a formal proposal is prepared, the proposer should submit a brief outline of the proposed work. The outline should provide enough background information to enable a decision as to whether or not the proposed work programmatically fits the mission of AEP.

Proposals

Once a programmatic interest of AEP in the proposed project has been established, a proposal should be submitted along the guidelines specified in DOE/MA-0095, "Guide for the Submission of Unsolicited Proposals." Each proposal must contain:

- o A cover page, prepared in a format specified in DOE/MA-0095, Appendix B.

- o A 200-300 word abstract, written in plain English, describing the essence of the project in terms understandable to a layman. The abstract should be in a form suitable for inclusion in DOE program presentations.
- o A technical discussion of the proposed concept and a description of the proposed work. While the discussion should be kept brief, there is no formal limitation on the number of pages allotted to this section of the proposal. Since it is this section that will form the basis for the evaluations by technical reviewers, the proposer is urged to make certain that all aspects of the proposed project which are relevant to forming a judgment of the project's merits are adequately covered.
- o A statement of work specifying all tasks to be performed in the course of the proposed work. A sample statement of work can be found on page 31.
- o Description of available facilities.
- o Resumes of key personnel.
- o Detailed information on any support for the proposed or related work, past, present or anticipated, including proposals submitted, or about to be submitted, to other organizations.
- o A cost estimate for the proposed effort.

Further Information

Inquiries should be addressed to:

Dr. Ryszard Gajewski, Director
Division of Advanced Energy Projects
Office of Basic Energy Sciences
ER-16, GTN
Department of Energy
Washington, D.C. 20545

Phone: 301/353-5995

OFFICE OF BASIC ENERGY SCIENCES

DIVISION OF ADVANCED ENERGY PROJECTS

Summaries of Projects Active in FY 1984

This section contains brief summaries of all projects active in this Division during Fiscal Year 1984 (October 1, 1983-September 30, 1984). The intent of this compilation is to provide a convenient means for quickly acquainting an interested reader with the program in Advanced Energy Projects. More detailed information on research activities in a particular project may be obtained by contacting directly the principal investigator shown below the project title. Some projects will have reached the end of their contract periods by the time this book appears, and will therefore no longer be active. Those cases in which work was completed in FY '84 are indicated by the footnote: *Project completed.

1. EXTREME ULTRAVIOLET AND SOFT
X-RAY INSTRUMENTATION FOR
MICROCHARACTERIZATION OF MATERIALS

ALTEX CORPORATION
P.O. Box 10084
Chicago, Illinois 60610-0084

Charles K. Rhodes

Date Started: August 15, 1984

Funding: FY '84 \$250,000 for 12 months

Anticipated Duration: 2 years

High quality, short pulse, excimer laser systems are prime candidates for the generation of spectrally-bright coherent radiation in the extreme ultraviolet and soft x-ray spectral regions. Such excimer systems consist of (1) a unit generating a short, high-quality pulse at visible wavelengths, (2) a frequency shifter, and (3) a chain of ultraviolet amplifiers. Our objective is to develop a prototype laser system which delivers a tunable, high quality pulse of ~ 10 psec duration in the range of <450 to 700 nm. In conjunction with suitable wavelength shifters, this instrument will cover the ultraviolet spectral range down to and probably below 240 nm. Its integration as the front end of an ultrahigh spectral brightness KrF laser system will result in a compact, low-cost laboratory instrument, delivering powers of >10 GW at 5 eV photon energy. This new, powerful, and cost-effective technology would overcome the fundamental limitations of the low-brightness incoherent sources presently available and permit application to an unusually broad spectrum of important technical areas relevant both to pure scientific and industrial spheres.

2. THE CONTINUOUS MEMBRANE
COLUMN: A LOW-ENERGY
ALTERNATIVE TO DISTILLATION

BEND RESEARCH, INC.
64550 Research Road
Bend, Oregon 97701-8599

Walter C. Babcock
Membrane Separations Division

Date Started: February 5, 1982

Funding: FY '84 \$134,000 for 12 months

Anticipated Duration: 3 years

The objective of this program is to evaluate membrane separation as an energy-efficient alternative to distillation. The study is focused on the separation of isopropanol from water, a process currently performed by distillation and azeotropic distillation. Work is under way in the areas of membrane development and assessment of membrane performance in a "continuous column" module configuration. Results thus far have been positive; for example, energy-consumption calculations based on membrane performance in laboratory tests indicate a 44% savings in energy is possible when a hybrid membrane/distillation approach is used in place of distillation alone to produce a 90 vol % isopropanol-in-water azeotrope.

3.* LIQUID MEMBRANES FOR
THE PRODUCTION OF
OXYGEN-ENRICHED AIR

BEND RESEARCH, INC.
64550 Research Road
Bend, Oregon 97701-8599

Harold K. Lonsdale
Membrane Separations Division

Date Started: April 16, 1979

Funding: FY '83 \$302,000 for 12 months

Anticipated Duration: 5 years

The objective of this program is to develop novel liquid membranes for the energy-efficient concentration of oxygen from air. Oxygen-enriched air will find use in a wide range of industrial, chemical, and combustion processes. The liquid membrane consists of a solvent that contains a dissolved oxygen carrier and that is held within the pores of a membrane support. The oxygen carrier selectively transports oxygen across the liquid membrane by the process of "facilitated transport", which results in a product gas highly enriched in oxygen. Recent efforts have focused on increasing the flux of oxygen across these membranes by reducing their effective thickness. Work in progress relates to development of membrane modules in regeneration techniques to extend their life.

*Project completed

4. EXTREME ULTRAVIOLET COHERENT
RADIATION DEVICE: TRANSVERSE
OPTICAL KLYSTRON

BROOKHAVEN NATIONAL LABORATORY*
Upton, New York 11973

C. Pellegrini and A. van Steenbergen
National Synchrotron Light Source

Date Started: September 26, 1983

Funding: FY '84 \$390,000

Anticipated Duration: 3 years

This project is for the development of a new radiation source to be incorporated with the VUV storage ring of the National Synchrotron Light Source (NSLS) which will produce coherent, radiation from 500 Å to 2000 Å. Specifically, this radiation source is a Transverse Optical Klystron (TOK) which makes use of a high power laser in the visible region and a permanent magnet undulator structure in conjunction with the circulating electron beam bunches in the storage ring to produce radiation at the harmonics of the laser. An exploratory experiment has been carried out with the installed FEL undulator. The design of an optimized, fixed gap, hybrid Vanadium Permendur - REC undulator is in progress, in addition to the design of the special vacuum chambers and overall optical configuration.

*Performed in cooperation with BELL LABORATORIES, 600 Mountain Avenue, Murray Hill, New Jersey 07974, Richard R. Freeman and Brian Kincaid co-principal investigators.

5.* FREE ELECTRON LASER TEST,
NATIONAL SYNCHROTRON LIGHT SOURCE

BROOKHAVEN NATIONAL LABORATORY
Upton, New York 11973

C. Pellegrini and A. van Steenbergen
National Synchrotron Light Source

Date Started: May 1, 1980

Funding: FY '83 \$21,000

Anticipated Duration: 3 1/2 years

The purpose of this program is to develop a free electron laser test module driven by the circulating beam of a storage ring. The program will explore the effect of the free electron laser on the parameters of the storage ring as well as involve the development of a coherent wiggler to provide the appropriate mechanism for electromagnetic radiation amplification due to repeated interactions of the laser field and the transversely oscillating electrons in the undulator (coherent wiggler). It is anticipated that a basic design for a tunable high average power ultraviolet source with a narrow spectral bandwidth may result from these studies.

*Project completed

6.* MEQALAC CLUSTER
ION FUSION

BROOKHAVEN NATIONAL LABORATORY
Upton, New York 11973

Lewis Friedman and Alfred Maschke
Chemistry & Accelerator Departments

Date Started: January 15, 1981

Funding: FY '82 \$240,000 for 12 months

Anticipated Duration: 3 years

Proof-of-principle experiments are proposed to demonstrate that isotopic hydrogen molecule cluster ions can be prepared and accelerated. The long range goal of these experiments is the utilization of plasmas produced by accelerated cluster ions for the production of thermonuclear reactions. A cluster ion source has been developed which has produced low intensity beams of narrow mass distribution hydrogen clusters with mass to charge ratios as high as 10^4 . Research on fundamental processes in this low temperature ion source designed to improve source intensity is in progress. A high precision "optical bench" beam transport system was developed for use with small aperture MEQALACs. High brightness beams of Argon and Xenon were accelerated in quadrupole focused acceleration columns. Laminar flow was observed in a 10 gap electrostatic quadrupole accelerating column and in a 50 quad transport line.

