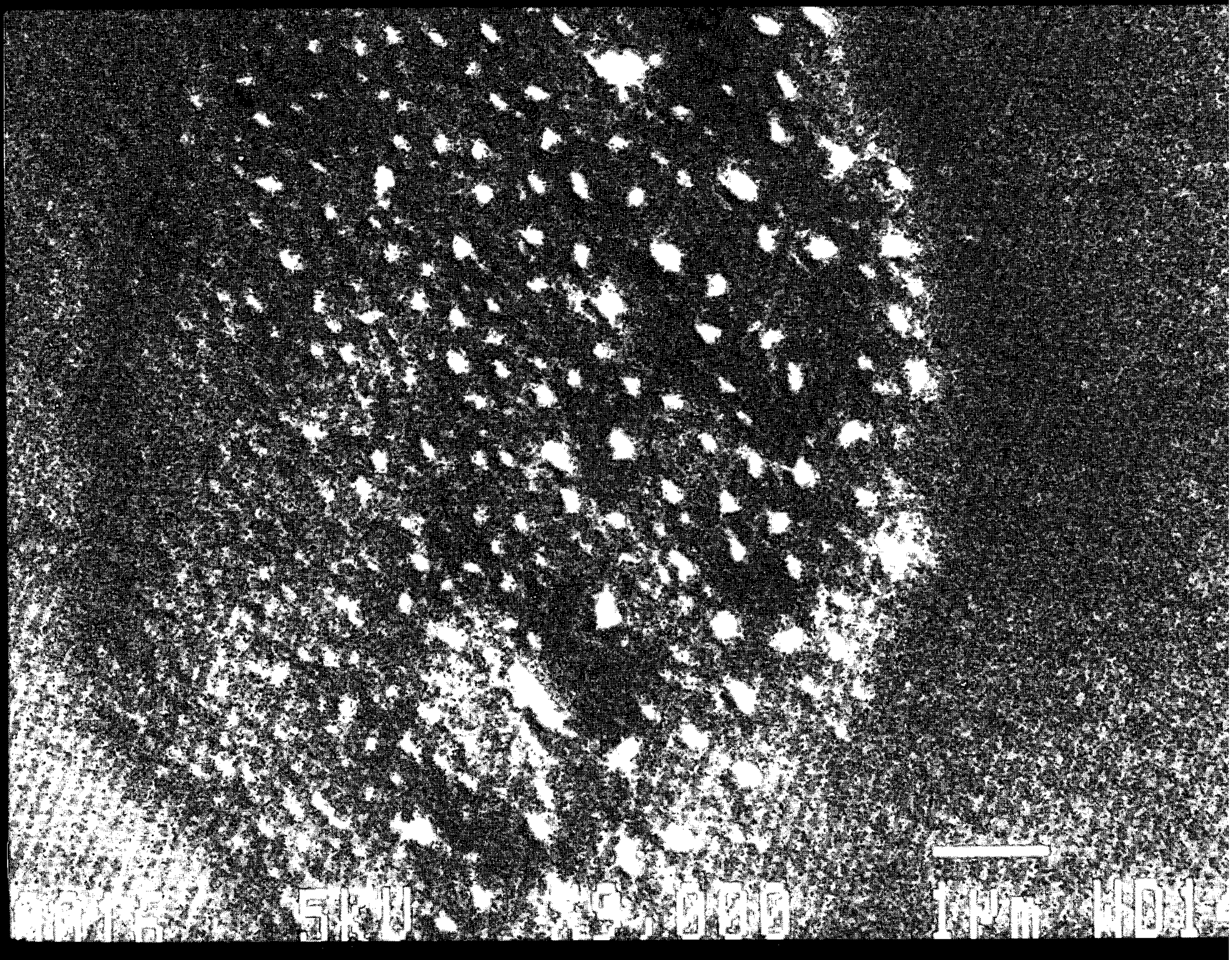
Advanced Energy Projects FY 1989 Research Summaries

September 1989



U.S. Department of Energy

Office of Energy Research

Office of Basic Energy Sciences

Division of Advanced Energy Projects

Cover photograph courtesy of Szymon Suckewer, Princeton University

This photograph is an SEM image of an X-ray laser produced replica of a granulocyte from the animal Limulus Polyphemus (Horseshoe crab). The specimen was exposed using a single shot of the Princeton University X-ray Laser using the Composite Optical X-Ray Laser Microscope (COXRALM).

