DOE/ER-0294

Advanced Energy Projects FY 1986 Research Summaries

September 1986

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

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Washington, D.C. 20545

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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 gamma-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

Annual funding level for projects varied from about $50,000 to a typical maximum in the $350,000 to $400,000 range.

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 the "Office of Energy Research Special Research Grants Program Guide for the Submission of Applications". Each proposal must contain:

- A cover page.

- 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, such as this brochure.

- 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.

- 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 33.

- Description of available facilities.

- Resumes of key personnel.

- 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.

- 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 1986

This section contains brief summaries of all projects active in this Division during Fiscal Year 1986 (October 1, 1985-September 30, 1986). 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 identified 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 '86 are indicated by the footnote: *Project completed. The annual funding level of each project is shown.

1. *THE CONTINUOUS MEMBRANE COLUMN; A LOW-ENERGY ALTERNATIVE TO DISTILLATION

Walter C. Babcock
Membrane Separations Division

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

Date Started: February 5, 1982

$121,000

Anticipated Duration: 3 1/2 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. 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.

*Project Completed

2. MEASUREMENT OF THE EFFICIENCY OF MUON-CATALYZED FUSION

BRIGHAM YOUNG UNIVERSITY
Provo, Utah 84602

Steven E. Jones
Department of Physics and Astronomy

Date Started: September 1, 1985

$215,000

Anticipated Duration: 3 years

In conventional approaches to nuclear fusion, hydrogen isotopes are heated to temperatures approaching or exceeding those found in the sun. The fusion reaction then occurs, releasing energy. As early as 1947, it was hypothesized that an elementary particle known as a muon could catalyze fusion so that it could proceed at "cold" temperatures, such as room temperature. However, theorists soon predicted that the reaction would proceed too slowly to be of much interest. Interest revived a few years ago when Soviet theorists postulated the existence of a resonance mechanism whereby the "cold fusion" reaction would go very quickly. They argued that it might be possible to achieve as many as 110 fusion reactions per muon. Experiments to test these new ideas have actually exceeded the predictions: as many as 150 fusions (average) per muon have been achieved. Still higher fusion yields are anticipated. The objective of the program is to explore the limits of muon catalyzed fusion to provide answers to questions regarding energy applications.

3. *EXTREME ULTRAVIOLET COHERENT RADIATION DEVICE; TRANSVERSE OPTICAL KLYSTRON

BROOKHAVEN NATIONAL LABORATORY
Upton, New York 11973

C. Pellegrini
National Synchrotron Light Source

Date Started: September 26, 1983

$290,000

Anticipated Duration: 4 years

This project is for the development of a new radiation source to be incorporated into 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. The basic approach to this objective is to overlap the macrobunch of electrons in a storage ring, in the field of an undulator magnet, with the radiation of an external laser. As a consequence, the electrons receive energy modulation, at an appropriate laser wavelength, due to coupling of the transverse electric field of the laser with the transverse velocity induced by the periodically varying field of the undulator (modulator section). While traversing the undulator, the energy modulation of the electrons will convert into spatial bunching at the laser wavelength (dispersion section). In the downstream part of the undulator, the electrons will have optimal bunching and radiate coherently at the harmonics of the laser (radiation section). A third harmonic TOK "pumping" scheme rather than the first harmonic pumping mode will be used in order to avoid unacceptable (for electron storage ring operation) undulator minimum gap parameter values.

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

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

UNIVERSITY OF CALIFORNIA, LOS ANGELES
Los Angeles, California 90024

Ken Nobe
Department of Chemical Engineering

Date Started: July 1, 1984

$70,000

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.

5. MUONIC MOLECULAR STRUCTURE, μ-STICKING PROBABILITIES AND FUSION RATES FOR MUON CATALYZED FUSION

CALIFORNIA STATE UNIVERSITY, LONG BEACH
1250 Bellflower Blvd.
Long Beach, California 90840

Chi-Yu Hu
Physics/Astronomy Department

Date Started: August 1, 1986

$66,000

Anticipated Duration: 1 year

In the muonic molecules such as $(dt\mu)^+$, $(dd\mu)^+$, the muon "confines" the two nuclei in a region small enough that fusion can occur. The average number of fusions induced by each muon determines the upper limit on energy production. In order to predict the average number of fusions per muon and other properties in the muon-catalysis cycle, it is essential to understand the details of the muonic molecular structures. The purpose of this project is to make extremely accurate calculations of the $(dt\mu)^+$ and $(dd\mu)^+$ molecular structures and then to use these wave functions to determine fusion rates, μ-sticking probabilities and other parameters necessary to understand the mesomolecular formation process and the fusion process. In this collaboration with the theoretical and the experimental teams at Brigham Young University, Los Alamos National Laboratory, and the Lawrence Livermore National Laboratory, the ultimate goals are to understand completely the muonic molecular structures and the muon-catalysis cycle.

6. MUON-CATALYZED FUSION IN GASES OF HD AND H_2 + D_2 MIXTURES

CALIFORNIA STATE UNIVERSITY, LOS ANGELES
5151 State University Drive
Los Angeles, California 90032

Konrad Aniol
Physics Department

Date Started: September 15, 1986

$27,000

Anticipated Duration: 1 year

Current measurements of muon induced fusion in deuterium-tritium mixtures show that the sticking probability is about 0.4%. At this level of sticking, other processes, such as the formation of $dd\mu$ or $pd\mu$ muonic molecules, have significant effects on the loss of muons from the fusion cycle. The molecular formation rates of $dd\mu$ and $pd\mu$ are about 100 times smaller than that of the $dt\mu$. Nevertheless, because of their substantially larger sticking probability, they are important sources of muon loss at the tenth of a percent level. Measurements have been made of the relative formation rates of $dd\mu$ and $pd\mu$ molecules in gas samples of H_2 + D_2 and HD. Substantially different temperature dependences of $dd\mu$ formation rates in these two gas samples were observed, but not of the type predicted by theory. In addition, temperature dependence was observed in $pd\mu$ formation more pronounced than predicted, and a difference in absolute yield of $pd\mu$ formation between HD and H_2 + D_2 where none was anticipated. It is planned to remeasure the $dd\mu$ and $pd\mu$ rates in a new target cell over a larger temperature range. It is important to verify, in a new experimental set-up, whether the preliminary experimental results are correct.