*Project completed

7. MOMENTUM RICH BEAM FUSION

BROOKHAVEN NATIONAL LABORATORY
Upton, New York 11973

Alfred Maschke

Date Started: April 29, 1983

Funding: FY '84 \$250,000 for 12 months

Anticipated Duration: 2 years

The objective of this study is to establish the feasibility of producing heavy ion beams with energies of a few hundred keV, and sufficient brightness that they might be used to implode a small volume of deuterium-tritium fuel. Computer simulations with the LASNEX code indicate that a beam temperature of around .1 eV, and an average current density of 10 mA/centimeter squared should be adequate to achieve thermonuclear ignition. A key element in achieving the high brightness is the laminar flow electrostatic quadrupole focused acceleration column that was developed under an earlier contract. Experimental results to date have measured the temperature of a Cesium beam from a hot tungsten contact ionization source. The beam temperature was found to correspond to the source temperature (about .1 eV). The acceleration column has been built and tested, and awaits being tested with beam.

8.* HIGH CURRENT BETATRON
FOR A FREE ELECTRON LASER

UNIVERSITY OF CALIFORNIA
Irvine, California 92717

Norman Rostoker and Amnon Fisher
Department of Physics

Date Started: August 1, 1981

Funding: FY '81 \$685,000 for 3 years

Anticipated Duration: 3 years

A modified Betatron is being developed that resembles an Astron. Electrons are injected into an elongated magnetic mirror. The Larmor radius is 6 cm; the distance between mirrors is 80 cm. With a field emission injector (50 kV, 1 amp, 150 nsec) about 20 nC have been trapped for about 10 μ sec. The electron trajectories are helical with an axial period of 40 nsec and an azimuthal period of 3 nsec. Rapid data acquisition is facilitated by a 1 Hz repetition rate. The purpose of the experiment is to study injection, trapping, acceleration and extraction in this new configuration. Multiturn injection has been demonstrated with electrostatic and magnetic inflectors. Acceleration to about 1 MeV has been accomplished with an iron powder ferromagnetic core and increasing the field at the beam from about 100 to 1000 gauss while maintaining the Betatron 2:1 condition. Electrons have been extracted with a gate coil for direct measurement of the trapped charge. The injection is very nearly tangential to the cyclic orbit which should produce a high-current low-emittance beam suitable for a free electron laser. Measurements of the emittance of an extracted beam are the next objective.

*Project completed

9. ELECTROCHEMICAL AND ELECTRO-
CATALYTIC PAIRED ORGANIC REACTIONS
IN UNDIVIDED FLOW CELLS

UNIVERSITY OF CALIFORNIA
Los Angeles, California 90024

Ken Nobe
Department of Chemical Engineering

Date Started: July 1, 1984

Funding: FY '84 \$70,000 for 12 months

Anticipated Duration: 3 years

Paired electrochemical syntheses for the production of organic chemicals can reduce energy consumption by as much as 50% compared to conventional electrochemical syntheses. A paired synthesis is more energy efficient because both the anodic and cathodic reactions contribute simultaneously to the formation of the final product(s). Additional energy savings can be achieved by performing the paired synthesis in an undivided flow cell and by incorporating an electrocatalytic hydrogenation as the cathodic partner of the paired reaction scheme. Moderate temperature, ambient pressure electrochemical hydrogenations at high surface area active electrocatalytic cathodes such as Raney nickel can be more energy efficient than chemical catalytic hydrogenations. The objectives of this research program are: 1) devise electro-organic paired syntheses, such as the oxidation and reduction of glucose to gluconic acid and sorbital, employing an active electrocatalytic cathode; 2) design, model and test continuous undivided flow cells for paired syntheses; and 3) evaluate the economic feasibility of the paired syntheses as opposed to producing the same chemicals individually by conventional chemical or electrochemical methods.

10. BIOEXTRACTION OF IRON FROM IRON OXIDES:
REDUCTION OF COKE DEMAND IN STEEL
PRODUCTION BY MICROBIAL BENEFICIATION

CALIFORNIA INSTITUTE OF TECHNOLOGY
Pasadena, California 91125

Michael R. Hoffmann
Engineering and Applied Science

Date Started: August 15, 1983

Funding: FY '83 \$237,000 for 3 years

Anticipated Duration: 3 years

A research program is in progress to investigate the kinetics and mechanisms of the reductive dissolution of iron oxide minerals such as hematite, goethite, lepidocrocite, and magnetite as catalyzed by Thiobacillus thiooxidans, Pseudomonas sp.200, Bacillus acidocaldarius, Pseudomonas aeruginosa, and Bacillus circulans. Kinetic parameters are being obtained from batch and continuous flow reactor experiments in which the partial pressure of oxygen, temperature, pH, carbon source, and total reactive surface area are primary variables. Data obtained within the first year of work has shown clearly that Pseudomonas sp.200 is the most effective iron-reducing organism. Its characteristic maximum growth rate constant has been determined to be 0.4 hr^{-1} ; this reaction rate constant indicates that P. sp.200 grows as fast as organisms active in biological reactors designed to treat domestic wastewater. The characteristic time for complete reductive dissolution of iron oxides and hydroxide solids is six to eight hours. Research is continuing on the mechanism of reductive dissolution. Plasmids of P. sp.200 have been isolated. They will be used to probe mechanistic details and to isolate and enhance the proteins responsible for iron reduction. Attempts will be made to isolate mutant strains of P. sp.200 capable of utilizing the Fe(II)/Fe(0) redox couple. If organisms possessing these capabilities are isolated and cultured continuously, it may be possible to produce elemental iron under ambient conditions.

11. NEW POLYMER ELECTRODES AND CONDUCTORS
BASED ON POLY(HYDROQUINONE/QUINONE)
OXIDATION/REDUCTION SYSTEMS

CASE WESTERN UNIVERSITY
Cleveland, Ohio 44106

Morton H. Litt
Department of Macromolecular Science

Date Started: September 15, 1983

Funding: FY '83 \$277,000 for 14 months

Anticipated Duration: 14 months

This project has the following goals: 1) To synthesize soluble linear fused ring polyaromatic polymers (ladder polymers) which have attached 1,4-hydroxyl groups; 2) To characterize these polymers. The polymer should be a good electrical conductor. It is expected that the hydroxyl groups can be reversibly oxidized and reduced - making this material a good candidate for a very high capacity electrode. High molecular weight polymers will be made into oriented fibers and films and their mechanical properties as well as electrical properties studied. Fiber of these polymers should be like graphite fibers, but should be solution processable. Polymers have been made which have the proposed structure. At present, they are obtained in an insoluble form. Work is going on in two areas. First, the mechanism of polymerization is being studied. The objective here is to get soluble polymers. Secondly, the initial polymers are being oxidized, and their oxidation/reduction properties will be studied.

12. *DEVELOPMENT OF A BIOCHEMICAL
PROCESS FOR PRODUCTION OF
ALCOHOL FUEL FROM PEAT

DYNATECH R/D COMPANY
99 Erie Street
Cambridge, Massachusetts 02139

Donald L. Wise

Date Started: June 1, 1981

Funding: FY '83 \$199,000 for 12 months

Anticipated Duration: 3 years

Peat and lignite represent a significant U.S. energy source. This research program is directed toward development of an aqueous, alkaline process for utilization of peat and lignite in liquid fuels production. The general approach to this process development can be described by three reaction chemistries. First, aqueous alkali is introduced to break the well-defined ethereal bonds in the peat and lignite structures and yield water-soluble carboxylic acids. Second, oxygen is added to promote the solubilization. Third, the solubilized aromatics are decarboxylated to give a water-immiscible aromatic fuel. An in-depth laboratory program has identified the necessary conditions for maximum breakdown of the peat and lignite to water-soluble carboxylic acids and for the greatest yield of decarboxylation products. Based on these results, preliminary conceptual designs and cost estimates were prepared for pilot and full-scale facilities.

