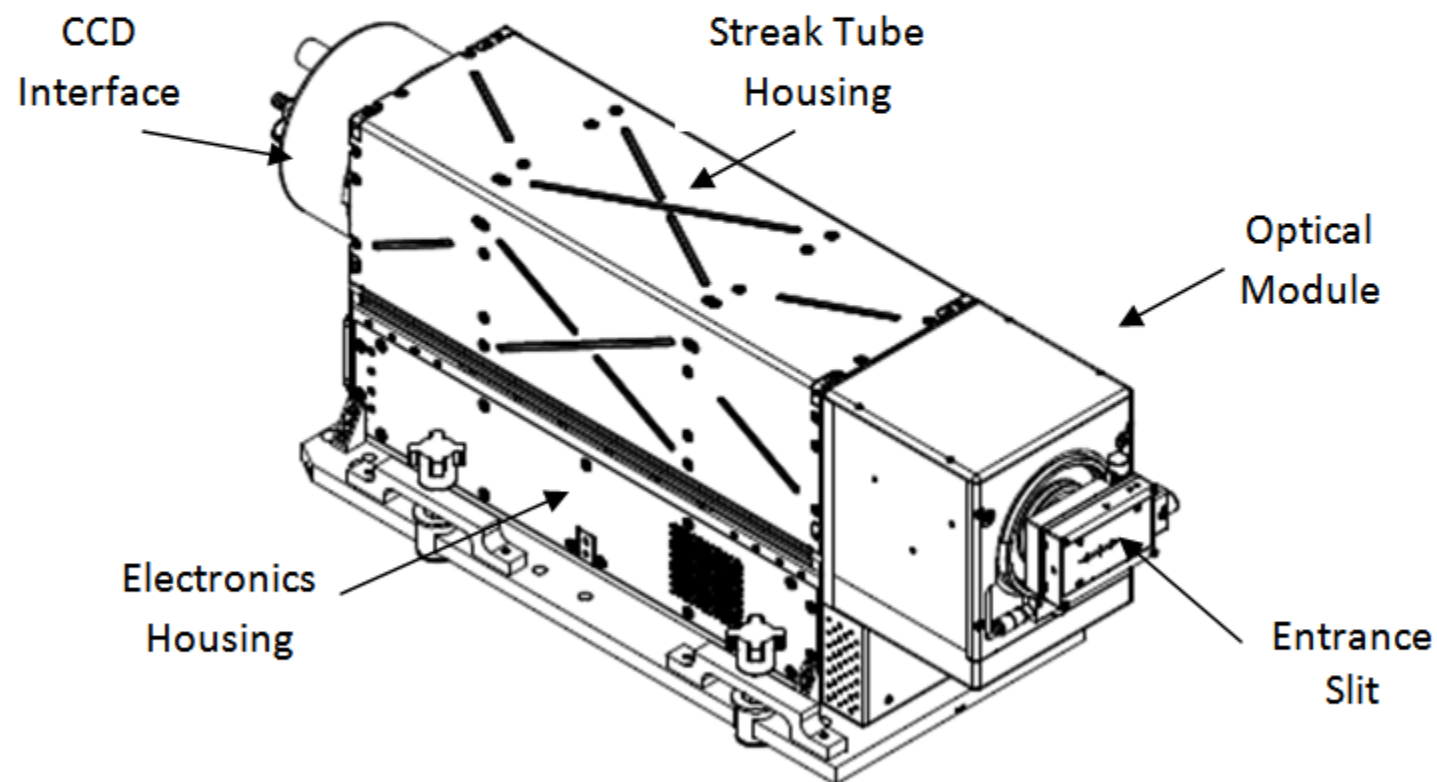


NIF

Diagnostic Workshop CEA/LLE/LLNL

Optical Streak Cameras and Related Info

Optical streak camera system used on NIF



NIF uses a single optical streak camera style for all of NIF. Sweep speeds are based on the specific diagnostic application.

Optical streak camera specifications

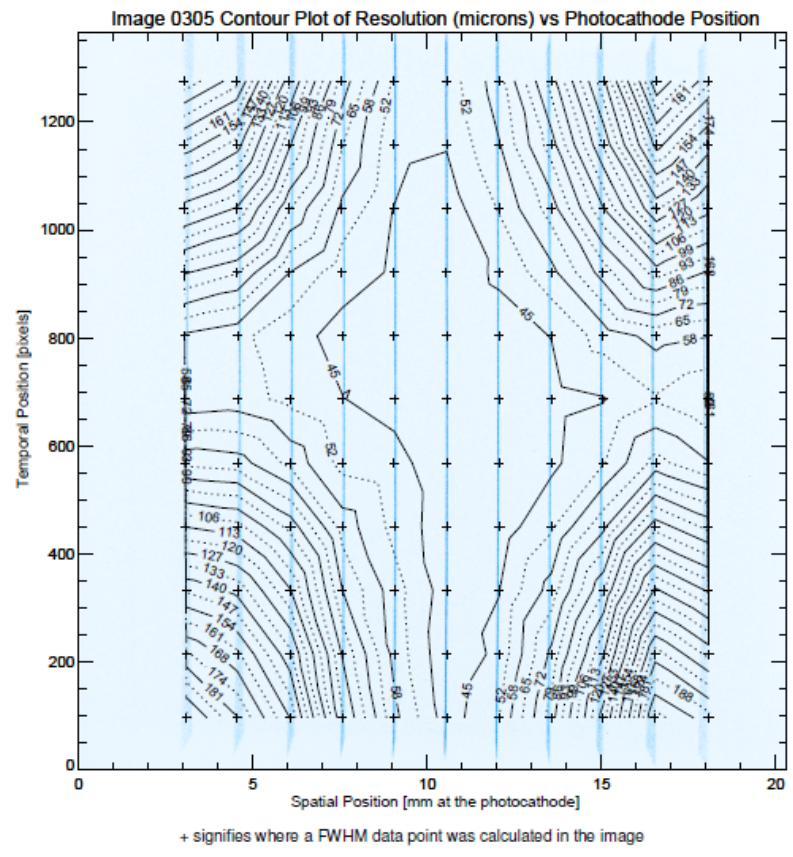
Optical Streak Camera Specifications (Typical)		
Wavelength Band	350nm – 1053nm	Covered with two tubes
Time Windows	2 ns – 90 ns	Choice of 4 windows per streak camera
Spatial Aperture	20 mm	
Streak Tube	P510-P43	Photonis with P43 Phosphor
CCD	4096 x 4096	Spectral Instruments
Pixel Size	9 μm	Before binning
Number of Bits	16 Bits	
Binning	3x3	27 μm after binning
Slit Spacing	500 μm	

Streak camera specifications are typical values and the results may vary once the calibration files have been applied.

Optical streak cameras require calibrations

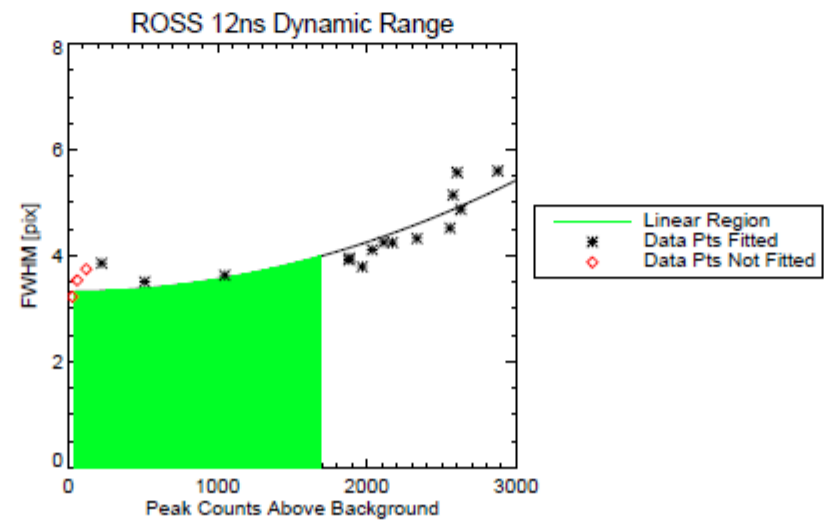
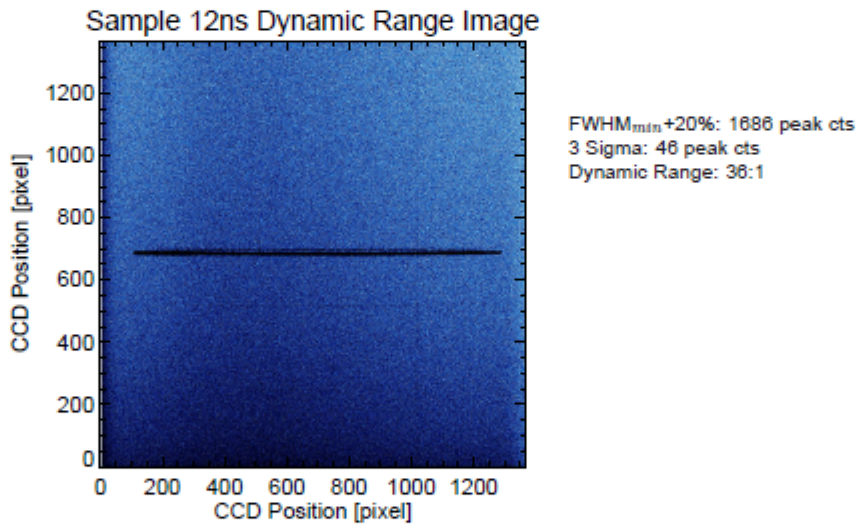
- **Optical streak cameras are not inherently linear and require calibration.**
- **Calibrations increase the measurement accuracy to the 2% level.**
- **Calibrations are used to generate a warp (2D) correction file that is applied to each sweep speed.**
- **This warp correction file removes the nonlinear effects in both space and time.**
 - **For calibration techniques see:**
 - ***“Reliable and Repeatable Characterization of Optical Streak Cameras”*, M. Charest Jr., P. Torres, C. Silbernagel, D. Kalantar, APS Topical Conference on High Temperature Plasma Diagnostics, Albuquerque, NM. May 11, 2008**

