EECS 243 – Advanced IC Processing and Layout

Fall 2000 **Office Hours** **Prof. A. R. Neureuther,**
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Solution Homework #3

3.1 Pupil Energy Distribution and Image Quality.

a) $2(2\pi)/\lambda = 2\pi/P_x$ => $P_x = \lambda/(2 \sin 20^o) = 363$ nm. $E_{max} = ½ + 1/\pi = 0.818$; $E_{min} = ½ - 1/p = 0.182$; => $I_{max} = 0.70$; $I_{min} = 0.033$ => C = 0.91.

b) Six plane waves make it through the lens. When the lens radius is normalized to unity as in the definition of the pupil functioon they are located as follows. 0,0 at (0.684, 0) = ¼ amplitude => 1/16 energy; 0,1at (0.684,0.684) = $1/2\pi$ => $(1/2\pi)^2$; 0,-1 at (0.684, -0.684) = $1/2\pi$ => $(1/2\pi)^2$; -1,0 at (–0.684,0) = $1/2\pi$ => $(1/2\pi)^2$; –1,0 at (–0.684,0.684) = $1/\pi^2$ => $1/\pi^4$; -1,-1 at (–0.684,-0.684)) = $1/\pi^2$ => $1/\pi^4$. (While 25% of the energy goes through the mask only 15.9% goes through the lens.

c) Doubling the period moves –1 order to the center of the lens and –2 to –0.684. Fortunately, the amplitude of –2 is zero so we are back to the two wave case of part a) and C = 0.91 as before. The interference fringe between –1 and 0 moves at an angle of $\sin^{-1}[(\sin 20^{o)}/2]$ = 9.85 degrees. The one sided DOF is [(1/4)(363nm)]/sin 9.85^o = 531 nm.

3.2 Small Feature Limit (Splat simulations assume $\sigma = 0.5$)

a) $I_{peak} = 8.55(0.2)^4 = 0.0136$; SPLAT = 0.012

b) $I_{min} = 1 - 2\ \mathrm{sqrt}(I_{peak}) = 1 - 2(0.117) = 0.767$; SPLAT = 0.77

c) $I_{min} = 1-2(1-\cos\phi)\ \mathrm{sqrt}(I_{peak}) = 1-2(1-(-0.5))(0.117) = 0.649$; SPLAT = 0.67

d) Worst possible situation is that the diffraction spreading from the defect that fills the full pupil edges picks up anther 60^o phase relative to the clear field beam going down the axis. I_{min} = 1-2(1-(-1)) sqrt = 1-2(2)(0.117) = 0.532; SPLAT 0.58

```
# Input Splat Code Here
2: 0.248
3: 0.5
4: 0.0
5: 0.5 0.0
6: 3.0 3.0 1.0
27: 1.5 0.0 0.0 3.0 at 1.0
27: 1.5 1.455 0.0992 0.0992 at -1.0 <0.0>
27: 1.5 1.455 0.0992 0.0992 at 1.0 <120.0>
10:;
14: 0.0 1.5 3.0 1.5 'defect.txt'
0:end;
```

Example Input for "Input Splat Code' option in 'Pattern and Aberration Interaction' applet

3.3 Defect Interactions With Features (Splat simulations assume $\sigma = 0.5$)

a) Slope is 2.31/ λ/NA

b) Sqrt(0.3) = 0.548, Sqrt(I_{peak}) = 0.117 => $E_{Tot} = 0.665$ => $I_{TOT} = 0.412$

c) $\Delta I = 0.122$ => ΔI /Slope = 0.122/2.31 = 0.053 λ/NA or 26 nm (8.7% of the linewidth).

d) Surprise! The E field is negative and the linewidth will get smaller instead of bigger. E_{defect} = $(\cos\phi)$Sqrt(I_{peak}) = -0.5(0.117) = -0.059 => E_{Tot} = 0.0.489; I = 0.239; $\Delta I = -0.061$ => ΔI /Slope = -0.061/2.31 = -0.026 λ/NA = -13 nm or –4.3%.

SPLAT Results from reading 0.3 levels: no defect 1.50-0.88 = 0.62 λ/NA; 0^o phase defect 1.55 – 0.88 = 0.67 λ/NA => $\Delta L = 0.05$ λ/NA; 120^o defect 0.147 –0.89 = 0.58 λ/NA. => $\Delta I = -0.04$ λ/NA. Note: The phase defect case was input by editing statement 27 and changing <0.0> to <120.0> in the SPLAT file.