*Project completed

13. CATALYSIS OF DIRECT METHANOL
ELECTRO-OXIDATION IN
BUFFERED ELECTROLYTES

EIC LABORATORIES, INC.
111 Downey Street
Norwood, Massachusetts 02062

S. Barry Brummer
Battery Division

Date Started: July 15, 1983

Funding: FY '84 \$146,000 for 12 months

Anticipated Duration: 3 years

The objective of this program is the exploration of the catalysis of methanol oxidation in aqueous, concentrated $K_2CO_3/KHCO_3$ electrolytes for direct methanol/air fuel cells. A major goal of the program is the elimination of all noble metal catalysts. The $K_2CO_3/KHCO_3$ electrolyte has a suitable conductivity, however, its water vapor pressure is higher than desired at the operating condition of 100 to 200°C. It should be possible to reduce the water vapor pressure by addition of a co-electrolyte. The chemical and electrochemical stability of potential non-noble metal catalysts are being determined in the $K_2CO_3/KHCO_3$ electrolyte. The electro-oxidation of methanol is being examined with both stable non-noble and noble metal catalysts.

14.*INVESTIGATION OF THE EXTRACTION
OF HYDROCARBONS FROM SHALE ORE
USING SUPERCRITICAL CARBON DIOXIDE

James H. Porter

Funding: FY '82 \$110,000 for 12 months

ENERGY & ENVIRONMENTAL ENGINEERING, INC.
1B Monsignor O'Brien Hwy
P.O. Box 215
E. Cambridge, Massachusetts 02141

Date Started: July 15, 1982

Anticipated Duration: 16 months**

Extraction of oil from shale was examined using carbon dioxide in its supercritical fluid state as the solvent. The experimental results showed that extraction yields were too low to be of commercial use at reduced temperatures ranging from 1.0 to 1.3 and at reduced pressures ranging from 1.0 to 2.8. Aqueous and hydrocarbon phases were extracted from the shale. The aqueous phase yield ranged from 1.6 to 4.0 times the hydrocarbon phase yield. Yields increased with increasing extraction time and as shale particle size was reduced. Yields also increased as the reduced temperature and solvent density increased. The hydrocarbon phase was predominantly alkanes and alkenes with boiling points ranging from 150 to 500°C.

*Project completed

**Includes unfunded extension

15. ULTRASONIC ATOMIZATION FOR
COMBUSTION EFFICIENCY IN
OIL BURNERS

William B. Tarpley, Jr.

Funding: FY '84 \$117,000 for 12 months

ENERGY & MINERALS RESEARCH CO.
964 E. Swedesford Road
Exton, Pennsylvania 19341

Date Started: June 1, 1984

Anticipated Duration: 2 years

This project involves utilizing controlled oil feed to an ultrasonic area atomizer and involving an optimum combustion air interface. Investigation of novel methods of presenting the liquid to be atomized, novel methods of designing the ultrasonic visibility face and mixing the low-velocity droplets with combustion air is to be carried out. Parametric relationships between liquid properties and ultrasonic variables will also be investigated.

16. DETECTION AND CHARACTERIZATION
OF NOVEL METAL-BINDING PROTEINS

GENERAL ELECTRIC COMPANY
P.O. Box 8
Schenectady, New York 12301

David S. Holmes
Corporate Research & Development

Date Started: July 1, 1984

Funding: FY '84 \$148,000 for 12 months

Anticipated Duration: 3 years

Metal binding proteins exist in nature. Apart from metalloenzymes, this unique group of organo-metallic molecules has received little attention. Yet metalloproteins might offer unique advantages for certain applications. These advantages include a remarkable specificity for binding individual metals or classes of related metals. This permits, for example, the chelation of silver in the presence of copper, or the chelation of virtually any transition or heavy metal in the presence of vast excesses of alkali metals such as sodium or potassium. More importantly, it is possible to isolate large quantities of metalloproteins and to modify them by using state-of-the-art genetic engineering. This latter ability could permit the construction of protein molecules exhibiting specificity toward more than one metal, with enhanced specificity towards one particular metal, or with enhanced functional stability. We propose to initiate a search for, and to characterize, novel metal-binding proteins in two unusual classes of microorganisms (Thiobacillus and Sulfolobus). These microorganisms exhibit unique advantages for this study including a remarkable tolerance to a broad range of metals in an acidic environment and the ability to oxidize many metals. Some of these organisms are thermophilic. Thermophilic proteins might exhibit enhanced functional stability or other unique properties.

17. FLUID DYNAMIC ENERGY
SEPARATION

GEORGE WASHINGTON UNIVERSITY
Washington, D.C. 20052

J.V. Foa
School of Engineering and Applied Science

Date Started: September 15, 1983

Funding: FY '83 \$294,000 for 2 years

Anticipated Duration: 2 years

The object of this study, the "energy separator", is a new kind of air conditioning and heating device that promises advantages of energy economy in a number of applications. This device has only one moving part, a free-spinning rotor, and its operating mechanism is very simple: it splits an initially uniform flow into two subflows and causes one of these to do work on the other. The energy separator derives its potential merit primarily from the fact that it permits the energy extracted from the cooling subflows to appear in the other subflow not as heat but rather in the form of recoverable mechanical energy. Experimental work has been in progress on three radically different models. An analysis has been developed for the selection of the configuration and operating conditions that will maximize the separation of energy under any given set of constraints, and its results are presently being used in the design of a fourth and improved experimental model. A study is also underway for the design of an air conditioning system that will incorporate this fourth model as its core component.

18.*RESEACH AND DEVELOPMENT OF
A MASS ACCELERATOR (MAID) AS
A DRIVER FOR IMPACT FUSION

GT-DEVICES
5705A General Washington Drive
Alexandria, Virginia 22312

Derek Tidman and Shyke Goldstein

Date Started: May 6, 1981

Funding: FY '83 \$297,000 for 12 months

Anticipated Duration: 3 years

The objective of this program is to demonstrate that high pressure plasma jets in the kilobar range can be used to propel solid projectiles to high velocity. The basic concept is to accelerate a solid mass (e.g., 0.5 gram) via a series of momentum kicks provided by sequentially directing the high pressure plasma jets onto the rear projectile surface as it passes through each module. This new approach to mass acceleration has been successfully demonstrated using 10 plasma discharge modules (with projectile sensing and timing circuits) aligned in a manner similar to a linear accelerator. Experiments in which the accelerator has been operated in a sense-and-kick mode have achieved velocities of 5.1 km/sec and a data base involving 575 shots has been established. The significance of this acceleration mechanism is that it can be used, in principle, to accelerate projectiles to several hundred kilometers per second as a driver for inertial fusion or another energy-related application. A theoretical base has also been developed to understand the physics of plasma jet generation and the coupling of the jet momentum to the projectile. This work has formed a solid basis for further experiments with larger scale devices.

*Project completed

19. MEASUREMENT OF THE EFFICIENCY
OF MUON-CATALYZED FUSION

IDAHO NATIONAL ENGINEERING LABORATORY
EG&G Idaho, Inc., P.O. Box 1625
Idaho Falls, Idaho 83415

Steven E. Jones
Scientific Information AGM

Date Started: March 8, 1982

Funding: FY '84 \$390,000 for 12 months

Anticipated Duration: 4 years

It is rather remarkable that the muon (symbol μ , an elementary particle like the electron) can induce the fusion reaction: $\mu + d + t \rightarrow \mu + He + n + 17.6 \text{ MeV}$. We have observed eighty fusions caused by a single muon (on the average) in deuterium-tritium gases at room temperature. Thus, the muon serves as a catalyst for the fusion process, permitting it to proceed rapidly without the need for high (plasma) temperatures. Is muon-catalyzed fusion just a scientific curiosity or could power production be achieved? Results so far show that the reaction proceeds more rapidly than theoretically predicted. Moreover, the loss of muons due to capture by the synthesized helium ion is significantly less than expected. Consequently, fusion energy yields are larger than anticipated - more than ten times the total energy of the muon driving the fusion reaction. Still, the output energy is less than the energy needed to initially produce a muon. Research continues in an effort to improve the energy balance.

20. GENERATION OF STIMULATED EMISSION IN
THE SOFT X-RAY RANGE BY NONLINEAR
PROCESSES WITH EXCIMER LASERS

UNIVERSITY OF ILLINOIS AT CHICAGO
Chicago, Illinois 60680

Charles K. Rhodes
Department of Physics

Date Started: September 15, 1983

Funding: FY '84 \$52,000

Anticipated Duration: 2 years

High spectral brightness excimer lasers can be used to generate coherent extreme ultraviolet radiation by either harmonic generation or direct multiphoton excitation of appropriate laser media. Recent studies of two-photon pumped lasers in H₂ and HD at ~120 nm with conversion efficiencies of ~10⁻² and of a four-photon inner shell excited laser in Kr at 93 nm and with ~10⁻⁴ efficiency, indicate that the latter mechanism, involving direct excitation, is considerably more promising. To study the basic properties of high order nonlinear processes in the ultraviolet, an experiment which evaluates the amount of optical energy transferred to various atomic species under collisionless conditions and at UV laser intensities of up to 10¹⁷ W/cm² is in progress. This experiment has led to the discovery of an anomalously strong energy coupling to high Z atoms which involves the absorption of as many as 99 photons. A time-of-flight photoelectron spectrometer which will address the question of state selectivity is in the testing phase. The experimental program is designed to (1) investigate the mechanisms leading to the anomalous ion production, (2) assess the limitations on the quantum state selectivity such processes can provide, and (3) attempt to observe genuine simulated emission in the 40 - 80 eV range. Success in this endeavor would imply the feasibility of a laboratory scale coherent source operating in the kilovolt range.