Optical Streak Camera Offline Calibrations



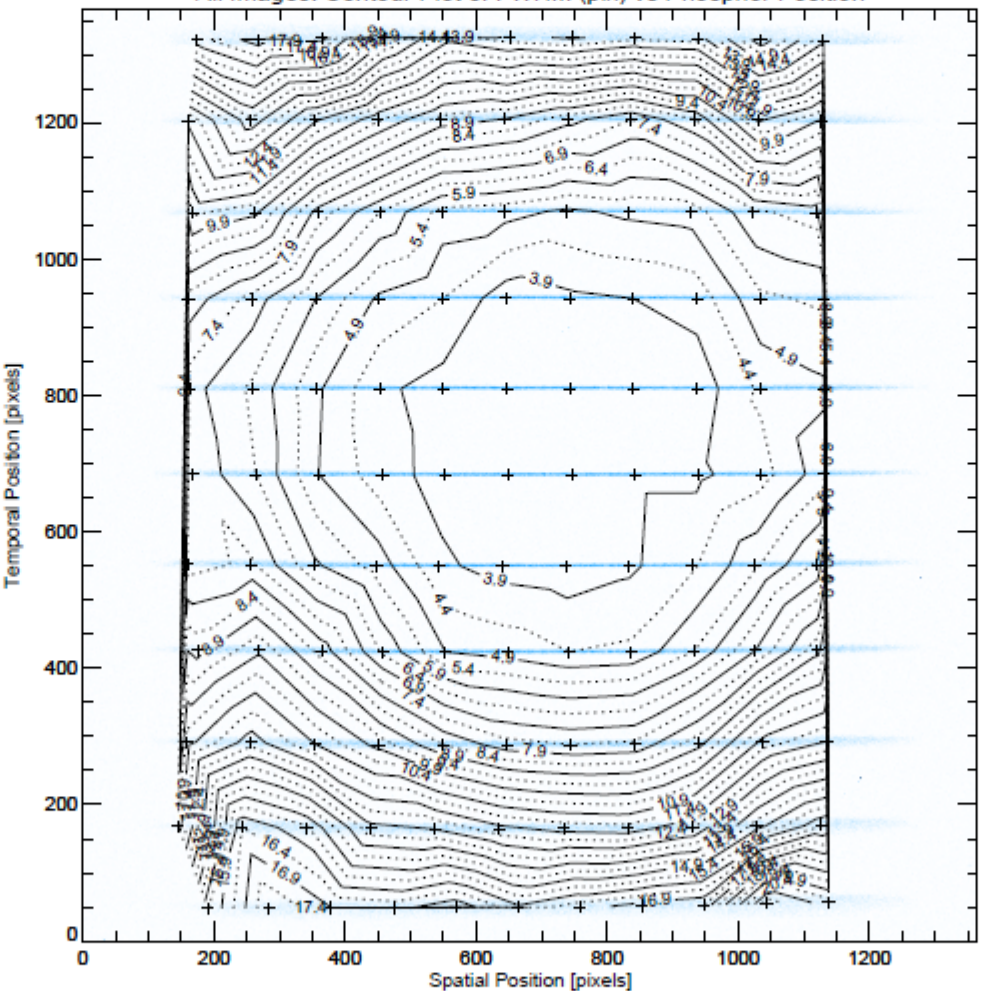
Line Spread Function

*** Temporal Dynamic Range Calculated at Spatial Center of Temporal Pulse ***

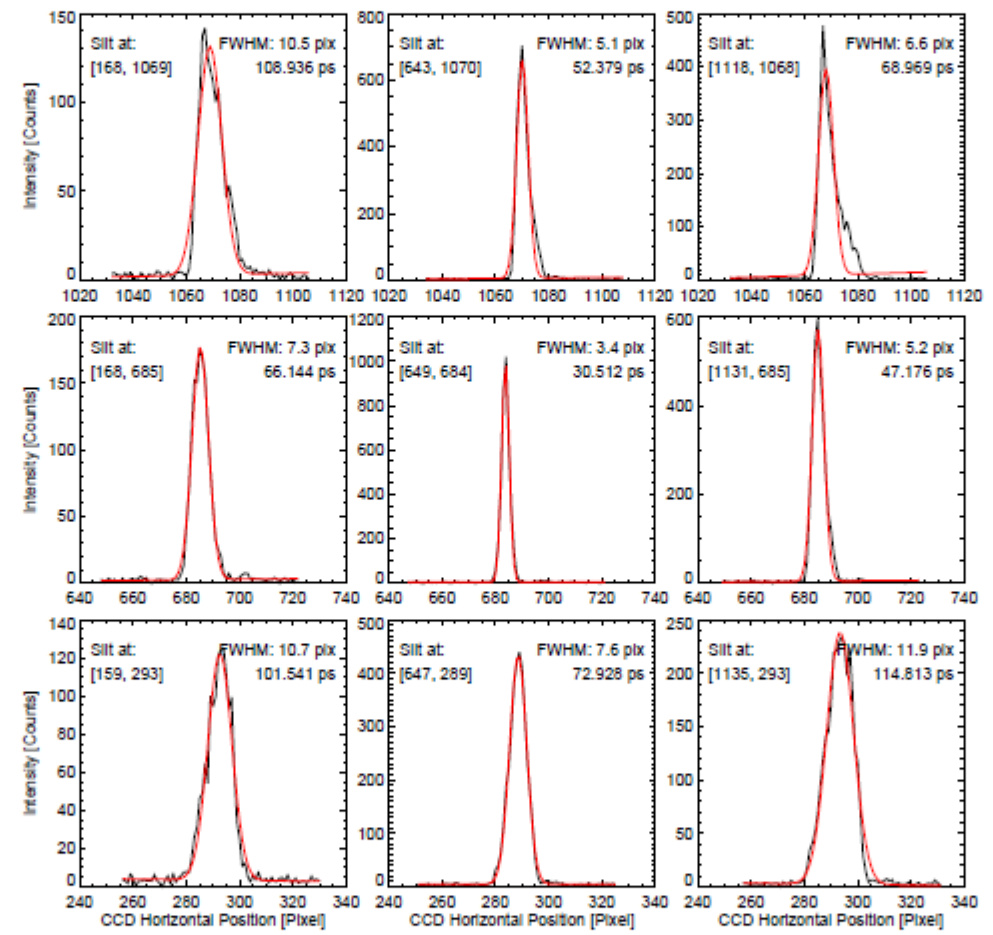


Optical Streak Camera Offline Calibrations, Continued

All Images: Contour Plot of FWHM (pix) vs Phosphor Position



+ signifies where a FWHM data point was calculated in the image



2D Temporal Dwell Curves

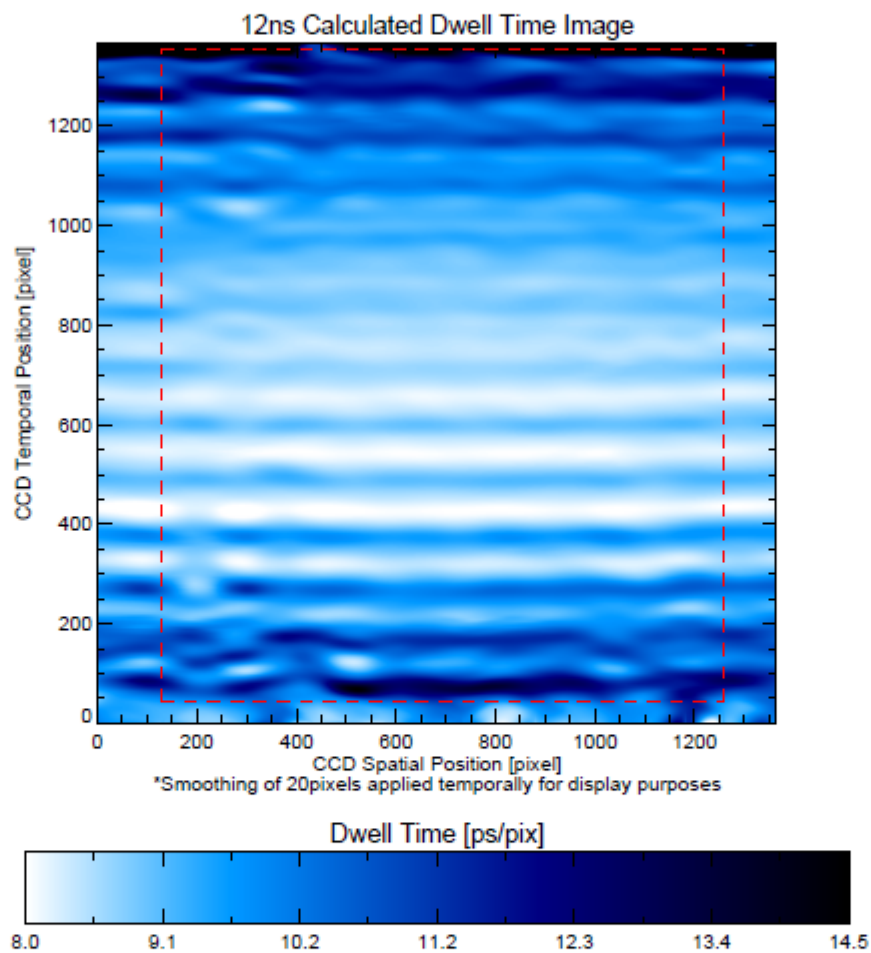
Optical Streak Camera Offline Calibrations, Continued

spacing: 1016.70 ps
 sweep Window: 13.438 ns

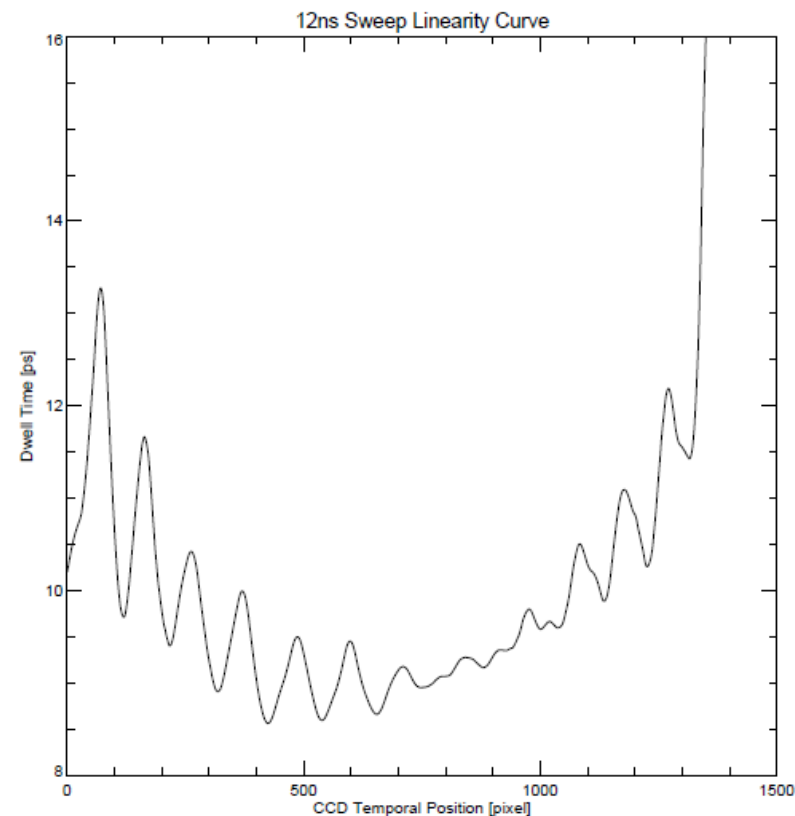
Etalon Spacing: 1016.70 ps
 Measured Sweep Window: 13.438 ns

*** Dashed Line Indicates Boundary of Etalon Calibration Data ***

*** Dwell Time Curve Shown from a Single Column at Center of Calculated Dwell Image ***



2D Dwell Curve



Dwell Curve

Measured streak camera calibration performance values

Example Calibration Report Summary: GSCP104, NOV 2012