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U.S. Department of Energy
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Washington, DC 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 and funding levels

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. Annual funding level for projects varied from about $30,000 to a maximum in the $500,000 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 23.

- 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.

<u>Further information</u>

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, DC 20545

Phone: 301/353-5995

<u>Heavy Ion Fusion Accelerator Research</u>

In addition to the program described above, the Division manages DOE's Heavy Ion Fusion Accelerator Research (HIFAR) program. The HIFAR objective is to acquire an appropriate data base for future decisions on heavy ion fusion based on induction linac drivers. Inquiries regarding HIFAR should be addressed to Dr. Walter M. Polansky, HIFAR Program Manager, ER-16, GTN, Department of Energy, Washington, DC 20545, phone 301/353-5935.

OFFICE OF BASIC ENERGY SCIENCES

DIVISION OF ADVANCED ENERGY PROJECTS

Summaries of Projects Active in FY 1989

*This section contains brief summaries of the projects active in this Division during Fiscal Year 1988 (October 1, 1988 - September 30, 1989). 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 '89 are indicated by the footnote: *Project completed. The annual funding level of each project is shown.*

1. PRODUCTION OF FUELS AND CHEMICALS FROM METHANE

Victor A. Maroni
Chemical Technology Division

ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue
Argonne, Illinois, 60439

$250,000

Date Started: July 1, 1989

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. ENERGY RELATED APPLICATIONS OF ELEMENTARY PARTICLE PHYSICS

UNIVERSITY OF ARIZONA
Tucson, Arizona 85721

Johann Rafelski
Department of Physics

Date Started: March 1, 1988

$326,000

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.

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

BROOKHAVEN NATIONAL LABORATORY
Upton, New York 11973

Hiroshi Takahashi

Date Started: October 1, 1987

$65,000

Anticipated Duration: 26 months

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.

4. 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 $a_w \approx 0.1$, wavelength $\lambda_w \approx 100$ μm and number of periods $N \approx 100$ 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, $\lambda_w \approx 10$ μm, $a_w \approx 1$, 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.

5. 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

$28,000

Anticipated Duration: 39 months

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.

6. PARALLEL NANOMETER SCALE FABRICATION

UNIVERSITY OF COLORADO
Boulder, Colorado 80309

Kenneth Douglas
Department of Physics

Date Started: September 15, 1989

$314,000

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 nanoheterostructures. 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.

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

UNIVERSITY OF DELAWARE
Newark, Delaware 19716

Krzysztof Szalewicz
Department of Physics

Date Started: May 1, 1988

$105,000

Anticipated Duration: 19 months

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.

8. 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 months*

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 $^5He(3/2+)$ resonance is crucial) and molecular physics. Eigenphase-shift techniques will be used to develop nuclear wavefunctions in the critical short distance regime.

*Includes no-cost extension.

9. 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 months*

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.

*Includes no-cost extension.

10. 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

$446,000

Anticipated Duration: 4 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 5×10^8 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.

*Project completed.