7. *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

$79,000

Anticipated Duration: 3 years

The objective of this project is to determine the potential uses of iron-metabolizing microorganisms for a variety of industrial and commercial applications. A research program is being carried out to study the kinetics and mechanisms of the bacterial dissimilative iron reduction. Pseudomonas sp. 200 was selected for detailed study based upon screening experiments in which the organism reduced Fe(III) 10 times more rapidly than other microorganisms tested and 2-3 times faster than the highest Fe(III) reduction rates reported in the scientific literature. Pseudomonas sp 200 is capable of electron transport to ferric iron at rates characteristic of transport during aerobic respiration. At such rates, the use of bacteria for reductive dissolution of iron oxides (e.g. rust removal) or extraction of iron from ores may be commercially feasible. Experimental iron-reduction rates are clearly dependent upon the chemical speciation (i.e., the particular chemical forms) of Fe(III). Furthermore, rates of microbial dissolution of iron oxides are inversely dependent upon mineral stability (reduction rate of amorphous $Fe(OH)_3(s)$ > goethite > hematite).

*Project Completed

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

CASE WESTERN RESERVE UNIVERSITY
Cleveland, Ohio 44106

Morton H. Litt
Department of Macromolecular Science

Date Started: September 15, 1983

$160,000

Anticipated Duration: 3 1/2 years

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. Fibers of these polymers should be like graphite fibers, but should be solution processable.

9. ALPHA STICKING FRACTION CALCULATIONS IN MUON CATALYZED FUSION

DUKE UNIVERSITY
Durham, North Carolina 27706

L.C. Biedenharn
Physics Department

Date Started: September 15, 1986

$52,000

Anticipated Duration: 1 year

Recent experiments on deuterium-tritium fusion, catalyzed by muons, show an unexpectedly large number of fusions per muon. This indicates that thermonuclear energy production, via muon catalyzed fusion, be considered as a possibility. The single most important parameter characterizing this process is the "alpha sticking fraction" W_s (the fraction of the muons lost by capture on the alpha particle per fusion cycle) since the average number of fusions per muon--which determines the feasibility for energy production--cannot exceed $(W_s)^{-1}$. A precise calculation of W_s is now important for determining a theoretical upper limit for feasibility studies; no such calculation currently exists. A cooperative program will be conducted for an accurate calculation of W_s. The calculation of W_s involves two different disciplines: nuclear physics (the ^{5}He(3/2+) resonance is crucial) and molecular physics. Eigenphase-shift techniques will be used to develop nuclear wavefunctions in the critical short distance regime.

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

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

Martin W. Rupich
Battery Division

Date Started: July 15, 1983

$151,000

Anticipated Duration: 3 1/2 years*

The objective of this program is the exploration of concentrated, aqueous $K_2CO_3/KHCO_3$ solutions as electrolytes for direct methanol-air fuel cells. A major goal of the program is the identification and development of electrocatalyst systems that are stable in the electrolyte and efficiently catalyze the electro-oxidation of methanol at low potentials. Numerous non-noble metal, noble metal and binary systems were evaluated as potential electrocatalysts in the $K_2CO_3/KHCO_3$ electrolyte. A number of systems, particularly binary systems containing platinum, were identified as potential electrocatalysts. These systems are evaluated in half cell tests.

*Includes no cost extension

11. ULTRASONIC ATOMIZATION FOR COMBUSTION EFFICIENCY IN OIL BURNERS

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

Jeffrey Solash

Date Started: September 1, 1984

$115,000

Anticipated Duration: 27 months*

This project involves the use of ultrasonics to produce an atomized fuel oil. Prior work indicated that the droplet size of the atomized fluid might be controlled by adjusting the area of liquid presented to the ultrasonic field. A number of variables thought to affect the atomization and particle size distribution were examined. A rotating screen device was constructed to feed liquid to the ultrasonic field. It was found that the feed rate could be changed without affecting atomization. Screen pore size and ultrasonic frequency appear to affect the particle size distribution. Detailed particle size data are being taken. A prototype continuous ultrasonic atomizer has been constructed and will be further tested.

*Includes no cost extension

12. ACCURATE ALPHA STICKING FRACTIONS FROM IMPROVED THREE-BODY CALCULATIONS RELEVANT FOR MUON CATALYZED FUSION

UNIVERSITY OF FLORIDA
Gainesville, Florida 32611

Krzysztof Szalewicz
Department of Physics

Date Started: September 1, 1985

$124,000

Anticipated Duration: 3 years

Interest in muon-catalyzed fusion is experiencing a dramatic revival. Experiments by Jones et al have shown that under proper conditions a single muon can catalyze about one hundred fifty fusions in its life time. This is much more than theory had predicted. The objective of this project is to calculate highly accurate values of the probability for a muon to stick to the alpha particle synthesized during the fusion. Stuck muons are lost for further fusions and at present this process seems to determine the fusion yield. The sticking probability will be extracted from high-accuracy three-body wavefunctions for muonic molecules containing the hydrogen isotopes. These functions will be computed with and without strong force modification to the Coulombic interaction between the nuclei. Better theoretical understanding of the process may be crucial for guiding future experimental work.

13. 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

$146,000

Anticipated Duration: 3 years

The principal research objectives are 1) the development of a High Pressure Liquid Chromotography (HPLC) system for the separation and detection of metal-binding proteins; 2) implement the HPLC technique for analyzing candidate organisms for the presence of metal-binding proteins; 3) to chemically synthesize and characterize metallothionein-like proteins. Current work has included a new HPLC on-line detection technique using a combination of bichiconicic acid and p-chloromer-curibenzoate to identify proteins with copper bound to them. Methods have been developed for a two-dimensional HPLC to provide a rapid separation of complex protein mixtures effectively and efficiently. Fragments of Neurospora metallothionein have been synthesized and characterized. Synthesis and purification of metallothionein and metallothionein analogs will be continued for synthetic model peptides.