Specifications	Sweep Speeds			
Sweep Speeds	3	6	16	40
Dynamic Range (Temporal)	230:1	41:1	35:1	28:1
Dynamic Range (Spatial)	193:1	139:1	N/S	N/S
Dynamic Spatial Resolution				
Line Spread Function (50% CTF)	3.8	4.0	4.1	4.3
lp/mm (50% CTF)	3.5	3.5	3.4	3.3
Dynamic Temporal Resolution (ps)	19.1	28.46	54.73	159.29

All streak cameras go through an extensive calibration to generate a Dynamic Warp Correction for each sweep speed. The listed values are typical for these sweep speeds. The warp correction removes the nonlinear effects in two dimensions, time and space.

VISAR requires higher accuracy than the standard calibration files can provide

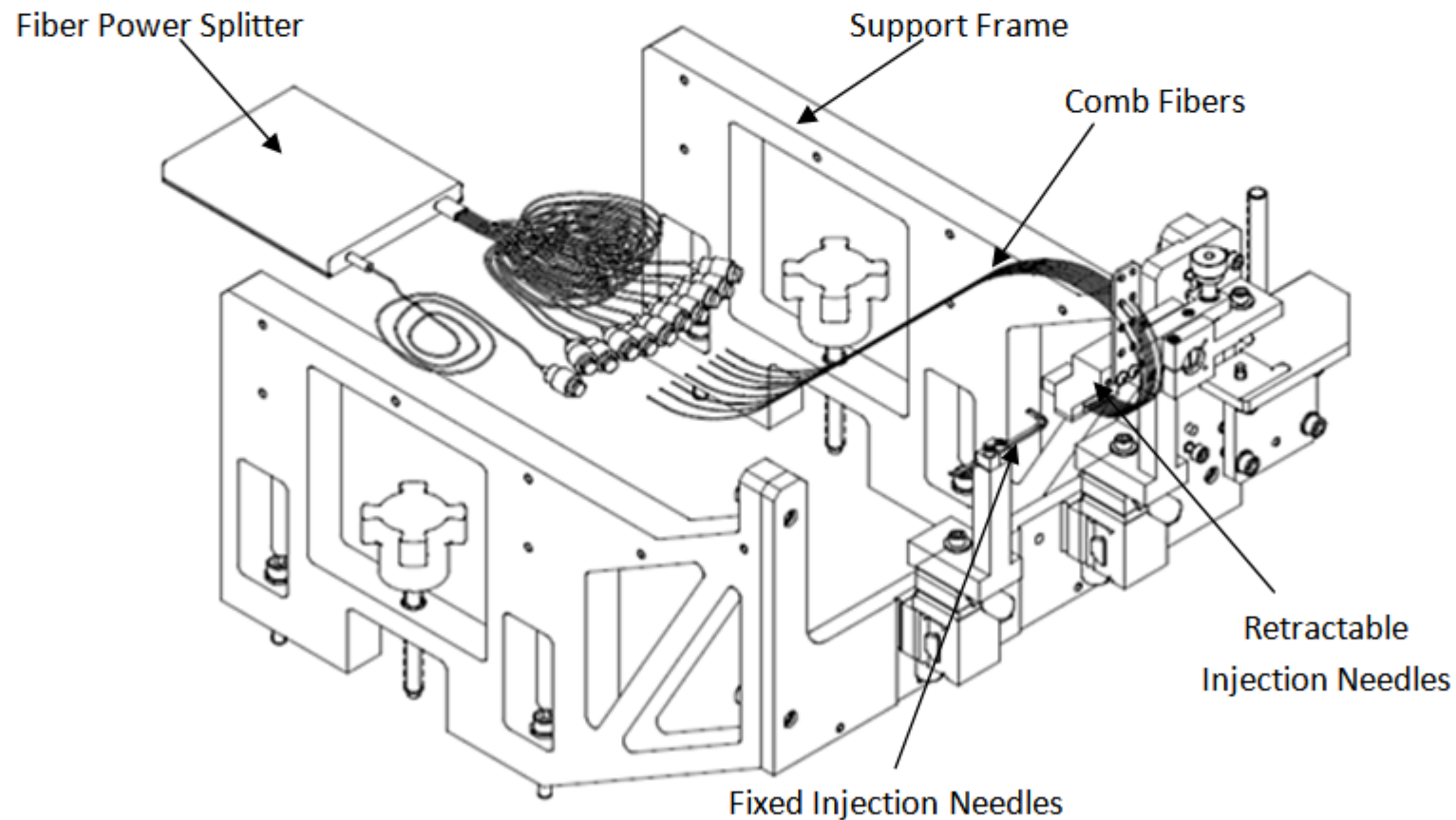
- **Additional calibration is required for key VISAR measurements**
 - **Additional calibrations account for long term drift**
 - **Sweep window jitter**
 - **Temperature variations associated with the electronics that vary from shot to shot**