11. HIGH REPETITION RATE PLASMA FOCUS SOURCE FOR X-RAY LITHOGRAPHY*

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

L.L. Reginato

Date Started: March 1, 1989

$345,000

Anticipated Duration: 7 months

The objective of this project is to develop a compact, efficient plasma focus x-ray source suitable for lithography. The key technology which must be demonstrated to develop such a source is an ultra low inductance driver. The driver must provide a discharge pre-ionization pulse and a prepulse in addition to the main drive pulse. The ultra-low inductance is achieved by applying magnetic pulse compression to a SCR switched two kilojoule input pulse. The peak current delivered will be over 300 kA which is required for efficient conversion of discharge energy into kilovolt x-rays. The total x-ray yield, spectrum and source size will be measured as a function of discharge energy and gas pressure.

*Project completed.

12. 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

$833,000

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.

13. THEORETICAL STUDY OF MUON-CATALYZED FUSION

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

James S. Cohen
Theoretical Division

Date Started: December 29, 1983

$313,000

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.

14. NUCLEAR EXCITATION BY A HIGH-BRIGHTNESS UV LASER*

Peggy L. Dyer
Physics Division

$358,000

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.

*Project completed.

15. DEVELOPMENT OF HIGH-REFLECTANCE MIRRORS FOR THE XUV

Brian E. Newnam
Chemical and Laser Sciences Division

$440,000

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

Date Started: October 1, 1987

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 <u>external</u> 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.

16. 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

$517,000

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.

17. 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

$405,000

Anticipated Duration: 3 years

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

18. BIOLOGICAL X-RAY HOLOGRAMS

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

Keith Boyer

Date Started: September 1, 1986

$249,000

Anticipated Duration: 39 months*

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 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 is the focus of this program.

*Includes no-cost extension.

19. SEPARATION OF ORGANIC AZEOTROPIC MIXTURES BY PERVAPORATION

MEMBRANE TECHNOLOGY AND RESEARCH, INC.
1360 Willow Road
Menlo Park, California 94025

Richard W. Baker

Date Started: September 15, 1989

$153,000

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. 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.

21. 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

$336,000

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 field 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.

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

OAK RIDGE NATIONAL LABORATORY
P.O. Box 2008
Oak Ridge, Tennessee 37831

Charles D. Scott
Chemical Technology Division

Date Started: July 1, 1986

$175,000

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. 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.

*Project completed.

24. ELECTRICITY ENHANCED FLUIDIZED BED HEAT EXCHANGER

PACIFIC NORTHWEST LABORATORY
Richland, Washington 99352

Delbert L. Lessor
Energy Sciences Department

Date Started: October 1, 1988

$153,000

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.

25. HOLOGRAPHIC RUGATE STRUCTURE FOR X-RAY OPTICS APPLICATION

PHYSICAL OPTICS CORPORATION
3305 Dow Avenue
Redondo Beach, California 90278

Joanna Jannson
Optics Lab

Date Started: September 25, 1986

$234,000

Anticipated Duration: 38 months*

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.

*Includes no cost extension.

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

Szymon Suckewer
Plasma Physics Laboratory

$1,225,000

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

Date Started: January 1, 1985

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.

27. SOFT X-RAY LASER MICROSCOPE

Szymon Suckewer

$251,000

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

Date Started: September 1, 1986

Anticipated Duration: 43 months*

The objective of this project is 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 Princeton University. This design will also have a provision to adapt the microscope to a new system involving 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.

*Includes no cost extension.

28. 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

$124,000

Anticipated Duration: 3 years

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.

29. INVESTIGATION OF PARAMETERS CRITICAL TO MUON-CATALYZED FUSION

S&J SCIENTIFIC COMPANY
P. O. Box 7070
University Station
Provo, Utah 84602

Steven E. Jones

Date Started: September 1, 1987

$231,000

Anticipated Duration: 27 months

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.

30. 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.

