Title of Proposed Project: **Fast Imaging Diagnostics and Physics on NSTX**

ER Program announcement: **LAB 98-07 National Spherical Torus Experiment Research Program**

Name of Laboratory: **Los Alamos National Laboratory**

PI: **Dr. Glen A. Wurden**

Position of PI: **MFE Team Leader, P-24 Plasma Physics Group**

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Requested funding for each year: **FY99 $527k, FY00 $808k, FY01 $645k**

Total Funding Requested: **$1.980 M**

Use of Human subjects: **NO**

Use of Vertebrate animals: **NO**

PI Signature: ____ Date: ____________________

Lab Official Signature: ________________________________ Date: ____________________

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3.4 ABSTRACT

Los Alamos proposes an experimental collaboration based upon fielding a set of advanced imaging diagnostics on the NSTX plasma. We will study plasma/wall interactions, plasma startup and positioning issues, plasma fluctuations, and spherical tokamak (ST) divertor problems. We propose to field two remote-controlled diagnostics: a fast-visible-filtered-intensified-digital video system, and a high-resolution infrared digital imaging video system. The power and utility of a general-purpose, filtered (to discriminate various impurities), fast (>1000 frames per second) intensified video system, keyed to the shot timebase, and retrievable by any user from a digital archive, is widely recognized. Similarly, an understanding of the power distribution on plasma-facing components is essential to good plasma operation, and survival of close-in components. This can be accomplished by multiple infrared views of the interior of the machine. LANL will provide one such system, which operates in the 3-5 micron band, with 12-bit dynamic range, enabling detection of temperatures from room temperature on up in excess of 1500° C. Initially it will be restricted to 60 fields/second video rate, but an upgrade will enable operation at up to 1400 frames/second. Both systems will require careful engineering of appropriate optical access (fibers or relay lens apparatus) to achieve optimal viewing of the vessel interior, and compatibility with mechanical and magnetic environments. These diagnostics are crucial for slow formation and sustainment studies (WG1; Working Group 1), antenna imaging and fast particle loss studies (WG2), power/particle handling and divertor monitoring (WG5), and if fast enough, are useful for macroscopic fluctuation studies (WG4) and monitoring of MHD edge perturbations, disruptions, and internal reconnection events (WG3).

3.5 Research Plan

Background and Significance

Imaging diagnostics, whatever their nature, can provide key insights for the successful operation of a modern plasma device. The importance and power of fast visible and infrared (IR) imaging was recognized during the last NSTX Research Forum held at the Princeton Plasma Physics Laboratory on December 3-5, 1997. During this Forum, all five research Working Groups (WG) expressed strong interests in utilizing one or both of the proposed diagnostics in their research. Some of the uses for these diagnostics mentioned during the FY98 NSTX Forum are:

WG1, Slow Mechanisms for Current Formation and Sustainment: Fast visible system useful for study of gas breakdown and dynamics during coaxial helicity injection (CHI), of the edge dynamics and MHD perturbations during helicity injection, and of the influx of impurities and fuel from the CHI electrodes. Meanwhile, an IR system will be useful to assess the heating of these electrodes.

WG2, Fast Mechanisms for Heating, Current Formation and Sustainment: IR system will be useful in the study of fast particle losses and RF antenna heating.

WG3, Magnetics and Stability Limits: Fast visible system useful for MHD studies and its effects on the edge plasma, general plasma dynamics, disruption, and internal reconnection events (IREs) studies.

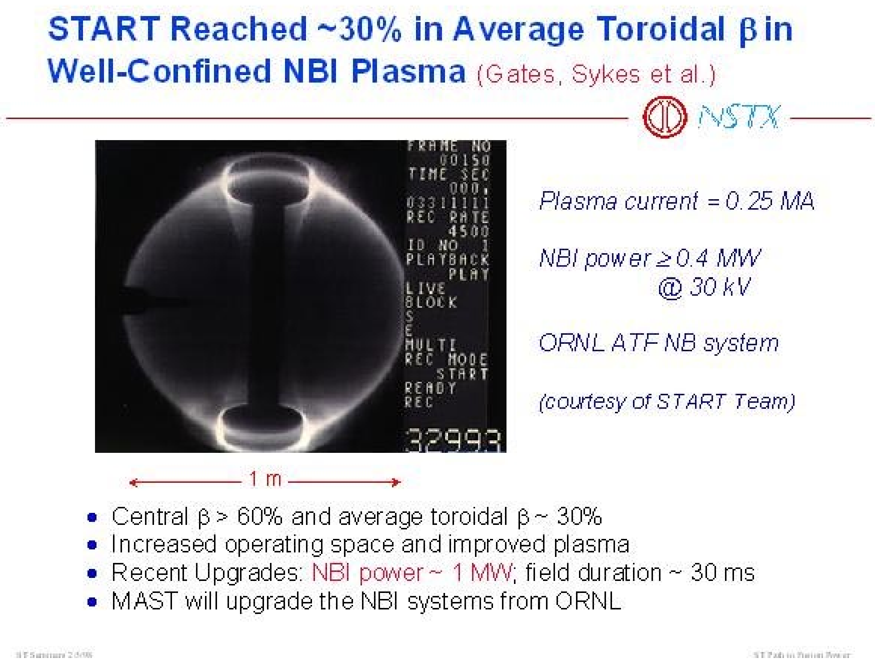
WG4, Transport and Fluctuations: Fast visible system useful for edge fluctuation studies.

