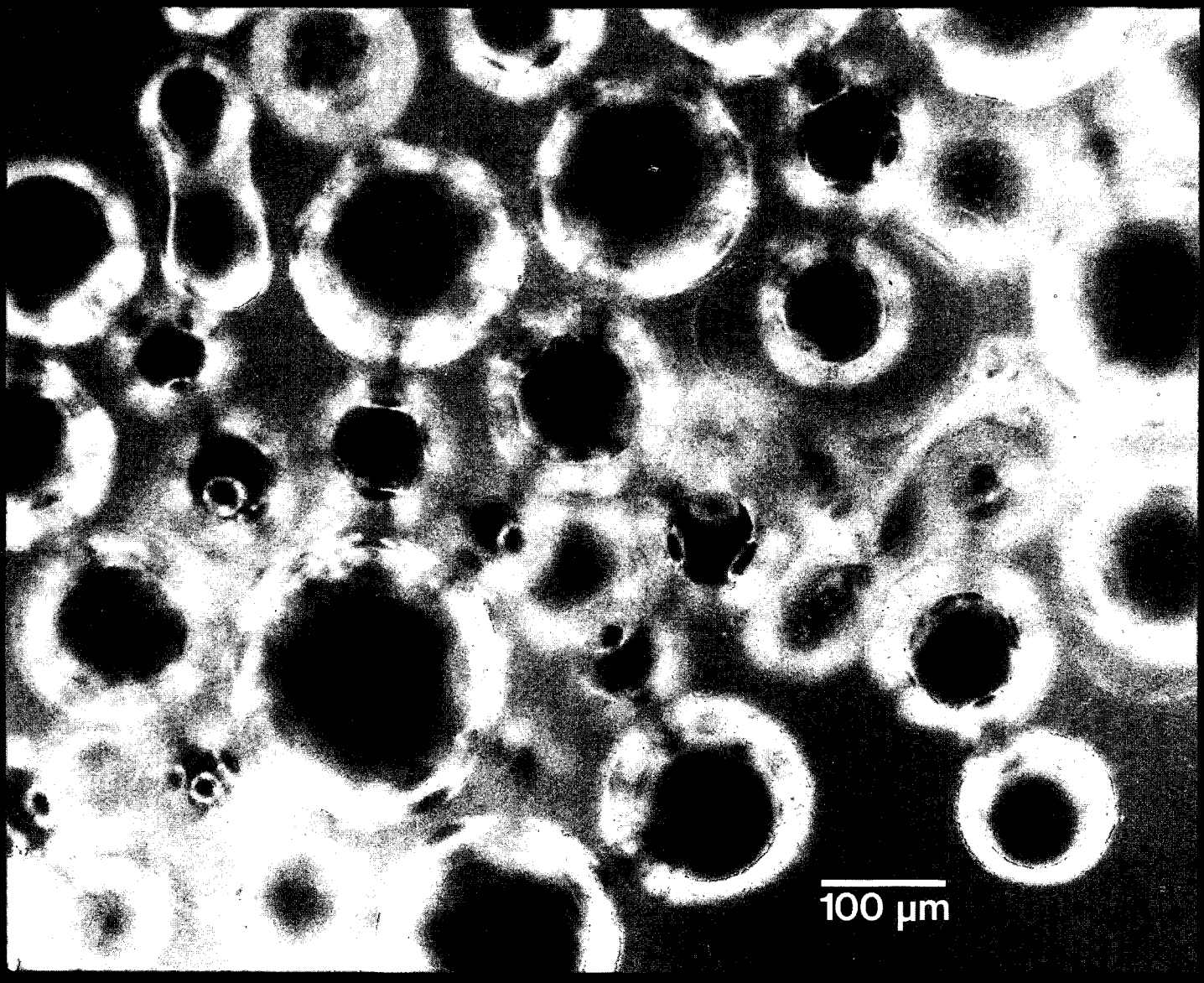
DOE/ER-0465T

Advanced Energy Projects FY 1990 Research Summaries

September 1990



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

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Cover photograph courtesy of Adam Heller, The University of Texas at Austin

Oil slicks can be "burned off" at sea temperature through a sunlight-driven process on photocatalysts such as titanium dioxide. The cleanup cost is reduced when the photocatalyst particles collect sunlight from an area greatly exceeding their diameter. The picture shows microbeads coated with a photocatalyst, floating on top of an oily film on water. The brightness of the periphery of the beads shows that light incident on the films is trapped by total internal reflection and efficiently channeled to the beads.

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Washington, DC 20585

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DIVISION OF ADVANCED ENERGY PROJECTS

PROGRAM OVERVIEW

CHARTER

The Division of Advanced Energy Projects (AEP) provides support to explore the feasibility of novel, energy-related concepts that evolve from advances in basic research. These concepts are typically at an early stage of scientific definition and, therefore, beyond the scope of ongoing applied research or technology development programs. The AEP also supports high-risk, exploratory concepts that do not readily fit into a program area but appear to have applications that may span several scientific or technical disciplines.

The Division provides a mechanism for converting basic research findings to applications that eventually could impact the Nation's energy economy. AEP does not support either ongoing, evolutionary research or large scale demonstration projects.

FUNDING

Projects are supported for a finite period of time, which is typically three years. Annual funding levels for projects can vary from approximately $50,000 to $500,000. It is expected that, following AEP support, each concept will be sufficiently developed and promising to attract further funding from other sources in order to realize its full potential.

SUBMISSION GUIDELINES

Unsolicited proposals can be submitted by universities, industrial organizations, non-profit research institutions or private individuals. The Division also considers ideas or concepts submitted by researchers at national laboratories. **Before a formal proposal is prepared**, the proposer should submit a brief outline (2-3 pages) of

the proposed work to the Division. The contents should be sufficiently detailed to enable an informed decision as to whether the proposed work programmatically fits the charter of the Division of Advanced Energy Projects.

After the AEP programmatic interest has been established, a proposal must be submitted consistent with the guidelines specified in the Office of Energy Research document, DOE/ER-0249, "Application and Guide for the Special Research Grant Program." Each proposal must contain:

- A cover page.

- A 200-300 word abstract 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 program book. Technical jargon and equations should be avoided.

- A technical discussion of the proposed concept and a description of the proposed work. While the discussion should be brief, there is no formal limitation on the number of pages allotted to this section of the proposal. Since this section provides 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 37.

- 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.

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 or 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?

FURTHER INFORMATION

Inquiries should be addressed to:

Dr. Walter M. Polansky, Acting Director
Division of Advanced Energy Projects
Office of Basic Energy Sciences
ER-16, GTN
Department of Energy
Washington, D.C. 20585

Phone: 301-353-5995

OFFICE OF BASIC ENERGY SCIENCES

DIVISION OF ADVANCED ENERGY PROJECTS

SUMMARIES OF PROJECTS ACTIVE IN FY 1990

This section contains brief summaries of the projects active in the Division of Advanced Energy Projects during Fiscal Year 1990 (October 1, 1989 - September 30, 1990). The intent of this compilation is to provide a convenient means for quickly acquainting the reader with the program in Advanced Energy Projects. More detailed information on a specific project may be obtained by contacting 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 1990 are indicated by the footnote: *Project completed. The average annual funding level of each project is shown.

