Optimal resolution for a fibre bundle imaging system using a phosphorus based pinhole camera

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Testing the optimal resolution of a pinhole camera using a fibre bundle, Negative resolution target and objective. Measurements were made when target was 2mm away from cylinder and 13mm away from cylinder, the distance change is due to the hopeful progression into using the Phosphorous plate in conjunction with a Thompson.

1 Introduction

Testing the resolution prior to main experimental use means the best possible resolution can be quantified using modulation Transfer Functions (MTF) in a standardised format [1]. Mathematically the resolution spot size can be found as long as the distance, wavelength and f number is known.

This report goes through characterisation resolution of a test target, presenting the test target when it is placed at closest possible distance from the cylinder and at the distance the phosphorus plate will be placed (13mm) to find out the resolution change, the efects the distance has on the resolution and how much the resolution decreases with distance.

2 Setup

The equipment set-up was the fibre bundle and cylinder (that is used for the X-ray pinhole) which contained an adjustable lens inside. At one end was the resolution target with the green light LED backlighter and the other end had the Neo camera with a F/1.4 objective and 20mm spacer. The software exposure time was 0.04 seconds and the frame rate was 18.

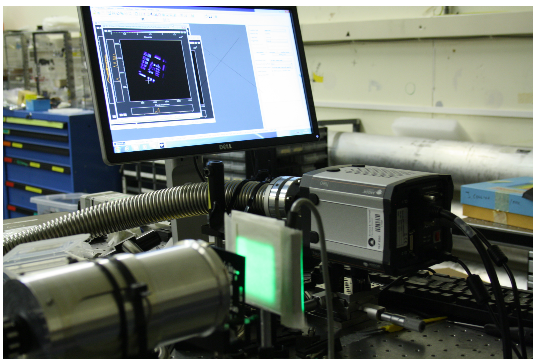

Figure 1: Equipment setup including backlighter, resolution target, cylinder, fibre and camera.

The order of the process was the LED backlight plate which illuminates the resolution target down the cylinder and fibre bundle to the objective which then focused the fringes on to the Neo camera chip.

After hardware setup the camera needed to be focused to optimal resolution so that the Modulation Transfer Function could be calculated and plotted after the images were taken (the lower limit resolution is 0.5 Relative modulation).

Once the camera was focused 2 sets of data were recorded. One at the the closest possible distance to the cylinder and fibre (*see Figure 2*). The second recording at the same distance as the phosphorous plate sits from the cylinder. A third image of the background was recorded for comparison if needed at a later date. (*see appendix 6.1 for resolution target*)

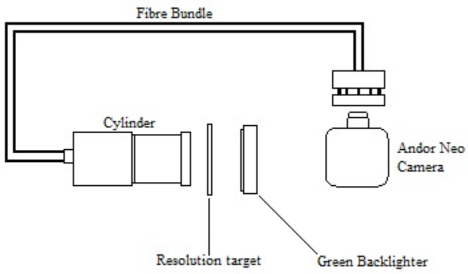

Figure 2: Schematic of the experiment setup

3 Results and Analysis

Using the modulation transfer function (Equation 2) meant the image was used for the intensity maximum and the intensity minimum of the fringes (Figure 3). The intensities were recorded, per fringe, then averaged over the peaks or troughs in its box section. These averages calculated the MTF, however, the background value was subtracted before plotting.

$$MTF = (Imax - Imin)/(Imax + Imin) \quad (1)$$

The graph displays the relative modulation against cycles/mm, the lower resolution limit is 0.5 Relative Modulation (Figure 4/5). At the closest distance the resolu-

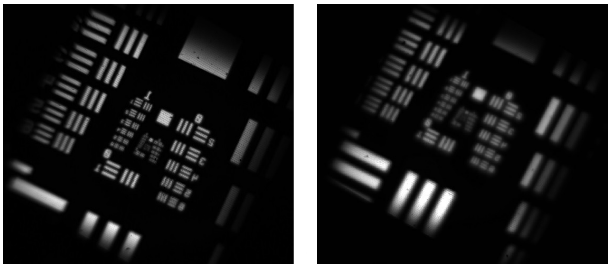

Figure 3: Picture of the grey-scale produced from the resolution target at both 2mm (left) and 13mm (right) distance from the cylinder

tion limit is 1.25 cycles/mm, on the test target fringes number 0,3. At the phosphorous plate distance away (13mm) from the fibre the number of cycles/mm is now 0.75 with the test target fringe number of -1,4. [2]