21. PRODUCTION OF ULTRAHIGH
MAGNETIC FIELDS

JAYCOR
11011 Torreyana Road
San Diego, California 92138

Franklin S. Felber

Date Started: September 15, 1984

Funding: FY '84 \$279,000 for 12 months

Anticipated Duration: 2 years

A general method has been discovered for producing controlled ultrahigh magnetic fields up to the order of 100 MG. The general method involves imploding a plasma in which a magnetic field has been entrained. The imploding plasma compresses the magnetic field to high strengths. The optimal method for producing the imploding plasma appears to be a gas-puff Z pinch. The objective of this two-year experimental program is to produce and measure controlled ultrahigh magnetic fields by this method. In the first year, the gas-puff Z pinch facility at the University of California at Irvine will be used for high-field tests at several megagauss. In the second year, a high-current gas-puff Z pinch facility will be used to demonstrate production of ultrahigh magnetic fields in the 15 to 20 MG range, which exceeds the highest controlled fields produced in this country. Applications for ultrahigh magnetic fields include reducing fusion ignition thresholds, producing collimated beams of gamma radiation, accelerating particles, and producing high-energy densities (hundreds of eV/A³) under controlled conditions for studies of plasma physics, atomic physics, and material properties.

22. FREE ELECTRON LASER
AT THE ETA*

LAWRENCE BERKELEY LABORATORY
University of California
Berkeley, California 94720

A.M. Sessler and D. Prosnitz

Date Started: February 8, 1982

Funding: FY '83 \$360,000 for 12 months

Anticipated Duration: 38 months

The purpose of this experiment is to develop a tapered-wiggler Free Electron Laser (FEL) as an efficient microwave source between 35 and 40 GHz. An application of this source is as electron cyclotron resonance heating of thermonuclear plasmas and a second application is as a high peak power source for high energy particle acceleration. The Lawrence Livermore National Laboratory's Experimental Test Accelerator provides the high-current, high voltage (1 kA, 4 MeV) low emittance electron beam used to drive the FEL amplifier. The electron beam wiggler which is electromagnetic, has no iron, and is pulsed; there is microwave input and microwave output diagnostics. Initial operation was developed a 8 mm wavelength, with the capability of studying 2 mm and 4 mm in the future. Beams of up to 450 A have been transported through the wiggler and super-radiant oscillations from noise have been observed as a function of length. This radiation (about 1 kW), which is coherent, has a gain of 13 dB/m and shows no sign of saturation in the 3.m wiggler. In an amplifier mode, with 23 kW fed in from a magnetron, the untapered wiggler, when tuned to resonance, gives 80 MW. Further study of the physics of a tapered FEL is planned.

*Experimental Test Accelerator at Lawrence Livermore National Laboratory.

23.*DETECTION AND ENRICHMENT
OF FRACTIONALLY CHARGED
PARTICLES IN MATTER

LAWRENCE LIVERMORE NATIONAL LABORATORY
P.O. Box 808, L-482
Livermore, California 94550

Charles D. Hendricks
Y Division, Laser Program

Date Started: May 1, 1982

Funding: FY '84 \$290,000 for 12 months

Anticipated Duration: 3 1/2 years

This project is an experimental search for fractional charged particles in matter. Such particles may be a manifestation of free quarks. At the heart of the experiment is a charge-to-mass measurement on very uniform mass particles. Thus, a measurement of q/m will yield relative values of the charge of the particles. Because most of the particles should have charges which differ by integer values of one electron charge, only relative charge measurements between particles need be made to determine the presence of fractional charges. Liquid drops which are about 45 micrometers diameter and spaced about 750 micrometers apart are made at a rate of approximately 3×10^4 drops per second. These values depend on the particular parameters set into the experiment as it is being done. The drops traverse the space between two vertical, parallel plates which may be maintained at a DC potential difference up to about 60 kV. With no potential between the plates the drops travel along a straight vertical line downward between the plates. With a high potential between the plates, the drops are deflected transversely along paths which depend on the charge on each drop. Data is being taken to determine the relative charges on the drops and, thus, determine the presence or absence of fractional charges.

*Projects 23 and 28 are cooperative interlaboratory projects.

24. PUMPING OF GAMMA-RAY LASERS:
EXPERIMENTAL AND THEORETICAL
INVESTIGATIONS

LOS ALAMOS NATIONAL LABORATORY
Los Alamos, New Mexico 87545

G. C. Baldwin
Physics Division

Date Started: September 27, 1983

Funding: FY '84 \$290,000 for 12 months

Anticipated Duration: 3 years

This project comprises a set of investigations related to concepts for exciting a laser that could operate with recoilless nuclear transitions in the sub-nanometer region without requiring excessive pumping power. Experiments to develop a technique for preparing a nuclear population inversion by selective photoionization of atoms containing the nuclear isomer Hg-197 are nearing completion. Another experiment in preparation is intended to demonstrate an effect of atomic (optical) excitation on the decay rate of the low-lying isomer of U-235. Theoretical investigations are addressing the problems of 1) transferring populations from long-lived isomers to short-lived nuclear states that can emit recoilless gamma radiation; 2) identifying nuclides with appropriate properties; 3) Mossbauer superradiance, which should govern the kinetics of the resultant gamma-ray emission.

25. MAGNETIC REFRIGERATION FOR
EFFICIENT CRYOGEN LIQUEFACTION

LOS ALAMOS NATIONAL LABORATORY
P.O. Box 1663, KS M764
Los Alamos, New Mexico 87545

John A. Barclay
Group P-10

Date Started: February 1, 1982

Funding: FY '84 \$270,000 for 12 months

Anticipated Duration: 3 1/2 years

The objective of this work is to consider conceptual designs, test models of those designs, and develop a data base for compact, reliable, high-efficiency magnetic refrigeration, with special emphasis on application of this technology to liquefaction of cryogenes. Data base generation consists of literature evaluation and experimental work. Files on magnetic materials, fluid dynamics, heat transfer, pumps, drive motors, dewars and magnets are being compiled. Experimental results on the physical, thermomagnetic, transport, and mechanical properties of several intermetallic rare earth compounds have shown that several materials may be suitable magnetic refrigerants between 4 K and 300 K. Examples include GdNi, GdPd, GdRh, GdZn and ErAl₂. Characterization of these materials continues. Heat transfer in magnetic refrigerators has been carefully studied including optimization of several geometries. Effective regeneration has been identified as a key problem for high-efficiency designs. Pump and drive motor efficiencies have been measured and are an area of concern. Using the data base information, a one watt 4 - 20 K refrigerator model has been designed, built and is entering the test mode. Several key problems in this temperature range have been identified and are being investigated. Design work on a 20 - 77 K device is underway.

26. THEORETICAL STUDY OF
MUON-CATALYZED FUSION

LOS ALAMOS NATIONAL LABORATORY
P.O. Box 1663
Los Alamos, New Mexico 87545

James S. Cohen
Theoretical Division

Date Started: December 29, 1933

Funding: FY '84 \$202,000 for 12 months

Anticipated Duration: 3 years

By virtue of the muon (μ^-) being about 200 times as massive as the electron, the molecular ion $(d\mu^-)^+$ is small compared to ordinary DT^+ and nuclear fusion occurs rapidly in it. The muon is usually freed after fusion and available to catalyze more reactions. In recent experiments on muon-catalyzed fusion in deuterium-tritium mixtures at high densities, almost 100 fusions per muon have been observed. However, enough information is not yet available to evaluate potential applications of muon catalysis. It is still desirable to explore new ideas for enhancing muon utilization. The present theoretical effort is designed to provide understanding of the observed kinetics and suggest improvements. There remain several fundamental processes which require further investigation, and theory is essential in this task. Problems being researched include muon production, muon capture by molecules, effects of impurities, resonant muonic molecule formation, muonic molecule binding energies and wave functions, muon sticking to the fusion alpha particle, and possibilities of reactivation if sticking occurs.

