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Calibration Facilities for NIF

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Calibration Facilities for NIF

Calibration of diagnostics on NIF will be an essential activity that is still only in the planning process. This document starts to list some of the calibration facilities needed and the steps necessary for calibration of the various diagnostics. Numerous people have contributed to this document. These contributors include physicists and technicians who have been closely associated with experiments that have been carried out on the various DOE experimental facilities. These include A. Abare, D.R. Bach, C.A. Back, P.M. Bell, D.K. Bradley, S. Compton, R. Costa, D. Desenne, D.A. Farley, S. G. Glendinning, B. A. Hammel, D. A. Hargrove, S.I. Iversen, D.H. Kalantar, J.D. Kilkenny, J.A. Koch, O. L. Landen, F.D. Lee, L.M. Logory, J. Oertel, T. Orzechowski, R. Pasha, T.S. Perry, K. Reinhardt, J.J. Satoriano, R.E. Turner, J.D, Wiedwald,and others.

The first three sections describe the essential reasons for the importance of calibration facilities. This discussion is reinforced and expanded in the Appendices which follow.

I. Calibration Philosophy

The main reason for requiring convenient and accurate calibration of NIF experiment diagnostics is due to the high cost of individual shots on NIF.

In the past, it was always possible to accept errors in calibrations (and calculations) because the design of a nuclear device was always subjected to experimental verification at NTS before manufacture. However, in experiments to be carried out on NIF related to stockpile stewardship, which are to be used for validating concepts used in nuclear weapon design, much more confidence in the results will be required.

In many of these experiments, there will be no place for normalization. This requires the absolute calibration of instruments. Due to the high shot cost, there will not be the opportunity for test shots, as we have been accustomed to in the past.

It is worthwhile to consider the example of nuclear reactor development that has been carried out for naval propulsion. Almost half a century after the first light water nuclear submarine was commissioned, an essential part of the continued development is the system of testing by the use of critical assembly experiments. We are being asked to validate, without experiment, nuclear devices that require much more complicated calculations (and experiments) than those needed for fission reactors. This will require a degree of accuracy in calculation and experiment that has never before been necessary.

Although the requirements for ICF experiments are somewhat different, the concentration on pre-shot calibration will greatly assist the rate of arriving at reliable comparisons of calculations with experiment.

II. Calibration Philosophy

The necessary calibrations which will be required for NIF experiments fall into several general areas. These areas include x-rays, neutrons, gammas, heavy particle, and visible and infrared light. One needs to be prepared for other unforseen diagnostics as well.

The calibrations will be carried out using a mix of dedicated facilities both within and outside the laboratories. There will also be occasional use of other facilities which will be used for specialized purposes.

In the discussion which follows, we will use examples of calibrations that have been important for previous experiments to give a feeling for the kind of testing which will be required for NIF experiments. The examples chosen were chosen by convenience and were not meant to reflect on the importance of those chosen over those which were not mentioned.

A word should be said regarding preparation for experiments. Usually, a diagnostic is conceptualized, designed, built, and then tested exhaustively before placing on an experiment. This involves redesign and adjusting until the device fulfills the experiment's requirement. Convenient access to calibration facilities at each of the laboratories is important and necessary for this iterative process, especially when innovative instruments are being designed and built.

III. Conclusion

The calibration facilities will be dynamic and will change to meet the needs of experiments. Small sources, such as the Manson Source should be available to everyone at any time. Carrying out experiments at Omega is providing ample opportunity for practice in pre-shot preparation. Hopefully, the needs that are demonstrated in these experiments will assure the development of (or keep in service) facilities at each of the laboratories that will be essential for in-house preparation for experiments at NIF.

Appendix A. Individual Calibration Procedures

1. X-Ray Calibrations

a. Dante Calibrations

The Dante [or DMX (CEA)] system, which has been used for hohlraum radiation temperature measurements on Nova and Omega, will be essential for performing the same task on NIF. Reliable calibration will be a necessary part of this activity, as absolute measurements of the time dependent radiation flux will be required to evaluate the ignition experiments. Due to the high cost of individual shots on NIF, it will be necessary to have the reliability of all shot diagnostics approach the degree of validation that was required for down-hole nuclear test experiments.