Dynamic multi comb calibration increases measurement accuracy

- **In situ calibration is accomplished with a multi optical comb injection system mounted on the outside of the streak camera.**

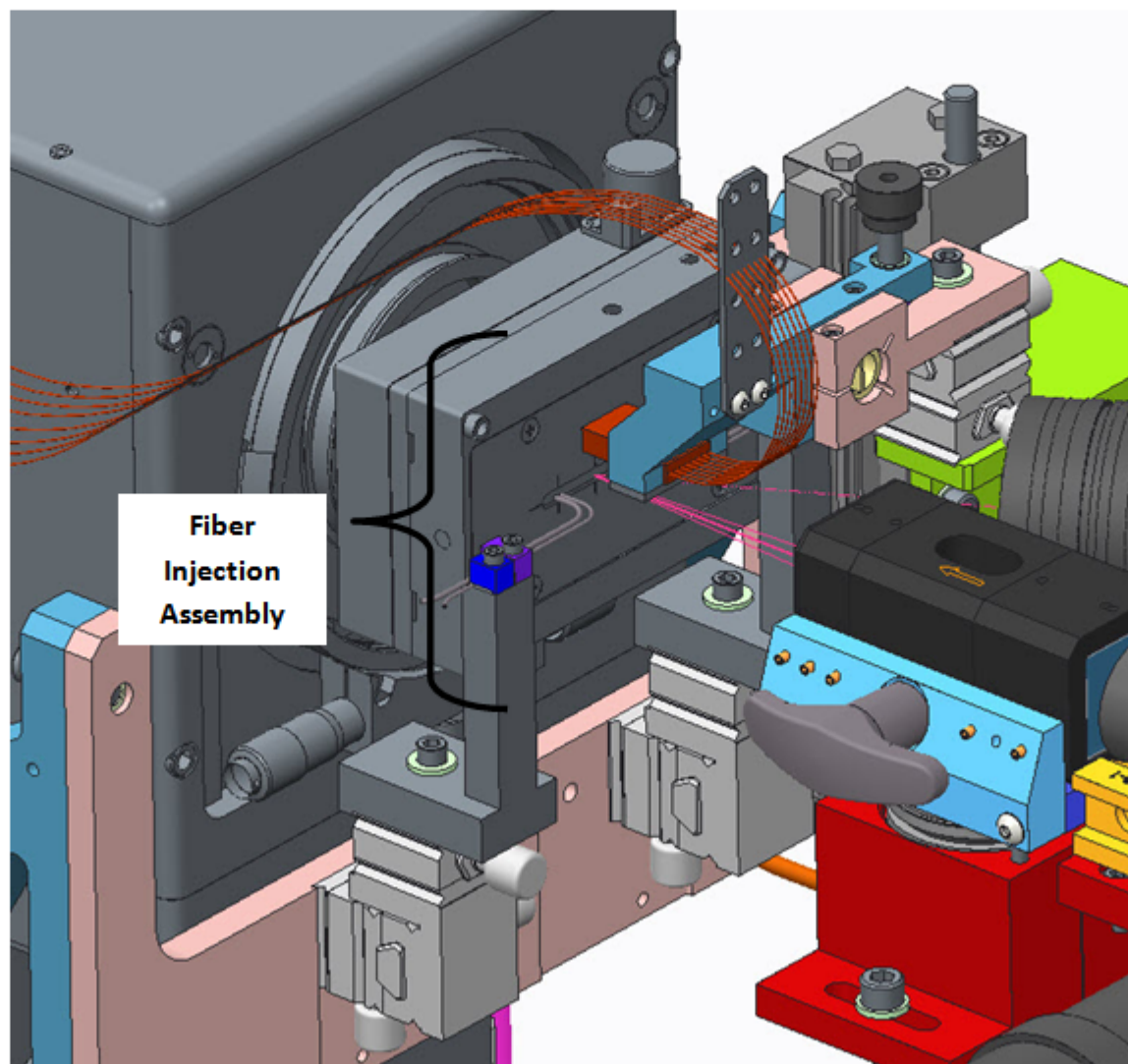
The multi optical comb injection system provides a way to dynamically calibrate the streak camera moments before a shot. Post shot signal processing uses new dynamic calibration data.

Multi optical comb mechanical assembly externally attached to streak camera



The multi optical comb mechanical assembly is externally attached to the streak camera and allows fiber light to be injected through the slit minutes before a shot.

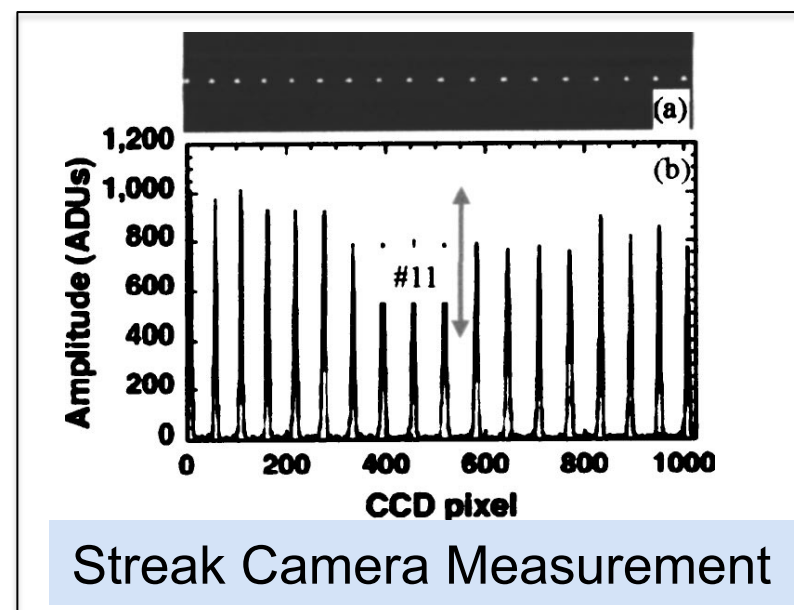
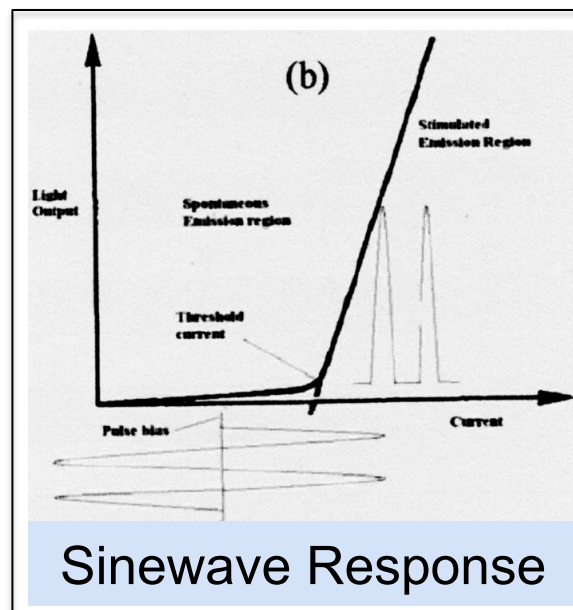
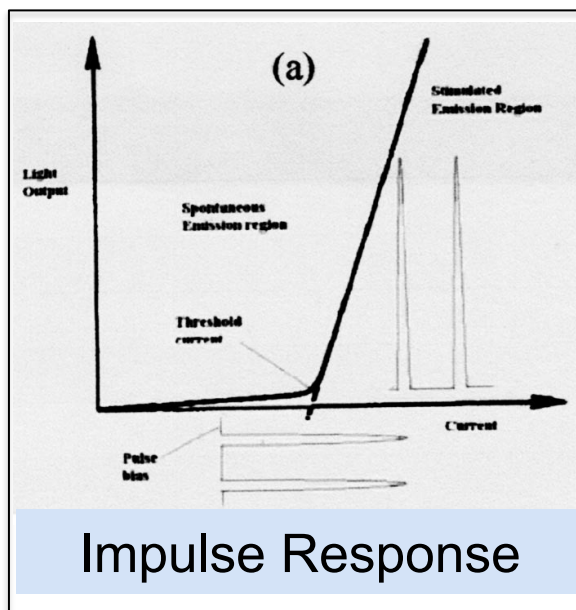
Multi optical comb implementation



The multi comb hardware implementation where the two outer optical combs are fixed and the 8 multi comb group can be cycled in and out of the beam path.