WG5, Divertor, Scrape-Off Layer, Power and Particle Handling: Fast visible system useful for study of the influx of impurities and fuel, either spontaneous (i.e., recycling, blooms, UFOs, etc.) or deliberate (i.e., pellets, DOLLOP, puffs, fast scanning probes, CT injection, etc.). IR system useful to study heat loads on plasma facing components including the divertor area.

We propose not only to field the imaging diagnostics for these studies but actively participate in the analysis of the phenomena mentioned above.

For startup and operations, multiple visible and IR cameras are being planned. Ideally, some will have wide-angle coverage, and others will be able to focus on particular regions of interest (i.e., the divertor or RF antennas). For the 0.5-5 second NSTX pulse length, the faster the framing rate, while still providing full coverage of the discharge duration, the better.

It is well-known that machine operators, and even many physics operators of today’s tokamaks, will not run their machine without "video coverage" of the inside of the vessel. The ability to have a high-speed movie of the shot, is essential. When coupled to H_α filters, even edge fluctuations can be imaged. Indeed, START already uses a high-speed, wide-angle Kodak video camera system (the Kodak HS4540 which we propose an intensified version of, in 2nd-year upgrade). An image from their system, at 4500 frames per second, is shown below:



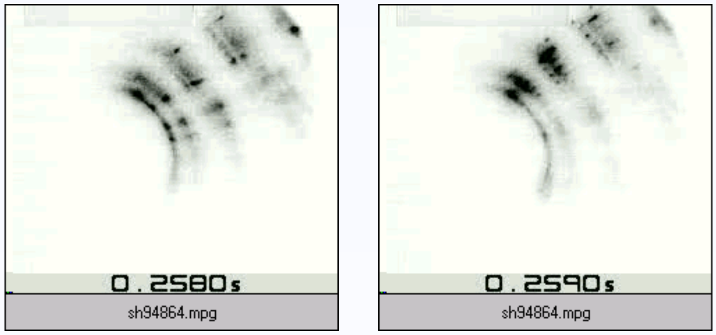
A key problem with the START system, is that their camera *is not* intensified.... and therefore cannot readily be used with narrow-band interference filters (not enough light)...which are important for quantitatively studying different impurity species.

It is planned to have several infrared video systems on NSTX. By making measurements in the infrared (from 1-10 micrometer range), it is well-known that the heat load on in-vessel components can be determined. Furthermore, fast measurements are useful to study the losses of energetic particles from MHD activity and/or disruptions. Because there are several key areas to measure (such as RF antenna structures, divertor regions, and outer wall ripple loss zones), it is essential to have more than one IR system. In addition, it may be the case that the dynamic range of any one system is inadequate to measure "standard" vs. "off-normal" events, and therefore useful to have two cameras viewing one region, as well.

Preliminary Studies

The LANL P-24 Plasma group has developed and used fast imaging diagnostics to record transient features of many experiments[1]. At TFTR the LANL P-24 Plasma physics team has fielded and used a fast visible imaging system (http://wsx.lanl.gov/tftr.htm) to image pellets, lithium wall-conditioning, disruptions, fast fluctuations, and UFO's from carbon tiles. Various MPEG movies (in white or filtered light) from this system can be viewed on the web, at http://wsx.lanl.gov/ricky/disrupt.htm. This system was first installed at the Alcator C-Mod tokamak in FY95[2], and then brought to TFTR in FY96 (for what was at the time thought to be the "final TFTR run").

Moving, coherent, light emission filaments are observed on the inner wall armor



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The fast camera system consists of a $140k Kodak intensified high-speed (nominal 1000 full frames/second) digital video camera, which is coupled to the tokamak by either an optical periscope (TFTR) or an imaging fiber bundle (Alcator C-Mod). The camera processor sits in the test cell with 400 Mb of dynamic memory (RAM), and talks to the control room Windows 95 PC via a fiber-optic GPIB interface. Gain and gate settings are remote controlled, and the operation of the camera, including automatic archiving to either digital or video-tape storage, with shot number and timebase information, is achieved from a custom LabView control program.

Fast imaging diagnostic components

- Intensified Kodak EktaPro EM1012 camera system:
  - Intensified imager
  - Intensified imager controller
  - Motion analyzer processor
- Fiber optic links for processor control (GPIB link) and analog video signal transmission.
- Intel based computer running a LabView virtual instrument controller, either under Windows NT or Windows 95.
- VCR for analog data storage.