14. FLUID DYNAMIC ENERGY SEPARATION

GEORGE WASHINGTON UNIVERSITY
Washington, D.C. 20052

C.A. Garris
School of Engineering and Applied Sciences

Date Started: September 15, 1983

$177,000

Anticipated Duration: 3 1/2 years*

The object of this study, the "energy separator", is a new kind of cooling 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 cooled subflow to appear in the other subflow not as heat but rather in the form of recoverable mechanical energy. Experimental work was done on four 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 for design and evaluation. Critical comparisons were made between energy separators and conventional devices and promising applications identified.

*Includes no cost extension

15. A VISIBLE TUNABLE SOURCE

HUGHES AIRCRAFT COMPANY
P.O. Box 9399, M/S 3C923
Long Beach, California 90810

I-Fu Shih
Advanced Products Laboratory

Date Started: September 1, 1985

$144,000

Anticipated Duration: 3 years

The objective of this program is to further understand the Salisbury-Smith-Purcell effect so that useful devices based on this effect can be developed. Salisbury-Smith-Purcell radiation occurs when an electron beam grazes a conducting grating. A tunable radiation source based on the Salisbury-Smith-Purcell effect could have wide-spread applications; for example, such a device can be used in interferometric sensors for acoustic, electromagnetic, pressure, or temperature sensing. These sensors can be used for geophysical exploration, and for a broad class of diagnostic, test, or control equipment. This program will focus on a feature of Salisbury's model that has not been exploited to date. The Salisbury model suggests that it is important to use a low divergence electron beam and to reflect some of the electrons from the grating surface to form sheets of periodic space charge above the grating. Both theoretical and experimental investigations are planned. The theoretical task is to refine the preliminary analysis to more accurately predict the radiation characteristics. The experimental task is to assemble an apparatus and to characterize the radiation.

16.*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

$200,000

Anticipated Duration: 3 years

Studies of multiphoton ionization of atoms have revealed several unexpected characteristics. The confluence of the experimental evidence leads to the hypothesis that the basic character of the atomic response involves highly organized coherent motions of entire atomic shells. The important regime, for which the radiative field strength E is greater than an atomic unit (e/a_0^2), can be viewed in approximate correspondence with the physics of fast ($\sim$ 10 MeV/amu) atom-atom scattering. This physical picture provides a basis for the expectation that stimulated emission in the x-ray range can be produced by direct highly nonlinear coupling of ultraviolet radiation to atoms.

*Project Completed

17.*PRODUCTION OF ULTRAHIGH MAGNETIC FIELDS

JAYCOR
11011 Torreyana Road
San Diego, California 92138

Franklin S. Felber

Date Started: September 15, 1984

$290,000

Anticipated Duration: 2 years

The objectives of this experimental program are to produce controlled ultrahigh axial magnetic fields by a new method and to measure the fields. The method involves imploding a plasma in which a magnetic field has been entrained, thereby compressing the field. The approach has been to inject magnetic fields in gas-puff Z pinches and mesure the compressed fields with Faraday rotation and Zeeman diagnostics. The gas-puff Z pinch facility at the University of California at Irvine was used to demonstrate feasibility of the method by producing field compressions up to 180 and peak fields up to 1.6 MG. The PROTO-II Z pinch facility at Sandia National Laboratories is being used for tests at higher field strengths. The method appears capable of producing fields of order 100 MG. Potential applications of ultrahigh magnetic fields include reducing fusion ignition thresholds, producing collimated beams of gamma radiation, accelerating particles, stabilizing high-current Z pinches, and producing high-energy densities (hundreds of $eV/\AA^3$) under controlled conditions for studies of plasma physics, atomic physics, and material properties.

*Project Completed

18. MECHANISTIC STUDY OF THE EFFECT OF MAGNETIC FIELDS ON SCALE FORMATION

THE JOHNS HOPKINS UNIVERSITY
Baltimore, Maryland 21218

J.L. Katz
Department of Chemical Engineering

Date Started: September 1, 1985

$91,000

Anticipated Duration: 3 years

This project involves investigation of the inhibition of scale formation by magnetic water treatment. Although commercial treatment devices are available, there is major controversy whether it works and how it works. Nonetheless, such devices have attracted great interest because, if effective, they are easy to use, reliable and very inexpensive. This project involves the testing of a mechanism which is able to account for all experimentally observed facts. The mechanism examined here builds on earlier work by Zubarev who described magnetic water treatment in terms of nucleation phenomena. Preliminary work in our laboratory has shown that under certain conditions the application of magnetic fields can change the concentration of ferric hydroxides in saturated solutions. These hydroxides may control the deposition of calcium salts from solution by providing heterogeneous nucleation sites. Additional experiments involving magnetic field strengths and magnetic field gradients in these processes are planned.

19. APPLICATION OF PERMANENT MAGNETS TO ACCELERATOR TECHNOLOGY AND GENERATION OF RADIATION WITH ELECTRON STORAGE RINGS AND FREE ELECTRON LASERS

LAWRENCE BERKELEY LABORATORY
Building 80-101
Berkeley, California 94720

Klaus Halbach

Date Started: October 1, 1985

$289,000

Anticipated Duration: 3 years

Because of saturation properties of soft ferromagnetic materials and of problems associated with the cooling of coils, the magnetic field strength achievable in small working volumes becomes smaller as the linear dimensions of an electromagnet become smaller. Since permanent magnets do not have the coil cooling problems, they can produce much larger fields than electromagnets when magnetically relevant dimensions have to be small. For that reason, permanent magnet undulators/wigglers and charged particle beam handling magnets have been developed over the last few years. It is the purpose of this project to bring the permanent magnet devices developed so far to maturity with regard to reliability and field quality. Consequently, the effect of construction and material tolerances on field quality will be investigated, and improved construction methods will be developed. In addition, work will proceed to incorporate permanent magnet materials into electromagnets, to make it possible to produce with permanent magnets assisted electromagnets fields of the same strength that permanent magnets produce. This work is particularly important for tapered undulators in free electron lasers, where one needs the combination of permanent magnet strength and electromagnet variability. In addition to developing new concepts, the tools employed to achieve these goals (a combination of analytical models, computer analysis and synthesis, and experimental work) will be perfected.