Optical Comb Generators for Streak Cameras

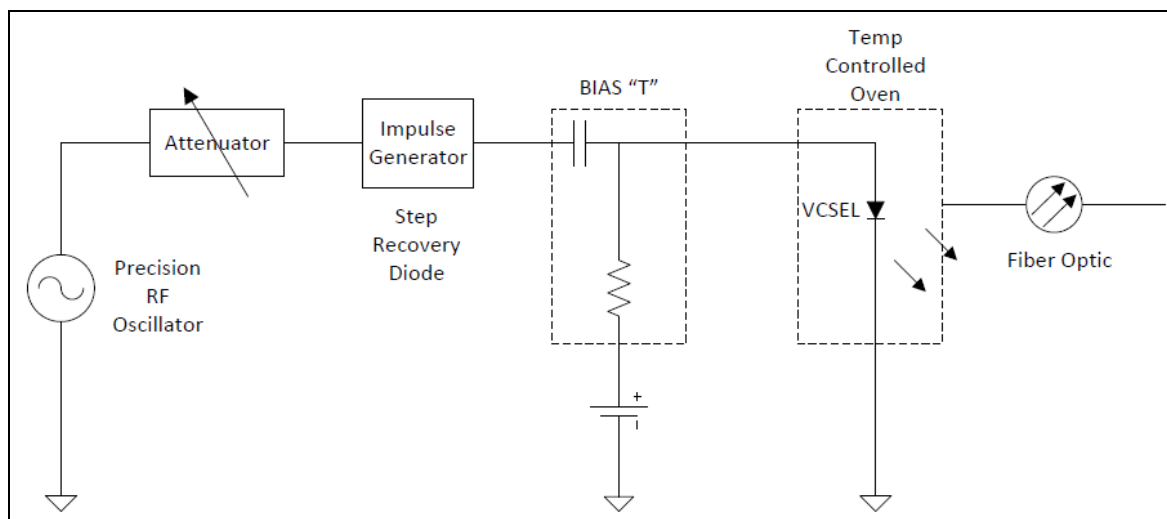
- Optical Comb Generators are based on VCEL technology
- Frequencies 0.1 to 10 GHz, and wavelength (780 nm)




Ref:

- RSI, Vol. 75, No. 10, 2004, pp. (3930-3933)
- RSI, Vol. 63, No. 10, 1992, pp. (4322-4326)


Optical Comb Generator Block Diagram



- Optical comb generators now available through Sydor Instruments



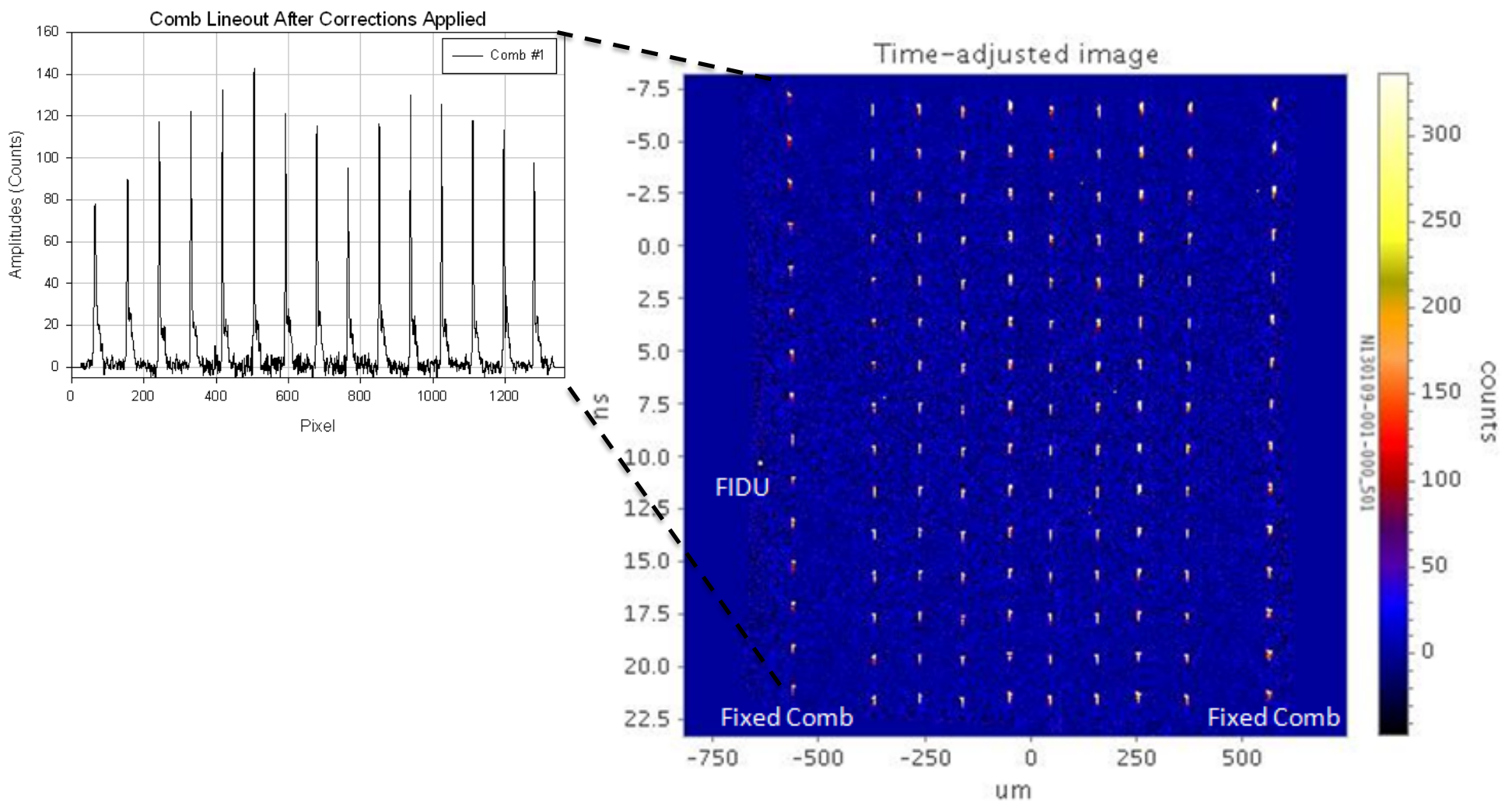
Product Specifications



SYDOR 2 GHz Comb Generator

Sydor Instruments' compact, VCSEL optical comb generator delivers 2 GHz visible pulses for the most demanding applications. It is ideal for accurate, time base calibration of electro-optic instrumentation, sensors, detectors, and streak cameras.

Multi comb data after initial corrections applied



The multi comb data based on a known frequency is used to generate a second warp correction that increases the measurement accuracy down to (0.5% - 1%).