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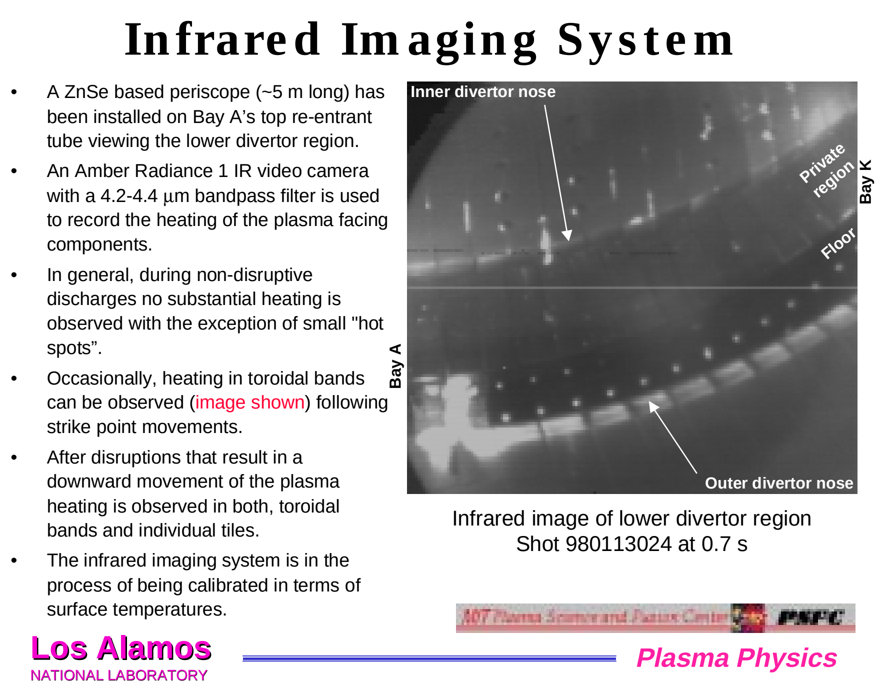
Of particular interest will be the use of the fast camera to observe internal reconnection events (IRE's), and other edge effects of MHD activity. Also, helicity injection is known to cause large-scale internal MHD activity, and effects of the modes should be visible in the fast camera system as energy is moved towards the edge of the plasma, lighting up different impurities. In addition, the fast camera will also be an invaluable tool for the operations team, as they learn to run the machine, and therefore it is an essential Day 1 diagnostic. By comparison, a standard video camera (which will certainly also be used on NSTX) would only show 3 frames (perhaps 6 fields) in a 100 millisecond discharge ...

LANL has also developed and fielded a standard-rate (60 fps) digital infrared video system to view the Alcator C-Mod divertor region. The machine interface and optical design work was performed at the end of FY96 at a cost of $25k. In FY97, the periscope hardware was built, assembled, and then tested in June of 1997. Total FY97 costs were ~$100k. These costs do not include the basic $70k cost of the existing IR camera, and an additional $25k for the long remote-controlled IR lens (250 mm) and various filters. First results with the system were presented (http://wsx.lanl.gov/ricky/aps97_poster.pdf) in Nov. 1997 at the APS Pittsburgh meeting. At C-Mod, the viewing geometry is extremely difficult, due to small ports and long re-entrant optics required. Here is an example of resulting IR view in Alcator C-Mod:



For NSTX, we anticipate that the IR camera will be invaluable to monitor the RF heating systems antennas, as well as to investigate regions of intense power deposition (i.e., the divertor area). IR video cameras have been useful on JT-60U (and other tokamaks) to observe the localized heating effects of fast ions which are lost to the walls of the machine. Presumably, with helicity injection current drive there won't be many relativistic electrons created by runaway processes..... but if there are, the IR system could be used to see their cyclotron emission, as has been observed in other tokamaks.

Research Design and Methods

We have presented an outline of our plans at the Dec. 3-5, 1997 NSTX Research Forum. (http://wsx.lanl.gov/ricky/nstx_fy98_forum.pdf). At a minimum, in FY99 we plan on installing two existing diagnostics on NSTX, which are presently operating on the Alcator C-Mod tokamak. However, the actual machine interface to both systems will be uniquely built to the constraints imposed by NSTX. Depending on the availability of funds, we intend to upgrade both the fast visible and infrared cameras in FY00 and FY01, to allow for much faster framing rates (up to 40,000 fps in the visible, and up to 1400 fps in the infrared). This upgrade would also provide dedicated camera systems to NSTX from LANL.

Fast visible imaging system

Desired measurements

- overall edge plasma dynamics
- visible edge phenomena: fluctuations, MHD perturbation of edge plasma, influx of impurities and fuel [both spontaneous (i.e. recycling, blooms, etc.) and deliberate (i.e. pellets, DOLLOP, puffs, fast scanning probes, etc.), IRE/disruptions (precursors and aftermath), UFOs, runaway electrons (cyclotron radiation and interaction with walls), etc.
- coaxial helicity injection gun plasma: gas breakdown and dynamics, influx of impurities and fuel, etc.

Approach

- Use a Kodak EktaPro fast visible digital video camera with substantial flexibility in the obtainable views of the torus.
- Use intensifier on camera to allow short exposures/frame rates while using narrow-band interference filters. (NOTE: INTENSIFICATION IS ESSENTIAL!)
- Use two imaging fiber bundles to couple camera to torus.