1. PRODUCTION OF FUELS AND CHEMICALS FROM METHANE

ARGONNE NATIONAL LABORATORY
9700 SOUTH CASS AVENUE
ARGONNE, ILLINOIS, 60439

Victor A. Maroni
Chemical Technology Division

Date Started: July 1, 1989

$282,000

Anticipated Duration: 3 years

In this project research is being carried out to develop novel bifunctional catalysts (BFCs) that can convert methane to fuels (e.g., liquefied petroleum gas or gasoline) and large volume industrial chemicals. The goal is to produce a catalyst that operates efficiently under moderate conditions of temperature (<500°C) and pressure (<10 atm), and for extended periods of time,

without need for frequent regeneration or replacement. The BFC concept involves integrating into one material the properties of C-H bond activation and product-selective chemical synthesis. Several types of C-H bond activation catalysts that rely on unique oxidation state chemistries and coordination geometries are employed in combination with molecular sieve materials having well defined intracrystalline pores and channels that constrain the size and shape of the active catalytic species contained therein and the chemical species formed therein. This research is expected to culminate in a demonstration of the feasibility of efficient conversion of methane to a liquid fuel and/or to one or more of the top fifty commodity chemicals.

2. DAMAGE LIMITATION OF OIL SPILLS BY COMBUSTION WITH LIQUID OXYGEN

UNIVERSITY OF ARIZONA
TUCSON, ARIZONA, 85721

Peter A. Franken
Optical Sciences Center

Date Started: January 15, 1990

$383,000

Anticipated Duration: 18 mos.

This program is intended to evaluate the feasibility of destroying oil slicks and beached oil by combustion with liquid oxygen (LOX). Initial experiments will be performed on a variety of oil slicks up to 10 meters in diameter which will be prepared at carefully controlled and instrumented inland sites. The parameters for ignition, as well as an evaluation of combustion products, will be measured with the view towards planning larger scale experiments. Beach clean-up problems will be addressed with simulations prepared by coating weathered oil on rocks and determining the extent that LOX assisted combustion is successful in removing this contamination. Combustion products and thermal effects on the sub-lying flora and fauna will be determined. On the basis of these experimental studies the feasibility of larger scale simulations will be evaluated, together with a preliminary design of actual field research.

3. ENERGY RELATED APPLICATIONS OF ELEMENTARY PARTICLE PHYSICS

UNIVERSITY OF ARIZONA
TUCSON, ARIZONA 85721

Johann Rafelski
Department of Physics

Date Started: March 1, 1988

$325,000

Anticipated Duration: 3 years

Muon catalyzed fusion proceeds via a cycle of complex quantum mechanical processes and leads to at least 150 d-t fusions per muon, releasing an energy equivalent of more than 30 times the mass of the muon. The economical applications thus demand that a method be found facilitating efficient muon production in elementary particle processes. Another way of improving the economics of the muon catalyzed fusion process is to accelerate the reactions by the proper choice of density, target composition, and magnetic fields. The influence on the cycle dynamics of vacuum polarization splitting in the excited muonic atom levels needs to be ascertained. Muon regeneration processes after muons are bound ('stuck') to alpha particles are important in determining the maximum number of fusions a muon can facilitate. In particular, regeneration in low temperature plasmas is an open issue. The greatest puzzle of muon catalyzed fusion is the exact understanding of the sticking process, which is a complex atomic/nuclear phenomenon, in which the 'spectator' of the fusion is caught by the nuclear fusion product. Both the theoretical formulation and numerical analysis of this process present formidable challenges to the understanding of few body reactions. Because antiprotons can be viewed as the only 'stable' storage of muons due to their annihilation into pions which decay into muons, antiproton annihilation phenomena may play a major role in future muon catalyzed fusion applications. In this context it is important to understand the processes leading to the deposition of annihilation energy in matter and the interactions of low energy antiprotons with matter and nuclei.

4. INVESTIGATION OF COLD NUCLEAR FUSION IN CONDENSED MATTER

BRIGHAM YOUNG UNIVERSITY
PROVO, UTAH 84602

Steven E. Jones
Department of Physics & Astronomy

Date Started: March 15, 1990

$367,000

Anticipated Duration: 18 mos.

Neutron emissions are seen during deuterium infusion into metals, implying the occurrence of nuclear fusion at low rates near room temperature. The phenomenon has been demonstrated in collaborative experiments at Brigham Young University, at the Gran Sasso Laboratory in Italy, and at the Los Alamos National Laboratory. The random neutron source rate is approximately 0.1 neutrons per second for 5 - 50g of partially deuterided metal, consistent in both electrochemical and gas-pressure techniques. Emissions of $\sim 10^2$ neutrons in bursts lasting less than 128 μs are also observed using both techniques. The effect will be carefully scrutinized with a view to potential applications and better understanding of fusion processes. Laboratory and geophysical experiments will complement theoretical efforts to understand the observations.

5. INVESTIGATION OF MUON FUSION CYCLE ENHANCEMENT (LASER ENHANCEMENT OF RESONANT MUOMOLECULAR FORMATION)*

BROOKHAVEN NATIONAL LAB.
UPTON, NEW YORK 11973

Hiroshi Takahashi

Date Started: October 1, 1987

$64,000

Anticipated Duration: 26 mos.

To use muon catalyzed fusion for energy production, it is desirable to get a high muon catalyzed fusion cycle rate even in the deuterium-tritium low density mixture. It has been demonstrated that muon catalyzed cycle rates increase rapidly with increased deuterium-tritium gas density. This experimental result is explained by noting that the $dt\mu$ molecular formation rate, which is the bottle neck of the cycle, is enhanced by giving the excess energy of this reaction to the third body of surrounding molecules. Using the coherent electromagnetic wave radiation, like laser radiation, as the third body, the $dt\mu$ molecular formation rate might be enhanced. The purpose of this program is to explore the characteristic mode of the coherent radiation (intensity and frequency) for such enhancement of the molecular formation rate, as well as other means for such enhancement.

*Project completed.

6. RF INDUCED PHENOMENA IN ELECTROLYTIC CELLS*

BROOKHAVEN NATIONAL LABORATORY
UPTON, NEW YORK 11973

Harold Wiesmann
Materials Science Division

Date Started: October 1, 1989

$74,000

Anticipated Duration: 1 year

A number of anomalous effects have recently been reported for electrolytes containing deuterium oxide. Excess heat evolution is the most widely discussed phenomenon but reports of radiation emission are also made. One objective of this work is to determine whether resonances, acoustic or otherwise, occur in deuterated palladium electrodes excited by an applied RF field. Various electrolytic solutions, containing light and heavy water and in combination with different electrode materials, are also being examined in a similar manner. Related to this is the observation by other research groups of radioactive emissions from electrolytic solutions subjected to RF radiation. An attempt is being made to determine the nature and origin of the species activating the radiation monitors, and whether the phenomena are chemical or nuclear in origin.

*Project completed.

