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V. Miller Kamm, A. Awwal, J. Di Nicola, P. Di Nicola, S. Dixit, R. Lowe-Webb, D. McGuigan, B. Raymond, K. Wilhelmsen

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SOFTWARE TOOL LEVERAGES EXISTING IMAGE ANALYSIS RESULTS TO PROVIDE IN-SITU TRANSMISSION OF THE NIF DISPOSABLE DEBRIS SHIELDS

Victoria Miller Kamm, Abdul Awwal, Jean-Michel Di Nicola, Pascale Di Nicola, Sham Dixit, Roger Lowe-Webb, David McGuigan, Brett Raymond, Karl Wilhelmsen
Lawrence Livermore National Laboratory, Livermore, CA 94550, USA

Abstract

The Disposable Debris-Shield (DDS) Attenuation Tool is software that leverages Automatic Alignment image analysis results and takes advantage of the DDS motorized insertion and removal to compute the in-situ transmission of the 192 NIF DDSs. The NIF employs glass DDSs to protect the final optics from debris and shrapnel generated by the laser-target interaction. Each DDS transmission must be closely monitored and replaced when its physical characteristics impact laser performance. The tool was developed to calculate the transmission by obtaining the total intensity of transmitted light with the debris shield inserted and removed. These total intensities are calculated in the Automatic Alignment image processing [6] algorithms. The tool uses this data, adding the capability to specify DDS to test, moves the DDS, performs calculations, and saves data to an output file. It operates on all 192 beams of the NIF in parallel. The tool has discovered a discrepancy between models and actual measurements. The software was qualified with DDS of known transmissions as supplied by the vendor. This demonstrated the tool capable of measuring in-situ DDS transmission to better than 0.5% rms.

INTRODUCTION

The National Ignition Facility (NIF) employs a vast set of optics to carry out laser experiments. The Final Optics Assembly (FOA) is the last set of optics before the laser reaches target chamber center. These optics are crucial to NIF for focusing and frequency conversion operation. To protect these optics, debris shields are utilized and reside between the FOA and the target. The optic transmission of these optics and also the debris shields are important to achieving the NIF experimental goals. Predictive computer models are employed to estimate the transmission of the debris shields, but without actual measurements, the validity of these models was unknown. To address this issue, a software tool was developed that coordinates two functions. First, it leverages existing Automatic Alignment (AA) software to measure beam quality metrics like image intensity. Next it coordinates movements of the debris shields for the measurements, and calculates the transmission based on this data.

Automatic Disposable Debris Shield (ADDS)

The NIF employs a Final Optics Assembly (FOA) to frequency convert and focus the laser on the target [4]. ADDSs are inserted between the optics and the target to protect the final optics. Figure 1 shows the elements in the final optics assembly and the location of the disposable debris shield. ADDSs are disposable because they absorb shrapnel damage from exploding targets and their transmission is diminished due to re-deposition of vaporized mass. Each NIF beamline contains a mechanism with 10 debris shields. The system is automatic because each shield is motorized and positioned remotely. Only one shield is inserted in the beam path at a time. Shields are disposable, but are also high quality optics. They are large (44 x 44 cm.) and are fabricated from borosilicate glass with anti-reflective coatings [3]. In order to maximize laser performance and minimize cost expense, it is essential to monitor each ADDS. Shields are tracked by serial number with their pertinent information stored in a database. Measurement and analysis is performed on a particular shield to determine transmission. The ability to perform this analysis coupled with the availability of 10 shields enables NIF to maintain the high transmission of its optics.

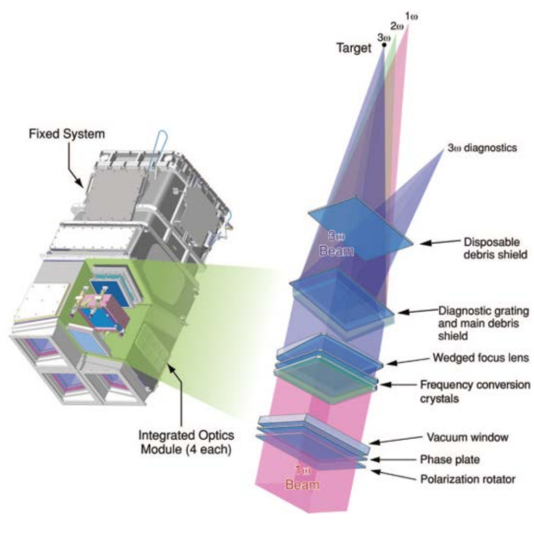

Figure 1: NIF Final Optics Assembly Layout showing location of ADDS

ADDS Attenuation Tool Software

The software tool allows the user to develop an Excel configuration file that defines which shields, 1 - 10, will be analyzed. The configuration file is selected and loaded