The existing LANL fast visible imaging system (Kodak EktaPro EM1012) is capable of storing 1600 frames per shot, at frame rates anywhere from 60 Hz to 6000 Hz, with a typical frame rate of 1000-2000 frames per second being found to be the most useful on TFTR. Exposure times from 1-100 microseconds (depending on the impurity light being selected, and the amount of auxiliary heating in the plasma) are used with intensifier gain settings ranging from 50-100%, depending in the case of TFTR on how dirty the viewing windows became over long time periods. We expect less problems with window darkening and access to the machine on NSTX. We propose to procure an intensified Kodak EktaPro HS4540 for full-time use at NSTX, eventually replacing the Kodak EM1012 that we will use on Day 1.

Table 1 Comparison of two visible fast camera options.

CAMERA SYSTEM	EktaPro EM1012	Ektapro HS4540
Frame Rate (full frame)	1000 Hz	4500 Hz
Max Rate (partial frames)	6000 Hz	40,500 Hz
Resolution (full frame)	239x192 pixels	256x256 pixels
Dynamic range	8 bit	8 bit
Minimum exposure	10 μsec	20 nsec
Frame storage	1638 full frames	5120 full frames
Spectral range	440-700 nm	180-850 nm
Status	LANL owned	To be purchased
NSTX availability	Partial, to full time	Full time

Infrared imaging system

Desired measurements

- Heat loads on plasma facing components including the “divertor” area, the coaxial helicity injection gun, and the RF antenna.
- Localization of hot spots, possible sources of impurities.
- Possible localization of effects of fast particle losses.

Approach

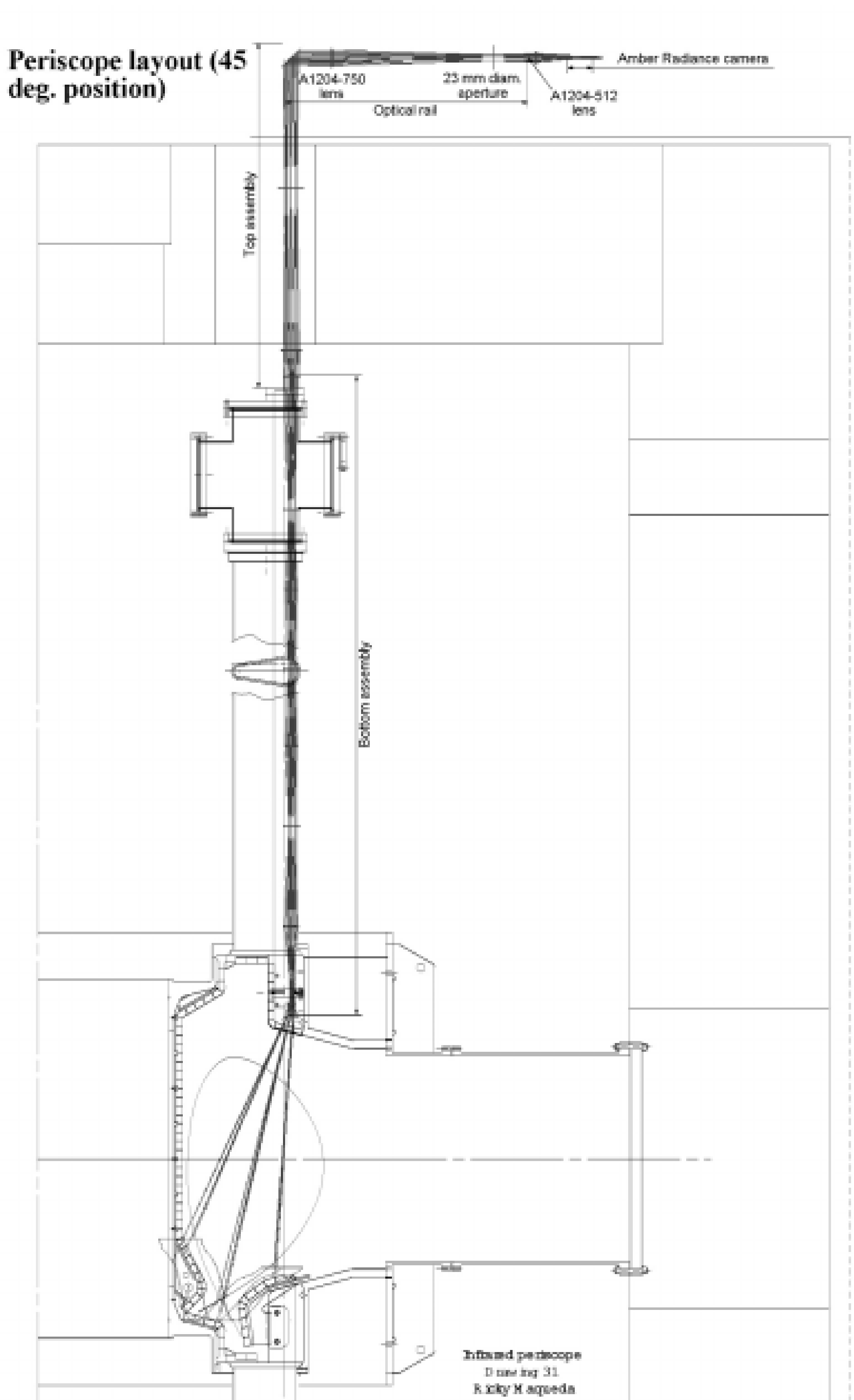
- Use an Amber Radiance video camera sensitive in the mid IR range: 3-5 μm.
- Use an IR periscope based in ZnSe optics to transport the image to the IR camera.
- Use removable steering mirrors on the machine end of the periscope to obtain different views the torus walls.

