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Performance Improvements of PCDs for measuring x-ray bang time

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ABSTRACT

The National Ignition Facility South Pole Bang Time diagnostic uses polycrystalline diamond photoconductive detectors to measure x-ray bang time on capsule implosion shots. The original Laboratory for Laser Energetics PCD design was redesigned to eliminate ringing near the peak of the impulse response, and provide 30 picosecond resolution. The detector design, performance and x-ray laser impulse response tests used to characterize the detector are presented.

Keywords:, PCD, polycrystalline diamond photoconductor, x-ray bang time

1. INTRODUCTION

The National Ignition Facility uses the South Pole Bang Time (SPBT) diagnostic to measure the time of peak x-ray emission from inertial confinement fusion capsules, "x-ray bang time" [1]. The SPBT detector head is located on the hohlraum axis 3 meters below target chamber center as shown in figure 1. The detector head shown in figure 2 is made of Hevimet [2] to shield the PCDs from background x-rays and electromagnetic interference (EMI). Additional EMI protection is achieved by using semi-rigid coax inside the aluminum support arm. Inside the head are five chemical vapor deposited polycrystalline diamond photoconductive x-ray detectors (PCD) with gold coated electrodes on the front and back for applying a DC bias voltage. X-rays reaches four of the PCDs via a hole in the top of the detector head and highly ordered pyrolytic graphite x-ray monchromator that limits the energy range of the x-rays on each PCD. The monchromator improves the contrast against laser plasma interactions hard x-rays from the hohlraum and to better define comparisons with simulations. A 3mm Kapton [3] blast shield over the entrance aperture protects the crystal from debris and a 20 um Aluminum liner provides electrical continuity to suppress electromagnetic interference caused by the implosion. The center PCD has no monochromator and is used for impulse timing and neutron measurements.

The signal from each PCD is recorded using a fast transient digitizer located ~200ft from the chamber in the diagnostic mezzanine. Bang time on a capsule shot is determined by deconvolving the temporal instrument response function (tIRF) from the record and subtracting the time of a deconvolved impulse shot at t=0 [1, 4]. Signal reflections associated with the PCD holder were reduced by eliminating the discrete connector at the at PCD/cable interface. In this paper we compare the response function obtained for both the "connectorized" and "connectorless" designs.

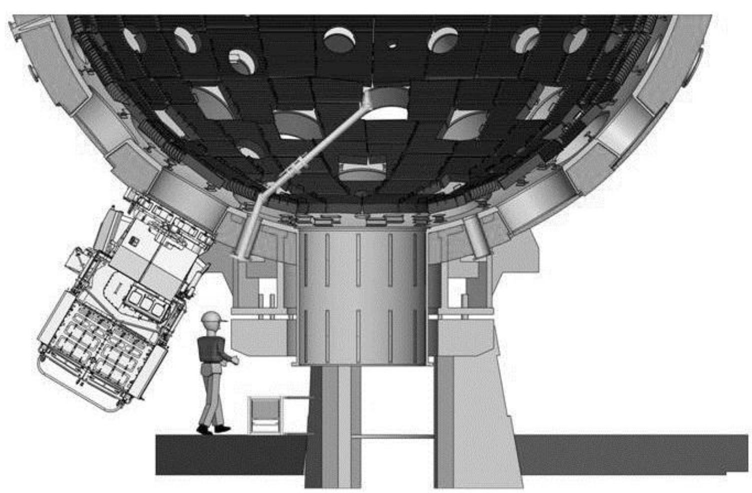

Figure 1.Cut away view showing SPBT in the target chamber

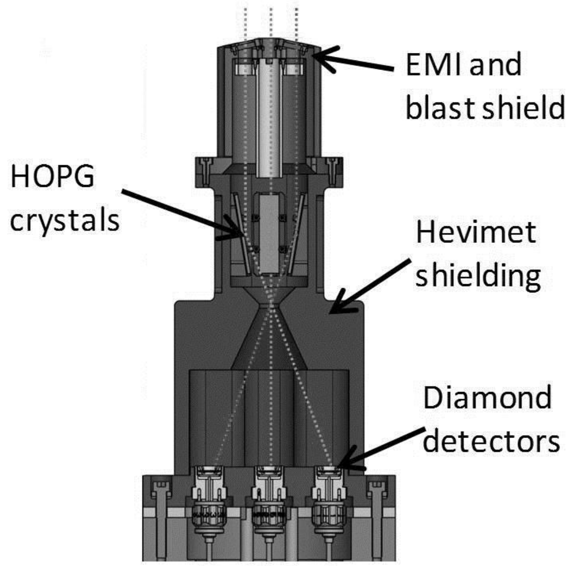

Figure 2. SPBT detector head details

2. METHODOLOGY

The temporal instrument response function for the combined PCD and cable system is measured using an x-ray pulse sufficiently short compared to the instrument rise time that it can be considered a delta function. The system rise time with cables is of the order ~100ps and a short x-ray pulse is produced using the Comet laser at LLNL's Jupiter Laser Facility. Comet delivers a sub picosecond ~10^{18}W/cm^2 laser spot sufficient to excite Cu K-alpha radiation that when filtered with 50um copper can saturate the PCD. The x-ray pulse length measured with a Kentech x-ray streak camera is ≤10ps. For quantitative sensitivity measurements the crystal reflectivity and absolute PCD sensitivity were measured on beamline 5.0.2 at The Advanced Light Source synchrotron at Lawrence Berkeley National Laboratory.