27. LIQUID METAL THERMO-
ACOUSTIC ENGINE

LOS ALAMOS NATIONAL LABORATORY
Los Alamos, New Mexico 87545

J. C. Wheatley
Physics Division

Date Started: September 27, 1983

Funding: FY '84 \$370,000 for 12 months

Anticipated Duration: 3 years

This project is concerned with studying a new type of thermoacoustic heat engine using a liquid metal, such as liquid sodium, as the working substance. The thermophysical properties of liquid sodium make it far superior to ideal gases as working substance in such an engine because of its very low Prandtl number, high density, and high sound velocity. We have developed an accurate theory of the thermoacoustics of liquid metals in acoustic engines, and, with a computer code based on it, studied optimization of the acoustic design of prime movers. In order to convert the acoustical power output to electricity, a more useful form of energy, we studied theoretically two approaches: an a.c. magnetohydrodynamic generator, in which the high electrical conductivity of sodium is used, and a variable reluctance generator. Both schemes are characterized by extreme mechanical simplicity. We have designed and are now constructing a laboratory engine to test the theory of the thermoacoustics, the magnetohydrodynamic generator, and the variable reluctance generator. The test engine is designed to produce 600 W of acoustic power at 31% of Carnot efficiency in a 4 cm diameter engine operating between 1000 K and 400 K.

28.*DETECTION AND ENRICHMENT
OF FRACTIONALLY CHARGED
PARTICLES IN MATTER

George Zweig
Theoretical Division

Funding: FY '84 \$334,000 for 12 months

LOS ALAMOS NATIONAL LABORATORY
P.O. Box 1663
Los Alamos, New Mexico 87545

Date Started: May 1, 1982

Anticipated Duration: 3 1/2 years

The basic unit of electric charge is one third that of the electron. It is therefore natural to ask if isolated particles of fractional charges $\pm 1/3e$, $\pm 2/3e$, $\pm 4/3e$. . . exist freely as elements of the earth. William Fairbanks' group at Stanford University has concluded that they do. Negative fractionally charged particles are interesting because they could replace electrons in atoms, molecules and solids, leading to super-dense states of matter. Under certain circumstances they would even catalyze fusion reactions. This project is a combined theoretical and experimental effort to search for fractionally charged particles in a wide variety of materials, to determine which materials are most abundant in fractionally charged particles, and to enrich the fractional charge content of sample materials. The crystal chemistry of fractionally charged particles is being theoretically developed and those materials most likely to contain enhanced concentrations of fractionally charged atoms are being identified. These materials will then be obtained, analyzed and used as samples for the experimental studies.

*Projects 23 and 28 are cooperative interlaboratory projects.

29. RESEARCH ON MILLIMETER AND SUBMILLIMETER
RADIATION FROM ROTATING ELECTRON BEAMS
IN RIPPLED MAGNETIC FIELDS

William W. Destler, Univ of MD
George Bekefi, MIT

Funding: FY '84 \$146,000 for 12 months

UNIVERSITY OF MARYLAND
College Park, Maryland 20742
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Cambridge, Massachusetts 02139

Date Started: July 1, 1984

Anticipated Duration: 2 years

The production of millimeter and submillimeter radiation from rotating electron beams interacting with an azimuthally periodic wiggler magnetic field is being studied experimentally and theoretically. Initial studies using a 2 MeV, 1 kA, 6 cm radius rotating beam interacting with a 1400 gauss wiggler field with six spatial periods around the azimuth have produced in excess of 200 kW of power in the frequency range 90-170 GHz. The radiation frequency spectrum is being measured in this range using a grating spectrometer, and the effects on radiation production of variations in electron energy, current, pulse length, and wiggler periodicity and magnitude are currently being investigated. A long pulse (5 μ s), low voltage (40 kV) experiment is currently in the design stages.

30. MAGNETIC ENHANCEMENT AND
DEMINERALIZATION OF EASTERN
COALS

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Cambridge, Massachusetts 02139

David R. Kelland
Francis Bitter National Magnet Lab

Date Started: June 1, 1984

Funding: FY '84 \$389,000 for 12 months

Anticipated Duration: 3 years

The inorganic sulfur and mineral content of high sulfur coals can be reduced by high gradient magnetic separation (HGMS). Enhancement of the magnetization of the mineral pyrite through selective heating by microwave irradiation to convert pyrite to more magnetic pyrrhotite should improve demineralization performance. This research program, to be carried out in cooperation with General Electric-Schenectady, will attempt to verify indications of successful microwave pretreatment of coals and investigate the effect of magnetic enhancement on HGMS performance on coals with insufficient pyrrhotite for effective magnetic desulfurization. Success in using HGMS on direct desulfurization on some coals and on converted pyrrhotite in coal liquids is an indication that improved magnetic enhancement by the recently observed effect of localized surface discharges should dramatically affect HGMS demineralization. The concept of effective selective heating and of combining magnetic enhancement with mineral separation needs to be proved feasible. A study of the conversion mechanism and necessary residence time will provide data for extending an encouraging early economic and engineering analysis of this method of precombustion coal cleaning.

31.*ZONE-MELTING RECRYSTALLIZATION
FOR SOLAR CELLS

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
77 Massachusetts Avenue
Cambridge, Massachusetts 02139

Henry I. Smith
Electrical Engineering & Computer Science

Date Started: September 1, 1982

Funding: FY '84 \$20,000

Anticipated Duration: 2 years

The objective of this project is to develop a process for producing oriented silicon films suitable for low-cost solar cells. A new technique, zone-melting recrystallization (ZMR), has been developed which produces crystalline silicon films having mobilities close to bulk values. Using a vertical-constriction technique, (100) texture has been obtained in films 60 μm thick. Single-grain films are produced by passing the molten zone through a lithographically-defined planar constriction. Solar cells have been fabricated using ZMR in conventional homojunction and interdigitated contact form. Current-voltage traces show a departure from ideal diode behavior principally due to shunt resistance effects. Efforts to isolate fabrication-induced defects are underway in which contact resistances and alloying procedures will be studied. Spectral response measurements indicate that cells produced by ZMR have current collection efficiencies comparable to cells fabricated in Czochralski silicon, and a minority carrier diffusion length of 30-100 μm in an unpassivated Si film. This has been confirmed by electron beam-induced current (EBIC) and diode reverse recovery techniques.

*Project completed

32.*DEVELOPMENT OF DIRECT-CONTACT,
HIGH EFFECTIVENESS DROPLET
HEAT EXCHANGERS

William J. Thayer III
Flow Technology Group

Funding: FY '83 \$257,000 for 12 months

MATHEMATICAL SCIENCES NORTHWEST, INC.
2755 Northrup Way
Bellevue, Washington 98004

Date Started: July 1, 1981

Anticipated Duration: 3 years

A reliable technique for transferring heat between gas and liquid streams in the 1200-2000 K temperature range could greatly improve the efficiency of industrial processes and power generation systems. The objective of this program has been to evaluate direct contact heat transfer between counterflowing droplets and gas as a means of eliminating the limitations of conventional heat exchangers imposed by solid walls. Computer codes have been developed to evaluate multi-dimensional, two-phase flow and heat transfer aspects and losses of droplet heat exchangers. Tests have been conducted to characterize, evaluate, and demonstrate processes which control the flow and heat transfer processes between counterflowing droplets and gas, and the formation of uniform droplets of viscous, high-surface-tension materials that simulate molten salts and slags. Comparisons of test data and model predictions have confirmed projected trends and demonstrated higher effectiveness heat transfer than expected. Cycle analyses and applications studies indicate that the droplet heat exchanger could provide energy savings of 70 percent by making possible high temperature waste heat recovery from dirty, corrosive gas streams.

*Project completed

33. PERVAPORATION: A LOW-
ENERGY ALTERNATIVE
TO DISTILLATION

Richard Baker

Funding: FY '84 \$89,000 for 8 months

MEMBRANE TECHNOLOGY AND RESEARCH, INC.
1030 Hamilton Court
Menlo Park, California 94025

Date Started: April 15, 1983

Anticipated Duration: 20 months

The object of this project is to develop selective pervaporation membranes. Pervaporation is a membrane separation process that could offer substantial energy savings compared to distillation. The principal problem inhibiting the development of pervaporation is the lack of suitably selective membranes. Thin film composite membranes have been made and evaluated in laboratory membrane cells and as small modules. Based on the experience obtained with these model mixtures we are determining the applicability of pervaporation to more economically significant organic mixtures. This data will be used to perform a technical and economic analysis of the process.