The existing LANL Radiance 1 IR video camera has: a sensitivity range of 3-5 μm, a 256 x 256 element focal plane array, uses a Stirling cooler (no liquid Nitrogen needed), is gated from <10 μs to 16 ms for exposure control, has full remote control through RS-232 link, uses a 2.23°/7.4° dual field of view Germanium/Silicon lens, has a filter wheel with narrowband or 10%, 1% , and 0.1% neutral density filters, and uses NTSC, S-Video or 12 bit digital output. We propose to procure (in the 3rd year) a more capable unit, the Radiance HS, which could be utilized full-time at NSTX.

Table 2 Comparison of IR camera options

CAMERA SYSTEM	Radiance 1	Radiance HS
Frame rate (full frame)	60 Hz	120 Hz
Max rate (partial frame)	Not available	1400 Hz
Resolution (full frame)	256x256 pixel	256x256 pixel
Dynamic range	12-bit	12-bit
Frame exposure	Progressive	Snapshot
Spectral Range	3-5 μm	3-5μm
Temperature range	-20 °C to 1200 °C	-20 °C to 1200 °C
Status	LANL Defense Programs-owned	To be purchased
NSTX availability	Part time	Full time

At Alcator C-Mod, we have developed an IR optical relay system that fits into a very narrow vertical port tubulation. Due to easier access on NSTX, we don't anticipate going to such "lengths"..... but a diagram is shown below, to indicate our capability.



The LANL-designed IR Periscope in use at C-Mod. NSTX won't have such a difficult access problem.

3.6 Literature Cited

[1] G. A. Wurden, "Pellet imaging techniques in the ASDEX tokamak", Rev. Sci. Instrum. 61, No. 11, 3604-3608 (1990). G. A. Wurden and D. O. Whiteson, "High-speed plasma imaging: A Lightning Bolt", IEEE Trans on Plasma Science, Vol 24, No. 1, 83-84 (1996). M. Karasik, L. Roquemore, G. A. Wurden, and S. J. Zweben, "Experiment and Modeling of Atmospheric Pressure Arc in Applied Oscillating Magnetic Field", BAPS, Nov. 1997.

[2] A. J. Allen, J. L. Terry, D. Garnier, J. A. Stillerman, and G. A. Wurden, "The high resolution video capture system on the Alcator C-Mod tokamak", Rev. Sci. Instrum. 68, No. 1, 947-950 (1997).

3.7 Budget and Budget Explanation

The Forms 4620.1, for each year individually, and a summary sheet, are on the following four pages. We also provide a sheet of LANL indirect rates, in the Appendix. Additional indirect taxes from Group, Program Office, and Division charges are added to the the "published rate". The table below summarizes main elements of the request.

Budget Item	FY99 (Pres. Revised)	FY00 (Pres. Revised)	FY01 (Pres. Revised)
Glen Wurden	0.25 FTE	0.25 FTE	0.25 FTE
Ricardo Maqueda	1.0 FTE	1.0 FTE	1.0 FTE
Technician	0.5 FTE	0.25 FTE	0.25 FTE
UGS (student)	1000 hrs	1000 hrs	1000 hrs
Travel (before burden)	$20k	$20k	$20k
M&S (before burden)	$15k	$15k	$15k
Capital (incl.GIRE,G&A)	$33.4k	$296.5k	$134.9k

Here I also wish to comment on some of the items being requested in the DOE proposal call.

- LANL does not release specific salary numbers in its proposals, but instead uses pay associated with certain classes of individuals or job types. This actually makes sense, because in reality, over the course of the year, various skills (and people) are drawn into the project and then "released" to other projects. Also, secretaries, safety officers, building personnel, division support, etc, are included in the overhead factors, and not broken down as such.
- Domestic travel is done as required to the off-site collaboration. We typically cover our collaborative obligations, as the experiment requires. Based on the amount of run-time in a fiscal year (often not a very precise quantity), or the estimated time to get new systems up and operating, we will make a guess as to the amount of Travel required (basically $2-3k per trip to PPPL). In addition, there are other significant expendable costs, such as lenses, fiber optics, software, and acquisition computers.
- DOE capital equipment is $25k, not the $5k threshold indicated in the call.
- Foreign travel is approved specifically by the "1512 form" process, and is not normally required to be identified ahead of time in our contract. Actually, if I didn't have to deal with the "1512's", and waiting for approvals, I'd be happy to go for a 3-year pre-approval.