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into the tool before performing a data acquisition. The first step after reading and evaluating the configuration file is populating the graphical user interface with the shield information. The user then selects the beamlines for measurement. The tool acquires data values of background images to use in the calculation. The user can also request to perform each step a number of times and the mean is used in the calculation. Next, the specified shield is positioned into the beam path to ready it for data acquisition. When positioning completes, the tool executes NIF AA software that aligns the beams to the Target Alignment Sensor (TAS). As this software executes it performs image analysis of the input image and calculates the total intensity of the 375 nm (3ω) wavelength beam. This result coupled with the total intensity of the beam, with the same shield removed from the beam path, is utilized in the following equation to calculate the attenuation presented by that particular debris shield.

$$Atten = \frac{IN\ Total\ Intensity - Background\ Total\ Intensity}{Out\ Total\ Intensity - Background\ Total\ Intensity}$$

As the software calculates each beam shield's attenuation the results are displayed in a table for all 192 NIF beams. The execution of the shield positioning, AA software, and calculations are performed on the beams in a parallel fashion to increase efficiency. Once the table is fully populated with the results it is available to be written to an output Excel file. Figure 2 shows the graphical user interface of the tool. The *Tool Input* is for selecting the DDS configuration file that is used by the tool. The *DDS Plan* area shows which shields have been identified in the plan file for analysis when the tool executes. Each beamline designation with an entry in the plan file has a shield number identified in the *DDS Plan* area of the display. The *Location Grid* area contains the control inputs for the tool. The beamline grid allows the operator to select any number of beamlines for the measurement.

The control buttons allow the operator to then select the *Run Bkg* button to acquire the background image data. The *Run DDS In* button positions the shield shown in the *DDS Plan* area into the beam path and perform the AA command and acquire the resulting data. Likewise, the *Run DDS Out* button removes the designated shield from the beamline, performs the AA command and obtains the data. The *Measurement Data* table is populated with data as the tool is run. Feedback is displayed on the GUI as the tool executes. Once data acquisition is complete the *Store*