34.* EXPERIMENTAL RESEARCH IN HIGH TEMPERATURE
SOLAR THERMOCHEMICAL PROCESSING. HYDROGEN
AND SULFUR FROM HYDROGEN SULFIDE

UNIVERSITY OF MINNESOTA
111 Church Street, S.E.
Minneapolis, Minnesota 55455

Edward A. Fletcher
Department of Mechanical Engineering

Date Started: July 16, 1982

Funding: FY '82 \$229,000 for 24 months

Anticipated Duration: 2 years

Highly concentrated sunlight is uniquely suited for supplying process heat at very high temperatures. The efficiency with which process heat is used to effect endothermic processes increases as the temperature at which the heat is added increases. This project makes use of a highly-concentrating solar furnace to study the production of hydrogen and sulfur from hydrogen sulfide in a high-temperature thermochemical process. We have studied the effect of hydrogen sulfide and its decomposition and oxidation products, as well as admixed hydrocarbons, on material for reactor construction, constructed three reactor-separators and their appurtenances, have evaluated various techniques for the construction of effusion membranes, and are now conducting experiments to test the efficacy of the process and evaluate the cost benefits which may be achievable by these kinds of processes vis-a-vis conventional methods of handling hydrogen sulfide.

*Project completed

35.* HOLOGRAPHIC TECHNOLOGY FOR
SOLAR ENERGY CONCENTRATION

NATIONAL TECHNICAL SYSTEMS
12511 Beatrice Street
Los Angeles, California 90066

Tomasz Jansson
Research Division

Date Started: June 1, 1981

Funding: FY '83 \$204,000 for 12 months

Anticipated Duration: 3 years

The objective of this project is to explore the possibility of using dichromated-gelatin holographic technology for solar energy concentration. Special emphasis has been given to spectrum-splitting holoconcentrators. During Fiscal Year 1984, significant progress has been made in the photochemistry, physics and optics of the holoconcentrators. It was verified that in Lippmann geometry, the reflectivity of the selective holographic mirrors can reach at least 99.9%, i.e. the photochemistry of the dichromated gelatin to a very good approximation preserves the physical properties of reflection Bragg holograms (predicted by Kogelnik theory and by the more general non-uniform WKB theory). In holoconcentrator geometry, the hologram diffraction efficiency, limited only by Fresnel losses has been obtained (up to 92%) and it was shown that in the case of zero-dispersion gratings with curved holographic coatings, the optical efficiency of the holoconcentrator system can reach this value. Hence, the holoconcentrator systems can be uniquely very close to the ideal PV spectrum-splitting systems. Moreover, several additional attractive holographic applications, such as high efficiency selective reflective filters, holo-windows and laser-protection selective mirrors, have been developed. The next generation of holoconcentrators will integrate focusing and spectrum-splitting of the visible spectrum, in the reflection mode, and focusing of near IR spectrum, in the transmission mode.

*Project completed

36. HIGH-FLUX, EXTENDED-PULSE
ION ACCELERATOR

UNIVERSITY OF NEW MEXICO
Albuquerque, New Mexico 87131

S. Humphries, Jr.
Department of Chemical and Nuclear Engineering

Date Started: September 27, 1983

Funding: FY '83 \$267,000 for 3 years

Anticipated Duration: 3 years

The objective of this program is to develop novel accelerator technology for ion implantation and materials modification. The technology is based on neutralization of ion beams by low energy electrons and control of the electrons through transverse magnetic fields. Plasma sources and acceleration gaps under investigation are capable of current density above 1 A/cm² for pulselengths from 0.1 to 1 ms. A vacuum arc array has produced 25 A pulses of Al⁺ ions; the geometry is suitable for a wide variety of metal ions. A second generation cross-field discharge source is currently being tested for ionization of gaseous species. The second year of the program will concentrate on studies of post-acceleration in a single gap. A 20 kV electrostatic test stand has been constructed for this purpose.

37.* MODIFICATION OF THE SURFACE
TEMPERATURE BY AN ARTIFICIAL
CIRRUS CLOUD

STATE UNIVERSITY OF NEW YORK
Albany, New York 12222

Bernard Vonnegut and Peter Chylek
Atmospheric Sciences Research Center

Date Started: September 1, 1980

Funding: FY '80 \$244,000 for 36 months

Anticipated Duration: 3 1/3 years**

The objective of this project was to explore the practicality of using artificially formed cirrus clouds to achieve significant energy savings in densely populated areas. Meteorological data for about 10 years in the Albany area have been analyzed to determine how often the situation favorable for formation of an artificial cirrus cloud occurs. Preliminary results indicate that a suitable situation in the middle and upper troposphere occurs about 10 times per cold season. The combined effect of clearing clouds during the daytime and making cirrus clouds during nighttime gives a benefit-to-cost ratio of about 4/1 for the Albany area. For large metropolitan areas the benefit-to-cost ratio may be up to 40/1. Experimental work carried out at the University of Alaska's site at Fairbanks was concerned with observing the details of how light is scattered by clouds of water droplets and ice crystals. Analysis has also been carried out on about 10 years of data showing the effect of cirrus clouds over Mauna Loa on hourly average diffuse and direct solar radiation. This analysis can be used to suggest what effects artificial cirrus clouds would have on solar radiation reaching the surface. A radiative-convective climate model has been used to estimate the effect of increased cloudiness on the surface temperature, and radiative properties of ice clouds have been studied.

*Project completed

**Includes unfunded extension

38. VALIDATING THE PARAMAGNETIC LOGGING EFFECT

PARAMAGNETIC LOGGING, INC.
3123 - 198th Place S.E.
Bothell, Washington 98012

W. Banning Vail

Date Started: August 1, 1984

Funding: FY '84 \$109,000

Anticipated Duration: 15 months

The Paramagnetic Logging Effect (PLE) is a recently predicted new magnetic phenomenon which will serve as the physical basis of a new borehole device capable of the direct measurement of the volume of petroleum reserves around a cased drill-hole to a radius of 50 feet or more into formation. The nucleons chemically bound in water and oil present in formation are preferentially aligned in the earth's magnetic field causing the natural nuclear paramagnetism within the formation. This paramagnetism causes a slight alteration in the strength of the earth's magnetic field in the vicinity of a borehole adjacent to the formation. Repeated application of an A.C. magnetic field at the Larmor frequency of the nucleons present yields an amplitude modulation of the earth's magnetic field. The magnitude of such modulation yields the total number of nucleons present and the phase contains information used to separate oil and water and identify the viscosity of oil present. The purpose of the project is to systematically study the new physical effect in a 4,800 gallon plastic tank which will be filled with water, then oil, and finally with mixtures of oil and water. The influence of borehole casing on these results will also be studied.

39.* ENERGY SYSTEMS BASED ON POLYACETYLENE:
RECHARGEABLE STORAGE BATTERIES AND
SCHOTTKY BARRIER SOLAR CELLS

UNIVERSITY OF PENNSYLVANIA
3451 Walnut Street
Philadelphia, Pennsylvania 19104

A. G. MacDiarmid
Department of Chemistry

Date Started: March 1, 1981

Funding: FY '82 \$101,000

Anticipated Duration: 3 years

Research has continued on the evaluation of polyacetylene, $(CH)_x$, the prototype conducting polymer as an electrode-active material in novel rechargeable batteries. There are currently only two, widely used rechargeable batteries -- the lead/acid battery and the nickel/cadmium battery. In view of the adverse environmental effects of cadmium it is essential to evaluate other types of cells as a possible replacement for the Ni/Cd battery, in the event this should become necessary. Conducting polymers offer a potentially enormous new type of non-toxic material for use in rechargeable batteries. The $TiS_2/Li^+A^-/Li$ cell (A^- = anion) which exhibits many excellent properties, suffers from a major disadvantage caused by the formation of Li dendrites on continued charging and discharging. We have developed a battery of the form $TiS_2/M^+A^-/[M^+y(CH)^-y]_x$ where $M = Li^+$ or Na^+ and $A^- = (C_{10}O_4)^-$ or $(PF_6)^-$ in which this problem has been eliminated by replacing the Li with n-doped polyacetylene. This cell exhibits excellent recyclability, coulomb efficiency and retention of charge. Preliminary studies of "polyaniline", which is stable in air and water, show that it might also serve as an excellent electrode-active material.