Basically, we are proposing a nominal ~1.5 FTE collaboration (~$450k/year of burdened personnel costs), coupled with significant capital equipment procurement in years 2 and 3. Glen and Ricardo are well experienced with the requirements of off-site collaborations, and appropriate travel to support experimental runs. We will enable as much remote-control of all our diagnostics as possible, so that we can observe and control hardware over the Internet. By having two physicists involved, we can provide more continuity to the project, so that the entire burden doesn't rest on the shoulders of one person. The 1/2 man-year of technician support is for CAD work, machining, and some on-site tech support from LANL (as we have done in the past with our prior TFTR collaborations).

The M&S funds in each year will be used for various lenses, filters, machining of mounting hardware, rotary filter wheels, etc, and cannot be reduced. Our computer hardware and software support also come from the M&S monies.

The capital items are:

1). Kodak HS4540 Intensified high-speed digital video camera and controller, to replace the 6-year old existing system, obtaining full-time availability at NSTX, and achieving 7x higher framing rates with better spatial resolution. This includes 5100 frames of digital storage, and the intensifier. Cost: $247.8k direct, +11.3% GIRE + 14% G&A taxes, assumed in year 2. If a cheaper comparable system could be found, we would happily consider it.

2). Amber Radiance HS or equivalent, 256x256 pixel Indium Antimony Infrared Video System, which allows a high-sensitivity, self-contained cooling, gated, 120-1400 Hz, 12-bit digital IR video camera to be installed continuously at NSTX. Cost: $103k, + 11.3% GIRE + 14% G&A taxes in year 3.

3). 10-meter Quartz fiber imaging bundle (or equivalent to ones available from Mitsubishi Heavy Cable, Inc.) Cost: $25k + capital taxes in year 1. While cheaper plastic or glass bundles could be purchased, and have been used at C-Mod, they invariably degrade (even from C-Mod's low level of neutrons and gammas).

Should for any reason, sufficient total funds not be available to support the plan we have outlined, we would still need Capital Item 3 in year 1, to couple the existing fast visible Kodak system to NSTX. The fiber bundle allows us to position the camera head far enough away from the magnetic field, that adequate soft-iron shielding can be employed, and also helps give a "flexible" mounting solution. The (high cost) capital items 1 & 2 could possibly be delayed if necessary.... but not indefinitely, for the reasons we have discussed earlier.

3.8 Other Support of Investigators

It is anticipated that Dr. Wurden will be supported 0.75-time by other Los Alamos National Laboratory programs during the proposed period of this project. It is anticipated that Dr. Maqueda will be full-time on this project. Because assignments of Laboratory Staff vary from year to year, depending on programmatic priorities and funding levels, it is not possible to determine precisely in advance to which programs Staff will be assigned.

As is customary at a National Lab, ... we have only vague clues as to what the actual budgets will be for the next Fiscal Year, and in the absence of specific funding information, therefore also only estimates of fractions of each person on a specific project. With that as a given, I can however try and make some best estimates of the situation, first using FY98 as a starting point, and then extrapolating.

In FY98, the P-24 MFE Team derives approximately 75% of its support from the Office of Fusion Energy Sciences. The other 25% comes from DOE Defense Programs (i.e., the Atlas project), or funds in agreements (for example, in FY97 $104k from Japan, but $0k in FY98), or Laboratory internal R&D funds (which supports our Magnetized Target Fusion project in FY97 at $270k, and $470k in FY98). In FY98, OFES supports 85% of Glen Wurden (team leader), 100% of Ricardo Maqueda (postdoc, soon to be staff member), 10% of Blake Wood (staff member), 20% of Leo Bitteker (postdoc), 10% of Cris Barnes (staff member), 10% of Bill Reass (staff member, power engineer), 65% of David Miera (electronics technician IV), 30% of Lou Schrank (staff member, electronics), 30% of Hank Alvestad (technician VI), 60% of Matthew Fresquez (UGS student tech), 20% of Gabriel Roybal (UGS student tech), 100% of Daniel Begay (UGS student tech), 100% of Adam Montoya (UGS student tech). I do not list the MTF personnel here, because they have no OFES support in FY98.

The following listing compares FY97 and FY98 estimates for the five projects in P-24 Plasma Physics, funded by OFES. *A key point is that we are planning on terminating the Alcator C-Mod and Columbia collaborations in FY98, to make way for the NSTX collaboration in FY99 and beyond. Also, the TFTR collaboration will finally be gone in FY99.*

1). **Rotamak Power Amplifiers for TCS Collaboration (Seattle)**
PIs: Bill Reass and Glen Wurden
This project will deliver and test two 60 Megawatt phase-controlled power amplifiers to the University of Washington FRC experiment, for the purpose of sustaining the magnetic fields (currents) in the plasma. This will be the first test of a "Rotamak" concept on a high temperature FRC plasma. The project was conceived of as a three-year effort, for a total of $940k. FY97 funding was $250k, and FY98 is $350k. Initially it focuses on engineering, but in FY99 should also have a significant physics component.
Collaboration at the University of Washington, http://www.aa.washington.edu/AERP/RPPL/TCS.html