7. **GENERATION OF RADIATION BY INTENSE PLASMA AND ELECTROMAGNETIC UNDULATORS***

UNIVERSITY OF CALIFORNIA, LOS ANGELES
405 HILGARD AVENUE
LOS ANGELES, CALIFORNIA 90024

Chan Joshi

Date Started: July 1, 1987

$300,000

Anticipated Duration: 3 years

This program involves the generation of short wavelength, UV-VUV, radiation by intense plasma and electromagnetic undulators. In this concept a relativistic electron beam is wiggled by either the oscillating electric field of an intense plasma density wave or by an electromagnetic wave causing it to radiate. Using these schemes it is proposed to generate tunable radiation in the 1500 Å - 3 μm range from an electron beam of only 1.5 MeV energy. The plasma wave with an effective wiggler strength parameter $a_w \sim 0.1$, wavelength $\lambda_w \sim$ 100 μm and number of periods $N \sim 100$ will be excited by resonantly beating two laser beams in a plasma. The electrons are made to wiggle transversely at the plasma frequency ω_p by injecting them parallel to the plasma wavefronts. Because of relativistic Doppler shift the radiated frequency is upshifted to $2\gamma^2\omega_p$. For even shorter wiggler wavelengths a powerful CO_2 laser, $\lambda_w \sim 10$ μm, $a_w \sim 1$, will be used. By counter propagating this laser beam with the electron beam it is proposed to generate 1500 Å VUV radiation. Because of the high wiggler strengths, some harmonic generation is expected. An applications study will also be undertaken to identify technologies which would likely be impacted by these sources.

*Project completed.

8. MUON-CATALYZED FUSION IN GASES OF HD AND $H_2 + D_2$ MIXTURES*

Konrad Aniol
Physics Department

$28,000

CALIFORNIA STATE UNIVERSITY, LOS ANGELES
5151 STATE UNIVERSITY DRIVE
LOS ANGELES, CALIFORNIA 90032

Date Started: Sept. 15, 1986

Anticipated Duration: 39 mos.

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.

*Project completed.

9. PARALLEL NANOMETER SCALE FABRICATION

UNIVERSITY OF COLORADO
BOULDER, COLORADO 80309

Kenneth Douglas
Department of Physics

Date Started: Sept. 15, 1989

$312,000

Anticipated Duration: 3 years

The thrust of this research is to explore fabrication of structures at the highest possible spatial resolution in which features are defined on the nanometer length scale by single molecules. Two-dimensional protein crystals will be used as the patterning elements for nanometer fabrication, employing masking and templating operations. Hundreds of two-dimensional biomolecular arrays, having lattice parameters in the 3-30 nanometer range, are available as patterning elements. The nanostructures to be fabricated will include patterned 1 nanometer thick metal films having, for example, arrays of 10 nanometer dimension holes, metal island arrays of nanometer periodicity, and biomolecular-solid state nanohetero-structures. By employing periodic patterns, structural fluctuations and defects can be effectively investigated, for example the placement of 1 nanometer dimension metal grains by molecules of the template. The research goal is to understand phenomena which limit nanometer fabrication at the molecular level, to extend the limits of fabrication resolution, and to develop applications of molecular fabricated nanostructures. This parallel technology will enable the efficient parallel manipulation of surfaces. The ability to structure surfaces on the nanometer molecular length scale makes it possible to profoundly alter their fundamental properties such as chemical reactivity, adsorption characteristics, and electrical and optical behavior. Such a technology would contribute broadly to the advance of interfacial chemistry, physics, and materials science.

10. ACCURATE ALPHA STICKING FRACTIONS FROM IMPROVED THREE-BODY CALCULATION RELEVANT FOR MUON CATALYZED FUSION*

UNIVERSITY OF DELAWARE
NEWARK, DELWARE 19716

Krzysztof Szalewicz
Department of Physics

Date Started: May 1, 1988

$91,000

Anticipated Duration: 22 mos.**

In the last decade muon catalyzed fusion has been a subject of intensive research efforts worldwide. Recent experiments have shown that a single muon can catalyze more than 150 fusions. At present the major bottleneck of the muon catalyzed cycle as applied for energy production seems to be sticking of the muons to the alpha particles synthesized in the nuclear reactions. Stuck muons are lost for further fusions. The probability of this sticking is being theoretically investigated. The muonic molecular ions are described by highly accurate three-body wave functions. The nuclear effects are included by imposing boundary conditions on the wave functions at the nuclear radius. To add flexibility in this region the basis sets contain irregular terms, i.e. negative powers of the nuclear distance. Alternatives to the classical expression for the sticking amplitude are being derived. Other topics of the work include calculations of the finite size corrections to energy levels of muonic molecules, improved determination of the molecular formation rates, and investigation of the role of the internal resonances in this formation.

*Project completed.
**Includes no-cost extension.

11. ALPHA STICKING FRACTION CALCULATIONS IN MUON CATALYZED FUSION*

DUKE UNIVERSITY
DURHAM, NORTH CAROLINA 27706

L.C. Biedenharn
Physics Department

Date Started: September 15, 1986

$47,000

Anticipated Duration: 45 mos.**

Recent experiments on deuterium-tritium fusion, catalyzed by muons, show an unexpectedly large number of fusions per muon. 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.

*Project completed.
**Includes no-cost extension.

12. INVESTIGATIONS AND CALCULATIONS TOWARDS INCREASING THE EFFICIENCY OF MUON CATALYZED FUSION*

UNIVERSITY OF FLORIDA
GAINESVILLE, FLORIDA 32611

H. J. Monkhorst
Department of Physics

Date Started: May 1, 1985

$105,000

Anticipated Duration: 51 mos.**

The phenomenon of muon catalyzed fusion offers an intriguing alternative to conventional fusion approaches for achieving energy production. The entire process, from entry of a muon into a mixture of hydrogen isotopic molecules (mainly made up of deuterium and tritium) to fusion reactions, involves several, subtly interlocking atomic, molecular, and nuclear physics effects. To fully understand and describe these effects, concepts and computational techniques from these disciplines have to be brought together. With quantitative explanations at hand ways could be identified to increase the number of induced fusions during a single muon's life time. This is the goal. Effort will be concentrated on two aspects in the muon catalyzed fusion cycle: nuclear effects on the "alpha sticking fraction" W_s and relativistic corrections to the binding of weakly bound muonic molecules containing deuteron and triton nuclei. It is crucial to know the W_s value a priori since its inverse determines the maximum number of fusions a single muon can induce (and hence the efficiency of muon catalyzed fusion), and its experimental determination is difficult. There are various hints that nuclear effects can be large, and can possibly be favorably influenced. Using experimental d-t scattering information, high-accuracy nuclear-molecular physics calculations will be performed. The theory is subtle, but now well understood and computable. Precise knowledge of relativistic effects on the weakly bound states will make it possible to fully describe, and subsequently "fine-tune," the dependence of muon molecular formation rates on temperature, density, and composition of the hydrogen

isotopic mixture in the fusion reactor vessel. High accuracy is required and the theory and calculations should include all relativistic corrections.

*Project completed.
**Includes no-cost extension.