*Project completed

40.*IMPLoding PLASMA
X-RAY LASER

PHYSICS INTERNATIONAL
2700 Merced Street
San Leandro, CA 94577

Sik-Lam Wong

Date Started: September 1, 1981

Funding: FY '83 \$375,000 for 12 months

Anticipated Duration: 2 1/2 years

A collisionally pumped Ne-like krypton x-ray laser scheme is being investigated using an imploded plasma source (~ 4 cm x 0.5 mm). The implosion is driven by the 5 TW Defense Nuclear Agency PITHON electrical pulse generator. According to theories developed at Lawrence Livermore National Laboratory, the measured plasma temperature ($T_e \sim 1$ keV) and density ($N_e \sim 10^{21}$ electrons/cm³) are nearly ideal for producing population inversions in XUV (~ 83 -100 eV) 3-3 Ne-like krypton transitions. Time integrated XUV spectral data are consistent with population inversion for 8 transitions. The measured line widths are about five times broader than that expected from doppler broadening and may be due to non-thermal plasma conditions. As a result, the gain in the lasing medium is about 0.5/cm. The available plasma length is 3.5 cm over a 2 ns time frame. We are investigating a number of schemes to reduce the linewidths, and thus increase the gain, by changing the plasma conditions, e.g., imploding a gas puff on an axial krypton plasma and use of an axial B-field for stabilizing the plasma.

*Project completed

41.*SOFT X-RAY LASING ACTION IN
A CONFINED PLASMA COLUMN

PRINCETON UNIVERSITY
Princeton, New Jersey 08544

Szymon Suckewer
Plasma Physics Laboratory

Date Started: September 13, 1979

Funding: FY '83 \$329,000 for 12 months

Anticipated Duration: 4 years

The objective of this project is an experimental investigation of lasing action in the soft x-ray spectrum region at wavelengths 182 Å, 135 Å and 520 Å corresponding to the 3→2, 4→2, and 4→3 transitions in the CVI ion. The basic idea is to use a multi-Z (e.g., carbon, oxygen) thin plasma column confined by a strong longitudinal magnetic field (100 kG), first heated by a CO₂ laser and then cooled rapidly by radiation losses. Calculations indicate a total gain in excess of 100 for the 3→2 transition, in excess of 10 for the 4→2 transition, and in excess of 300 for the 4→3 transition for a 10 cm long plasma column heated by a 10-20 GW CO₂ laser beam. Experiments showed good plasma confinement in magnetic fields 50-100 kG and effective radiation cooling of such a plasma, especially with additional small amounts of higher-Z elements such as Ar or Xe. Measurements of gain for CVI 4→3 (520 Å) and 3→2 (182 Å) transitions indicate the possibility of obtaining a high gain for 4→3 transitions, and also for the 3→2 transitions with improved CO₂ laser optics.

*Project completed

42. DEPOSITION OF HIGH QUALITY
CuInSe₂ BY SPRAY PYROLYSIS

RADIATION MONITORING DEVICES, INC.
44 Hunt Street
Watertown, Massachusetts 02172

Gerald Entine

Date Started: September 15, 1982

Funding: FY '83 \$116,000 for 12 months

Anticipated Duration: 2 3/4 years

The ultimate success of any terrestrial photovoltaic energy conversion approach requires that the following factors be satisfied: 1) high individual solar cell conversion efficiency, 2) low cost per unit area to produce the cells, 3) adequate availability of the constituent materials to produce the cells, 4) long term stability. CuInSe₂ is a material which promises to meet these requirements, but to date can only be made using expensive laboratory techniques. This project is a proof-of-concept effort to show that CuInSe₂ can be prepared by spray pyrolysis. CuInSe₂ is a promising solar cell material and spray pyrolysis is a technique well-suited for use in a manufacturing process. High quality, uniform and continuous films have been produced and solar cell device testing is underway.

43. IONIZATION FRONT ACCELERATOR

SANDIA NATIONAL LABORATORIES
Albuquerque, New Mexico 87185

Craig L. Olson
Plasma Theory Division - 1241

Date Started: June 1, 1981

Funding: FY '84 \$190,000 for 12 months

Anticipated Duration: 3 1/2 years

The goal of this project is to accelerate ions to high energies using the large space charge field (-100 MV/m) from the potential well at the head of an intense relativistic electron beam (IREB). The Ionization Front Accelerator (IFA) uses laser photoionization of a special working gas to control the motion of the potential well. A second generation system (IFA-2) is now operational. This system includes an IREB machine (1.0 MV, 30 kA, 30 nsec) with laser-triggered switches with a command firing jitter of 1 nsec, a beam conditioning cell to steepen the current rise time to < 3 nsec, a heated experimental cell with Cs as the working gas, a dye laser (852.1 nm) to pre-excite the Cs, an XeCl laser (308 nm) to photoionize the excited Cs, a Pockels deflector to provide a continuous sweep of the XeCl laser beam, and beam front and ion diagnostics. The deflector system produces a quadratic temporal sweep of the XeCl laser beam over 30 cm in 20 nsec, but it has a transmission efficiency of only ~3% and delivers < 0.15 mJ/cm² in the swept beam. Initial tests with the "lasers early" demonstrate that the photoionization scheme works, and that an XeCl laser intensity of ≥ 0.5 mJ/cm² is required to control the front, in agreement with theoretical calculations. Intense efforts are being made to increase the swept XeCl laser beam intensity to the required level for successful IFA operation.

44. *PLANAR FLOW CASTING
OF SHEET SILICON FOR
PHOTOVOLTAIC CELLS

Mandayam C. Narasimhan

Funding: FY '83 \$208,000 for 12 months

SOURCE TECHNOLOGY APPLIED METALLURGICALS, INC
SOLAMAT DIVISION

885 Waterman Avenue
East Providence, Rhode Island 02914

Date Started: August 1, 1982

Anticipated Duration: 2 years

The object of this research program is to evaluate the castability of silicon sheets for photovoltaic application by the planar flow casting process and a newly developed roller quench casting process. The double roller quench casting process was used to cast sheet silicon 100 to 625 microns thick, 2 to 7 cm wide and 15 to 40 cm long at casting speeds of 10 to 90 meters per minute. This process works both in ambient and inert atmosphere. These sheets consists of columnar grains having in plane dimensions between 100 to 1000 microns. Sheets which are p-type with electrical resistivities in the 5 to 20 ohm-cm range have been prepared and solar cells have been fabricated. A solar conversion efficiency of 8.7% has been demonstrated under air mass-1 solar spectrum with a non-optimized anti reflection coating on the solar cells. Methods to improve the casting process reliability and techniques to improve solar cell efficiency are under investigation.

*Project completed

45. SYNTHESIS AND PHOTOELECTROCHEMICAL CHARACTER-
IZATION OF SEMICONDUCTING GROUP VIII TRANSITION
METAL CHALCOGENIDES AND Pnictides

Bruce Parkinson
Photoconversion Research Branch

Funding: FY '84 \$172,000 for 12 months

SOLAR ENERGY RESEARCH INSTITUTE
1617 Cole Boulevard
Golden, Colorado 80401

Date Started: September 26, 1983

Anticipated Duration: 2 years

Semiconducting electrodes, which are illuminated in the proper solution, are capable of converting solar energy directly into useful chemicals and fuels. Conventional semiconductor materials do not contain the elements (Fe, Co, Ni, Ru, Rh, Pd, Os, Ir, Pt) which are known to be most active for the catalytic conversion of simple molecules (CO_2 , H_2O , CO , N_2) to useful fuels and chemicals (HCO_2H , H_2 , O_2 , CH_3OH , NH_3 , N_2H_2 , CH_2O). We have been synthesizing and growing crystals of new semiconductors (i.e., PdPS , PdPSe , PdP_2 , $\text{Pd}_3(\text{PS}_4)_2$, PtS_2), containing group VIII metals combined with a chalcogen (S, Se, Te) and/or pnictogen (P, As), and examining their electronic properties (bandgap, carrier type and mobilities, doping densities etc.) with photoelectrochemical techniques. Materials with suitable electronic properties and stability to photocorrosion reactions will be tested for catalytic activity towards the reactions of interest.

46. GAS-LOADED, FREE-
ELECTRON LASER

STANFORD UNIVERSITY
Stanford, California 94305

Richard H. Pantell
School of Engineering

Date Started: August 1, 1984

Funding: FY '84 \$381,000 for 12 months

Anticipated Duration: 3 years

The objective of this program is the demonstration of a high peak power, coherent source tunable over the range from 5000 Å to 2000 Å. An innovative feature is the introduction of a gas into the interaction region of an FEL so as to provide a refractive index for phase matching the optical wave to the relativistic electron beam. The additional degrees of freedom made available in the choice of wiggler parameters and electron beam energy lead to much higher gains and less costly components than is possible in the vacuum FEL for these wavelengths. Theoretical considerations of electron scattering and ionization of the medium have led to the choice of hydrogen for the gas and to an electron beam energy of 40 MeV. Gains of order 20% per pass are predicted for this design at gas pressures of a few atmospheres.

