NSTX-U GPI Zoom Optics Upgrade

November 4, 2015

1 Design

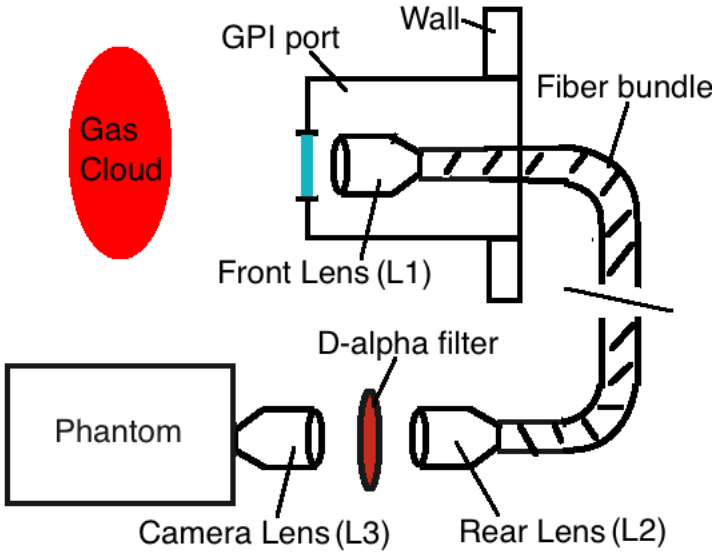
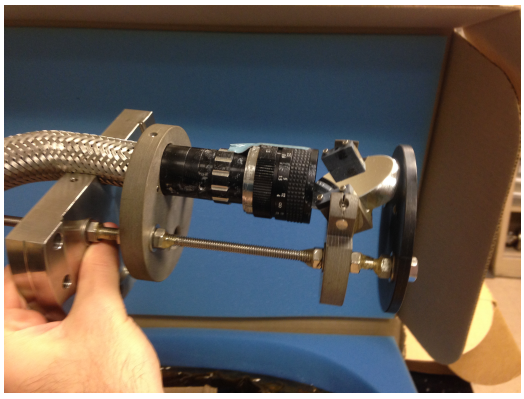


Figure 1: Schematic



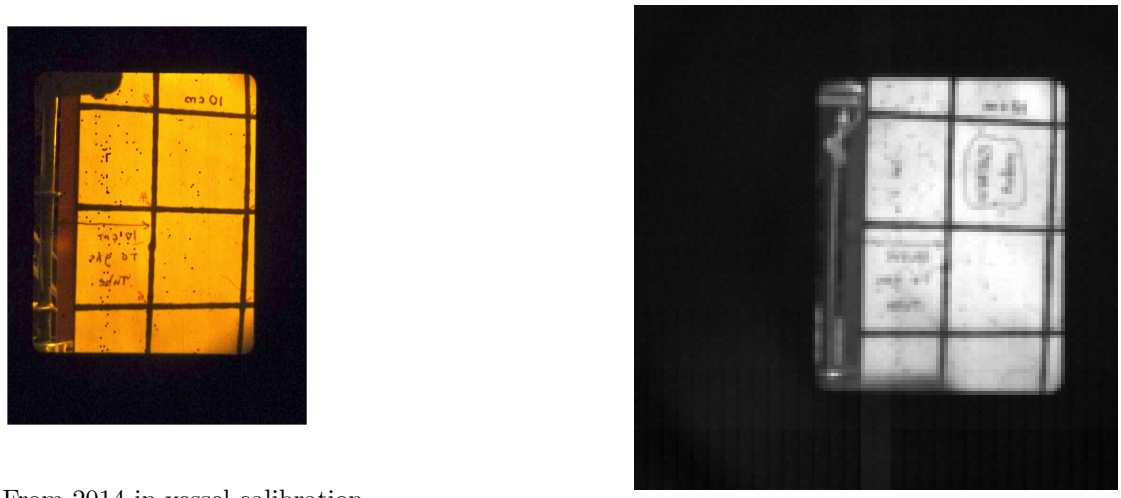
(a) Old 2010 optics

(b) New zoom optics

Figure 2: Front end optics

2 Calibration Procedure

1. Mount old optics on optical bench, so that view looks at calibration plate mounted ~ 55 cm from mirror.
2. Use 128x128 camera resolution so that bundle image is not cut off.
3. Set camera zoom lens (L3) to $f_3 = 8$mm.Compare image to 2014 calibration image. Adjust position of calibration plate until images match. This determines the correct position of the calibration plate relative to the optics mounted on the optical bench. See Figure 3.



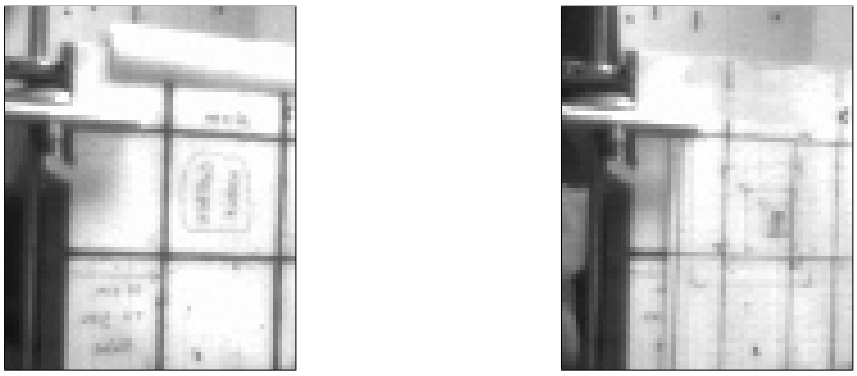
(a) From 2014 in-vessel calibration

(b) Lab recreation of 2014 calibration

Figure 3: Old (2010) optics calibration

4. Mount new optics.
5. Use 80x64 camera resolution.
6. Set L3 to $f_3 = 50$mm, and front zoom lens (L1) to $f_1 = 8$mm. Note position of image. Set L3 to $f_3 = 8$mm, and L1 to $f_1 = 50$mm. Position of image should be the same as previous. If not, adjust tilt angle of 50mm camera-facing fixed focal length lens (L2). Repeat until images match. This determines alignment of back-end lenses (L2 and L3).

