Office of Science
Notice DE-FG01-04ER04-24

National Spherical Torus Experiment
Innovative Fusion Energy Science Research

Department of Energy

Office of Science Financial Assistance Program Notice DE-FG01-04ER04-24; National Spherical Torus Experiment - Innovative Fusion Energy Science Research

AGENCY: U.S. Department of Energy

ACTION: Notice inviting grant applications.

SUMMARY: The Office of Fusion Energy Sciences (OFES) of the Office of Science (SC), U.S. Department of Energy (DOE) hereby announces its interest in receiving grant applications for collaborative research on the National Spherical Torus Experiment (NSTX) at Princeton Plasma Physics Laboratory. The NSTX program addresses two of the long term goals of OFES: **Configuration Optimization and developing a Predictive Capability for Burning Plasmas**. Collaborative research must support the NSTX Program in addressing key scientific issues related to these goals in plasma turbulence and transport, plasma control and stability, heating and current drive using high harmonic fast waves or electron Bernstein waves, edge plasma measurements and modeling, and solenoid free current initiation, ramp-up, and sustainment. To be considered for funding, applicants must have discussed their proposed research with the NSTX National Research Program Leaders and must include a Record of Discussion indicating the benefits of proposed research to the planned NSTX research program and the interface support required by the proposed collaborative work. Applications to renew an on-going NSTX collaboration research must include a summary of the accomplishments and the funded statement of work of this research. Applications focusing primarily on diagnostic development or implementation on NSTX will not be considered under this notice.

Please review the Supplementary Information sections below for further discussion of programmatic needs and for details on evaluation criteria.

DATES: Letters of intent, including information on collaborators, areas of research, and a one-page summary of the proposed research, should be submitted by October 1, 2004. They should be submitted directly to OFES at the address listed below.

Formal applications submitted in response to this notice must be received by 4:30 p.m., Eastern Time, October 14, 2004, in order to be accepted for merit review and to permit timely consideration for award in Fiscal Year 2005.

ADDRESSES: Letters of Intent referencing Program Notice DE-FG01-04ER04-24, should be sent to Mr. John Sauter by E-mail: john.sauter@science.doe.gov, with a copy to Dr. Stephen Eckstrand at: steve.eckstrand@science.doe.gov.

Formal applications referencing Program Notice DE-FG01-04ER04-24 must be sent electronically by an authorized institutional business official through DOE's Industry Interactive Procurement System (IIPS) at: http://e-center.doe.gov. IIPS provides for the posting of solicitations and receipt of applications in a paperless environment via the Internet. In order to submit applications through IIPS your business official will need to register at the IIPS website. **Although IIPS offers the option of using multiple files, please limit submissions to one volume and one file if possible, with a maximum of no more than four PDF files.** The Office of Science will include attachments as part of this notice that provide the appropriate forms in PDF fillable format that are to be submitted through IIPS. Full page color images should be submitted in IIPS as a separate file in PDF format and identified as such. These images should be kept to a minimum due to the limitations of reproducing them. They should be numbered and referred to in the body of the technical scientific grant application as Color image 1, Color image 2, etc. Questions regarding the operation of IIPS may be e-mailed to the IIPS help desk at: HelpDesk@pr.doe.gov or you may call the help desk at (800) 683-0751. Further information on the use of IIPS by the Office of Science is available at: http://www.science.doe.gov/grants/.

If you are unable to submit an application through IIPS, please contact the Grants and Contracts Division, Office of Science at: (301) 903-5212 or (301) 903-3064, in order to gain assistance for submission through IIPS or to receive special approval and instructions on how to submit printed applications.

FOR FURTHER INFORMATION CONTACT: Dr. Stephen Eckstrand, telephone: (301) 903-5546, E-mail: steve.eckstrand@science.doe.gov, Office of Fusion Energy Sciences, U.S. Department of Energy, SC-55/Germantown Building, 1000 Independence Avenue SW, Washington, DC 20585-1290.

