AN015

Power Sensitivity of a CCD-based Hartmann Wavefront Sensor at 1064 nm

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In this application note we are documenting an experiment we ran on the sensitivity of a Sony CCD to 1064 nm radiation. The camera we used for this experiment was a Sony Smart Camera XCI-V100/XP. We mounted a 150-micron pitch 5.1-mm focal length lens array on the front of the device to make it into a Shack-Hartmann wavefront sensor.

Neutral Density Filter Characterization

Most absorptive ND filters are calibrated at a wavelength in the visible spectrum and attenuate light in the infrared spectrum significantly differently, so we began by characterizing a set of absorptive ND filters from ThorLabs with a ~5 mW Nd:YAG laser source. The table below summarizes the results of this characterization. In general, we found that the ND filters attenuated the 1064-nm light much less than they were rated for in the visible. Although the power meter head was rated down to the 10 nW range, the Coherent FieldMaster GS was only able to reliably read down to the 50 µW range, so our measurements could have been affected by this limited accuracy. We also report the transmission extracted from a graph provided by the manufacturer.

Part Number	OD	Input	After ND	Measured Transmission	Manufacturer Estimated Transmission
	0	5.37	5.37	100.00%	
NE05B	0.5	5.37	1.8	33.52%	35%
NE10B	1	5.31	0.47	8.85%	7.00%
NE20B	2	5.25	0.28	5.33%	4.00%
NE30B	3	5.33	0.06	1.13%	0.80%

We found with this CCD that exposure intervals less than 100 µs caused very significant background streaking, so we used 100 µs as our minimum exposure. At this exposure level, we found that the incident beam needed to be attenuated with a 1.0 and a 0.5 OD filter to a power level of 5.3 µW. We then were able to change the exposure to 66 ms leaving the gain at 0 dB and achieve a reasonable signal at an incident power level of 36 nW. By adding 18 dB of gain, we were able to drop the power level to 9.5 nW and still achieve a good signal, but we needed to do background subtraction of the dark image due to some pixels having a large signal due to the gain increase. The following table summarizes our results.

ND Configuration	Total Transmission	Incident Power (W)	Camera Exposure (ms)	Camera Gain (dB)	Maximum Intensity	Background Subtraction
1+0.5	2.96689%	5.3404E-06	0.1	0	85%	No
3+2+0.5	0.02012%	3.62238E-08	66	0	89%	No
1+2+3	0.00531%	9.5653E-09	66	18	94%	Yes

Conclusions

In this testing, we were able to show that a standard CCD can be tuned over a 147:1 range of incident power levels at 1064 nm by only changing the exposure time. By changing the gain from 0 to 18 dB, we were able to increase the range to 560:1. We were also able to show that the camera was sensitive down into the nanowatt regime.