The central components of the Dante/DMX system are the system of x-ray diodes, the accompanying filters to select the photon energy bands measured, and mirrors to eliminate undesired flux from higher energies from some channels.

The diodes and mirrors require synchrotron calibration. The most recent diode calibrations were carried out using the synchrotron at CEA, in France. The Brookhaven synchrotron had been used in the past.

Filter transmissions require the use of a low energy x-ray source like the Henke with a secondary fluorescer which provides transmissions as a function of photon energy. The filter transmissions are measured at certain energies and fit to the calculated transmission as a function of energy.

Due to the importance of absolute values of radiation flux, checking of the entire Dante system against a similar system is highly desirable. Such a comparison has already been carried out at Omega. Measurements made by the LLNL Dante system have been compared to measurements made by the French DMX system, which employs diodes of a different geometry. Those differences are being evaluated and will provide an extremely worthwhile validation of the overall radiation flux measurements. It will be important to continue this type of cross-checking as NIF experiment are being carried out.

Dante (DMX) will also need extensive use of the NIF Electrical Calibration System as the measurements consist of time-dependent signals.

b. X-Ray Spectrometer Calibrations

X-ray spectrometers will be used on NIF for plasma temperature measurements, opacity, and radiation flow. Whereas the experience with Nova and previous laser systems allowed for validation and calibration using test shots with simple targets on the laser, NIF experiments will require checking and validation using facilities other than NIF due to the cost of individual shots.

In addition, many of the spectrometers employed on Nova used photographic film as the recording medium. The NIF experiments will employ digital recording which has the advantage of immediate data retrieval at the expense of reliability. This will require adequate supporting calibration and testing facilities.

Geometrical testing of the spectrometer to determine whether the overall instrument alignment and energy coverage is as desired for the experiment requires a simple but essential system using an alignment laser. Additional measurements of crystal reflectivity, uniformity, energy coverage, and rocking curves, require the use of Manson and or Henke x-ray sources.

When the complications of time dependent spectroscopy are coupled to the spectrometer, additional facilities are required. These calibration requirements include electrical testing to determine the time response of the detectors which will be done using transient digitizers, and fast oscilloscopes. The efficiency and uniformity of multi-channel-plates and other components of the streak and gated cameras require the use of x ray sources of the appropriate energy.

c. X-ray Imager and Streak Camera Calibrations

In considering the calibration requirements for NIF x-ray diagnostics it is worthwhile to reflect on the history of the development of electronic x ray diagnostics used on Nova. In the paragraphs below, we will describe examples of some of the calibrations and tests that were carried out during the Nova years. Traditional film was the recording method of choice when Nova experiments began. Snapshots were made by using the short pulses of lasers on backlighters, for example. Electronic recording provides flexibility but to approach the reliability of film recording it is necessary to carry out exhaustive testing and calibration. In view of the reduced shot rate at NIF and cost of each shot, this will become even more important. A further difficulty is that many Nova shots were dedicated to diagnostic development and calibration. This will not be possible at NIF and will require the use of other facilities, such as Omega.

A basic test required of all electronic diagnostics was timing calibration and verification. At Nova, these were done using 0.5 ns square pulses. Many of these tests were ride-along tests, but some were dedicated shots for the diagnostics.

Again, Nova shots were required to carry out flat fielding tests of cameras such as the SXFRC, WAX and GXI. Flat-fielding was shown to be important in improving the signal to noise ratio as well as providing the calibration of the position dependent sensitivity of components of the diagnostic.

A DC x-ray source was used to measure the signal versus voltage characteristics of microchannel plate devices. This was done for serpentine and flat plates having various micropore length to diameter ratios. This source was also used for a series of measurements on the relative sensitivity of framing camera phosphors.

The short pulse laser facility was used to measure gain saturation (due to high electron density in the micropore) and gain depletion on longer strips (due to voltage reduction along the channel plate due to high current production over an area of the plate). Measurements of gate profiles for MCP based x-ray framing cameras were done here using electronic pulsers and the short pulse laser. Using this facility, stripline synchronization and jitter measurements were made.

The pulsed characteristics of gated, microstrip, microchannel plates were measured using 20 and 500 ps x-ray irradiation and 3 to 60 ps 202 and 213 nm spatially smoothed laser irradiation.