20. ACCELERATION OF A COMPACT TORUS PLASMA RING

LAWRENCE LIVERMORE NATIONAL LABORATORY
P.O. Box 5511
Livermore, California 94550

Charles Hartman

Date Started: July 1, 1985

$292,000

Anticipated Duration: 3 years

This project has the objective of demonstrating acceleration of plasma rings confined by the dipole and entrapped B magnetic fields of a compact torus. The 6 m long accelerator is in the form of a coaxial rail-gun with the plasma ring, which acts as a moving short, accelerated by a 250 kJ capacitor bank. Successful acceleration will yield 10^{-5} to 10^{-3} gram plasma rings with 100 kJ kinetic energy and velocities up to about 5 x 10^{8} cm/sec. Rapidly moving plasma rings will be tested for focusing by injecting them into a conducting core where eddy currents will compress the magnetic field and confined plasma to small size. This new type of collective accelerator employing magnetic confinement will allow access to power, power density, and energy density regimes heretofore inaccessible in the laboratory. Following demonstration of acceleration, applications can be tested, including rapid compression of rf fields to produce an ultra high power rf source, nanosecond generation of high temperature radiation, a fast opening in megampere switch, and, in a scaled up accelerator, focusing to produce an efficient, simple inertial fusion driver.

21.*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

$250,000

Anticipated Duration: 4 1/2 years

This project is an experimental search for fractionally 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 in diameter and spaced about 750 micrometers apart are made at a rate of approximately 3 x 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 21 and 31 are cooperative interlaboratory projects.

22.*PUMPING OF GAMMA-RAY LASERS;
EXPERIMENTAL AND THEORETICAL

LOS ALAMOS NATIONAL LABORATORY
Los Alamos, New Mexico 87545

G.C. Baldwin
Physics Division

Date Started: September 27, 1983

$300,000

Anticipated Duration: 3 years

A laser for sub-nanometer wavelengths would operate with recoilless nuclear, rather than electronic transitions, and be pumped in two steps, first creating and isolating a long-lived nuclear isomer, and then transferring its excitation to a nearby state that can emit a relatively narrow gamma-ray line. Problems involved in this approach are being explored in collaboration with the Theoretical Division (internally funded), with MIT and Rice University. Isomer separation by selective photoionization has been demonstrated. A second method is being investigated. An experiment to observe an effect of atomic excitation on the decay of isomeric U-235 is underway. Other tasks being done are computer studies of the development of superradiance after the transfer step, defining specifications for candidate nuclides, and studying how Bragg reflection in crystal lattices can reduce the requirements for both lasing and interlevel transfer.

*Project Completed

23.*MAGNETIC REFRIGERATION FOR
EFFICIENT CRYOGEN LIQUEFACTION

LOS ALAMOS NATIONAL LABORATORY
P.O. Box 1663, MS K764
Los Alamos, New Mexico 87545

John A. Barclay
Physics Division, Group P-10

Date Started: February 1, 1986

$270,000

Anticipated Duration: 4 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 cryogens. Data base generation consists of literature evaluation and experimental work. Design data on magnetic materials, fluid dynamics, heat transfer, pump, 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 are suitable magnetic refrigerants between 4 K and 300 K. Prototype devices will be developed and this technology is being transferred to the private sector.

*Project Completed

24. THEORETICAL STUDY OF MUON-CATALYZED FUSION

James S. Cohen
Theoretical Division,

$200,000

LOS ALAMOS NATIONAL LABORATORY
MS-J569
Los Alamos, New Mexico 87545

Date Started: December 29, 1983

Anticipated Duration: 3 years

This study is designed to formulate a detailed description of the muon-catalyzed fusion cycle, with the objectives of aiding the experimental program and obtaining parameters needed to evaluate the ultimate limitations on energy production. Nuclear fusion occurs when a negative muon ($\bar{\mu}$, an unstable particle about 200 times as massive as the electron) is stopped in a high-density mixture of deuterium and tritium and the small dtμ mesomolecule is formed. Experiments at the Los Alamos Meson Physics Facility have detected 150 fusions per muon. Some unexpected transient behaviors and dependencies of the mesomolecular-formation and muon-loss rates on temperature and target density have been observed; understanding of these effects may lead to still higher yields. The physical problems being addressed theoretically include muon capture and transfer, muonic molecule formation (with nonthermal and hyperfine effects) and structure, and muon loss (to impurities as well as helium) and regeneration. In collaboration with the experimental team, tests of theoretical predictions are planned.

25. NUCLEAR EXCITATION BY A HIGH-BRIGHTNESS UV LASER

Peggy L. Dyer
Physics Division

$330,000

LOS ALAMOS NATIONAL LABORATORY
Los Alamos, New Mexico 87545

Date Started: July 1, 1986

Anticipated Duration: 3 years

In the conceptual two-step pumping scheme for a gamma-ray laser, the most difficult remaining problem lies in exciting nuclei from long-lived storage isomers to nearby short-lived states (that will then spontaneously decay to upper lasing levels), without destroying the solid state structure required for the Mossbauer effect and for Borrmann modes. A novel mechanism recently proposed for this transfer will be experimentally investigated: nuclear excitation by electrons driven to oscillate collectively by a bright, picosecond ultraviolet laser. As a test case it will be attempted to excite the 75-eV isomer of ^{235}U, the excitation signal being delayed internal conversion electrons. Following parameter-dependence studies with a vapor target in a collision-free environment, nuclear excitations in solid substrates of the crystalline form required for a gamma-ray laser will be investigated. Finally, nuclear isomeric targets will be used, in preparation for first experiments to look for stimulated emission in nuclei.

26. LARGE APERTURE RARE GAS HALOGEN POWER AMPLIFIER FOR FEMTOSECOND OPERATION AT EXTREME PEAK POWER

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

C.A. Fenstermacher
Defense Research Programs
Fusion Research and Applications

Date Started: March 1, 1985

$375,000

Anticipated Duration: 2 years

A collaborative research effort between the University of Illinois, Chicago Circle, and the Los Alamos National Laboratory has been underway for several years with the goal of producing a high brightness, extremely short pulse laser system operating at 248 nm to produce the extreme power believed needed to pump x-ray lasers. Work at the University of Illinois has identified a mechanism for x-ray laser pumping, and current research results show high promise. Based upon this, a laser pumping system concept has been developed and implementation is underway. A major component of this laser oscillator-amplifier chain is the final amplifier which is proposed to be a large aperture KrF amplifier module. Because of its current efforts in large KrF amplifier development for the Inertial Confinement Fusion program, the Laboratory has developed an in-depth expertise in all the related technologies and is therefore in a unique position to oversee the development of this prototype amplifier. Preliminary survey indicates that an x-ray pre-ionized discharge amplifier of dimensions 10x10x100 cm is within the state of the art and will provide output energy in the 1-2 joule range in a 5 ps. pulse.