   Note: Image of bundle will probably be uncentered when L3 is zoomed all the way out, as in Figure 3b.



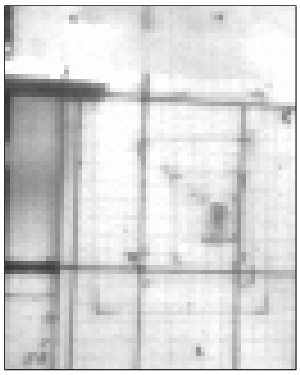
(a) View A w/ old calibration plate

(b) View A w/ new calibration plate

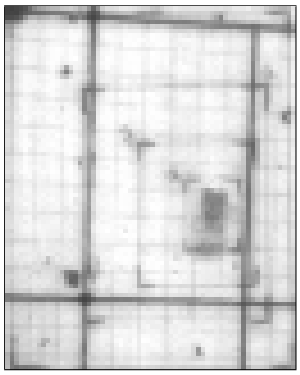
Figure 4: Reproduction of 2010 view with new optics

7. Set L3 to $f_3 = 25$mm, and L1 to $f_1 = 8$mm. Adjust mirror angle until horizontal viewing area is same as 2014 calibration image. Imaged region will probably be slightly higher than 2014 calibration image (see Figure 4a from new optics, compared to Figure 3b with old optics). Make note of final mirror angle. These settings will be called 'View A', which is the closest representation of the old optics view using the new optics. Record image with old calibration plate (Figure 4a) and new calibration plate (Figure 4b).

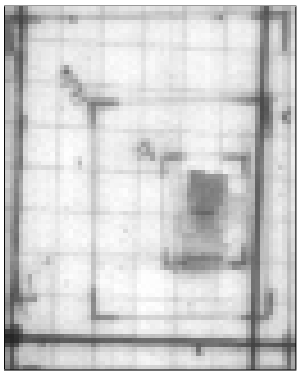
8. Record several images of new calibration plate, varying front zoom lens (L1) from $f_1 = 8$-48mm. Leave camera zoom lens (L3) at $f_3 = 25$mm, and mirror angle at 'View A' setting. These settings will be called 'Views B-E'. Mark corners of each view on new calibration plate; see Figure 5. For each view, measure horizontal width and vertical height of view region. Measure horizontal and vertical distance from center of view to calibration point 3 (from original calibration plate).



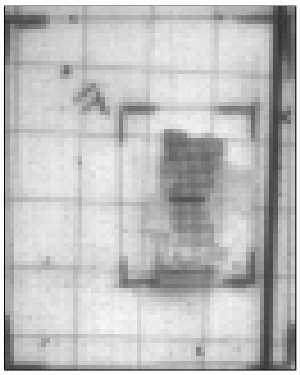
(a) View B: $f_1 = 12$mm, $f_3 = 25$mm



(b) View C: $f_1 = 20$mm, $f_3 = 25$mm



(c) View D: $f_1 = 30$mm, $f_3 = 25$mm



(d) View E: $f_1 = 48$mm, $f_3 = 25$mm

Figure 5: Zoom views with new optics

9. Set L1 to $f_1 = 48$mm. Set L3 to $f_3 = 48$mm. This final view, called 'View F' will be the maximum possible zoom of the optical system. Mark corners of view on calibration plate, and repeat measurements as in (8). See Figure 6.

10. For each view, change mirror angle to measure horizontal shift distance of view per degree.

11. Move all settings away from Position X. Return settings to Position X. Ensure that image matches image recorded for Position X in (10) to verify repeatability.

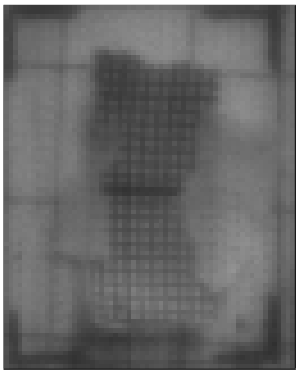


Figure 6: View F: $f_1 = 48\text{mm}$, $f_3 = 48\text{mm}$

3 Calibration Data

		SETTINGS		DATA	(all lengths cm)	center position relative to point 3:		
label	f1	f3	mirror angle	horizontal width	vertical height	horizontal	vertical	horizontal distance per degree mirror angle
A	8	25	4°	25	30	12	5.5	
B	12	25	4°	17	21	8.5	4.5	
C	20	25	4°	10.5	13	7.5	3.5	2.5
D	30	25	4°	6.9	8.45	6.5	3.5	2.5
E	48	25	4°	4.4	5.1	5.8	3.2	2.5
F	48	48	4°	2.1	2.6	5.3	2.3	2.5