13. EXPERIMENTAL INVESTIGATION OF MUON-CATALYZED FUSION*

LOS ALAMOS NATIONAL LABORATORY
P.O. Box 1663
LOS ALAMOS, NEW MEXICO 87545

James N. Bradbury
MP Division

Date Started: October 1, 1985

$831,000

Anticipated Duration: 5 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. The 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.

*Project completed.

14. THEORETICAL STUDY OF MUON-CATALYZED FUSION*

James S. Cohen
Theoretical Division

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

Date Started: December 29, 1983

$312,000

Anticipated Duration: 6 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 (μ^-, 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 $dt\mu$ 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.

*Project completed.

15. DEVELOPMENT OF HIGH-REFLECTANCE MIRRORS FOR THE XUV*

LOS ALAMOS NATIONAL LABORATORY
P. O. BOX 1663, MS J564
LOS ALAMOS, NEW MEXICO 87545

Brian E. Newnam
Chemical and Laser Sciences Division

Date Started: October 1, 1987

$440,000

Anticipated Duration: 2-1/2 years

The object of this project is to develop broadband, high-reflectance mirrors for the extreme ultraviolet and soft x-ray regions which extend from 10 nm to 100 nm. These are urgently needed for a number of laser schemes that involve resonators, e.g. XUV free-electron lasers, and for steering reflectors for synchrotron light sources. The approach used is to exploit the principle of total external reflection on multiple-facet metal surfaces to turn an optical beam by 180°. With certain metals (Al, Si, Rh, Ag) it is possible to attain retroreflectance ≥40% over the 35- to 100-nm and 10- to 14-nm spectral ranges. Preliminary experiments at Los Alamos have verified the feasibility of this approach at 58 nm for Al and Si surfaces in a UHV environment. The sequence of experiments will include: 1) spectral reflectance measurements on prototype, multifacet Al and Si reflectors over the 30- to 100-nm range, 2) evaluation of methods to control and/or renew the retroreflector surfaces, 3) extending the experiments to metal-reflector candidates (Rh, Ag) below 30 nm, and 4) transfer of the experiments to a large (60-cm dia.) UHV chamber to coat and test practical-size reflectors with 9 to 10 reflector facets.

*Project completed.

16. INVESTIGATION OF SOME ASPECTS OF COLD FUSION*

LOS ALAMOS NATIONAL LABORATORY
LOS ALAMOS, NEW MEXICO 87545

Edmund K. Storms
NMT-1 Division

Date Started: October 1, 1989

$345,000

Anticipated Duration: 1 year

The purpose of this research is to understand the processes that produce tritium and, to a lesser extent, excess heat in electrolytic cells. As the processes are made reproducible, the study will emphasize making the cells more efficient through a guided parametric study. Special cell designs will be developed to make the measurement of x-ray, gamma, and neutron radiation more sensitive. The proposed research will be directed mainly toward a study of tritium production in electrolytic cells. Gas phase charging of palladium using a plasma will also be explored. Because measurement of heat requires expensive apparatus, an extensive parametric study is too costly if heat production is used as a criterion for fusion. Neutron production also has been found to be unsatisfactory because of the very low emission rate combined with an uncertain background. Instead, tritium production in a series of simple cells will be used to demonstrate a successful nuclear reaction. After the critical parameters are identified and tritium can be produced in a predictable way, the cathodes will be moved to a calorimeter. Once tritium has been produced, emission of x-ray, gamma, and neutrons will be measured. After evidence for fusion has been obtained, similar cells will be constructed using various concentrations of ordinary water in D_2O.

*Project completed.

17. HIGH FREQUENCY CARM DRIVER FOR RF LINACS

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE, MASSACHUSETTS 02139

Bruce G. Danly
Plasma Fusion Center

Date Started: September 15, 1989

$514,000

Anticipated Duration: 3 years

Future linear colliders will require high frequency rf sources together with high gradient accelerating structures in order to be economically feasible. The cyclotron autoresonace maser (CARM) is a promising source for application as an rf accelerator driver. This project will investigate and evaluate the CARM amplifier as an efficient source of high peak power microwaves capable of fulfilling this future requirement. Experiments at a frequency of 17 GHz will be performed using two different technologies for generation of the high voltage electron beam required by the CARM. A long pulse (1 μs), 700kV pulse modulator and a short pulse (50 ns), 1.2 MeV induction accelerator will be employed for generation of the electron beam. This will allow a comparison of two alternate methods for producing the high peak power, ~50 ns microwave pulses required by the high gradient structures. A long pulse modulator-driven CARM together with pulse compression techniques, or an induction linac driven CARM are both capable in principle of delivering the required rf pulses to the structure. In both experiments, the details of CARM amplifier operation will be investigated, including linear and nonlinear gain, stability, efficiency, and phase sensitivity.

18. DEVELOPMENT OF A COLLISIONAL EUV LASER USING Ni-LIKE AND Nd-LIKE IONS

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE, MASSACHUSETTS 02139

Peter L. Hagelstein
Research Laboratory of Electronics

Date Started: May 1, 1989

$403,000

Anticipated Duration: 3 years

It is proposed to construct a small scale extreme ultraviolet (EUV) laser at 200-300 Å based on electron collisional excitation in low-Z nickel-like ions. The laser is to be pumped by a 10 joule Nd:glass laser pulse train, consisting of about 5 short 100 picosecond (2 joule) pulses spaced every several nanoseconds. The short wavelength amplifier will be well-adapted to cavity studies, and both multi-layer and whisper gallery optics will be explored. The use of a glass slab power amplifier in this system will allow for a repetition rate which is high (0.1 Hertz) for EUV lasers. As a result, the proposed system will be especially well suited for applications. Future systems could be based on high average power slab lasers and operate at the 1-10 Hertz regime. Applications of short wavelength lasers will be explored which at present includes EUV nonlinear spectroscopy and phase sensitive thin film and surface probing. New short wavelength laser schemes will be explored including the extension of the collisional excitation scheme to Nd-like (60 electron) ions.

19. SEPARATION OF ORGANIC AZEOTROPIC MIXTURES BY PERVAPORATION

Richard W. Baker

MEMBRANE TECHNOLOGY AND RESEARCH, INC.
1360 WILLOW ROAD
MENLO PARK, CALIFORNIA 94025

Date Started: September 1, 1989

$152,000

Anticipated Duration: 2 years

This program concerns the development of improved membranes and modules that could be used to separate organic/organic mixtures by pervaporation. In pervaporation, a liquid mixture is introduced into an array of membrane modules. One or more components pass preferentially through the membrane as a vapor and, after condensation, are removed as a concentrated permeate. The remaining non-permeating components are removed as the liquid residue. Pervaporation has so far been developed commercially for the separation of aqueous/organic solutions. The process has not been applied to organic/organic separations because of the lack of suitable solvent-resistant membranes and modules. The performance of existing membranes and modules with important organic/organic mixtures found in the chemical processing industry will be examined. The data thus generated will be used to guide research into higher performance membranes that can withstand prolonged exposure to organic mixtures. Module design will be tailored to enable components to withstand a harsh chemical environment. The program will conclude with a study of the technical and economic feasibility of commercial-scale pervaporation systems for organic/organic separations. Single and multi-stage designs will be evaluated, and a cost comparison with rival separation technologies will be made.