47. COGENERATION OF ELECTRIC
ENERGY AND USEFUL CHEMICALS
IN A HIGH TEMPERATURE FUEL CELL

TUFTS UNIVERSITY
Medford, Massachusetts 02155

Michael Stoukides
Department of Chemical Engineering

Date Started: April 1, 1984

Funding: FY '84 \$90,000 for 12 months

Anticipated Duration: 2 years

Solid electrolyte fuel cells can be used to generate simultaneously electric energy and useful industrial products. The present project examines the synthesis of hydrogen cyanide in zirconia cells with appropriate electrodes. A platinum electrode deposited on the outside wall of an yttria stabilized zirconia solid electrolyte is exposed to the ambient air. A platinum-rhodium electrode deposited on the inside wall is exposed to a CH₄-NH₃ mixture and serves as a catalyst as well. At 1 atm total pressure and temperatures about 1000°C oxygen passing through the O²⁻ conducting solid electrolyte will oxidize the CH₄-NH₃ mixture to produce HCN and H₂O. In the same time the current produced will convert into electric power part of the free energy of the reaction. The primary goal is to establish optimal operating conditions for maximum HCN yield.

48. MULTIFUNCTION WALL SYSTEM FOR
APPLICATION WITH SOLAR HEATING
AND GROUND COOLING

VIRGINIA POLYTECHNIC INSTITUTE
AND STATE UNIVERSITY
Blacksburg, Virginia 24061

James F. Riley
College of Architecture & Urban Studies

Date Started: September 1, 1981

Funding: FY '84 \$48,000 for 12 months

Anticipated Duration: 4 1/4 years

The purpose of this project is to conduct a program of research on an alternative energy building system concept which utilizes a multifunction wall system with solar heating and ground cooling. The concept of the building system is to expand the use of structure and enclosure elements of a building to function additionally as: the ductwork for the solar heated or earth cooled air, the heat transfer membrane between the heated or cooled air and the living environment of the building, the heat storage medium (in winter), and the temperature leveling and control medium. Activity in FY '84 will include the development of pilot building designs, testing of the existing experimental building with different floor massing, and testing of the durability of glass reinforced cement coatings as utilized in surface bonding cements and exterior insulation systems (critical components of the building system).

49.*A METHOD OF ACHIEVING SUPER-PRESSURES
BY ADVANCED GASDYNAMIC TECHNIQUES

UNIVERSITY OF WASHINGTON
Seattle, Washington 98195

A. Hertzberg, A.P. Bruckner and Y.K. Rao
Aerospace and Energetics Research Program

Date Started: September 27, 1982

Funding: FY '83 \$131,000 for 12 months

Anticipated Duration: 1 1/2 years

After a careful review of the theoretical analysis of the concept suggested in our original proposal, it was mutually agreed upon by the contract monitor and the principal investigator that the superpressure approach originally suggested and studied during the 1982-1983 contract period, did not offer sufficient advantages to warrant continuation. Therefore, the remaining funds in the project were re-directed towards alternate concepts which had emerged in preliminary form during the final phases of previous effort. The investigations resulted in the development of a novel approach whereby relatively large masses (several kg) could be accelerated using chemical energy to velocities in the 25 km/sec range. The availability of a technique which can accelerate large masses into this velocity range naturally suggested additional linear velocity multiplication to ultra velocities (100 km/sec range) and hence, formed the core of our remaining study effort. While the proposed new approach is not without problems, the potential efficiency and the ability to use chemical energy in a convenient form led to a series of theoretical studies which suggested that a thorough experimental exploration was warranted. In addition, due to the wide range of potential applications of this technique, this project has now been selected by the Air Force and DARPA for additional funding to carry out exploratory experimental studies. The investigators hope that this new approach will provide a way of accelerating masses of 10 g or more to ultrahigh velocities.

*Project completed

50.*ANALYSIS OF IMPACT FUSION
TARGET DYNAMICS

UNIVERSITY OF WASHINGTON
Seattle, Washington 98195

F.L. Ribe
Aerospace and Energetics Research Program

Date Started: April 15, 1983

Funding: FY '84 \$111,000 for 12 months

Anticipated Duration: 3 years

In conjunction with rail-gun experiments on macroparticle acceleration we study the conversion of rectilinear projectile motion to a spherical or quasi-spherical implosion. Initial work involves one-dimensional numerical solutions of the hydrodynamic and transport equations, matched at the interface of a compressible metallic shell and an internal fusile gas for planar and spherical geometry. Present work also involves the two-dimensional problem of converting rectilinear to quasi-spherical particle and gas motion. In both cases, numerical hydrodynamic codes with particle and radiation transport have been written and applied to this problem. Analytical scaling estimates are compared with the numerical results.

*Projects 50 and 51 are cooperative interlaboratory projects.

51.*INVESTIGATION OF HIGH-VELOCITY
ELECTROMAGNETIC LAUNCHER BEHAVIOR
FOR USE IN IMPACT FUSION

WESTINGHOUSE R & D CENTER
1310 Beulah Road
Pittsburgh, Pennsylvania 15235

Y. Chia Thio
Electrotechnology Department

Date Started: July 18, 1983

Funding: FY '84 \$386,000 for 12 months

Anticipated Duration: 4 years

In conjunction with impact fusion modeling study conducted at the University of Washington, Seattle, the present program is directed towards investigation of the scientific and technological problems associated with the electromagnetic acceleration of gram-size projectiles to ultrahigh velocity using a multi-stage distributed energy injection railgun. The major program milestones accomplished to date include the detailed design of the entire 84 ft multi-stage launcher, detailed design of the 24 MJ distributed energy capacitive pulsed power supply, development of an advanced simulation code for multistage launcher, the fabrication, assembly and testing of the launcher first stage (8 ft). Using only half the energy available for the first stage 1.2-g projectile was successfully accelerated to 5.1 km/s. In the second year of the program, extension of the launcher to 36 ft is planned. This will provide the opportunity to conduct launcher experiments upto approximately 20 km/s and associated high-pressure and high-velocity plasma studies.

*Projects 50 and 51 are cooperative interlaboratory projects.

SAMPLE

Statement of Work

1) Project Objective

The contractor shall investigate the electrocatalytic oxidative dehydrogenation of ethylbenzene and butane in solid electrolyte fuel cells. The effort is directed toward defining optimal operating conditions for achieving high yields of styrene and butadiene with simultaneous electric energy generation.

2) Scope of Work

The work to be performed consists of the following tasks:

- 2.1. Construction of tubular stabilized zirconia fuel cells with a platinum cathode and an iron oxide or platinum anode. Both anode materials are quite promising and a decision between the two will be made after preliminary runs.
- 2.2. Measurement of the styrene cell activity and yield as a function of temperature, inlet ethylbenzene concentration and external resistive load.
- 2.3. Measurement of the cell electric power output and overpotential as a function of the operating parameters described in 2.2.
- 2.4. Determination of the nature of the overpotential according to the results of 2.3. If ohmic overpotential dominates, a small well mixed cell with thin (150 microns) electrolyte discs will be constructed to increase power density.
- 2.5. Development of correlation for styrene yield and electrical power output in terms of operating and design parameters for use in future scale up.
- 2.6. Repeat tasks 2.2. through 2.5. using butane and/or butene as the fuel.
- 2.7. Preliminary engineering and economic analysis according to the results of 2.2. through 2.6.

3) Deliverables

The contractor shall provide the data of experiments performed according to paragraphs 2.2., 2.3., 2.4., 2.5. and 2.6 along with analyses and conclusions based on this data.

4) Performance Schedule

- 4.1. Complete construction of cells three months after start of work.
- 4.2. Complete ethylbenzene experiments within twelve months after start of work.
- 4.3. Complete butane and butene experiments and data analysis twenty months after start of work.
- 4.4. Complete data correlation, economic analysis and final report 24 months after start of work.

OFFICE OF BASIC ENERGY SCIENCES
DIVISION OF ADVANCED ENERGY PROJECTS

Fiscal Year 1984 Program Data

FY '84 Budget

Operating Funds.....\$9,298,000
Capital Equipment Funds.....\$ 310,000

Distribution of Projects by Institutional Sector

Universities	40%
Small Business	27%
Other Industry	8%
DOE Laboratories	<u>25%</u>
	100%

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