By employing a Manson x-ray source, spatial resolution tests of a variety of phosphor screens were measured at 1.5, 3, 4.5, and 7.5 keV.

Measurements of the relative sensitivities of gated imagers (FFC2, WAX, GXI2, and GXI for UV and x-ray irradiation in DC and pulsed mode were made.

X-ray backlighting has been used over the years more and more for many laser-plasma experiments including, hydrodynamic, radiation drive, instability, shock, implosion, and many others. Studies have shown that it is apparent that the same backlighting systems which have been used at Nova will not be efficient at NIF. New backlighting studies are in progress and include the backlit-pinhole point projection technique, pinhole and slit arrays, distributed polychromatic sources, and picket-fence backlighters.

It is imperative that these studies, which include shots at Omega, be continued in order to assure that the initial experiments done at NIF will be diagnosed properly.

Studies of the signal/noise ratio from film to CCD devices show that the CCD devices come out ahead by an order of magnitude if proper flat fielding is done. This puts all the more emphasis on the importance of calibration and testing of these electronic detection devices, because it may be that film may not be the reliable fall back alternative we once thought it had.

We follow with a list of calibrations and tasks which will be necessary for each component of the imaging camera system:

Photocathode quantum efficiency as a function of x-ray wavelength

Distribution in angle and energy of emitted photoelectrons

Sensitivity, light output per photoelectron, saturation

Spatial resolution: modulation transfer function, point spread function, resolution as a function of intensity, blooming, recovery from saturation, static and dynamic resolution, resolution as a function of cathode voltage

Static and dynamic range

High frequency noise on sweep circuits

Temporal resolution,

Noise sources, background levels

Barrel and pincushion distortion

Flat field response including repeatability

Power supply noise and regulation

Susceptibility to magnetics fields, particularly the earth's magnetic field

Degree of ion feedback as a function of vacuum and applied voltage

Susceptibility to EMP

Extinction ratio

Retrace times and holdoff voltages

Develop and document safe operation and maintenance procedures (high voltage, toxic materials, x-ray production)

Jitter times, trigger levels, effect of overvoltage on trigger times

Calibration stability

Mechanical stability

Reliability

2. Neutron Detector Calibrations

Measurement of the neutrons emitted from ICF targets provides an essential part of the understanding of the physics of the experiment. Experiments done at Nova and Omega have provided a solid background in neutron detection and analysis. The neutron time-of-flight distribution is used to determine the neutron yield, the ion temperature, and neutron emission time of ICF targets.

Geometrical verification of the shape of the neutron emission volume can be carried out by neutron pinhole camera imaging. Time integrated neutron yield can be done using radioisotope activation techniques.

Calibration facilities for the single particle neutron counting systems are readily available (a few hundred kilovolt D-D and D-T source at LLNL, the rotating target source at Berkeley, radioactive sources such as C252 and many others). Counting systems for radioisotope counting are also available at LLNL.Calibration of detectors used in the current mode (scintillator plus photomultiplier or CCD) in which the signal involves the addition of pulses may require testing with a more intense neutron source, as will the neutron pin-hole cameras. These calibration and validation tests may have to be done at Omega, unless other accelerator based sources (i.e., spallation, LINAC photo-neutron etc.) could be utilized.

The neutron experimental facilities will also make use of the electrical timing systems.

Appendix B - Basic Calibration Infrastructure

1. Description of Laboratory Sources

a. DC Line Sources

Each NWT Laboratory has at least several dc x-ray sources, most commonly Manson and Henke types. As rough rules of thumb for both types, the optimum x-ray output is achieved if the applied accelerating voltage from the power supply is approximately twice the energy of the characteristic anode x-rays, and the x-ray output scales with the power supply current.

