OPTI 415/515 Final May 11, 2011

Undergraduate students choose any two problems. Graduate Students do all three problems.

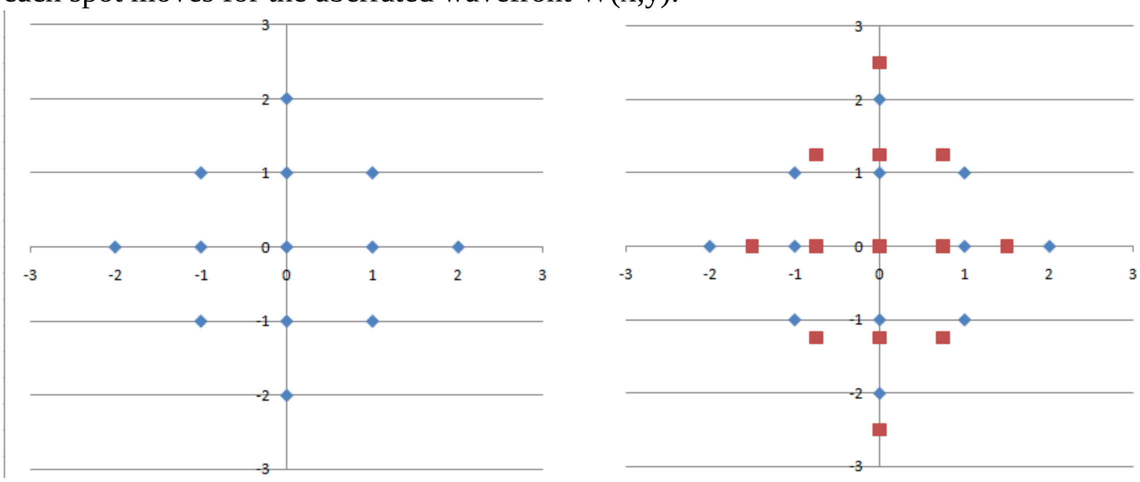
1. Suppose we have a wavefront error given by $W(x,y) = W_{22}(x^2 - y^2)$.

   (a) For a Shack Hartmann sensor with lenslets of focal length = f and pitch = p, write an expression for the displacement of the spots formed by the lenslets.

   The displacements of the spots are given by

$$\Delta x = -f\frac{\partial W(x,y)}{\partial x} = -2W_{22}fx \quad \textit{and} \quad \Delta y = -f\frac{\partial W(x,y)}{\partial y} = 2W_{22}fy\,.$$

   (b) The lenslet focal length f = 10 mm, the pitch p = 1 mm and $W_{22} = 0.0125\ mm^{-1}$. The figure below shows the spot pattern for a system with a 4 mm diameter pupil. Show how each spot moves for the aberrated wavefront W(x,y).



   (c) If we use a 2/3" CCD array (Dimensions 8.8 x 6.6 mm) to record the spot pattern. What is the largest value of W_{22} that will keep all of the spots on the sensor?

   Rearranging the spot displacement in the vertical direction gives

$$\Delta y = 2W_{22}fy \Rightarrow W_{22} = \frac{\Delta y}{2fy}$$

   The uppermost spot will be on the edge of the sensor when $2 + \Delta y = 3.3$*, so* $\Delta y = 1.3$ *mm. This means the largest value of* W_{22} *is given by*

$$W_{22} = \frac{1.3}{2 \cdot 10 \cdot 2} = 0.0325\,\text{mm}^{-1}$$

2. Suppose we measure the same wavefront error $W(x, y) = W_{22}(x^2 - y^2)$ with a Twyman-Green interferometer with $\lambda = 0.6328$ μm. The reference beam has an irradiance of 1 unit, while the test beam has an irradiance of 0.04 units.

(a) Write an expression for the interference pattern for this wavefront error. You can assume the relative phase difference $\phi = 0$.

The interferogram is given by

$$I(x, y) = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\left[\frac{2\pi}{\lambda} W_{22}\left(x^2 - y^2\right)\right]$$

(b) What is the visibility of the fringe pattern?

$I_1 = 1$ and $I_2 = 0.04$. The visibility is given by

$$\text{Visibility} = \frac{2\sqrt{0.04}}{1.04} = 0.385\,.$$

(c) For $y = 0$, what is the separation between bright fringes?

Bright fringes occur when

$$\frac{2\pi}{\lambda} W_{22} x^2 = 2m\pi \Rightarrow x_m = \sqrt{\frac{m\lambda}{W_{22}}}\,.$$

The separation between two adjacent fringes is

$$x_m - x_{m-1} = \sqrt{\frac{m\lambda}{W_{22}}} - \sqrt{\frac{(m-1)\lambda}{W_{22}}}\,.$$

(d) We use a CCD array with 10 μm square pixels to capture an image of the interferogram. The interferogram has a diameter of 4 mm on the sensor. What is maximum value of W_{22} that keeps the spacing between the bright fringes to at least 2 pixels? HINT: The narrowest fringe spacing occurs along the x-axis at the edge of the interferogram.

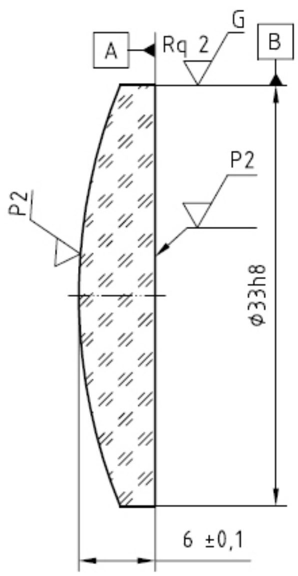
For $x_m = 2\,\text{mm} = \sqrt{\frac{m\lambda}{W_{22}}} \Rightarrow m = \frac{4W_{22}}{\lambda}$ *.The fringe spacing at this point is*

$$x_m - x_{m-1} = \sqrt{\frac{4W_{22}\lambda}{\lambda W_{22}}} - \sqrt{\frac{(4W_{22}/\lambda - 1)\lambda}{W_{22}}} = 0.02$$

$$2 - \sqrt{\frac{(4W_{22} - \lambda)}{W_{22}}} = 0.02$$

$W22 = 0.00795 mm^{-1}$.

4. Describe the meaning of all of the various features and codes in the attached ISO 10110 drawing.



Surface 1		Material specification		Surface 2	
R	37,449 CX	Hoya LaC9 or Schott N-LaK9		*R*	∞
$\varnothing_e$	30,5			$\varnothing_e$	29
Protective chamfer 0,4 to 0,6		*n* (1 060 nm) 1,675 9 ± 0,001		Protective chamfer 0,4 to 0,6	
(λ)	AR 209.1060	*ν*	—	(λ)	AR 209.1060
3/	5 (1)	0/	20	3/	5(1)
4/	1,4′	1/	5 × 0,1	4/	—
5/	5 × 0,1; C 5 × 0,16; L 3 × 0,004; E 0,4	2/	1; 2	5/	5 × 0,1; C 5 × 0,16; L 3 × 0,004; E 0,4
6/	—			6/	—
Indications in accordance with ISO 10110				Lens 114.379	