2). **Advanced International Diagnostics**
PIs: Glen Wurden, Cris Barnes, and Blake Wood
LANL has had a long-term advanced diagnostic development effort for a number of years, covering a variety of diagnostics (neutrons, fast visible cameras, IR imaging, bolometry) for both present and future machines. We also include our ITER diagnostics work into this category. In 1994 we first shipped triton burn-up 14 MeV neutron detectors to JAERI JT-60U (Naka, Japan), and have continued to further expand the capabilities of this diagnostic and related physics studies. In 1996 we began a collaboration with NIFS LHD (Toki, Japan) to develop an infrared imaging bolometer, useful on long-pulse and high-radiation plasma machines. In FY96 funding was $300k/year, in FY97 it was $110k (supplemented by an additional $104k directly from Japan), and in FY98 is projected at $220k from OFES. ITER funding for specific ITER reports has separately been $60k in FY96, $95k in FY97, and is $95k in FY98. The ITER funding is used for Phase III neutron source monitor task report, an IR bolometer Diagnostic Design Description report,

support for the JCT on DDD's, and finishing (an overdue) Phase I Intense Neutral Beam diagnostic report. Due to the ITER EDA schedule, most of this writing has to be front-loaded into the next few months. An additional $90k of ITER R&D money supports experiments on the CHAMP intense ion source (http://wsx.lanl.gov/Status/idnbchampprop.html) development effort, from Dr. Ken Young. Collaborations at: NIFS, JAERI, ITER

3). **PPPL TFTR Collaboration**
PIs: Glen Wurden and Ricky Maqueda
Experimental efforts at TFTR were concluded in FY97 (funding level $120k). In FY98, $30k was provided to finish some analysis and TFTR papers, on disruptions, lithium pellet & blowoff experiments, and fast MHD fluctuations seen by our fast digital visible camera system. Collaboration at PPPL, http://www.pppl.gov

4). **MIT Alcator C-Mod Collaboration**
PIs: Ricky Maqueda and Glen Wurden
LANL has built two diagnostic systems for the Alcator C-Mod tokamak. They are a digital fast imaging system for studying transients and fluctuations, and an infrared video system for viewing heat loads on the divertor. The level of funding was $25k in FY96 for design, $75k in FY97 for installation and initial operation, and has been projected at $83k in FY98, which is well under the $200k/year level of effort that is desired by LANL. LANL hardware installed at C-Mod has a value in excess of $300k. In light of the reduction of our TFTR collaboration, we have intended (and hoped) for a number of years to expand our C-Mod efforts. For FY99, we have consequently decided to give up this struggle, and terminate the C-Mod collaboration. Collaboration at MIT, http://www.pfc.mit.edu/cmod/cmod_home.html

5). **Columbia HBT-EP Collaboration**
PIs: Glen Wurden and Bill Reass
LANL is involved in active control of MHD instabilities with the Columbia University HBT-EP machine. We have provided two high-power wideband amplifiers to HBT for the purpose of powering external coils to modify internal MHD plasma behaviour. In late FY97, and early FY98 we are also modifying a 200kw RF oscillator/amplifier to provide heating power for high(er) beta studies. However funding levels have dropped from $200k in FY96, to $75k in FY97 and FY98. Consequently, LANL physics efforts for intelligent active controllers and data analysis in conjunction with this equipment have been largely zeroed out. Collaboration at Columbia Univ, http://www.ap.columbia.edu/plasma/plasmaintro.html

OVERALL FUNDING STATUS BY OFES in P-24 in FY97 and FY98

	Actual FY97 Funding	FY98 Funding Requested	FY98 Promised-to-date
Rotamak TCS	$250k	$340k	$350k
AdvDiag./US-Japan/ITER	$110k+ $104k + $95k	$300k	$220k +0+$185k
Alcator C-Mod	$75k	$200k	$83k
Columbia HBT-EP	$75k	$470k	$75k
TFTR	$120k	$60k	$30k
TOTAL	$829k	$1380k	$943k

- Note: The total for FY97 included $104k of direct Japanese money to DOE/LANL.

3.9 Biographical Sketches

GLEN ANTHONY WURDEN

Glen A. Wurden, presently a staff physicist and Team Leader of the MFE Section in the P-24 Plasma Physics Group at Los Alamos, was born on Sept. 9, 1955 in Anchorage, Alaska. He attended public schools in western Washington, and went to the University of Washington on a National Merit Scholarship. There he earned three simultaneous B. S. degrees, in Physics, Mathematics, and Chemistry, summa cum laude (1977), graduating with the highest class honors as President's Medallist. He was awarded a National Science Foundation Graduate Fellowship, and chose Princeton University's department of Astrophysical Sciences to specialize in Plasma Physics for his M.S. (1979) and Ph.D. (1982) Degrees. He is a member of Phi Beta Kappa, IEEE, and the American Physical Society.