b. Manson X-Ray Source

At the lower end of complexity is a micro-focus source manufactured by J. E. Manson Co.Electrons produced from a hot filament impinge on an anode, creating an x-ray continuum at energies up to the accelerating voltage with characteristic anode lines superimposed. Mansons typically come in two varieties: a single-anode inside the source chamber, with the option to break vacuum to exchange anode materials, or multi-anode, in which a number of anode materials are selectable without opening the chamber. Particular x-ray line energies are selected by choice of anode material, and the characteristic x-ray spectrum can be sharpened with the use of x ray filters. Advantages of the Manson source are its simplicity, compact size (roughly table-top), lack of cooling requirements, and small spot size; disadvantages are the limitations in available x-ray energies (discrete lines up to typically 10 keV), spectral purity issues associated with line emission from contaminants on the anode and the continuum produced by bremsstrahlung x-rays from the direct electron bombardment, and the relatively low x-ray output intensity.

c. Henke X-Ray Source

This source is named for the inventor of a unique non-line-of-sight filament/anode geometry that prevents evaporated material from contaminating the anode, and that employs grids biased at the anode potential to reduce space charge buildup around the filament. These two innovations permit the Henke source to be operated at high current (up to 1 A), also creating the added requirement for water cooling of the x-ray head. The anode x-ray spectrum may be used directly, with or without filtering, but it is more common to employ the Henke anode spectrum to excite secondary x-ray fluorescer foils. Moderate additional filtering of the fluorescer output yields a spectrum well concentrated in the characteristic fluorescer line. The major advantage of the Henke over the Manson is the purity of the x-ray spectrum, although, like the Manson, it is limited to discrete x-ray energies provided by the available fluorescers (also typically up to 10 keV). A disadvantage is the added complexity due to the large power supply and the cooling system.

d. Pulsed. High-Power Laser Sources

Among the NWT Laboratories there are also several pulsed x-ray sources based on a highly-focused, high-power laser beam directed onto a target, producing a hot plasma. The x-rays originate as bremsstrahlung radiation from the deflection of the plasma electrons in the intense plasma electric field. A high-power laser operated in "focus mode" produces a continuum of x-ray energies up to the bremsstrahlung end-point, superimposed with characteristic x-rays produced from the target at allowed energies up to the end-point. Depending on laser power, the photon spectrum can extend into the MeV range, with high intensities of x-rays in the region of a few keV to 10 keV or so. The characteristic target x-rays can be selectively filtered to purify the spectrum, although laser facilities commonly utilize a crystal or grating monochromator to provide continuous energy selection. In "defocus mode" the plasma x-ray spectrum resembles that from a black body at temperatures up to several hundred eV.

In principle, a well-maintained and characterized laser plasma source can be used to perform all required x-ray characterization and calibration experiments. A noteworthy advantage of a short-pulse, high-power laser source is the range of prompt x-ray intensities achievable compared to nearly any other available source, making it the source of choice for detector linearity and time response measurements. It also produces very high-energy photons (> 1 MeV), such as encountered in experiments at Z or NIF, making it useful for detector background response measurements.In practice, however, a high-power laser is very expensive to build and operate, can be temperamental, and the pulse repetition rate of once every few minutes or longer makes large-volume data-taking for detailed spectral scans of detector response and/or large numbers of detectors difficult.

e. Synchrotron Radiation Sources

The key distinguising features of x-rays from synchrotron sources compared to those from conventional x-ray sources are:

1. Continuously tunable over a broad energy range;
2. High intensity;
3. Broadband spectrum ("white light") available and well characterized;
4. CW or pulsed time structure.

The first two, in particular, are essential features for many characterization and calibration experiments. These features may be available at some laser x-ray sources, but the ease and rapidity of measurements at a synchrotron make it the preferred source. At present, a principal disadvantage of the synchrotron beamlines at BNL (or any source utilizing a monochromator to achieve spectral purity) is spatial non uniformity within the x-ray spot, making such a source difficult to use for calibrating larger detectors such as photoconductive detectors (PCDs) with active areas of 1 mm or greater. However, the beam uniformity can be improved by using a beam diffuser and/or fast-rastering techniques. (Note also that the high brightness of the synchrotron source allows the user to employ a collimator and use the collimated beam to study spatial response uniformity for large detectors).

f. Neutron Sources

The simplest fast neutron source is the isotope Californium^{252} which has half-life of 2.64 years and produces a spectrum of neutrons averaging at about 2.1 Mev. One mg of C^{252} produces up to 2.3×10^9 neutrons per second. These sealed sources are available from ORNL in up to 50 mg sizes.