27. ANTIPROTON TECHNOLOGY

LOS ALAMOS NATIONAL LABORATORY
Los Alamos, New Mexico 87545

M.V. Hynes
Physics Division

Date Started: November 15, 1985

$520,000

Anticipated Duration: 3 years

From the initial observation of the antiproton in 1955 until the present, matter-antimatter annihilation as a compact energy source has been at best a visionary concept whose realization appeared beyond reach. A number of technological developments in both particle and atomic physics have brought the prospect of antimatter as an energy source much closer. The possibility now exists for performing experiments with the objective of storing substantial numbers of cold antiprotons, a critical step toward an antimatter energy source. As a part of experiment PS200 at CERN to measure the gravitational acceleration of antiprotons a number of interrelated problems central to evaluating prospects for antimatter storage as a potential advanced energy source will be investigated both experimentally and theoretically. These are: 1) demonstrate the storage of low temperature protons, antiprotons and ^{-}H ions externally injected into a Penning type ion trap, 2) the cooling of trapped antiprotons to low temperatures ($\leq 10^{o}K$), 3) trap a substantial quantity of antiprotons and release them in a controlled manner, and 4) carry out theoretical investigations in condensed matter, nuclear, and particle physics to establish a framework for further experimentation with low temperature antiprotons relevant to improved storage concepts.

28. EXPERIMENTAL INVESTIGATION OF MUON-CATALYZED FUSION

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

Melvin Leon
MP Division

Date Started: July 1, 1985

$800,000

Anticipated Duration: 2 years

The remarkable ability of a single negative muon to catalyze many d-t fusions has given rise to speculations about the possibility of harnessing this reaction for practical power production. In order to put such discussions on a sound basis, it is essential that as complete an understanding as possible be developed of the subtle and intricate molecular physics involved. To this end, it is intended to investigate the physics of muon-catalyzed fusion, continuing the experimental program at LAMPF of the Brigham Young University-Los Alamos National Laboratory-Idaho National Engineering Laboratory collaboration. Our long range goals are to understand completely the muon-catalysis cycle, and to determine the maximum number of d-t fusions that can be obtained from a single negative muon.

29. DEVELOPMENT OF A BROADLY TUNABLE FREE-ELECTRON LASER FOR THE EXTREME-ULTRAVIOLET SPECTRUM

LOS ALAMOS NATIONAL LABORATORY
P.O. Box 1663, MS-J564
Los Alamos, New Mexico 87545

Brian E. Newnam
Chemistry Division

Date Started: June 1, 1985

$290,000

Anticipated Duration: 3 years

The overall goal of this project is to determine the feasibility of a free-electron laser (FEL), based on a single rf linear accelerator, for production of broadly tunable, coherent radiation extending from the extreme ultraviolet to the visible spectrum (>50-400nm). The inherent temporal structure will be continuous trains of 10- to 30-ps pulses. Initial calculations indicate that below 200 nm the peak and average power output would surpass the capabilities of any existing, continuously tunable sources by many orders of magnitude. The present research will extend present FEL theory to XUV wavelengths for which a three-space dimensional FEL code has been developed to numerically simulate variations of key oscillator parameters. Electron beam, magnetic undulator, and resonator optics parameters will be optimized to attain maximum laser gain and output power. To reach still shorter wavelengths in the x-ray region, e.g. 5 nm, methods to enhance production of the optical harmonics of the FEL will be analyzed.

30.*LIQUID METAL THERMO-
ACOUSTIC ENGINE

LOS ALAMOS NATIONAL LABORATORY
Los Alamos, New Mexico 87545

G. W. Swift
Physics Division

Date Started: September 27, 1983

$290,000

Anticipated Duration: 44 months

A sound wave is usually thought of as consisting of pressure oscillations, but always attendant to the pressure oscillations are temperature oscillations. The combination produces a rich vareity of "thermoacoustic" effects. These effects are usually so small that they are never noticed in everyday life, but under the right circumstances they can be harnessed to produce powerful heat engines, heat pumps, and refrigerators. This project is a combined theoretical and experimental study of thermoacoustic effects in liquid sodium. In the liquid sodium thermoacoustic engine, heat flow from a high temperature source to a low temperature sink will generate a high-amplitude acoustic wave in the sodium. This acoustic power will be converted to electric power by a simple magnetohydrodynamic effect at the acoustic oscillation frequency. Hence the engine will produce electrical power from heat with no moving parts. In a kilowatt laboratory model engine the heat-to-acoustic and the acoustic-to-electric conversion processes will be studied.

*Project originated by the late John C. Wheatley

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

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

George Zweig
Theoretical Division

Date Started: May 1, 1982

$330,000

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 suggested 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.

*Project Completed
**Projects 21 and 31 are cooperative interlaboratory projects.

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

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

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

Date Started: July 1, 1984

$160,000

Anticipated Duration: 3 years

The objective of this project is to determine if a circular geometry Free Electron Laser can be constructed by subjecting a rotating electron beam to a transverse wiggler magnetic field. In this concept, a rotating electron beam is produced by passing a non-rotating cylindrical beam through a narrow magnetic cusp, and the transverse wiggler field is produced by samarium-cobalt magnets placed behind smooth conducting boundaries interior and exterior to the beam. Potential advantages of such a device include a more compact geometric configuration and internal feedback resulting from the recirculation of the electromagnetic field around the device. The latter feature may mean that the device can operate as an oscillator without external mirrors, in contrast to conventional Linear Free Electron Lasers. Work is being pursued theoretically and on three different experiments operating at a range of electron energies and currents.