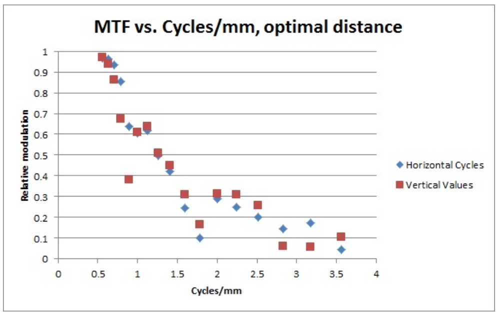

Figure 4: Graph of the relative modulation of the cycles/mm of the test target at closest possible distance to the cylinder (2mm)

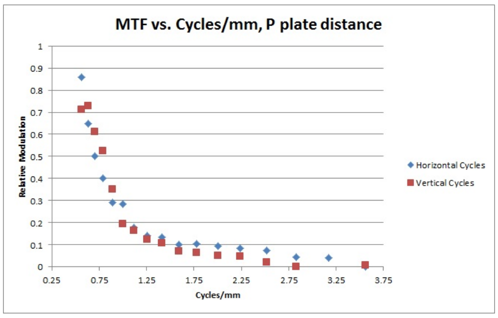

Figure 5: Graph of the relative modulation of the cycles/mm of the test target at the same distance as that of the Phosphorus plate (13mm)

Looking at both target results there is a steeper decline in the resolution target that is further away. The lower resolution limits of both graphs have a difference of 0.5 cycles/mm. The spread of difference between the horizontal and vertical fringes is less sporadic in the target placed further away.

4 Conclusion

When placing the resolution targets at the closest possible distance the lower resolution limit is 1.25 cycles/mm. When the distance was changed to a distance equal to the phosphorous plate (13mm) the lower resolution limit decreased to 0.75 cycles/mm. As expected the resolution limit decreases as the distance increases.

References

[1] *Edmund Optics - Introduction to Modulation Transfer Function* http://www.edmundoptics.eu/resources/application-notes/optics/introduction-to-modulation-transfer-function/

[2] *Thorlabs - 1951 USAF Resolution Test Targets, 3" x 3"* http://www.prodyntech.com/wp-content/uploads/2013/10/Baluns-11-22-2013.pdf

5 Appendix

5.1 Resolution target

To find the resolution limit a resolution target was used (Figure 6), the grid system mean it was easy to find if you used in conjunction with the table below (Figure 7).

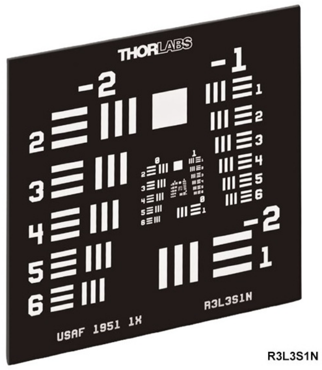

Figure 6: Thorlabs resolution target used in the experiment [1]

Element	Group Number									
	-2	-1	0	1	2	3	4	5	6	7
1	0.250	0.500	1.00	2.00	4.00	8.00	16.00	32.00	64.00	128.00
2	0.280	0.561	1.12	2.24	4.49	8.98	17.95	36.0	71.8	144.0
3	0.315	0.630	1.26	2.52	5.04	10.10	20.16	40.3	80.6	161.0
4	0.353	0.707	1.41	2.83	5.66	11.30	22.62	45.3	90.5	181.0
5	0.397	0.793	1.59	3.17	6.35	12.70	25.39	50.8	102.0	203.0
6	0.445	0.891	1.78	3.56	7.13	14.30	28.50	57.0	114.0	228.0

Values are in lp/mm.

Figure 7: Table showing the conversion of group number and element to cycles/mm [1]