In tIRF testing to determine the best design for the PCD assembly a cable setup identical to the actual NIF installation at the target chamber but does not include the longer infrastructure cables to the mezzanine. The PCD is connected to a 62 inches semi-rigid 402 cable used in the upper support arm. Next, representing the lower arm, is a feedthrough and 76 inches of semi-rigid 402 cable to the target chamber vacuum feedthrough. An 82 inch long LMR 400 cable [5] goes to a Picosecond Pulse Labs Model 5531 Bias Tee [6]. The bias tee limits the signal 3dB bandwidth to between 750 kHz and 10 GHz. The signal then goes though a 72 inch MegaPhase TM18 cable [7] to the input of a Greenfield Technology FDT10000 transient digitizer [8]. The signal path is terminated in 50 ohms after an additional 72 inches of MegaPhase TM18 cable on the output of the digitizer. The additional cable length prevents reflections affecting the signal. In addition there is an RG58 cable to the Stanford Research Systems Model PS350 high voltage power supply [9] which sets the PCD bias voltage at -1500VDC.

The Greenfield Technology digitizer is a scan conversion type, recording the fast image on a cathode ray tube and reading out with a CCD. The digitizer has a 7GHz bandwidth (-4dB) and a signal input damage limit of 2000 V. The high damage input limit permits direct recording of the PCD signal without risk of damaging the digitizer.

Four PCD detector assemblies were developed and tested. The objective in all designs is to reduce signal reflections by maintaining the 50 ohm characteristic impedance up to the PCD. The first two are shown in figure 3. The first design is a Laboratory for Laser Energetics design to measure neutron bang time [10, 11]. The second design, which is the standard design now fielded on SPBT, is a modified version of the first design as shown in figure 3. The third design is the standard design modified to hold a 5mm diameter PCD instead of the normal 12mm diameter PCD. The "connectorless" design prototype shown in figure 4 integrates the cable and the PCD. The cable is a Micro-Coax FB293C-0-1500-50U55 VTAC [12] which has precision N plug on end and a Precision N straight 4 hole flange jack on the other. The flange jack is removed and only the end of the cable with center conductor, the surrounding insulator, and the threaded mount is left. The PCD assembly directly connects the back of the diamond to the center conductor. The electrical contact on the front side is spring loaded. The spring loading combined with a limit thread on the front housing reduces the possibility of breaking the PCD due to over tightening. The standard design reduced the number of abrupt changes in the ratio of the conductor diameter to ground. The “connectorless” design only has one change at the PCD.

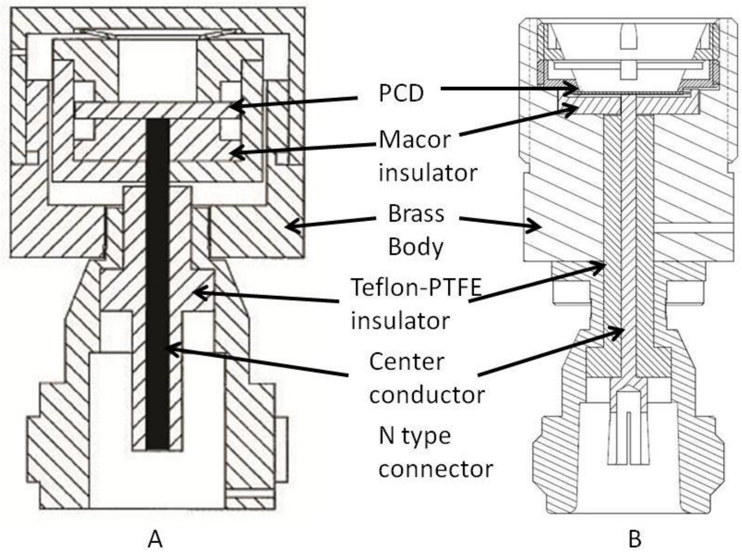

Figure 3. SPBT PCD detector details. A is the original design and B is the improved design