33. MAGNETIC ENHANCEMENT AND DEMINERALIZATION OF EASTERN COALS

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Cambridge, Massachusetts 02139

David R. Kelland
Francis Bitter National Magnet Laboratory

Date Started: June 1, 1984

$330,000

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 coal pyrite through selective heating by microwave irradiation to convert the pyrite to more magnetic pyrrhotite should improve demineralization performance. This research program, carried out in cooperation with General Electric-Schenectady, is an attempt to verify indications of successful microwave pretreatment of coals and investigate the effect of magnetic enhancement on HGMS performance. Microwave experiments on coal have produced pyrite conversion to troilite/disordered pyrrhotite, Fe_3O_4 and Fe. The magnetization of mineral pyrite has been enhanced in both air and inert gas by high voltage electrical discharge in our effort to study the mechanism of conversion. Coal characterization, in particular by Mossbauer, electron microprobe, and magnetization measurements is being carried on along with baseline magnetic separations on 3 Eastern coals.

34. BIOLOGICAL X-RAY HOLOGRAMS

MCR TECHNOLOGY CORPORATION
P.O. Box 10084
Chicago, Illinois 60610

Keith Boyer

Date Started: September 1, 1986

$192,000

Anticipated Duration: 1 year

A new ultrahigh brightness x-ray technology is emerging which will enable high contrast imaging of the pure living state on an atomic scale, a microvisualization of biological materials impossible to achieve by any other known means. The goal of the proposed program is the development of the technology and instrumentation needed for the application of x-ray biological microholograms to living matter. The approach used involves the use of ultrahigh brightness ultraviolet lasers as the technical means for producing the needed short wavelength radiation. The instrumentation required to control the ultraviolet energy features as the focus of this program.

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

MCR Technology Corporation
P.O. Box 10084
Chicago, Illinois 60610-0084

Charles K. Rhodes

Date Started: August 15, 1984

$250,000

Anticipated Duration: 2 1/2 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. The objective is to develop a prototype laser system which delivers a tunable, high quality pulse of $\sim$10 psec duration in the range of $\sim$740 - 780 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 technology would overcome the fundamental limitations of the low-brightness incoherent sources presently available and permit application to a broad spectrum of technical areas relevant both to pure scientific and industrial spheres.

*Includes no cost extension

36.*PERVAPORATION; A LOW-ENERGY ALTERNATIVE TO DISTILLATION

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

Richard W. Baker

Date Started: April 15, 1983

$141,000

Anticipated Duration: 32 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. Currently, we are using 0.7 micron thick silicone rubber composite membranes; other membranes have been made and are under test with model organic solvent mixtures. Based on the experience obtained with these model mixtures, we are determining the applicability of pervaporation to more economically significant organic mixtures. In particular, we are concentrating on the recovery of organic solvents from industrial effluent streams. These solvents represent both a pollution problem and a reuse opportunity. This data will be used to perform a technical and economic analysis of the process.

*Project Completed

37. APPLICATION OF HIGH POWER MODULATED INTENSE RELATIVISTIC ELECTRON BEAMS FOR DEVELOPMENT OF A WAKE FIELD ACCELERATOR

NAVAL RESEARCH LABORATORY
Washington, D.C. 20375-5000

Moshe Friedman

Date Started: August 1, 1986

$327,000

Anticipated Duration: 3 years

Future progress in accelerators and their applications depend critically on the development of new mechanisms capable of generating high voltage gradients. The objective of this program is to show that high electric fields can be established in a structure by the wake field of a modulated intense relativistic electron beam (MIREB) propagating through the structure. The simplicity and high efficiency of generating MIREBs with power $\gtrsim 10^{10}$ watts by an external low power RF source suggests advantages of a wake filed accelerator over a more conventional approach to generating high currents of high energy particles. It is anticipated that at the end of the project, proof-of-principle results demonstrating particle acceleration through a voltage gradient $\gtrsim 100$ MV/m will be at hand with scaling laws needed to design practical devices for future applications.

38.*HIGH-FLUX, EXTENDED-PULSE ION ACCELERATOR

UNIVERSITY OF NEW MEXICO
Albuquerque, New Mexico 87131

S. Humphries, Jr.
Institute for Accelerator and Plasma Beam Technology

Date Started: September 27, 1983

$89,000

Anticipated Duration: 3 years

The objective of the program is to develop new technology for high flux plasma sources to generate ions and extractors to accelerate them to high energy. Success of the technology could motivate new industrial processes for ion implantation and materials modification. Metal vapor vacuum arcs as high flux plasma sources have been investigated. Ion species from deuterium (deuterated titanium electrodes) to indium have been produced and analyzed with a time-of-flight spectrometer. Useful flux exceeds 0.1 A/cm^2. Arrays of arcs have been triggered in parallel to generate 25 A pulses of Al^+ ions. A new arc geometry that will extend operation to multi-ms pulses with high reproducibility and long lifetime has been developed. A magnetically insulated plasma source to generate ions from gases has produced ms pulses of argon ions at 0.5 A/cm^2. A new method of ion extraction based on electrostatic control grids that decouples ion optics from the properties of the plasma source has been developed. This method can lead to significant enhancement of beam brightness for applications such as ion beam lithography.

*Project Completed

39. REDUCTION IN ENERGY AND OPERATING COSTS FOR ENZYMATIC CELLULOSE HYDROLYSIS BY A NOVEL METHOD FOR ENZYME RECOVERY

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831

Charles D. Scott
Chemical Technology Division

Date Started: July 1, 1986

$170,000

Anticipated Duration: 3 years

The objective of this program is to significantly reduce the costs associated with enzymatic cellulose hydrolysis for the production of high energy fuels and chemicals by demonstrating the feasibility of a novel method for the recovery of the enzyme cellulase from aqueous solutions and from undigested cellulosic residues. The method is based upon the ability of specific absorbent molecules to either "mop" up cellulase from solution or to effect the desorption of cellulase from the residues because of their affinity for the enzyme. Subsequent release of cellulase from the absorbents will allow reuse of the enzyme. For example, cellulase absorbed onto inorganic kieselguhr granules coated with concanavalin A desorbs from this support when contacted with cellulose. The work will be divided into three categories: (1) identification of appropriate support materials with affinity for cellulase, (2) determination of the effect of fuels and chemicals (fermentation products) on the affinity of appropriate supports for cellulase, and (3) design and development of suitable reactor systems for enzymatic cellulose hydrolysis with enzyme recovery.