20. DEVELOPMENT AND APPLICATIONS OF THE POSITRON MICROSCOPE

UNIVERSITY OF MICHIGAN
ANN ARBOR, MICHIGAN 48109

David W. Gidley
Department of Physics

Date Started: January 15, 1990

$174,000

Anticipated Duration: 3 years

The operation of the first positron microscopes in 1988 demonstrated a totally new contrast mechanism for microscopic imaging. Specifically, the positron reemission microscope images anti-matter positrons that have been implanted into a sample and subsequently reemitted from its surface. Image contrast, determined by the sample's positron reemission probability, depends on the unique behavior of positrons in solids. The goal of this research is to move this new technology beyond the current demonstration phase (3,000-10,000 Å resolution) by constructing and operating a 100 Å resolution instrument. This device would allow the assessment of the technique's ultimate capabilities, as well as allow investigation of several outstanding problems which the proposed microscope should make a unique contribution to solving. These problems include: (1) analysis of sub-25 Å films by positron tunneling microscopy, (2) unique applications in surface catalysis including, for example, analysis of systems with high Z substrates where electron microscopic techniques fail, (3) analysis of operation and failure modes of microelectronic devices, and (4) imaging of selected biological systems such as lipids and proteins in cell membranes. A program complementary to this has been initiated at the Idaho National Engineering Laboratory to construct a positron beam with a minimum intensity of 10^{10} positrons/sec. A beam of such intensity would be required for several applications including use in a sub-10 Å resolution microscope which would be constructed if, based on the results of this project, it is judged to be feasible and useful.

21. THE MAGNETICALLY INSULATED INERTIAL CONFINEMENT FUSION (MICF)-A NOVEL APPROACH*

UNIVERSITY OF MICHIGAN
ANN ARBOR, MICHIGAN 48109-2104

T. Kammash
Department of Nuclear Engineering

Date Started: June 1, 1987

$89,000

Anticipated Duration: 3 years

The objective of this project is to study the relevant physics issues that bear directly on the potential of the Magnetically Insulated Inertial Confinement Fusion (MICF) concept as a power-producing reactor. In this novel approach the favorable aspects of both magnetic and inertial fusions are utilized in that the hot, dense, fusion grade plasma is physically contained by a metallic shell while its heat is insulated by a strong, self-generated magnetic field. Experimental studies at Osaka University using 100 Joule, CO_2 laser impinging on a target of parylene shell of few milimeters in radius have resulted in a Lawson parameter (product of density and confinement time) of 5×10^{12} sec cm^{-3} at a plasma temperature of 0.5 keV. In contrast to implosion type inertial confinement schemes the MICF approach allows for the creation of the desired plasma within a shell by means of laser radiation that enters through a hole in the shell and strikes the fuel-coated inner surface. The return currents generated by the energetic ablated electrons give rise to the strong magnetic field that provides the desired thermal insulation. Because of this unique arrangement the lifetime of the burning plasma will be significantly higher than in conventional implosion type inertial fusion and the energy efficiency will be superior since the input laser energy is put directly into the plasma. It is therefore expected that the ignition conditions will be much less severe, and the energy multiplication will be much larger than in the conventional counterpart and this project is aimed at verifying these properties and how they impact the reactor aspects of this concept.

*Project completed.

22. THE EMULSION-PHASE CONTACTOR: AN INNOVATIVE APPROACH TO ENHANCED EFFICIENCY IN SOLVENT EXTRACTION

OAK RIDGE NATIONAL LABORATORY
P.O. BOX 2008
OAK RIDGE, TENNESSEE 37831

Charles H. Byers
Chemical Technology Division

Date Started: October 1, 1988

$333,000

Anticipated Duration: 3 years

The use of electric fields is explored to drive continuous liquid-liquid solvent extraction processes. Pulsed electric fields can be used to efficiently create interfacial mass transfer surface area, help induce countercurrent motion between the dispersed and continuous phases, and promote droplet coalescence and phase separation. These combine to produce enhanced continuous multistage solvent extraction operations. The effort is directed towards understanding the controlling phenomena in electrified liquid-liquid emulsification and coalescence processes and demonstrating latitude of operational capabilities which are suitable for industrial development. This electrohydrodynamic behavior shows every indication of being capable of becoming the basis for a new solvent extraction concept which is far more efficient in both energy utilization and mass transfer performance than present day systems.

23. ELECTRICITY ENHANCED FLUIDIZED BED HEAT EXCHANGER

PACIFIC NORTHWEST LABORATORY
RICHLAND, WASHINGTON 99352

Delbert L. Lessor
Energy Sciences Department

Date Started: October 1, 1988

$152,000

Anticipated Duration: 3 years

The objective of the proposed work is to demonstrate the contact-charging, electrically-enhanced fluidized bed heat exchanger concept. In this concept, bed particles are of two material types, which acquire different signs of electric charge on contact with each other

or with other materials present. An alternating electric field is applied to increase particle motion, erode thermally-resistive boundary layers, and improve thermal contact between particles and heat exchanger tubes. Increased heat transfer should result. Increased heat transfer rates in fluidized beds should allow lower equipment costs, lower pressure drops, better energy recovery, and a broader spectrum of energy recovery applications. To test the concept, a series of bench-scale experiments and a modeling effort are being done. The experiments and modeling will seek to: 1) demonstrate that heat transfer enhancement can be achieved, and 2) provide insights for achieving or optimizing the effect by choices of materials composition, size, field strength, frequency, and flow velocity.

24. STUDY OF THE FEASIBILITY OF X-RAY LASING ACTION IN A CONFINED PLASMA COLUMN 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

$1,222,000

Anticipated Duration: 6 years

The main goal of this project is the experimental investigation of methods, based on a powerful picosecond laser (PP-laser), for obtaining high gain and lasing action, initially in the spectral region 100-200 Å, as well as the study of possibilities for creating a high gain at shorter wavelengths in the region of 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 at the proper state 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 interaction of the PP-laser radiation with ions in a recombining plasma column by photo-ionization and multiphoton ionization, and (iii) creation of a strong population inversion (high gain) in multi-electron ions by multiphoton excitation.

25. ELECTROCATALYTIC HYDROCRACKING*

RESEARCH TRIANGLE INSTITUTE
P. O. BOX 12194
RESEARCH TRIANGLE PARK, NC 27709

Donald R. van der Vaart
Center for Process Research

Date Started: February 15, 1988

$118,000

Anticipated Duration: 26 mos.**

Conventional hydrocrackers rely on extremely high hydrogen partial pressures (>1500 psi) both to facilitate hydrogenation and reduce coke formation on the catalyst surface. In an electrochemical cell using a proton selective solid electrolyte, protons formed on the counter electrode can, as charge carriers, be transported through the electrolyte to the surface of the working electrode which is exposed to the liquid hydrocarbon at ambient pressure. The dual functionality required of hydrocracking catalysts is provided by this hydrogenating/ dehydrogenating (metal) site and the cracking sites of

the solid electrolyte. The ready supply of hydrogen delivered directly to the reaction interface should limit coke formation and, hence, greatly reduce the operating pressure requirements. This decrease in the rate of surface deactivation would enable lower quality (heavier) feeds to be (electrocatalytically) hydrocracked to produce gasoline and middle distillates at significantly lower costs.