Streak Camera Correction Files

- Correction files have been generated to take out the non-linear effects.
- Warp correction file per sweep speed is generated



LLNL-CONF-666164

A Robust In-Situ Warp-Correction
Algorithm For VISAR Streak Camera
Data at the National Ignition Facility

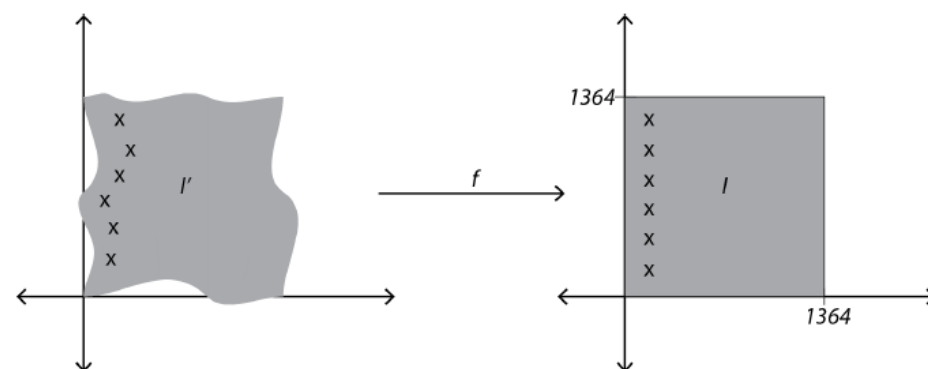
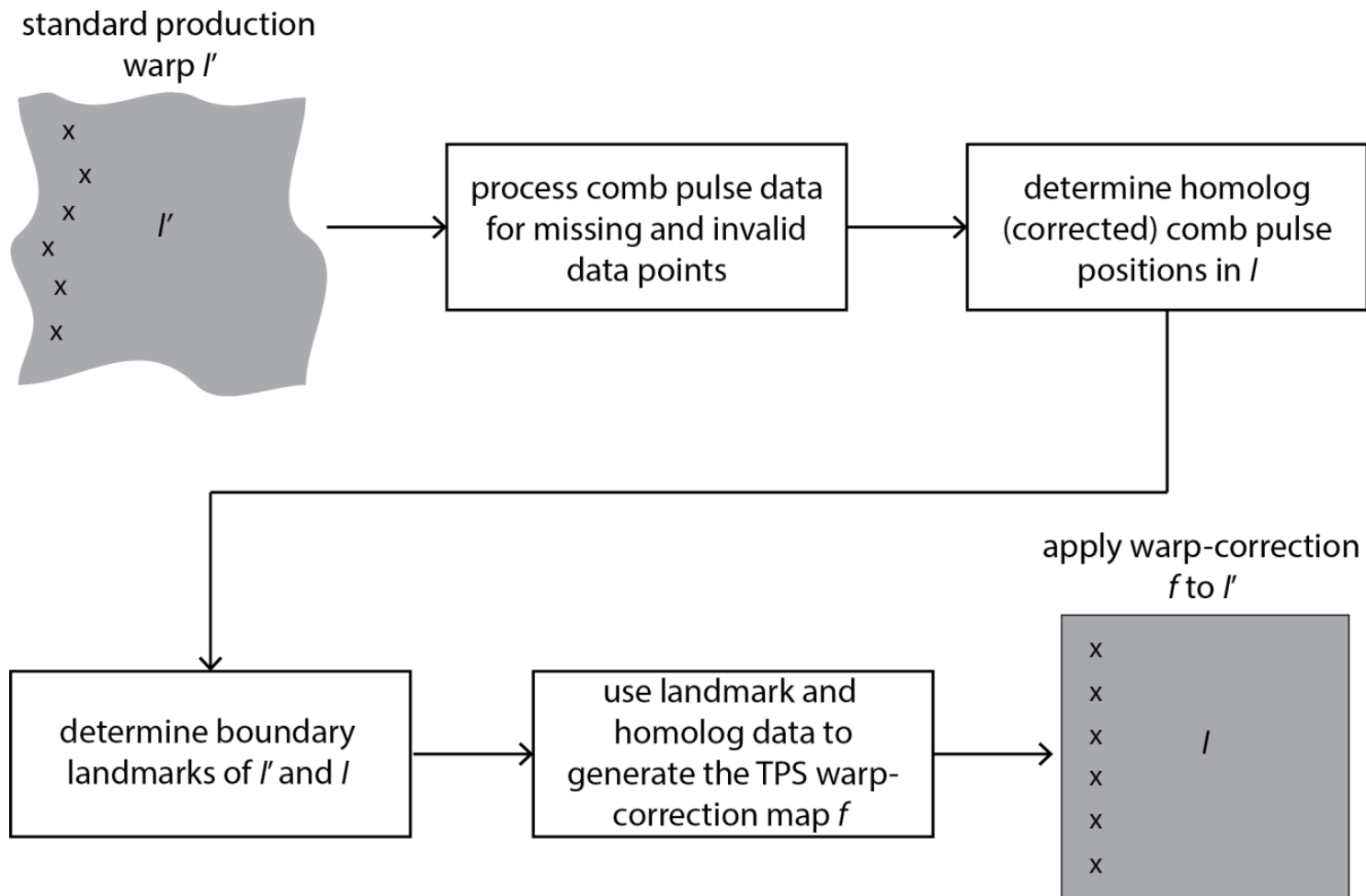


Figure 1 – Illustration of a TPS warp correction.

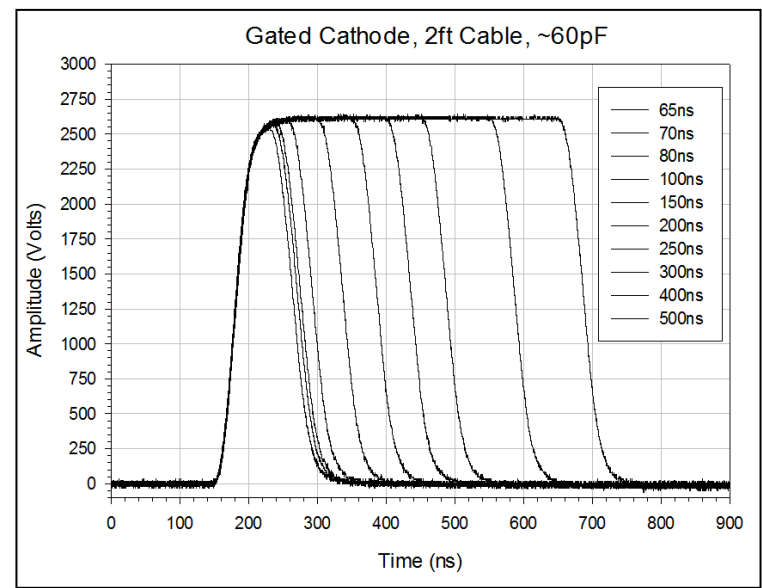
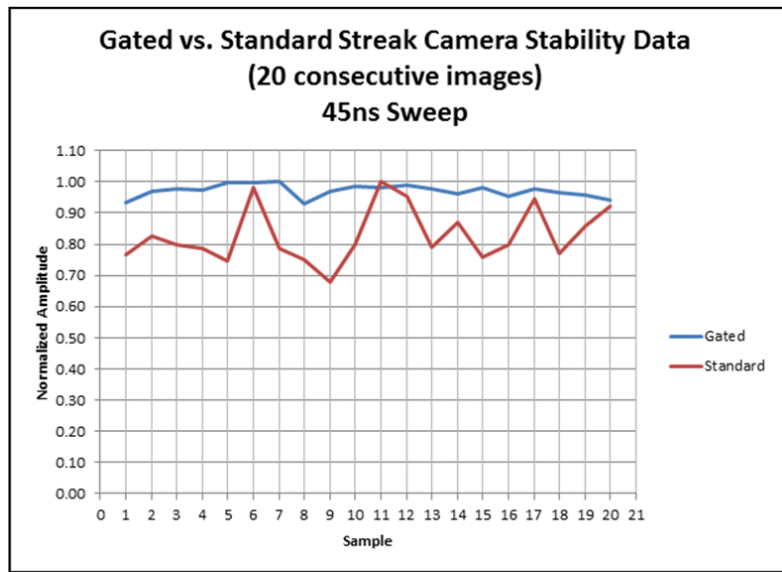
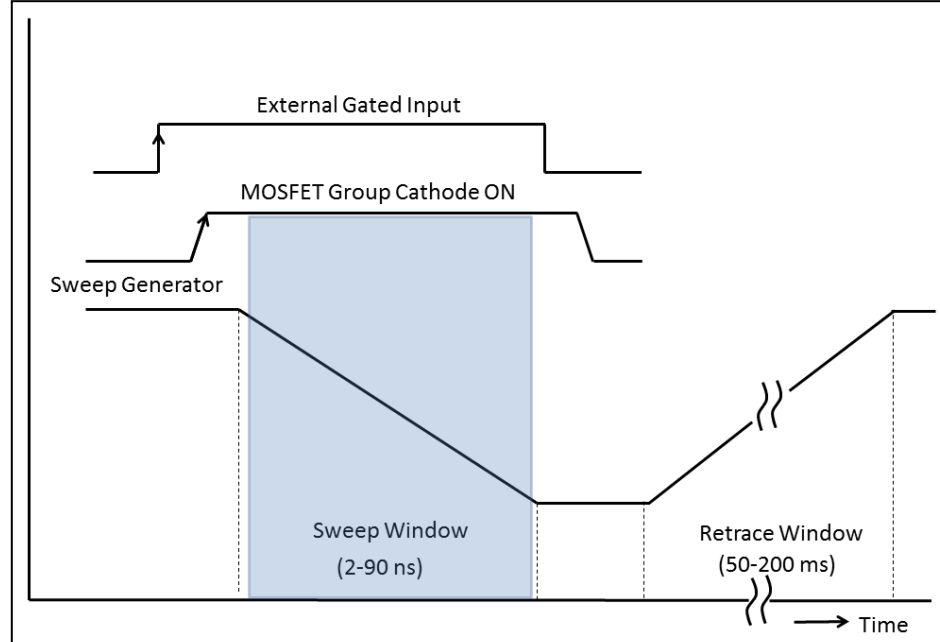
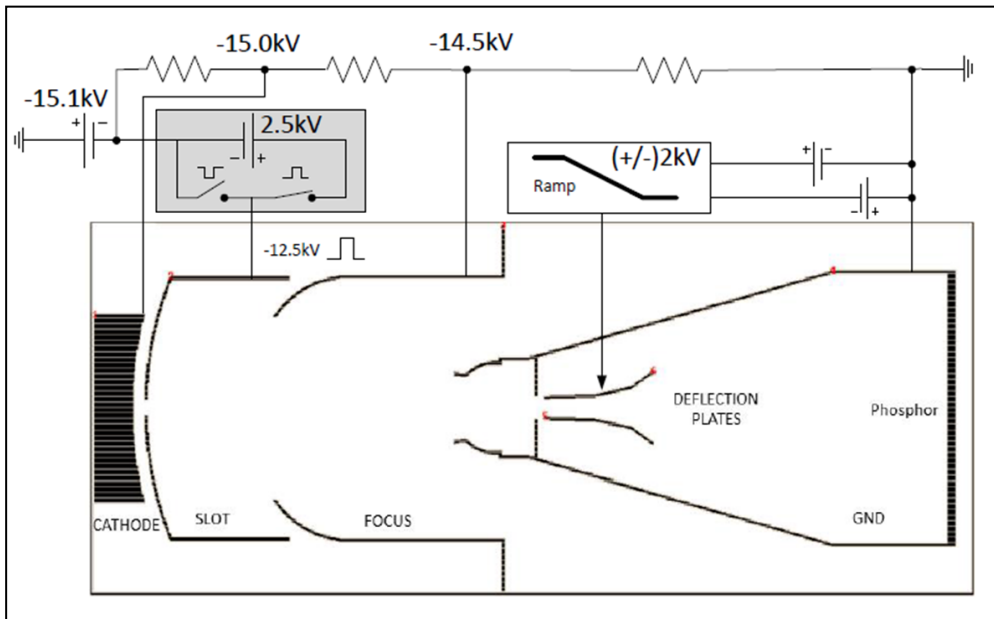
REF:

Proc. SPIE 9345, High Power Lasers for Fusion Research III, 93450Q
(February 26, 2015); doi:10.1117/12.2085127

Thin Plate Spline (TPS) Warp Correction Flow Chart



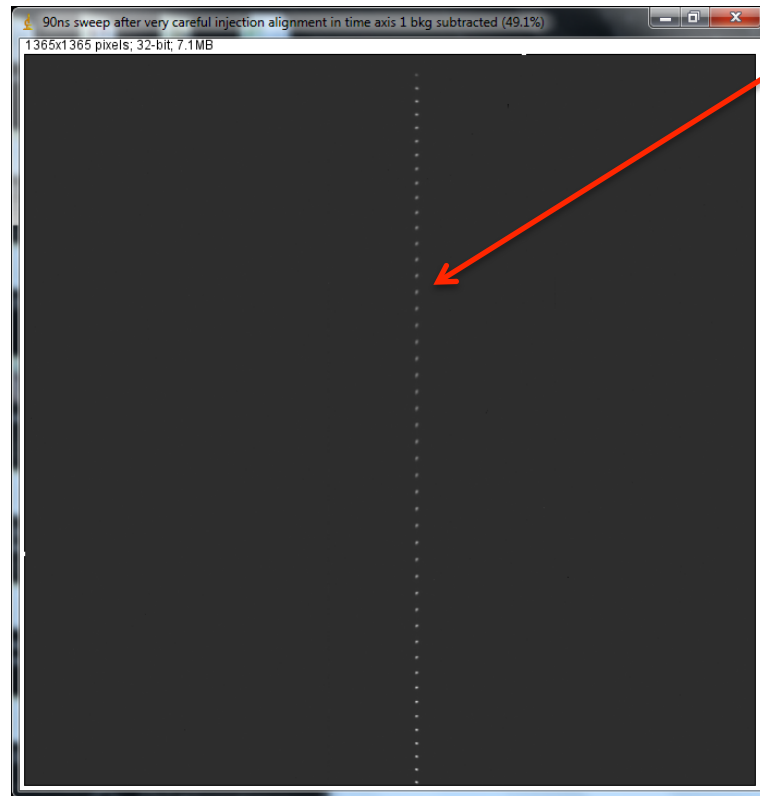
Ambient Noise Reduction Through Cathode Gating



Gated Cathode Data Example

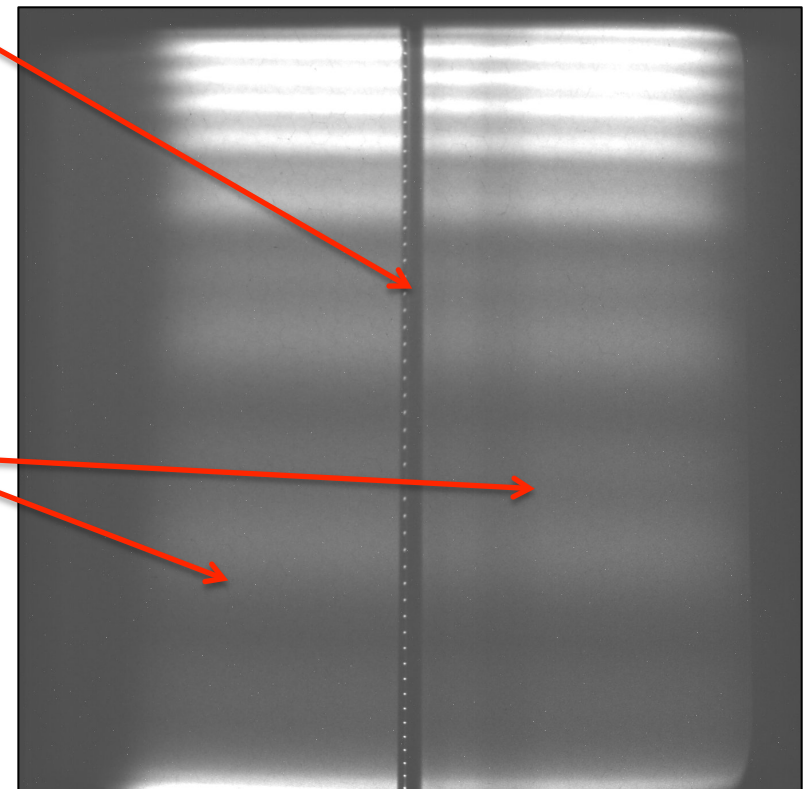
Room Light

Room Light



Comb

Room Light Noise



Gated Cathode SC

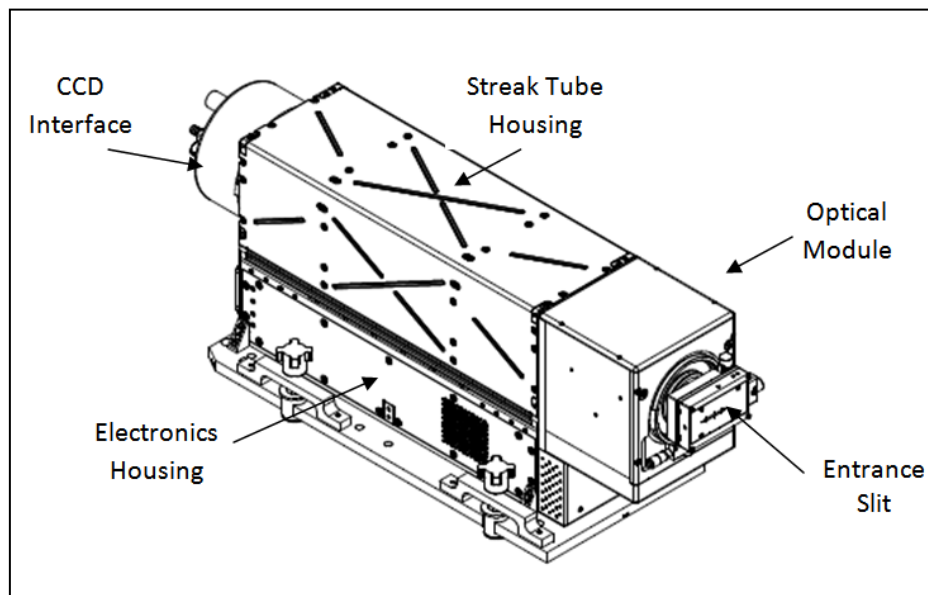
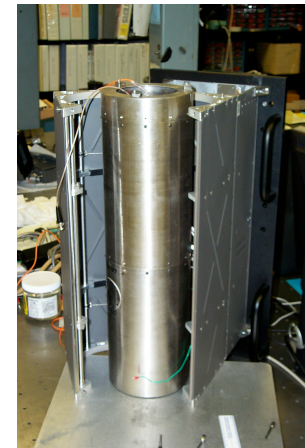
Standard SC