40. RESEARCH ON X-RAY OPTICS WITH THE ULTIMATE AIM OF PRODUCING A SYNCHROTRON RADIATION PUMPED SOFT X-RAY LASER

UNIVERSITY OF OREGON
Eugene, Oregon 97403

Paul L. Csonka
Institute of Theoretical Science

Date Started: January 1, 1985

$154,000

Anticipated Duration: 2 years

The immediate goal of the project is to achieve significant improvements in the areas of synchrotron radiation focusing, pulse shaping and the development of new types of radiation energy filters. These results are expected to lead to superior x-ray imaging, higher radiation brilliance, better spectral and time resolution for a variety of experiments with a wide field of applications, including materials science, solid state physics and biology. Furthermore, these developments are designed so as to ultimately permit construction of a soft x-ray Li laser pumped with synchrotron radiation, with a repetition rate which cannot be matched by other methods.

41. VALIDATING THE PARAMAGNETIC LOGGING EFFECT

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

W. Banning Vail

Date Started: September 28, 1984

$148,000

Anticipated Duration: 2 1/2 years

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 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 ac 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 distinguish oil from 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.

42. HOLOGRAPHIC RUGATE STRUCTURE FOR X-RAY OPTICS APPLICATION

PHYSICAL OPTICS CORPORATION
3305 Dow Avenue
Redondo Beach, California 90278

Joanna Jannson
Optics Lab

Date Started: August 15, 1986

$183,000

Anticipated Duration: 1 year

A new approach to x-ray optics fabrication is based on the single-step holographic fabrication of highly-efficient x-ray dispersion elements, as well as imaging optics, gratings, lenses and mirrors. In this investigation, the holographic recording of interference patterns produced by two coherent electromagnetic waves is used to create the desired transmission and reflection Bragg holographic structures in the soft x-ray region of less than 30 nm. For applications involving grazing incidence, an argon laser can suffice as a recording coherent source, while for generating normal incidence optics, x-ray laser radiation will be used to create the large number of Bragg multilayers (>1000). Unlike conventionally deposited multilayer films, these Bragg structures are quasi-sinusoidal in composition and thus eliminate the problems with discrete interfaces. As a result, such holographic optics possess superior mechanical and laser damage properties, higher operating efficiency, and is potentially more economical to be mass-produced.

43. THIN-FILM COMPOSITE MEMBRANES FOR ARTIFICIAL PHOTOSYNTHESIS

PORTLAND STATE UNIVERSITY
Portland, Oregon 97207

Carl C. Wamser
Portland State University

Date Started: July 15, 1985

$239,000

Anticipated Duration: 3 years

The objective of this program is to develop polymeric membranes which will be useful for photosensitization of separate oxidation and reduction reactions on opposite sides of the membrane. Ultimately these redox reactions will be coupled to the oxidation and reduction of water or other energy-storing reactions. Membranes will be optimized with respect to the following characteristics: a) absorption of the solar spectrum, b) photoinduced electron transport across the membrane, c) photosensitization of appropriate redox reactions at the membrane surfaces, d) durability, and e) economic considerations.

44. STUDY OF THE FEASIBILITY OF X-RAY LASING ACTION IN A CONFINED PLASMA COLUMN BY USING A POWERFUL PICOSECOND LASER

PRINCETON UNIVERSITY
P.O. Box 451
Princeton, New Jersey 08544

Szymon Suckewer
Plasma Physics Laboratory

Date Started: January 1, 1985

$600,000

Anticipated Duration: 3 years

The main goal of this program is the experimental investigation of methods based on a powerful picosecond laser (PP-laser) of obtaining high gain and lasing action, initially in the spectral region 100-200 Å, as well as to study possibilities of creating high gain at shorter wavelengths in the region 60-70 Å. Theoretical modeling of obtained results should make it possible to predict conditions for lasing action at 10-20 Å using the same experimental method. The basic idea is to provide interaction of a PP-laser with a confined plasma column by resonance multiphoton excitation of ions in order to obtain, in a short time, a large population inversion in multi-electron high-Z ions as well as in H- and Li-like ions of low-Z elements (low-Z elements are considered here for picosecond laser powers significantly exceeding 10^{15} W/cm^2). The interaction of the PP-laser with a plasma column, which is created by a CO_2 laser, distinguishes this project from studies of the interaction of a PP-laser with cold gas or solid targets. Ions of the proper stage of ionization will be created independently in the plasma, and the role of the PP-laser will be reduced to providing a high population inversion. Such a plasma column has favorable conditions for population inversion and gain even without a picosecond laser pulse due to fast radiation. The experimental program has three stages: (i) the design and construction of the PP-laser based on KrF* excimer laser, (ii) study of the process of the interaction of the PP-laser with ions in a recombining plasma column by photo-ionization and multiphoton ionization, and (iii) creation of strong population inversion (high gain) in multi-electron ions by multiphoton excitation.

45. SOFT X-RAY LASER MICROSCOPE

PRINCETON X-RAY LASER
P.O. Box 3526
Princeton, New Jersey 08540

Szymon Suckewer

Date Started: September 1, 1986

$179,000

Anticipated Duration: 1 year

It is planned to design and construct a Soft X-ray Laser Microscope which will be incorporated into the Soft X-ray Laser Experiment presently operating at a wavelength of 182 Å at the Princeton University. This design will also have a provision to adapt the microscope to a new system involving of a Soft X-ray Laser significantly below 100 Å, with very short pulses (1 - 10 ps), currently under study at Princeton University. Therefore, the uniqueness of the Soft X-ray Microscope design will be in the application of coherent radiation from a soft x-ray laser.

46. GAS-LOADED, FREE ELECTRON LASER

STANFORD UNIVERSITY
Stanford, California 94305

Richard H. Pantell
School of Engineering

Date Started: August 1, 1984

$370,000

Anticipated Duration: 3 years

The purpose of this project is to demonstrate free-electron laser (FEL) interaction in a gaseous medium by obtaining energy transfer from an electron beam to an electromagnetic wave. Synchronism between the electrons and the electromagnetic wave is achieved primarily by reducing the phase velocity of the wave. The advantage of this approach over the vacuum FEL is that at a fixed wavelength the particle energy is lower, resulting in higher gain per unit length and reduced equipment cost and size. As a first step, the propagation of a 40 MeV electron beam from a linear accelerator through hydrogen gas in the pressure range from one to 1000 Torr will be studied. The picosecond nature of the beam precludes many of the beam-plasma instabilities that can occur with a longer pulse, and there has not been a prior investigation of beam propagation through a plasma for our range of parameters. Beam dimensions will be observed by fluorescence emission and angular divergence will be measured by Cherenkov radiation. It is anticipated that multiple scattering will be the primary problem encountered. This limits the length of the FEL, but not before significant gain can be obtained. The second step will be to add gas to an existing FEL, to observe a shift in wavelength as a function of gas pressure.