*This project is being continued at Virginia Polytechnic Institute, project number 30.
**Includes no-cost extension.

26. INVESTIGATION OF PARAMETERS CRITICAL TO MUON-CATALYZED FUSION*

Steven E. Jones

$208,000

S&J SCIENTIFIC COMPANY
P. O. BOX 7070
UNIVERSITY STATION
PROVO, UTAH 84602

Date Started: September 1, 1987

Anticipated Duration: 2-1/2 years**

It has been demonstrated (in conjunction with others on the program) that muon catalysis cycling rates increase rapidly with increasing deuterium-tritium gas temperatures and densities. Furthermore, muon-capture losses are significantly smaller than predicted before the experiments began. As a result of these effects, muon-catalyzed fusion yields of 150 fusions/muon (average) have been achieved. The fusion energy thereby released, nearly 3 GeV/muon, significantly exceeds theoretical expectations, and still higher yields are expected. Therefore, it is proposed to explore the limits of muon-catalyzed fusion, to provide answers to questions regarding energy applications of muon-catalyzed fusion.

*Project completed.
**Includes no-cost extension.

27. GAS JET DEPOSITION OF METALLIC, SEMICONDUCTING AND INSULATING FILMS

SCHMITT TECHNOLOGY ASSOCIATES
25 SCIENCE PARK
NEW HAVEN, CONNECTICUT 06511

Bret Halpern

Date Started: November 15, 1987

$183,000

Anticipated Duration: 3 years

Gas Jet Deposition (GJD) is a new method for depositing thin films at high rate and controlled energy. The basic physics of GJD will be investigated in order to develop its technological capabilities. GJD deposits films by "seeding" atoms or molecules into a free jet expansion, e.g., of helium, and directing the jet at a substrate at relatively high pressure. GJD promises many advantages over established methods. Deposition rates of 10 microns per minute have been attained, and microns per second should be within range. The impact energy of depositing species can be gasdynamically controlled over a range of electron volts, so that film properties can be influenced during deposition. The substrate, which can be almost any material, can remain cool during deposition. Film composition and doping profile can be easily varied. Clusters can be deposited as well as atoms and molecules. GJD is flexible, and any metal, semiconductor, or insulator that can be seeded in the free jet can be deposited. The combination of these features in one method makes GJD singularly versatile. The goal of this project is to explore the feasibility of GJD as the basis of a usable technology. To do this, the fundamentals of GJD will be investigated, in particular its high rate and impact energy control, and the GJD apparatus will be refined. The properties of the films produced will be determined.

28. GROWTH OF HIGH T_c SUPERCONDUCTING FIBERS USING A MINIATURIZED LASER-HEATED FLOAT ZONE PROCESS

STANFORD UNIVERSITY
STANFORD, CALIFORNIA 94305

Robert S. Feigelson
Center for Materials Research

Date Started: January 15, 1989

$402,000

Anticipated Duration: 3 years

The primary objective of this project is to thoroughly explore the potential of the laser-heated pedestal (float zone) growth method for the preparation of flexible wires (fibers) of the new copper-oxide ceramic superconductors, in particular, the Bi containing compounds which are capable of carrying high currents at temperatures above 77°K. This method, which involves drawing wires directly from a melt, has many advantages over other methods, most important of which is that it allows precise control of the growth process through the control of melt composition. Critical issues which will be considered in this superconducting fiber program include: 1) determining the most suitable compositions to be grown, 2) the maximum allowable growth velocity which can be used to grow fibers with high T_c, and 3) the maximum length of fiber which can be produced. To address these issues, the program will involve an in-depth study of: 1) the thermodynamic and kinetic factors which affect growth rate and the properties of the fibers produced, 2) the development of an advanced fiber growth system which will permit better control of system parameters, and 3) the development of techniques to enhance fiber throughput via increased growth velocity, postgrowth heat treatments, and the possibility of growing many fibers simultaneously.

29. PHOTOASSISTED OXIDATION OF OIL FILMS ON WATER

THE UNIVERSITY OF TEXAS AT AUSTIN
AUSTIN, TEXAS 78712

Adam Heller
Department of Chemical Engineering

Date Started: January 1, 1990

$309,000

Anticipated Duration: 3 years

The objective of this project is to develop a new environmentally safe technology for eliminating crude oil slicks from oil spills. To accomplish this, microbeads that float on oil slicks are used. Under solar illumination, the microbeads accelerate the oxidation of the oil. The low-cost, hollow glass microbeads will be partially coated with a layer of titanium dioxide, a known photocatalyst for oxidation of contacting organic compounds. The beads will harvest light from areas substantially larger than their own, because oil films between air and water trap and propagate light, waveguiding it to the beads, which, in turn, waveguide it to the titanium dioxide photocatalyst particles. The waveguiding is associated with increasing indices of refraction. The required coverage of oil slicks with microbeads depends on their optical properties, increasing for heavier crudes. Coverage of 1% of the surface with microbeads is projected to be adequate for the photodissolution, under average solar illumination, in 1 month, even for the heavy crude spills.

30. ELECTROCATALYTIC HYDROCRACKING*

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
BLACKSBURG, VIRGINIA 24061

Donald R. van der Vaart
Department of Chemical Engineering

Date Started: April 15, 1990

$115,000

Anticipated Duration: 1 year

Conventional hydrocrackers rely on extremely high hydrogen partial pressures (>1500 psi) both to facilitate hydrogenation and reduce

coke formation on the catalyst surface. In an electrochemical cell using a proton selective solid electrolyte, protons formed on the counter electrode can, as charge carriers, be transported through the electrolyte to the surface of the working electrode which is exposed to the liquid hydrocarbon at ambient pressure. The dual functionality required of hydrocracking catalysts is provided by this hydrogenating/ dehydrogenating (metal) site and the cracking sites of the solid electrolyte. The ready supply of hydrogen delivered directly to the reaction interface should limit coke formation and, hence, greatly reduce the operating pressure requirements. This decrease in the rate of surface deactivation would enable lower quality (heavier) feeds to be (electrocatalytically) hydrocracked to produce gasoline and middle distillates at significantly lower costs.

*This is a continuation of project number 25.

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) 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 3 months after start of work.