Ref:

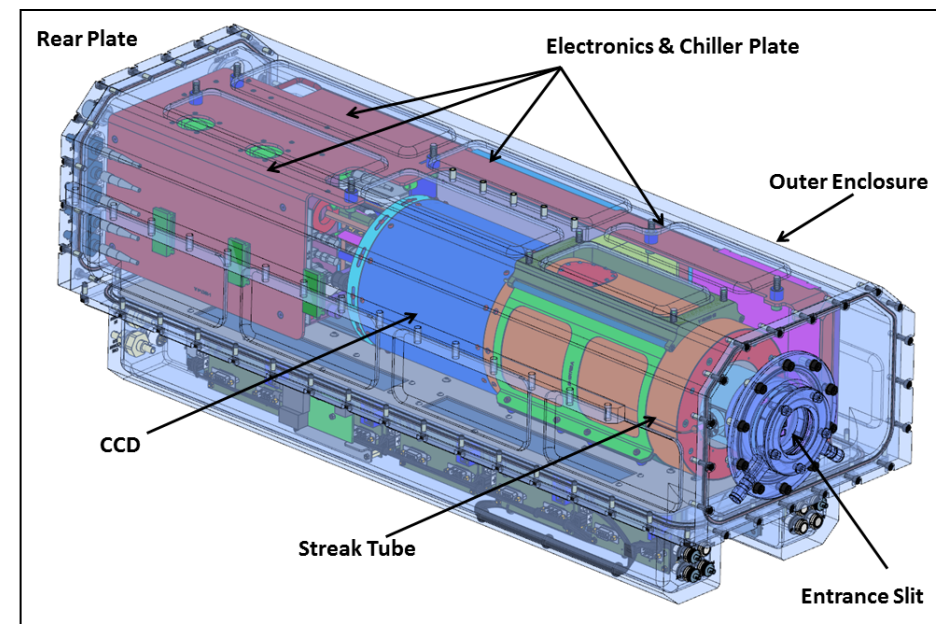
SPIE 9591, Target Diagnostics Physics and Engineering for Inertial Confinement Fusion IV, 95910D (31 August 2015)

Steal Camera EMP Mitigation

- All streak cameras have “MuMetal” enclosures around all electronics.
- All cabling is double shielded cabling
- All electronics is packaged in a outer enclosure assembly

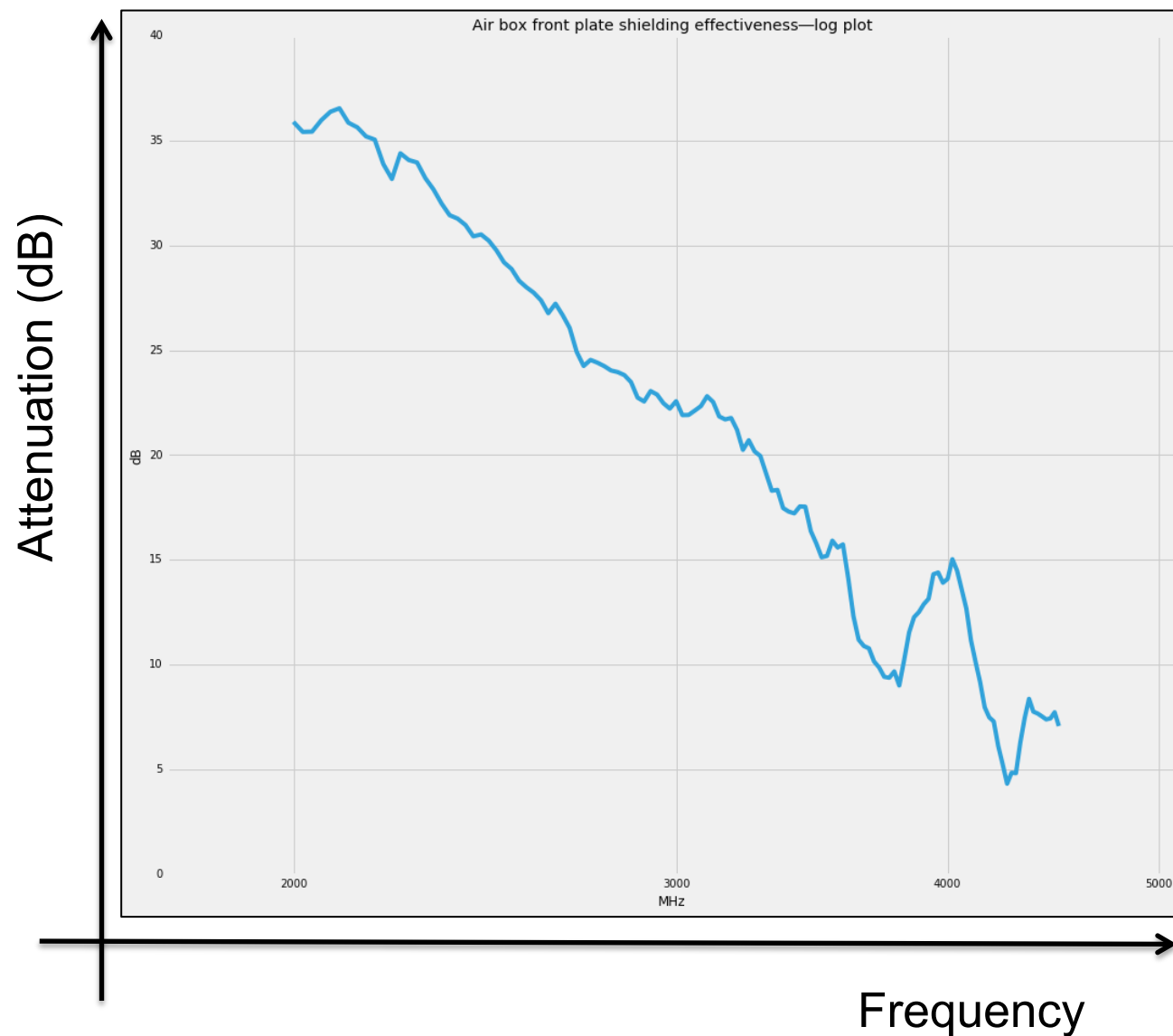


Optical Streak Camera



DIM Optical Streak Camera

OTS Airbox Aperture Electrical Shielding Effectiveness



Typical Streak Camera Sweeps for NIF Systems

Diagnostic	Sweep Window	Notes
VISAR - A	4,9,21,47 (ns)	Updating to a choice of 8 selections
VISAR - B	6,14,31,71 (ns)	Updating to a choice of 8 selections
VISAR - SOP	4,14,45,90 (ns)	Adding gating capability
OST - Airbox	5,10,15,35 (ns)	Requires gating capability
Backscatter	3,6,16,40 (ns)	Only Uses 40 ns

Summary

- **Optical streak cameras are complex instruments and play an important role on several NIF diagnostics systems requiring sophisticated measurement techniques.**
- **Camera warp correction calibrations are required in order to get reproducible accuracies of 2%.**
- **Fiber based recording systems allow for multi channel acquisition of complex data sets that can reduce the channel cost of the program.**
- **External comb injection capability can extend the camera accuracy for critical measurements . (0.5%-1%)**
- **New Airbox camera is now being designed for Optical Thomson Scattering**
- **New cathode gating will be deployed for VISAR and Optical Thomson Scattering**

NIF