31. MAGNETICALLY INSULATED IMPACT FUSION*

SCIENCE APPLICATIONS INTERNATIONAL CORP.
206 Wild Basin Road, Suite 103
Austin, Texas 78746

Daniel C. Barnes

Date Started: May 1, 1987

$199,000

Anticipated Duration: 1-1/2 years

This theoretical study will develop and investigate a concept for combining magnetic insulation of particle energy with impact driven compression of thermonuclear fusion targets. A novel approach to formation of a wall-confined spheromak inside an imploding metallic liner is considered. The resulting system is expected to achieve a few hundred times inertial energy confinement. Thus, in contrast to uninsulated impact fusion targets, present or near-term electromagnetic launch technology could deliver the impact of 10-20 km/s required to produce significant thermonuclear yield. Energy confinement, target preparation, and shell hydrodynamics will be investigated. Experimentally relevant target designs will be developed and analyzed.

*Project completed.

32. 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

$404,000

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.

33. AERODYNAMIC FOCUSING OF PARTICLES AND HEAVY MOLECULES*

YALE UNIVERSITY
P. O. Box 2159
Yale Station
New Haven, Connecticut 06520-2159

Juan Fernandez de la Mora
Department of Mechanical Engineering

Date Started: July 1, 1987

$62,000

Anticipated Duration: 27 months **

Theoretical predictions indicate that, by accelerating a gas-particle mixture through a converging nozzle, it is possible to concentrate dense beams of small uncharged particles into a narrow focus under previously unexplored conditions. Because high resolution aerodynamic focusing could be exploited in a variety of applications, including "direct writing," basic studies are proposed in order to assess its limits and potential technological impact. Experiments with micron-size aerosol particles (for which Brownian motion effects are negligible) will first examine the ratio between the diameters of the nozzle exit and the focal region size, for which theory predicts values well in excess of 100. These studies will be subsequently extended down to the molecular level, by substituting the suspended particles with neutral vapors of a heavy species (Au, WF_6, etc.) diluted in gaseous H_2 or He. The non- negligible Brownian motion of the heavy component leads then to a finite diffusive broadening of the focal region and sets a limit to the writing resolution attainable. Two theoretical approaches are proposed to study this defocusing phenomenon, one based on Brownian-dynamics simulations and the other exploiting the smallness of the random velocity as compared with the mean velocity of the heavy molecules. The phenomenon will also be studied experimentally, first visually by laser-induced fluorescence (LIF) of I_2 molecules seeded in high-speed jets of H_2 and He and also by sampling from He-Hg jets through a small orifice in a plate and analyzing for the concentration of Hg.

*Project completed.
**Includes no cost extension.

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

Fiscal Year 1989 Program Data
(does not include HIFAR or SBIR data)

FY '89 Budget

Operating Funds....................$9,001,000

Capital Equipment Funds............$ 328,000

Distribution of Projects by Institutional Sector

Universities	36%
Small Business	18%
Other Industry	6%
DOE Laboratories	36%
Federal Laboratories	4%

The Division of Advanced Energy Projects also manages the Heavy Ion Fusion Accelerator Research (HIFAR) program. In this program, research and development is performed on the heavy-ion induction linear accelerator method to assess its suitability as a "driver" for electric power plants based on the principle of inertial confinement fusion. HIFAR addresses the generation of high-power, high-brightness beams of heavy ions, the understanding of scaling laws in this novel physics regime, and the validation of new accelerator strategies for reducing costs. The program strategy is to attack these issues in a sequence of experiments of increasing scale. The present HIFAR experimental capability represents the early stages of this sequence. The four beam experiment, MBE-4, now under way following completion of the apparatus in FY 1987, models longitudinal beam control and acceleration in the electrically focused portion of a driver. An ion injector is being built to explore physics and technology issues associated with the generation of as many as sixteen 500 mA beams of C^+ ions accelerated to 2 MeV.

In FY 1989, the HIFAR budget was $5,537,000 in operating funds and $647,000 in capital equipment funds. The majority of the HIFAR effort is being performed at the Lawrence Berkeley Laboratory. Supporting research on specific HIFAR program elements is under way at the Lawrence Livermore National Laboratory, and the Stanford Linear Accelerator Center.