4.2. Complete ethylbenzene experiments within 12 months after start of work.

4.3. Complete butane and butene experiments and data analysis 20 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

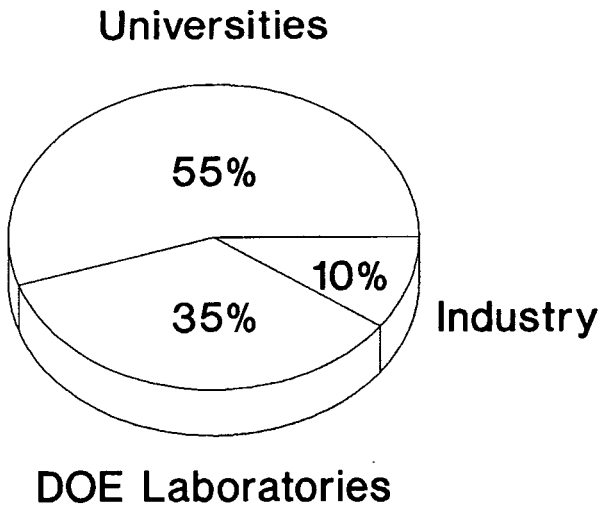
PROGRAM DATA

(EXCLUDES HIFAR AND SBIR)

BUDGET

	FY1989	FY1990	FY1991 (REQUEST)
OPERATING	$9,000,000	$9,000,000	$8,600,000
EQUIPMENT	328,000	330,000	340,000

DISTRIBUTION OF FY1990 PROJECTS BY SECTOR



DIVISION OF ADVANCED ENERGY PROJECTS
HEAVY ION FUSION ACCELERATOR RESEARCH

The Division of Advanced Energy Projects also manages the Heavy Ion Fusion Accelerator Research (HIFAR) program, an effort that is not subject to the prevailing three-year funding limit. The HIFAR program is investigating the scientific and technical feasibility of using an induction linac to generate multiple beams of heavy ions to repetitively drive inertial fusion targets for commercial energy production. Issues under study include: the acceleration and transport of space-charge-dominated ion beams; the preservation of transverse and longitudinal beam quality in induction linacs; and beam interactions with the target and with the chamber gases. The HIFAR strategy is to address the key issues through theoretical simulations and a sequence of experiments of increasing scale and sophistication. Past experiments have examined space-charge-dominated beam transport. Results have been encouraging. Present experiments are studying current amplification, beam quality, and longitudinal beam control in the MBE-4, an apparatus which models the physics embodied in the electrically focused portion of an accelerator driver. An ion injector is also being fabricated to explore the physics and technology issues associated with generating sixteen, high-current beams of carbon ions at 2 MeV.

The HIFAR effort is centered at the Lawrence Berkeley Laboratory. Important contributions are also being made by research teams at the Lawrence Livermore National Laboratory and the Stanford Linear Accelerator Center.

	FY1989	FY1990	FY1991 (REQUEST)
OPERATING	$5,500,000	$5,600,000	$5,400,000
EQUIPMENT	647,000	645,000	650,000

SMALL BUSINESS INNOVATION RESEARCH PROJECTS

AEP manages a number of projects in the Small Business Innovation Research program. The goal of Phase I projects is to determine the feasibility of the proposed concept. Phase II projects are a continuation of successful Phase I projects and are the principal research or research and development effort of the project. The principal investigator is identified below the project title. The total funding for each project is shown.

PHASE I SBIR PROJECTS

31. A PULSED X-RAY SOURCE USING K-EDGE TRANSITION RADIATION

ADELPHI TECHNOLOGY, INC.
285 HAMILTON AVENUE, STE. 430
PALO ALTO, CALIFORNIA 94301

Melvin A. Piestrup

Date Started: July 23, 1990

$49,993

Anticipated Duration: 6-1/2 mos.

The objective of the proposed research program is to investigate the use of a novel transition-radiation source to produce a low-cost, laboratory-scale, intense, pulsed X-ray source. By designing transition radiators to emit X-rays at the foil material K-shell photoabsorption edge, the X-ray spectrum is narrowed. The source is thus quasi-monochromatic (20 to 50% bandwidth), directional, intense and uses an electron beam whose energy is considerably lower than that needed for synchrotron sources. By using a pulsed electron source, foil heating is minimized and high-peak currents can be obtained. The radiation produced can be in the warm (5 to 15 keV) and hard (>15 keV) X-ray regions of the spectrum depending upon the foil material used, the foil thickness, and the electron-beam energy. Phase I research will be to design radiators, determine their theoretical X-ray flux and determine experimentally the total output power using the Ross filter technique. Bremsstrahlung contamination will be calculated and measured.

32. PRECISION UNDULATOR ADJUSTMENT TOOL

David A. Deacon

DEACON RESEARCH
2440 EMBARCADERO WAY
PALO ALTO, CALIFORNIA 94303

Date Started: July 23, 1990

$49,999

Anticipated Duration: 6-1/2 mos.

The development of free electron laser light sources in the XUV requires the use of long, high precision undulators. No undulator with the required quality has yet been attempted because of the lack of the appropriate measurement technology. Means are needed for measuring the electron trajectory so that the field errors can be corrected. The available approaches (Hall probes, pulsed wire) are sensitive either to the first or second derivative of the trajectory. As a result, the measurement errors accumulate in the calculation of the trajectory itself, making these techniques ineffective for the adjustment of long wigglers. We propose to adapt the ion beam technology heretofore used to adjust wigglers in the infrared. This adaptation requires the development of a new detection technology with a precision appropriate to the XUV application. We have developed the concept for such a detection system, and plan to optimize its design and demonstrate its precision experimentally in the Phase I program. If we are successful, in Phase II we would assemble a prototype ion beam system, and use it to demonstrate the precision to which one can trim up the fields of a long undulator. Our approach will make possible the construction of the high precision long undulators required for constructing free electron laser light sources in the XUV region and beyond.

33. HOLOGRAPHIC AND REFLECTION X-RAY LASER MICROSCOPE FOR LITHOGRAPHIC INSPECTION

R. J. Rosser

$49,937

PRINCETON X-RAY LASER, INC.
PRINCETON CORPORATE PLAZA
1-H DEERPARK DRIVE
MONMOUTH JUNCTION, NEW JERSEY 08852

Date Started: July 23, 1990
Anticipated Duration: 6-1/2 mos.

We propose to develop a system for high resolution (≈0.05μ) inspection of defects on relatively large area integrated circuits (IC). The system would combine a high resolution hologram (interferogram) of an IC with a reflection X-ray microscope. The X-ray hologram would enable the fast localization of defects, and the X-ray microscope would provide a high resolution image of any defects. Initially a soft X-ray laser, which was developed at Princeton University, will be used as a coherent source of radiation. However, Princeton X-Ray Laser, Inc. (PXL) is planning to build a small (portable) soft X-ray laser with a multilayer mirror cavity and this will be used for the construction by PXL of an engineering (commercial) device. The inspection system will be based on the fact that surfaces of different materials have significant reflection coefficients (up to several percent) for soft X-ray radiation in the region 10-20 nm. The reflection coefficient strongly depends on the material of the surface and the angle of incidence of the radiation, therefore, good contrast can be obtained for lithographic materials. The inspection of IC will consist of two steps. In the first step a high resolution hologram (interferogram) of a relatively large area of an IC will be registered using a charge coupled device. The hologram of the IC under investigation will be compared by computer with a hologram (interferogram) of a non-defective IC stored in the computer memory in order to rapidly identify areas with defects. In the next step, these specific areas will be imaged at 0.05 μm resolution by the reflection X-ray microscope. Phase I would be dedicated to: the computer ray tracing, detailed analysis of noise, contrast and speckle problems, and the methods of eliminating or minimizing these problems, reduction of data transmitted to the computers memory and the design of the system.