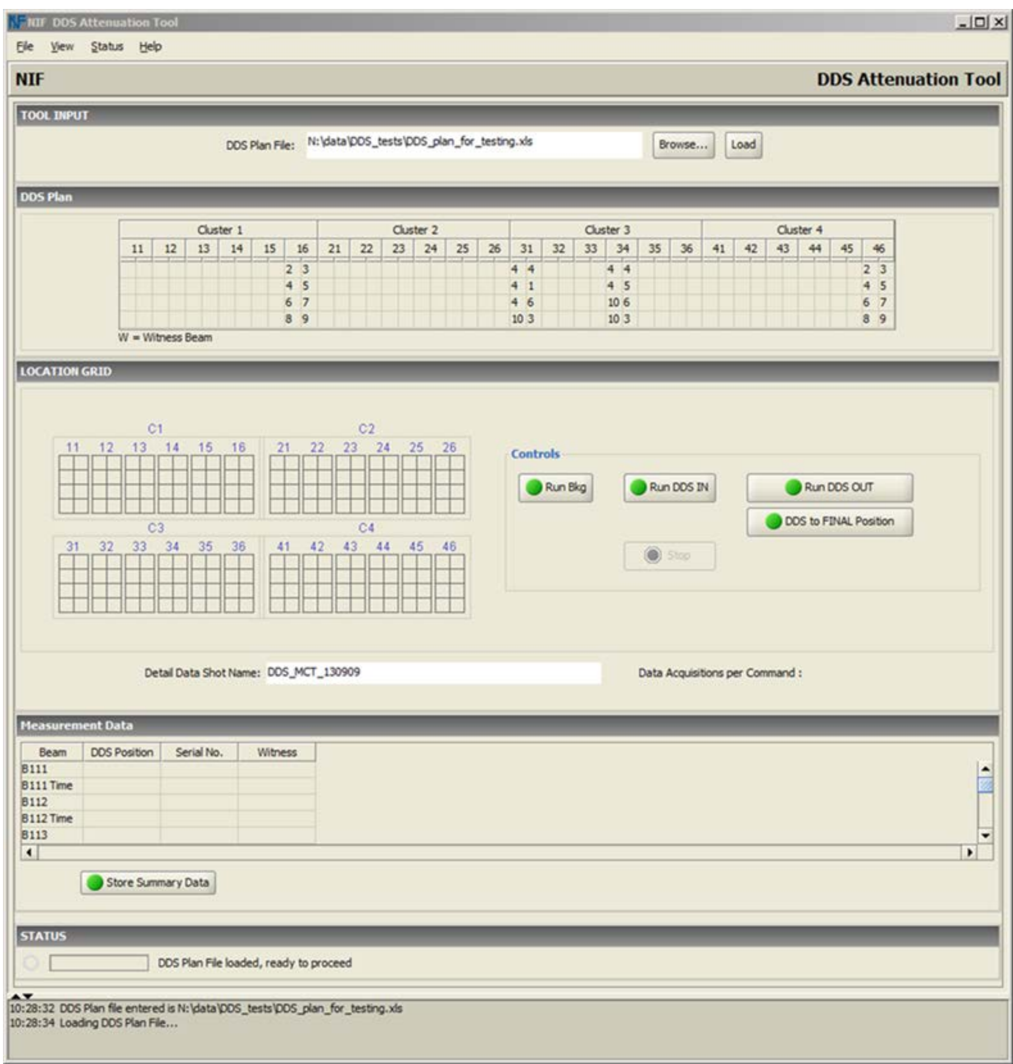

Figure 2: ADDS Attenuation Tool Graphical User Interface

Summary Data button is used to write the acquired and calculated data to the output file. The *DDS to Final Position* button is a convenience function for operations that inserts the specified shield into the beam path from the configuration plan file.

The software has proven an accurate method for determining transmission, and helps in experiment planning. After a high energy NIF experiment, shields are usually measured to quantify the effect from the laser experiment and to determine the optic quality and transmission for meeting the criteria of the upcoming laser experiments.

Automatic Alignment (AA) Control Software

The tool initiates execution of AA commands that align the beam to the target alignment sensor. This software is in operation daily to align the NIF laser beams on target in preparation for an experiment. It analyzes camera images through sophisticated image processing algorithms and calculates new positions of actuated optics and positions these elements to align the laser. See reference [1][5] for details of NIF AA. As part of this operation, AA calculates a wide range of image metrics that are available for the ADDS Attenuation software. AA also archives the images obtained during the alignment commands. The ability to retrieve these archived images has proved valuable in testing the software and to validate the processing steps. It has been important in a trouble-shooting role also, when the tool measured and calculated output data that was unexpected. The software was able to utilize the AA alignment commands, with no modification and take advantage of an existing interface that enabled initiation of AA commands and retrieval of the results, in the implementation of this tool.

In Figure 3 below is a typical image acquired during the alignment operation that is processed in the ADDS Attenuation tool measurements.

A typical measurement consists of 10 acquired images per beamline. A single background analysis, and 3 with the shield inserted, 3 more with the shield removed and another set of 3 with the shield inserted to ensure valid measurements. All these images are archived by AA and available for review.

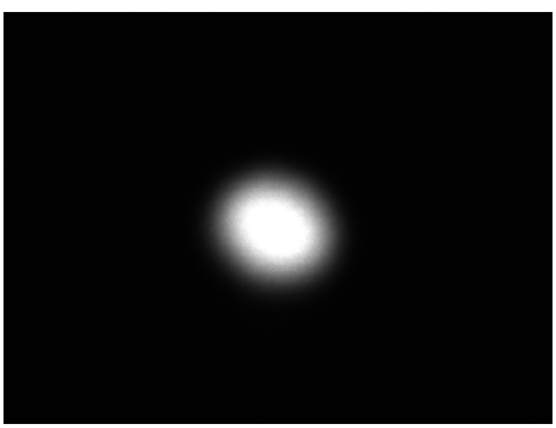

Figure 3: Image acquired by AA from Target Alignment Sensor

Measurement Accuracy

As mentioned the tool was verified by calculating the transmission of shields with a known transmission from the vendor. The vendor transmissions have a small error rate that is noted in Figure 4, which correlates to the online measurements by the attenuation software [2].