SUPPLEMENTARY INFORMATION

An overall goal of the NSTX program is to evaluate the attractiveness of the spherical torus for fusion applications by assessing the scientific basis of stability, confinement, self consistent high bootstrap operation, and acceptable divertor heat fluxes of strongly rotating, high beta plasmas of very low aspect ratio, for pulse lengths much longer than the energy confinement time and ultimately much longer than the current relaxation time. To be attractive, a spherical torus must, in these extended plasma regimes, efficiently confine the plasma energy and particles and simultaneously maintain good plasma stability at high beta. In addition, it must also achieve plasma initiation, ramp-up, and sustainment operations without the use of a central solenoid. Investigation of the science of the spherical torus plasma therefore effectively contributes to as well as challenges the understanding of key scientific issues concerning the dynamics and fields in high- temperature plasma.

More detail of the NSTX program is described in the peer reviewed five-year research program for NSTX starting in FY2004, available at http://nstx.pppl.gov/Pages_folder/research_folder/5YrPlan.html. A NSTX Program Letter providing updated information on the NSTX research priorities and collaboration opportunities during the next three years, accounting for the advice of the NSTX Program Advisory Committee, will be available on September 15 at http://nstx.pppl.gov/Pages_folder/research_folder/Research_Programs.html.

Research on NSTX is carried out by a broadly based research team, which includes scientific personnel from many of the leading U.S. fusion research institutions. These researchers are involved in nearly all areas of research on NSTX. The following sections provide a description of the topical areas that are included in this solicitation.

- **I.** Specifics for Plasma Turbulence and Transport
- **II.** Specifics for Plasma Control and Stability
- **III.** Specifics for the Heating and Current Drive Using High Harmonic Fast Waves or Electron Bernstein Waves
- **IV.** Specifics for Plasma Boundary Measurements and Modeling
- **V.** Specifics for Solenoid Free Current Initiation, Ramp-up, and Sustainment

I. Specifics for Plasma Turbulence and Transport

Studies of turbulence and transport on NSTX are aimed both at determining the attractiveness of the spherical torus and on contributing understanding transport in toroidal confinement configurations by addressing the question: How does turbulence cause heat, particles, and momentum to escape from plasmas?

New and continuing opportunities for collaboration include the following activities:

- Develop a comprehensive neo-classical model of momentum, energy, and particle (including impurity) confinement in the spherical torus, including the effects of sonic and Alfvénic plasma rotation and flows in order-unity beta plasmas, as a reference condition that supports the turbulence and transport properties
- Model turbulence and transport mechanisms in plasmas with the above properties, introducing a large extension of the conventional regimes of interest and a severe test of the models developed for lower beta larger aspect ratio plasmas
- Determine beam ion deposition profile and study confinement of energetic ions and their effect on fast-ion driven instabilities
- Understand the dependence of the H-mode pedestal width and gradients on gyro- radius, and fueling, accounting of the ST edge geometry

II. Specifics for Plasma Control and Stability

Research on this topical area is focused on developing the understanding and control tools needed to achieve high beta, long pulse operation. The research also addresses the questions: How does magnetic field structure impact fusion plasma confinement? What limits the maximum pressure achievable in laboratory plasmas? How much external control versus self-organization will fusion plasma require?

The following elements of the program provide opportunities for collaboration:

- Study the physics of global MHD modes at high normalized beta and low internal inductance, including the effect of toroidal rotation on stability
- Use passive stabilization techniques and current profile control to achieve a plasma pressure greater than the no-wall limit for long pulses
- Study the physics and control of resistive wall modes up to the theoretically predicted normalized beta limit
- Design and implement an optimized feedback control system and demonstrate active stabilization of resistive wall modes
- Develop a real-time predictive capability for stability
- Study physics of neoclassical tearing modes (NTMs) and develop techniques for NTM control
- Understand and optimize ELM stability in the ST edge geometry
- Assess the effect of fast-ion driven instabilities on high-beta operation

III. Specifics for the Heating and Current Drive Using High Harmonic Fast Waves or Electron Bernstein Waves

Because of the high dielectric constant in high-beta, spherical torus plasmas, wave- plasma interactions in NSTX are different from those in tokamak plasmas. Lower hybrid waves and electron cyclotron waves cannot reach the core of high beta, spherical torus plasmas. However, high harmonic fast waves (HHFW) and electron Bernstein waves (EBW) can access the plasma core to provide heating and current drive in such plasmas. Localized electron heating may be required for solenoid free initiation of the plasma current. Off axis current drive is required for solenoid free current ramp-up and steady- state operation. It is also required to complement the bootstrap current and neutral beam driven current in high beta operation. The research also addresses the question: How do electromagnetic waves interact with plasma?