34. USE OF CHANNELING RADIATION AS A NOVEL, POWERFUL ELECTROMAGNETIC RADIATION SOURCE

SFA, INC.
1401 McCORMICK DRIVE
LANDOVER, MARYLAND 20785

Redge A. Mahaffey

Date Started: July 23, 1990

$48,400

Anticipated Duration: 6-1/2 mos.

SFA, Inc. proposes to investigate the feasibility of using channeling radiation (CR) as a novel, powerful source of electromagnetic radiation for a variety of important scientific and commercial applications. CR is the radiation emitted by relativistic electron (or positron) beams made to traverse thin single crystals in directions close to major crystal planes or axes. Predicted theoretically in 1976 by M. A. Kumakhov of Moscow State University, its existence was shown experimentally at high energies (greater than 1 GeV particle energy) by Miroshnichenko et al. at Stanford University, and at low energies (tens of MeV) by Berman et al. at Lawrence Livermore National Laboratory. Several hundred publications, mainly in the Soviet Union, present theoretical studies, and a hundred or so (one-third Soviet, one-third American) describe experiments on this phenomenon. The literature characterizes CR as a monochromatic, tunable X-ray or gamma radiation (keV to tens of MeV energy) and presents favorable comparisons of CR intensity with that of other radiation types (synchrotron radiation, ordinary or coherent bremsstrahlung, and transition radiation). However, no subsequent development of a CR source has been pursued. A dozen or more potential scientific and industrial applications of CR have been proposed, yet only a few of the scientific applications (e.g., the study of crystal structure or of the CR production mechanism) have been realized to date. The proposed Phase I study will evaluate the feasibility of CR as a radiation source, both in general and for specific scientific and commercial applications. The work will involve investigating the suitability of existing electron and positron accelerators and of target crystal types, as well as calculating CR transition line intensities. The completion of the

Phase I effort will prove the feasibility of using CR as a source for many important scientific and technical applications.

PHASE II SBIR PROJECTS

35. LOW TEMPERATURE PROCESSING OF HIGH T_c SUPERCONDUCTOR FILMS FOR INTEGRATION OF DETECTOR ARRAYS WITH SILICON CIRCUITRY

ADVANCED FUEL RESEARCH, INC.
P. O. BOX 380343
EAST HARTFORD, CONNECTICUT 06138

David G. Hamblen

Date Started: June 15, 1990

$499,782

Anticipated Duration: 2 years

The discovery of high temperature superconductivity (HTS) has led to renewed interest in the application of superconductivity. One such application is superconducting infrared detectors, either as bolometers or as grain boundary Josephson junctions. Infrared detectors, especially arrays for imaging, are not widely used due to the difficulties in integration with the necessary biasing and readout circuitry. The overall objective of this program is, therefore, integration of infrared detectors, based on HTS films, with silicon substrates on which the associated control and amplifier circuits can also be installed. The achievement of this goal requires the solution to a wide number of problems in the materials' quality control and fabrication (the substrate and buffer-layer surfaces, and HTS films), in device physics to understand and optimize the IR detectors and in electronic processing to integrate the required procedures with circuit fabrication technology. The key Phase I achievements include: 1) the first demonstration of an infrared detector using an HTS film on a silicon substrate, 2) the first demonstration of on-line characterization of the oxygen dependent transition in yttrium-barium-copper-oxygen (YBCO) from an insulating, non-superconducting phase to the metallic superconducting

phase using in-situ Fourier Transform Infrared (FT-IR) reflection, 3) demonstration of all required components to show that integration of detectors and silicon circuitry is feasible, and 4) identification of a complete methodology for deposition of high quality YBCO on silicon, using a 700°C substrate deposition temperature and an yttria-stabilized zirconia buffer layer to provide a lattice match and a diffusion barrier between the silicon and the superconductor. The Phase II program will continue this development using in-situ FT-IR to monitor the deposition process (especially the surface temperature and oxygen stoichiometry), and will continue to optimize the integration of the infrared detectors and accompanying circuitry in order to reach the ultimate goal of detector arrays.

36. THE DEVELOPMENT OF MULTIFILAMENTARY SUPERCONDUCTING COMPOSITE

EIC LABORATORIES, INC.
111 DOWNEY STREET
NORWOOD, MASSACHUSETTS 02062

Stuart F. Cogan

Date Started: May 20, 1989

$500,000

Anticipated Duration: 2 years

The contractor will develop multifilamentary high temperature $YBa_2Cu_3O_{7-x}$ (123) superconducting composites for high current applications. The composites will have an array of 123 filaments embedded in an aluminum matrix that provides flux-jump stability and mechanical support. High critical temperature (T_c) superconducting filaments will be fabricated by extrusion, pyrolysis, and oxidation of polymeric molecular precursors. The precursor is synthesized by a novel molecular level reaction that produces ductile polymers with a molecular structure consisting of copper oxide (CuO_2) planes isostructural to those of the superconducting 123 phase. The superconducting filaments will be incorporated into a composite by use of a liquid metal infiltration process. Phase I demonstrated the fabrication of crystallographically oriented 123 filaments and ribbons with a $T_c > 90$ K and a critical current density (J_c) of about

30 A/cm^2. The Phase II development will optimize the J_c of 123 filaments by improving filament density, optimizing crystallographic orientation of the high J_c planes, and improving current contacts. The fabrication of high T_c ceramics that are less susceptible to weak-link limitations on J_c across grain boundaries, namely $Tl_2Ca_{n-1}Ba_2Cu_nO_{4+2n}$, will also be investigated by similar techniques. The program will seek to develop a technologically viable process for fabricating multifilamentary composites with acceptable values of J_c. The overall objective is the fabrication of high T_c superconducting wire that can be incorporated into tapes, cables, and monolithic structures for practical high J_c applications.

37. AN ORIENTED HIGH TEMPERATURE SUPERCONDUCTOR FABRICATED BY A NOVEL TECHNIQUE FOR USE IN POWER APPLICATIONS AT LIQUID NITROGEN TEMPERATURE

IGC/ADVANCED SUPERCONDUCTORS, INC.
1875 THOMASTON AVENUE
WATERBURY, CONNECTICUT 06704

Leszek R. Motowidlo

Date Started: May 20, 1989

$499,996

Anticipated Duration: 2 years

In Phase I, multifilament wire and tapes were fabricated from high temperature superconducting $YBa_2Cu_3O_{7-x}$ (123) material. Model composites were designed and processed to final size by cold drawing and rolling techniques. The finished product had filament dimensions on the order of 15 to 20 microns in multifilament wire. Tape conductors were either rolled or pressed to thicknesses of 0.015 inches over the silver sheathing. Preliminary critical current density measurements were up to 1,000 A/cm^2 at liquid-nitrogen temperature and zero field. In Phase II, the principal effort will be to scale up and further improve the electrical characteristics of the wires and tapes through processing methods demonstrated in Phase I. Sufficient quantities of material will be produced to fabricate and demonstrate small scale devices.

INVESTIGATOR INDEX
(Project Numbers)

INSTITUTIONAL INDEX
(Project Numbers)