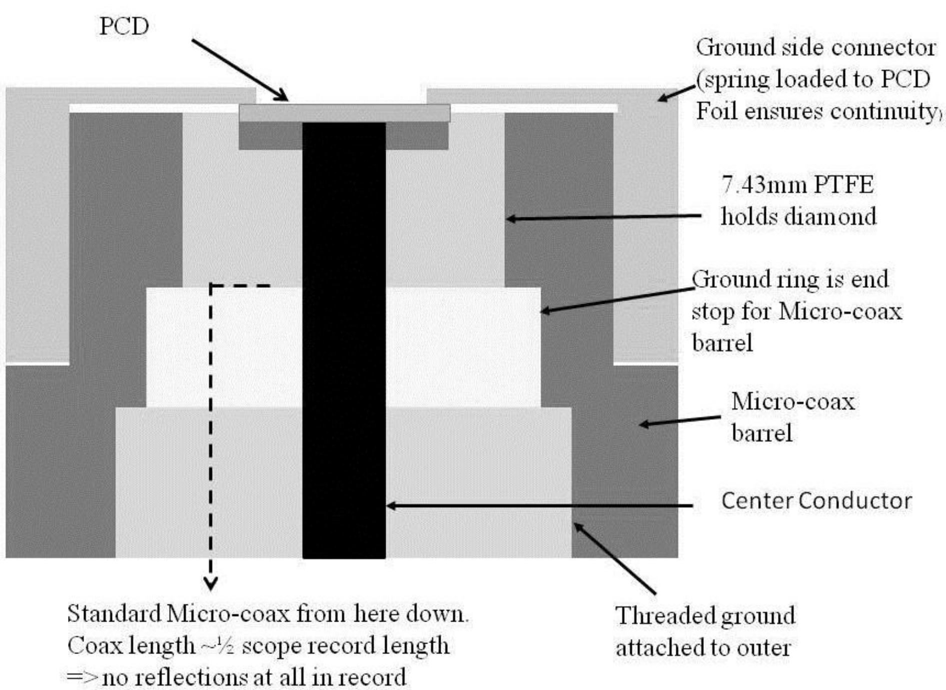

Figure 4. Connectorless design

3. RESULTS

Test results for all the PCD detectors are shown in figure 5. The PCD thickness is 1 mm and the diameter varied between 5, 10 and 12 mm. The PCD gold coating was 1um thick on the x-ray side and up to 15um thick on the center conductor side. In all cases rise time is dominated by the capacitance of the system. The fall time is dominated by the recombination time in the diamond. Waveform ripple is due to impedance mismatch causing reflections in the signal. The impedance drops significantly at the PCD electrode due to increase in diameter of the conductor at the gold coating.

Reducing the number of abrupt changes in the ratio of the conductor diameter to cable or detector ground (going from version 1 to 2) significantly reduced the shoulder on the rising edge. Eliminating the impedance mismatch in the vicinity of the diamond (going from version 2 to 4) produced a shoulder free and recombination time limited impulse response.

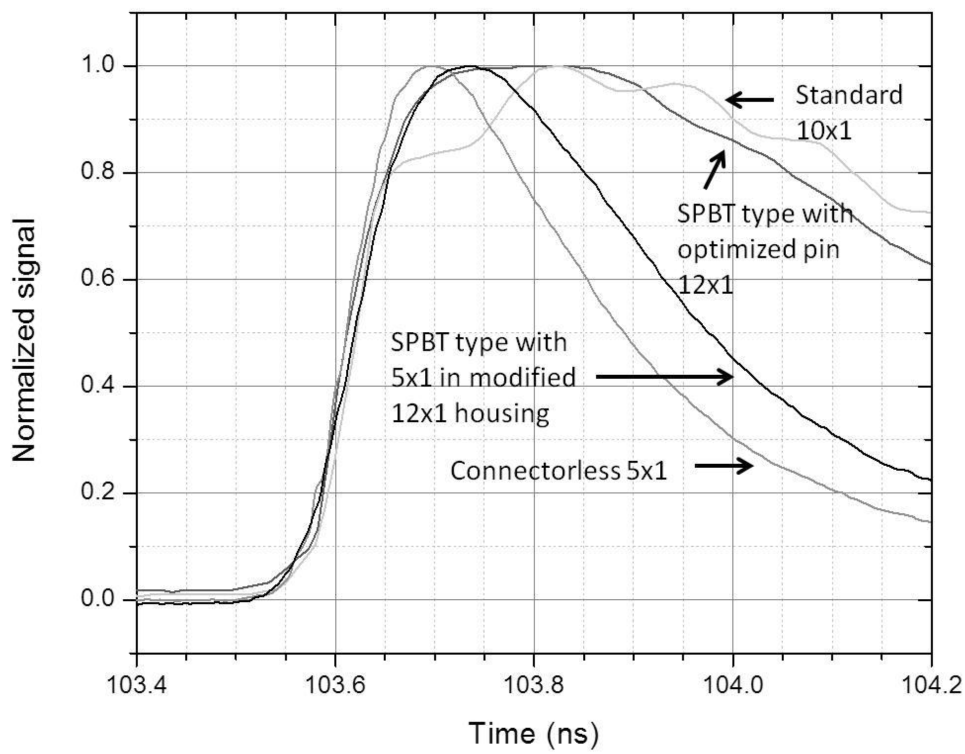

Figure 5. Comparison of the temporal instrument response functions (tIRF) for the 4 designs.

4. CONCLUSION

Tests on the prototype “connectorless” PCD assembly demonstrated a shoulder free temporal response function. The prototype is now in the design process to deliver a more robust and NIF fieldable instrument. This final design will be tested on Comet and replace the existing PCD assemblies.

5. ACKNOWLEDGEMENTS

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