A second source of fast neutrons is a sealed tube containing a small accelerator, which is nothing more than a high voltage discharge tube with a deuterium loaded metallic source and tritium loaded target. These make use of the $T(d,n)^4He$ reaction which produces 14.1 Mev neutrons. A commercial source of these tubes was the Kaman Corporation, which is now known as MF Physics.

For example, their Model A-801 produces 10^8 neutrons in a 3-5-microsecond pulse. The maximum pulse rate is 10/sec and the maximum neutron output is 5×10^8 neutrons per second. The intensity during the pulse is $> 2 \times 10^{13}$ neutrons per second. This source is commonly used for detector calibration, liquid flow measurements, in-situ assay of uranium ores using the delayed fission neutron technique, and the analysis of short lived isotopes.

In order to increase the neutron output for these D on T sources, which was mainly limited due to the rapid evaporation of tritium from the titanium tritide target as it was heated by the deuterium beam, the rotating target arrangement was invented and an example of such a source was RTNS-1 and RTNS-2 at LLNL. The output was up to 3.7×10^{13} neutrons/sec.

A novel concept for an even more intense fast neutron source was to use the same nuclear reaction but to make the target a magnetically confined plasma, thus obviating the heating problems inherent in the TiT2 target system. The design of a neutron source based on this concept was reported by Coensgen by the device apparently was never constructed. The output from this source was expected to be up to 3.7 x 10^{17} neutrons/sec.

More recently, considerable effort has gone into spallation sources, in which high energy particles, e.g., fast protons (~ few hundred Mev) impinge on a high z target and the nucleus is shattered with the release of fast neutrons. The spectrum produced is known as an evaporation spectrum and the yield per fast proton approaches one neutron per proton in the region of neutron energy from one to ten Mev. Among these sources (there may be more) are: Intense Pulsed Neutron Source (IPNS) at ANL, KFK Neutron Source (KENS) at KFK (Japan), ISIS at Rutherford-Appleton Laboratory (UK) and Los Alamos Neutron Science Center source (LANSCE) AT LANL IPNS, KENS, and ISIS are synchrotron driven and LANSCE uses a linear accelerator. The spallation sources supposedly produce up to 10^{15} neutrons/pulse in a 2.5 nanosecond pulse produced in what they call their microstructure pulse.

The record intensity to this date is probably the output quoted from Omega, at Rochester, which was measured from a gas filled microballoon. This was 10^{13} neutrons in a one ns laser pulse (probably a 100 psec) neutron pulse which would make the peak intensity $10^{13}/10^{-10} = 10^{23}$ neutrons/second.

In conclusion, there are many different types of neutron detector calibration sources available for use for the NIF experiments. Which would be the most convenient and cost effective remains to be decided.

2. Facilities Dedicated to NIF Support

a. Bechtel Nevada Livermore Operations Laboratory - optical, x-ray, and electrical calibrations

b. Brookhaven National Laboratory Synchrotron - absolute x-ray calibrations

c. D-D and D-T pulsed neutron source at LLNL

d. Scheduled portions of Omega at Rochester,Trident at Los Alamos, Z machine at Sandia which can be used for x-ray, gamma, and neutron diagnostic calibrations.

e. Bechtel Special (?) Technology Laboratory (Santa Barbara) - Febetron 2 Mev Electron source

Other Facilities Which Can Be Used

a. Linear Accelerator at University of Idaho - electrons, gammas

b. LANSCE at Los Alamos- neutrons

3. Instruments To Be Calibrated

Dante-Multichannel Diode Array
DMIX-DIM-based Dante
Static X-Ray Spectrometer
SSC/Kr-Streaked Spectrometer
Henway-High Energy Crystal Spectrometer
SXI-Static X-Ray pinhole Imager