Research tasks that can benefit from collaboration include:

- Identify and model HHFW parasitic and parametric absorption mechanisms that can limit HHFW current drive, with and without energetic ions.
- Model HHFW heating and current drive in non-standard conditions, such as during CHI and outer poloidal field only startup
- Model EBW power deposition and current drive to determine optimal current drive scenarios for various plasma conditions
- Examine EBW start-up scenarios, alone or in combination with HHFW or coaxial helicity injection
- Investigate radial transport effects on EBW current drive and heating localization
- Model propagation and absorption of EBWs for localized current drive for application to current profile control for high beta operation or for suppression of MHD instabilities such as neoclassical tearing modes

IV. Specifics for Plasma Boundary Measurements and Modeling

Understanding the physics of the edge plasma in NSTX is necessary to control the edge plasma conditions in such a way as to be able to attain the operational regimes needed for the other elements of the research program. The very large in-out asymmetry of the ST edge and scrape-off layer plasma introduces potentially new mechanisms and provides severe tests of the conventional understanding in this topic. This research will also contribute to understanding the physical process governing the boundary plasma in toroidal devices and the effect that the boundary plasma has on the characteristics of the core plasma. The research also addresses the question: How to interface high temperature plasma to its room temperature surroundings?

Elements of the boundary physics available for collaboration include:

- Measure edge electron density and temperature profiles, radial electrical field profiles, and the fluctuations in these parameters and magnetic field
- Model and interpret data from edge turbulence diagnostics; assess role of edge plasma convection relative to diffusive transport
- Model resistive X-point and other modes to understand SOL turbulence
- Model and interpret data on the L-H transition
- Explore innovative divertor heat flux mitigation techniques

V. Specifics for Solenoid Free Current Initiation, Ramp-up, and Sustainment

An in-board ohmic heating solenoid, along with the shielding required to protect it would increase the size and cost of a fusion power plant. Hence, an attractive spherical torus fusion power plant cannot have an in-board solenoid and must have options for solenoid free current operation. The research also addresses the questions: How are electromagnetic fields and mass flows generated in plasma? How do magnetic fields in plasmas rearrange and dissipate their energy?

Opportunities for collaboration include the following tasks:

- Initiate plasma using transient co-axial helicity injection (CHI) and transfer to other techniques of current ramp-up using the outer poloidal field coils
- Achieve high temperature plasmas using CHI, neutral beam injection, high harmonic fast wave, or EBW heating
- Assess usefulness of CHI for edge current drive and controlling edge flows in long-pulse plasmas
- Develop theory and approach to use HHFW or EBW to initiate and ramp-up plasma current
- Develop theory to analyze results and extrapolate techniques to future devices

Program Funding

It is anticipated that about $1.3 million will be available from DOE/OFES for new collaborative research awards during FY 2005, contingent upon the availability of funds. Multi-year funding of grant awards is expected, and is also contingent upon the availability of appropriated funds in future years, progress of the research, and continuing program need. It is expected that up to 12 awards will be made, depending on the size of the awards. Most awards will be for 3 years and will range from $50,000 to $300,000 per year (total costs).

Collaboration

Applicants must collaborate with researchers from other institutions who are part of the NSTX National Research Team, which includes researchers from Princeton Plasma Physics Laboratory, industry, universities, and other DOE National Laboratories, as appropriate. In addition, applicants must include a collaboration plan and a Record of Discussion indicating the benefits of proposed research to the planned NSTX research program and the interface support required by the proposed collaborative work.

Additional information on collaboration is available in the Application Guide for the Office of Science Financial Assistance Program that is available via the Internet at: http://www.sc.doe.gov/grants/Colab.html.

Merit and Relevance Review

Applications will be subjected to formal merit review and will be evaluated against the following criteria, which are listed in descending order of importance as set forth in 10 CFR Part 605. (http://www.science.doe.gov/production/grants/605index.html). Included with each criteria are the detailed questions that are asked of the reviewers.

1. Scientific and/or technical merit of the project;

- Does this application address an important problem in fusion energy science?
- How does the proposed research compare with other research in its field, both in terms of scientific and/or technical merit and originality?
- What is the likelihood that it will lead to new or fundamental advances in its field?

In answering these questions, please identify the topics described in Supplemental Information to which the proposed research will most likely contribute and why.