Also, AEP manages a number of projects in the Small Business Innovation Research (SBIR) program. These projects are shown on pages 25 to 28.

SMALL BUSINESS INNOVATION RESEARCH PROJECTS

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

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

David G. Hamblen

$49,900

ADVANCED FUEL RESEARCH, INC.
P.O. Box 18343
87 Church Street
East Hartford, Connecticut 06108

Date Started: August 16, 1989

Anticipated Duration: 6-1/2 months

The discovery of superconductors with transition temperatures above liquid nitrogen temperature has led to renewed interest in the application of superconductivity. These new materials can potentially be used as detectors more conveniently than can "classical" superconductors. The larger energy gap of these new high critical temperature (T_c) materials also provides the opportunity to fabricate Josephson Junction (JJ) detectors capable of sensing optical radiation at much lower wavelengths, offering new competition to semiconductor infrared (IR) detectors in the 10 to 100 μm region. Phase I and Phase II will develop IR detector arrays based on granular high T_c superconducting thin films that can be deposited on and integrated with silicon integrated circuits. This objective relies on current progress in the development of granular high T_c discrete detectors, the capabilities of the laser ablation process for integration on silicon, and the demonstrated capability of Fourier transform infrared spectroscopy as an in-situ diagnostic for monitoring the deposition and annealing of the perovskite films. The Phase I approach will use thin films of YBaCuO or BiCaSrCuO materials to demonstrate the low deposition temperature and interfacial thin film material required for achieving high T_c laser ablated thin films. Phase II will further develop the deposition process and assess the performance of the detector arrays. Silicon substrates with diagnostic circuits will be used to assess circuit operation before and after detector processing.

35. FABRICATION OF SUPERCONDUCTING CERAMIC FILAMENTS BY A VISCOUS SUSPENSION SPINNING PROCESS

HiTc SUPERCONCO, INC.
13 Village Row
Logan Square, P.O. Box 487
New Hope, Pennsylvania 18938

Roland R. Loh

Date Started: August 16, 1989

$49,958

Anticipated Duration: 6-1/2 months

Early experiments showed that high critical temperature (T_c) superconducting filament can be produced in a continuous fashion by a viscous suspension spinning process (VSSP). VSSP is a modified cellulose fiber manufacturing process based on established manufacturing technologies and using existing installed production equipment. In the envisioned process, a suitable Y-Ba-Cu-O or other high T_c superconducting fine powder is incorporated into a destructible, fiber-forming carrier. Carrier fibers filled with superconducting materials are formed in the usual way by either wet- or dry- spinning. The destructible carrier is then removed, and the remaining powder sintered and heat-treated to yield coherent filaments. Preliminary tests have shown promise, but more work is needed before the process yields a practical, flexible superconducting multifilament cable or wire. Fundamental experiments in Phase I will examine such key areas as the attainment of a high solid fraction in the "green" filament, control of VSSP with various particle loadings, mechanical and crystallization techniques for achieving preferred crystal orientation, chemical reactions between carrier and high T_c ceramic powders and their effect, "green" filament mechanical strength, and process issues with high temperature densification of filaments. The work plan is focused on maximizing both the critical current (J_c) and mechanical strength of the superconducting filaments.

36. TECHNIQUES FOR THE PULSED ENERGY DEPOSITION OF PARTICLE-FREE, ULTRA-SMOOTH HIGH CRITICAL TEMPERATURE SUPERCONDUCTING THIN FILMS