TRXI(GXI)-Gated Pinhole Imager
QCI-Gated Crystal Imager
TSPEC- 1D Crystal Imager
TRXI-Gated Pinhole Imager
SXRI-Soft X-ray Imager
Static X-Ray Spectrometer
SSC/SMP-1D Streaked Imager
SSC/SMP-2D Streaked Imager
SSC/KBS-Streaked 1D Soft X-ray Imager
SSC/KBH-Streaked 1D Hard X-ray Imager
SSC/Kr-Streaked Spectrometer
ASBO-Active Shock Break-out
SOP-Streaked Optical Pyrometer
nTOF-Neutron Time of Flight
NS-Neutron Spectroscopy
YN-Neutron Yield
FABS-Full Aperture Backscatter Station
NBI-Near Backscatter Imager
Side Scatter Diodes
TBD-Forward Scatter Plate and Diode
Large Angle Detectors and Diodes
PCD-Photoconductive X-ray Detector
PS-Tertiary Proton and Charged Particle Spectrometer
FFLEX-Filter Fluorescer Detector
SXPD-Transmission Grating Power Diagnostic
RHS-Reaction History System

Appendix C - Examples of Diagnostic Characterization

1. Characterization of Streak Cameras

Introduction

Streak cameras are inherently quite difficult to characterize due to their susceptibility to external and self generated EMP noise. The camera may couple to an exterior source of noise or couple to itself. By performing very detailed electrical calibration of the individual components the response of the assembled streak camera can be more closely approximated.

After the camera is assembled, the electron beam is propagated through the tube in the unswept or D.C. mode. Static focusing and dynamic range can then be determined.

Once characterized and understood in the static mode of operation the camera is then run in the dynamic or swept mode. The following dynamic measurements are of highest priority: spatial and temporal resolution, dynamic range, sweep speed and linearity.

When the above requirements are satisfied the camera must then be 'field hardened'. One must determine the cameras' response when used under experimental conditions. Conditions adversely affecting camera performance include; EMP noise and insufficient vacuum.

Electrical Characterization

Electrical characterization of streak cameras includes insuring that the D.C. high voltages that focus and accelerate the electron beam are stable. It is also necessary to verify that the input ramp signals are as linear as possible and that the electron beam is held off the edge of the phosphor the required amount of time after sweeping across. This requires very high impedance probes and an oscilloscope of a minimum one
Ghz bandwidth.

D.C. Characterization

D. C. tests are performed on a low level D.C. x-ray source. The incident x rays generate electrons at the photocathode which are then extracted, accelerated and focused on to the output phosphor. The D.C. tests determine photocathode sensitivity, or its quantum-efficiency, static focusing and the range of x-ray intensities over which the camera is linear. The experimenter can also determine static spatial resolution. The latter two tests are helpful when determining dynamic range and dynamic spatial resolution.

Dynamic Tests

Dynamic tests are performed on a short pulse laser that is frequency quadrupled (200 nm). This short pulse is sent through an etalon to produce a series of pulses spaced equally in time and decreasing exponentially in amplitude. The pulse train is then directed onto the streak camera photocathode. A CCD camera captures the streak camera output.Dynamic tests allow us to measure spatial and temporal resolution, sweep linearity and the intensity range over which the camera's output is linear. Direct correlation of the D.C. tests with the dynamic tests provides confidence that the instrument is working properly.

Field Hardness

When well understood and characterized in a laboratory the camera must be run in the environment where it is to be used. Typically, the high energy laser experiments generate a great deal of EMP/EMI noise. The streak camera's electron beam must be adequately shielded from this radiation to avoid being deflected in an unpredictable manner. This requires that the camera be exercised on as many different experiments and run in varied configurations.

Table I lists the basic streak camera characterizations and the equipment needed to performed these tests.

TABLE I Streak Camera Characterization

Electrical Measurements	Equipment Needed
Photocathode & Grid Voltage	High bandwidth cable / High bandwidth attenuators
	High bandwidth / high voltage attenuators
	1GHz bandwidth oscilloscope w/ probes
	Sampling Scope w/ TDR ability
Focusing ring voltage	
Deflection Plate Capacitance	

Ramp voltage, ramp voltage hold off
TDR of Ramp path

Static Characterization	
Photo-cathode sensitivity	D.C. x-ray source CCD Camera
Focusing & Spatial Resolution	
Input vs. Output linear range	
Dynamic Characterization	
Spatial & Temporal resolution	Short pulse laser lab CCD camera
Sweep Linearity	
Instrument dynamic range	

Field Tests

Test of in-situ camera operation & camera shielding	Large experimental laser facility

2. Characterization of Gated Imagers

Introduction

There are a number of characterization tests one needs to perform on a gated imager to validate its operation. The gated imager basically consists of a large pulser, a pulse delivery system and the detector. To adequately characterize the imager these three sub-systems must be checked separately.