He spent the summer of 1979 as a staff physicist working on x-ray and alpha particle imaging of inertial fusion targets on the Shiva laser at Lawrence Livermore Laboratory in California. Upon finishing his Ph.D. degree ("CO_2 Laser Scattering on Radio-Frequency Waves in the Advanced Concepts Torus") at Princeton, he obtained a position at Los Alamos National Laboratory in New Mexico as a J. R. Oppenheimer Postdoctoral Fellow in the CTR-8 plasma diagnostics group, and after two years, a permanent staff position in the CTR-2 reversed field pinch experimental group. In August 1988 he moved to Germany for 16-months as a DOE Exchange scientist, working in the Max Planck Institute for Plasma Physics on the ASDEX tokamak, in Garching near Munich. After his return to Los Alamos at the end of 1989, he worked on the ZTH construction project (FIR interferometer, soft x-ray arrays, pellet injection) before taking a leave of absence to the U of Washington as an Acting Associate Professor of Nuclear Engineering in August 1990. He returned to the P-1 group (High Energy Density Physics, now P-24 Plasma Physics) at LANL in April 1992, and is presently working on diagnostic collaborations at TFTR (Princeton), JT-60U (Naka, Japan), Alcator C-Mod (MIT), and HBT-EP (Columbia University). He is a member of the ATLAS Design Team, principally involved in diagnostic, target chamber, and MTF issues.

His research interests include a wide range of plasma diagnostic techniques[1], and their application to better understanding complex processes in hot fusion plasmas. He has particular research interests in far-infrared lasers, laser scattering, bolometry, fast pellet injection, fast x-ray and visible light imaging, neutron measurements, and concept improvement in fusion devices.

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[1]G. A. Wurden, B. J. Peterson, and Shigeru Sudo, "Design of an imaging bolometer system for the large helical device", Rev. Sci. Instru., 68(1), 766-769 (1997).
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RICARDO J. MAQUEDA

Ricardo J. Maqueda is a 3rd-year post-doctoral researcher at Los Alamos National Laboratory specializing in experimental plasma physics and unique diagnostics. (We expect, and hope he will become a staff member at LANL in FY99). A native of Argentina, Ricky received his Physics Licentiate from the University of Buenos Aires in 1988 doing research on a small, fast theta-pinch at the Argentine Atomic Energy Commission. He did his Ph.D. work at the University of Washington, receiving his degree in 1993 for experimental research on field-reversed configurations including the Large s Experiment at Spectra Technologies, Inc. and the Coaxial Slow Source. His thesis was on radiation-balance in the LSX plasma, including both experimental design, data-taking, and modeling. He was subsequently employed to work on the Tokamak Refueling by Accelerated Plasmoids project at the Redmond Plasma Physics Laboratory, before coming to LANL. At LANL he worked on remote collaborations at TFTR and Alcator C-Mod. where he designed (full ray-trace optical analysis, and CAD) and installed an IR-imaging system, where he is taking data during the FY98 run-period.

Selected Publications:

"Proton recoil detector of fusion neutrons using diamond natural diamond", R. J. Maqueda, C. W. Barnes, S. S. Han, P. A. Staples, and R. S. Wagner, Rev. Sci. Instrum. 68 (1997) 625.

"Wideband Silicon Bolometers on the LSX Field Reversed Configuration Experiment," R. J. Maqueda, G. A. Wurden, and E. A. Crawford, *Rev. Sci. Instrum*. **63** (1992) 4717.

"Confinement and Stability of Plasmas in a Field-Reversed Configuration," J. T. Slough, A. L. Hoffman, R. D. Milroy, E. A. Crawford, M. Cecik, R. Maqueda, G. A. Wurden, Y. Ito, and A. Shiokawa, *Phys. Rev. Letters* **69** (1992) 2212.

"Initial Results from Parallel Coil Operation of the Coaxial Slow Source Field Reversed Configuration Device," W. F. Pierce, R. J. Maqueda, R. D. Brooks, and R. Farengo, *Nucl. Fusion* **33** (1993) 117.

3.10 Description of Facilities and Resources

For the research proposal we describe here, there are many capabilities at LANL, and resources which we bring to the project. Within the group, the team has a full optics lab, an electronics shop, CAD capabilities, access to internal and external machine shops, optical design software (and people that are familiar with it), specialized optics coating facilities (if needed), and an extensive inventory of "data acquisition hardware". In addition, we have remote collaboration tools.... such as ISDN video conferencing, computers on high-speed internet lines, web servers to display archive digital data, etc.

With regards to specific high-value hardware*, to be fielded at NSTX, we have (among other things) the following instruments which will be used in this proposal:

1). Kodak Ektapro EM1012 controller and intensified digital video camera with lenses.	Value:	$140k
2). Two Windows NT PCs, framegrabbers, and LabView software for MDS+ interface.	Value:	$14k
3). Fiber-optic GPIB and RS-232 links	Value:	$8k
4). Amber Radiance 1 12-bit digital infrared video camera with two lenses.	Value:	$73k
5). 1.2 Gbit/sec digital fiber-optic link for the Amber camera	Value:	$6k
5). Remote-controlled filter wheel and remote focus long 250/75mm IR lens	Value:	$26k
	Total:	$267k

*Note: The numbers in the list are the direct acquisition costs (unburdened).

Figure 1: Side view of Amber IR video camera, 250 mm Ge/Si lens, with soft-iron shield box partly removed.

3.11 Appendices

Attachments detailing performance for the two largest procurements (new Kodak fast visible camera, and an Amber Raytheon fast IR camera) are included. Also included is a copy of LANL burden rates, our initial "Letter of Interest", and a fax copy of the "Record of Discussion".