NEOCERA ASSOCIATES
P.O. Box 815
Piscataway, New Jersey 08855

Roger Edwards

Date Started: August 16, 1989

$49,869

Anticipated Duration: 6-1/2 months

Applications of the new high temperature superconductors in electronic components require the development of well-controlled techniques for fabricating thin films of the materials. Considerable success has been obtained with pulsed excimer laser deposition. This method has demonstrated excellent control over chemical composition and phase. However, the films often contain unwanted particulate material ejected from the source. Minimizing the number of particles in the films is essential for patterning small device features and fabricating multi-layer structures without pinholes or electrical shorts. Smooth, particle-free surfaces also are required to achieve low microwave losses. The purpose of this study is to reduce the incidence of these particles by designing and constructing a velocity filter or shutter mechanism that will block the passage of the slower moving particles while allowing the desired faster moving vapor species of the evaporant to deposit on the substrate. The particle- trapping technique will be applied to the film deposition of the yttrium- barium-copper-oxide superconductor on suitable substrates, e.g., strontium titanate or lanthanum aluminate. Processing conditions will be optimized to achieve films with low particle content and good superconducting properties.

37. A NEW TECHNIQUE FOR HIGH TEMPERATURE SUPERCONDUCTING THIN FILM PRODUCTION: PULSED ELECTRON BEAM EVAPORATION IN A PLASMA ENVIRONMENT

PLASMA AND MATERIALS TECHNOLOGIES, INC.
222 West Orange Grove Avenue
Burbank, California 91502

Gregor A. Campbell

Date Started: August 16, 1989

$50,000

Anticipated Duration: 6-1/2 months

This project involves a novel approach to pulsed electron beam (e-beam) evaporation in the presence of an oxygen plasma for the deposition of high temperature superconducting (HTS) thin films. Recently reported work showed that smoother thin films of $YBa_2Cu_3O_x$ can be deposited using pulsed laser evaporation. Independent work using molecular beam epitaxy techniques demonstrated that the presence of atomic oxygen in situ during film deposition is one key to lowering the required substrate and anneal temperatures from the 850° to 900°C range. This project adopts a novel approach. It will use a pulsed e-beam that is already operational and has 75 kV beam energy, up to 1,000 A current, and 1 μs pulse width (with beam diameter on target of under 1 cm yielding about 100 J/cm^2 or 10^8 W/cm^2) to flash evaporate $YBa_2Cu_3O_x$ pellets for deposition on heated substrates. This power density is comparable to that reported using lasers for pulsed evaporation. The e-beam system is efficient (about 80%), the electrons have long range (10 to 20 μm compared to lasers, and the coupling efficiency to the material target is essentially 100%. The greater range should result in a smoother evaporation process as compared to the "explosive" evaporation reported under certain conditions of laser ablation. Other key advantages of this approach include pulsed evaporation of the material in the presence of plasma; this in turn produces atomic oxygen atoms and ions (as well as O_2). Phase I will develop the operation of this unique pulsed e-beam plus a plasma arrangement to evaporate HTS material and form thin films on substrates. The films will be characterized by Rutherford backscattering spectrometry to determine the stoichiometry. After an anneal, the resistivity versus temperature will be determined with a four-point probe.

38. SUPERCONDUCTING CURRENT LEADS USING HIGH TEMPERATURE SUPERCONDUCTORS

SUPERCONDUCTIVE COMPONENTS, INC.
1145 Chesapeake Avenue
Columbus, Ohio 43212

Edward R. Funk

Date Started: August 16, 1989

$49,968

Anticipated Duration: 6-1/2 months

In Phase I various high temperature superconductors will be used in composite configurations with noble metals and low temperature superconductors to construct conductors to serve either as "cold ends" or "intermediate-temperature ends" of current leads that will transport current from ambient-temperature equipment into a device operating in a cryostat at liquid helium temperatures. The sample composite conductors will be carefully characterized as to their microstructure, magnetization properties, and transport current. The cryogen savings realized by using these materials will be compared with the use of standard tubular copper current leads.

39. THE DEVELOPMENT OF MULTIFILAMENTARY SUPERCONDUCTING COMPOSITES

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.

40. 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)

UNITED STATES
DEPARTMENT OF ENERGY
WASHINGTON, D.C. 20545

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

ER-16