Electrical checks are performed on the pulser and the pulse delivery system to insure proper timing, pulse amplitude and continuity of the pulse path to the detector. Optical checks are then performed on the micro-channel plate (MCP) / phosphor combination to guarantee the gain and uniformity of the output. The above tasks are the minimum checks one would perform on a gated imager.

Other, specialized, measurements one could perform include the photon MCP interaction, spectral and angular sensitivity, the noise and spatial resolution of the MCP / phosphor combination as well as the maximum linear output of the MCP, gain saturation, and the resistive losses of the MCP conductive strip, flat field measure.

Electrical Characterization

The electrical checks are most conveniently performed with 3 different types of oscilloscopes as well as high bandwidth cable and attenuators. The pulsers on the gated imagers typically output 6 Kv with in 100 ps Pulses of this magnitude and speed require high bandwidth measurement capabilities. Since we can repetitively trigger the imagers, up to 50 Hz at air, our most reliable measure of the pulse amplitude and rise time is recorded on a sampling scope. The error associated with this measurement is dependent on the relative trigger jitter between the scope and gated imager. Triggering both instruments from the same fast rise time source minimizes this error.

Another standard electrical measurement performed is a Time Domain Reflectometry, TDR. This quantifies the impedance differences from the pulser to the detector. The frequency content of the output pulse is so wide that any small discontinuities in impedance along the transmission path is cause for a large voltage reflection. The impedance differences are minimized in order to introduce the maximum voltage across the MCP.

Trigger timing of the instrument is also an important parameter to be determined. This is a relative time measurement with respect to other gated imagers. A fast trigger pulse is split so that one leg triggers the imager with the other leg being recorded on a scope. The output pulse of the imager is recorded on the same scope. When this same measurement is performed on a number of imagers one can obtain relative trigger differences between the imagers.

Optical Characterization

We define optical characterization to be checks of the MCP and phosphor.Static tests are performed on a D.C. X-ray source.The output X ray flux from these sources is so low that the imagers must be operated in the ungated, or static, mode. These tests confirm operation of the MCP and Phosphor bias voltages. One is also able to determine any spatial non uniformities across to MCP / Phosphor combination. Other specialized tests would include the gain at varying input energies, bias voltages and MCP angles with respect to incident photons.

Dynamic tests of the gated imagers are performed with a short pulse (<5ps) of U.V. radiation (<220 nm). The incoming laser pulse and gate pulse of the imager are synchronized in time to essentially freeze an image of the gate pulse on a MCP strip. A wealth of information is obtained from these dynamic tests.One can determine; gate pulse synchronization and relative timing jitter between gate pulses, gate pulse width and profiles and gain and saturation of the MCP.

Using a longer pulse laser (>500ps) one can determine the resistive losses of the MCP strip line. The amplitude of the gate pulse will decrease as it propagates across the strip line.This is due to losses within the strip line and can be measured by the decreased gain at opposing ends of the strip line.

Table I summarizes the characterization tests and tools needed to perform these tests.

Table I - Gated Imager Characterization

Electrical Measurements	Equipment Needed
Pulse Output; Timing, amplitude shape	High bandwidth cable and / High bandwidthattenuators High bandwidth / high voltage attenuators Fast Pulser (> 10v<500ps rise) Medium bandwidth oscilloscope High bandwidth oscilloscope(5GHz) Sampling oscilloscope w/ TDR
Trigger in to pulse out; timing	
Time Domain Reflectometry; of MCP	
X-Ray Characterization (static)	
Instrument gain Instrument spatial resolution Spatial non-uniformities Spectral Sensitivity (Q.E.) Angular Sensitivity	Manson D.C. X-ray Source (1-9 KeV)
X-Ray Characterization (dynamic)	
Flat Field (ohmic losses of strip line)	Long Pulse Laser Lab
Optical Characterization	
Gain and Saturation Timing and Jitter	Short Pulse Laser Lab

Gate pulse rise and profile

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Coordination Between the HEU Transparency Program and the Material Protection, Control and Accountability Program

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