47. FOCUSED SHOCK DRILLING EXPLORATORY RESEARCH PROGRAM

TETRA CORPORATION
4905 Hawkins NE
Albuquerque, New Mexico 87109

William M. Moeny

Date Started: March 1, 1985

$270,000

Anticipated Duration: 33 months

The objective of this program is to determine the feasibility of the high energy focused shock drill as a new approach to drilling oil or gas wells. This technology utilizes electrical sparks in water to fracture rock, taking advantage of recent advances in pulse power technology. This program is to construct a proof of principle focused shock drill and demonstrate rock cutting characteristics at very high energy and power levels. This machine is expected to have greater than a ten fold energy increase and 10 to 100 fold pulse power increase over previous spark drilling schemes. The characteristics of focused shock drilling will be determined as a function of energy deposition and peak power; also studied will be the impulse transmitted to the rock, rock fracture rate, and the steerability of the drill.

48. MOMENTUM-RICH BEAM STUDY

TRW
MS-01/1020
1 Space Park
Redondo Beach, California 90278

Alfred Maschke

Date Started: September 25, 1985

$260,000

Anticipated Duration: 1 1/2 years

The objective of this study is to establish the feasibility of producing neutral 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 .1 eV or less, with an average current density of 10 mA/centimeter squared should be adequate to achieve thermonuclear ignition. Cesium beams of the requisite brightness have been produced with both hot tungsten button sources and liquid metal field emission sources. The key experiments now underway are to demonstrate that this brightness can be preserved in the resonant charge exchange neutralization process.

49.*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

$77,000

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 CH_4-NH_3 mixture and serves as a catalyst as well. At 1 atm total pressure and temperatures about 1000°C oxygen passing through the O-- conducting solid electrolyte will oxidize the CH_4-NH_3 mixture to produce HCN and H_2O. At the same time the current produced will convert into electric power part of the free energy of the reaction. Due to the significant homogeneous gas-phase reactions that occur at these temperatures a specific design for the reactor cell has been prepared. The primary goal is to establish optimal operating conditions for maximum HCN yield.

*Project Completed

50. A CHEMICAL METHOD OF ACHIEVING THE ACCELERATION OF MACROPARTICLES TO ULTRAHIGH VELOCITIES

UNIVERSITY OF WASHINGTON
Seattle, Washington 98195

A. Hertzberg
Aerospace and Energetics Research Program

Date Started: June 1, 1985

$192,000

Anticipated Duration: 20 months

The collision of macroparticles at velocities in excess of 100 km/sec has been suggested as an effective method of creating a controlled thermonuclear burn. An exploratory program of theoretical studies is being carried out on a new approach which is capable in principle of accelerating large macroparticles (up to 100 grams) to velocities of 100 km/sec. The method employs a novel gasdynamic approach whereby relatively large masses (several kilograms) may be accelerated using chemical energy to velocities in the 50 km/sec range and possibly higher. The overall ballistic efficiency of this approach (ballistic efficiency is defined as the conversion of chemical energy into kinetic energy) appears to be about 25%. With the achievement of these velocities of a relatively large mass it is possible in principle to use linear velocity multiplication techniques with sophisticated buffers to carry heavy macroparticles into the 100 km/sec range and beyond. The availability of heavy macroparticles in this velocity range suggest the creation of a pulsed light source with blackbody radiation intensity of 10^{15}W/cm^2 to perhaps as high as 10^{17}W/cm^2 with output energies of several megajoules. A program of theoretical studies is being carried out to examine the potential of this concept and its applications. If these studies prove to be encouraging, design of critical experiments will be initiated.

51.*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

$79,000

Anticipated Duration: 3 years

The purpose of this project is to study the conversion of rectilinear projectile motion to a spherical or quasi-spherical implosion. In conjunction with rail-gun experiments at Westinghouse Research Center, dynamical calculations are provided to describe the impact of rail-gun projectiles with a solid target. A one-dimensional hydrodynamic numerical calculation has been successfully developed, taking account of thermal conduction in both the gas and the metal shell and radiation loss in the gas. The numerical calculations are extended to the two-dimensional case of two projectiles approaching each other from opposite directions, showing that the initial rectilinear motion can be converted into a quasi-spherical cavity implosion at approximately the rectilinear velocity. This work has the encouraging conclusion that quasispherical shock heating followed by nearly isentropic compression to 1000-mbarr pressures and interesting thermonuclear conditions can be achieved by rectilinear impact in next-generation rail guns and, at 100 km/sec, in fusion reactors.

*Project Completed
**Projects 51 and 52 are interlaboratory projects.

52.*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

$389,000

Anticipated Duration: 3 years

In conjunction with the impact fusion modeling study conducted at the University of Washington, Seattle, the present program is directed towards investigating the problems associated with the electromagnetic acceleration of gram-size projectiles to ultrahigh velocity. The program involves the construction of a multi-stage railgun using distributed energy injection which has the potential of accelerating a 1 g projectile to a velocity in excess of 20 km/s. Theoretical considerations clearly indicated that plasma ablation, arc restrike, plasma armature instability, plasma turbulence and non-ideal plasma properties could potentially degrade accelerator performance. Experimental investigations of these problems were done with the commissioning of the SUVAC-1 launcher facility.

*Project Completed
**Projects 51 and 52 are interlaboratory projects.

SAMPLE

Statement of Work

1) Project Objective

The proposer 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 proposer 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 1986 Program Data

FY '86 Budget

Operating Funds.....$7,195,000

Capital Equipment Funds.....$308,000

Distribution of Projects by Institutional Sector

Universities	38%
Small Business	22%
Other Industry	8%
DOE Laboratories	30%
Federal Laboratories	2%

INVESTIGATOR INDEX
(Project Numbers)

INSTITUTIONAL INDEX
(Project Numbers)

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