2. Appropriateness of the proposed method or approach;

- Are the conceptual framework, methods, and analyses adequately developed and likely to lead to scientifically valid conclusions?
- Are there significant potential problems and how well does the applicant address these problems?

3. Competency of the applicant's personnel and adequacy of the proposed resources;

- How well qualified are the applicant's personnel to carry out the proposed research? (If appropriate, please comment on the scientific reputation and quality of recent research by the principal investigator and other key personnel.)
- Are the applicant's research environment and resources adequate?
- Does the proposed work take advantage of unique facilities and capabilities and/or make good use of collaborative arrangements?
- In the case of an application to renew an on-going research project, how effectively has the applicant delivered on the statement of work of this research?

4. Reasonableness and appropriateness of the proposed budget.

The reviewers are also asked to comment on **Other Appropriate Factors**:

- How is the proposed project relevant to the Office of Fusion Energy Science's goals?
- Could the proposed research make a significant contribution to another field?
- Is there potential for spin-offs?
- If applicable, please comment on the educational benefits of the proposed activity.

The evaluation will include program policy factors such as the relevance of the proposed research to the terms of the announcement, the Department's programmatic needs, and quality of previous performance. External peer reviewers are selected with regard to both their scientific expertise and the absence of conflict-of-interest issues. Non-federal reviewers may be used, and submission of an application constitutes agreement that this is acceptable to the investigator(s) and the submitting institution. Applications found to be scientifically meritorious and programmatically relevant will be selected in consultation with DOE selecting officials depending upon availability of funds in the DOE budget. Funding under this Notice is limited to supporting research activities based in the U.S., though subcontracts with limited funding for collaborators outside the U.S. may be allowed with appropriate justifications. The selected projects will be required to acknowledge support by DOE in all public communications of the research results.

The Application

(PLEASE NOTE INFORMATION BELOW ON PAGE LIMITS)

Information about the development and submission of applications, eligibility, limitations, evaluation, selection process, and other policies and procedures may be found in the Application Guide for the Office of Science Financial Assistance Program and 10 CFR Part 605. Electronic access to the Guide and required forms is made available via the World Wide Web: http://www.science.doe.gov/grants/guide.html. DOE is under no obligation to pay for any costs associated with the preparation or submission of applications if an award is not made.

Adherence to type size and line spacing requirements is necessary for several reasons. No applicants should have the advantage of providing more text in their applications by using small type. Small type may also make it difficult for reviewers to read the application. Applications must have 1-inch margins at the top, bottom, and on each side. Type sizes must be 10 point or larger. Line spacing is at the discretion of the applicant but there must be no more than 6 lines per vertical inch of text. Pages should be standard 8 1/2" x 11" (or metric A4, i.e., 210 mm x 297 mm). Applications must be written in English, with all budgets in U.S. dollars.

Applicants are asked to use the following ordered format:

- **Face Page** (DOE F 4650.2 (10-91))
- **Project Abstract Page**; single page only, should contain:
  - Title
  - PI name
  - Abstract text should concisely describe the overall project goal in one sentence, and limit background/significance of project to one sentence. Short descriptions of each individual aim should focus on what will actually be done.
- **Background and Recent Accomplishments** (recent accomplishments subsection is mandatory for renewal applications, but optional for new applications)
- **Budget pages** for each year and a summary budget page for the entire project period (using DOE F 4620.1)
- **Budget Explanation**
- **Project Description, 20 pages or less,** exclusive of attachments. Applications with Project Descriptions longer than 20 pages will be returned to applicants and will not be reviewed for scientific merit. The project description should be a clear statement of the work to be undertaken and should include: objectives for the period of the proposed work and expected significance; relation to the longer-term goals of the NSTX project; and relation to the present state of knowledge in the field. The statement should outline the general plan of work, including project scheduled, milestones and deliverables, and an adequate description of methods and procedures.
- **Literature Cited**
- **Biographical Sketches** (please limit to 2 pages per senior investigator)
- **Facilities and Resources** description
- **Current and Pending Support** for each senior investigator
- **Letters of Intent** from collaborators (if applicable)

The Catalog of Federal Domestic Assistance number for this program is 81.049, and the solicitation control number is ERFAP 10 CFR Part 605.

Martin Rubinstein
Grants and Contracts Division
Office of Science

Posted on the Office of Science Grants and Contracts Web Site
August 6, 2004.