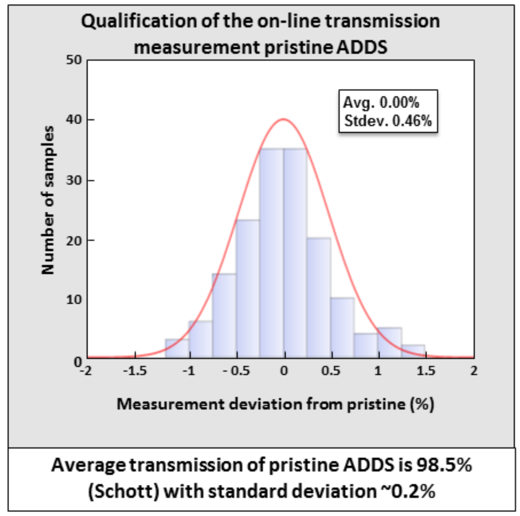

Figure 4: Measurement Deviation of Pristine Shields

Laser Performance and Operations Model (LPOM) [7] is used to predict the transmission of each shield used in NIF, and this debris and solarization modelling is a useful tool to predict transmission. The ADDS Attenuation tool is employed to measure transmission of online shields

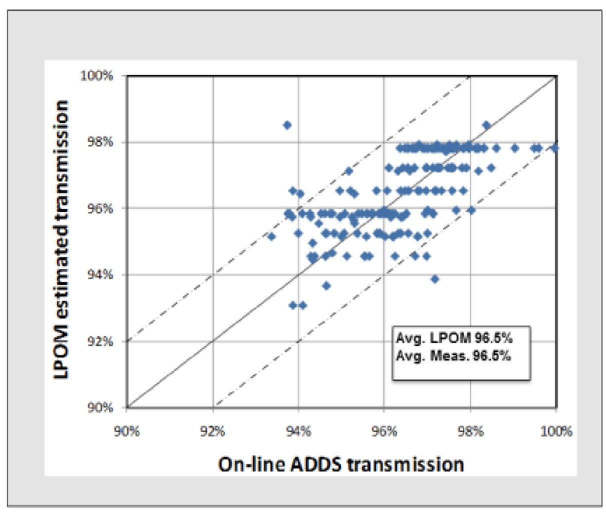

Figure 5: ADDS predicted versus measured

that have been subjected to possible physical environments that the modelling does not compensate for. The online measurements are used as input to the modelling software. With these inputs, the modelling software can adjust the transmission loss model and re-baseline the future accumulated transmission loss from additional laser operations. Figure 5 below highlights the online measurements versus the predicted for two beamlines [2]. Online measurements do take up valuable NIF operational time, but the accurate measurements taken online validate and catch discrepancies of the model predictions. The ADDS transmission is monitored closely to ensure high, well-characterized 3ω transmission. The data from online measurements is continually compared

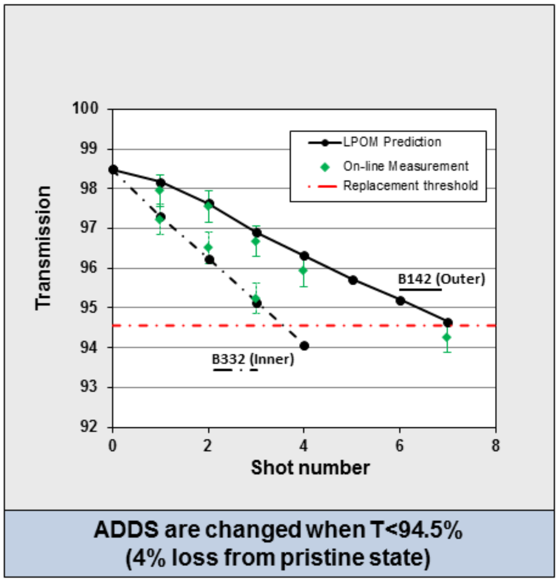

Figure 6: 192 beamlines predicted versus measured after 1.3 MJ experiment

with the predicted output from the laser model predictions. The shields are taken out of service when their respective transmission goes below 94.5%.The online measurements have proven accurate and give a good benchmark for updating and validating the modelling software. Additional data is shown in Figure 6 with predicted transmissions and online calculated measurements for 192 shields after a 1.3 MJ NIF experiment [2]. The average of the predicted and measured transmissions are both in agreement at 96.5%. The model is resynchronized with this data after a few laser experiments. The model predictions give a good representative value of transmission between online measurements.

Summary

The ADDS Attenuation Tool software was developed taking advantage of existing software functionality to provide transmission data important for efficient NIF operation. Prior to tool, the only shield transmissions were from laser performance modelling. While the modelling is a very crucial component, it was enhanced by online actual measurements to validate and improve certain model parameters. The tool has been shown to be accurate by measuring pristine shield optics, for which the transmission values were known. Its ability to execute in a parallel manner on all 192 beamlines concurrently has made it a useful tool for NIF operations and planning activities, while still minimizing the use of NIF facility time.

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