

Lab 1: Spatial Filtering — Executive Summary

Sessions 1–7 — Ahilan & Nathan

Repository: <https://github.com/Ahilan-Bucket/phys332W-sfu/tree/main/Lab1-SpatialFiltering>

Main Figures

Figure	Description	Page
Fig 1	Experimental setup sketch (Köhler illumination)	3
Fig 2	Error/placement sketch (lens orientation issue)	14
Fig 3	Updated sketch with corrected lens orientations	26
Plots B i–iii, C	Prelab Q2: Fraunhofer diffraction vs N , a , b/a	15–21
Sketch 1	Top view of secondary rail & Fourier arm setup	43
Images 4, 5	Dual-camera optics setup & LabVIEW interface	48
Figure 1	Ray sketch of back-reflection (image doubling)	58
Figure 2	Fourier camera positioning idea	64
Fig 6.1	Diffraction pattern with order spacing measurements	67
Fig 6.2a–b	LabVIEW screenshots: default vs blocked orders	68
Fig 6.3	Fourier mask setup (Allen key on translation stage)	69
Fig 6.4a–b	Mask configurations (Allen key, iris)	70
Fig A.1–A.6	Model overlay plots for Cases (a), (b), (d), (e), (f), (j)	74–76
Fig 7.1	Thorlabs birefringent target setup	97
Fig 7.2	Case I — Reference (all visible orders transmitted)	92
Fig 7.3	Case C — Zero order only (DC component)	92
Fig 7.4	Case H — Orders 0, +1 (Abbe minimal criterion)	92
Fig 7.5	Case K-m3 ($m_{\max} = 3$, orders 0, ± 1 , ± 3)	93
Fig 7.6	Case K-m5 ($m_{\max} = 5$, orders 0, ± 1 , ± 3 , ± 5)	93

Main Tables

Table	Description	Page
Table 6.1	Measured vs theoretical diffraction order positions	67
Table 6.2	Summary of spatial filtering results (cases a–k)	74
Table 6.3	Quantitative support for Abbe criterion (Case B vs D)	76
Table 6.4	Quantitative comparison: all orders (A) vs dark-field (J)	78
Table 6.5	Uncertainty sources for calibration (random vs systematic)	79
Table 6.6	Calibration results: λ , f , a with uncertainties	79
Table 7.1	Phase object imaging technique comparison (contrast values)	101
Table 7.2	Measured Gibbs ringing parameters ($m_{\max} = 3, 5, 7$)	91

Boxed Conclusions

Session	Result	Page
1	Köhler illumination: $M_{\text{field}} = 2$, $D_{\text{FS}} = 2.5$ mm for 5 i mm FOV	
1	Sharp focus achieved with equipment square to optic axis	6
2	Resolved 12.5 lp/mm grating (exceeded 10 lp/mm goal)	11
2	Non-uniform illumination caused by L4/L5 lens orien- tation errors	14
3	Uniform illumination achieved after corrections	28
3	Measured magnification $M \approx 1.585$ (expected $M = 2$)	29
4	Dual-camera Fourier plane system operational	48
4	BS placed at 82 ± 0.05 cm; FL at 29 cm on secondary rail	44, 46
5	Image doubling resolved via condenser lens realign- ment	58
5	Effective focal length $f_{\text{eff}} = 139$ mm measured	61
5	Confirmed overlap of 26+50 lp/mm diffraction orders	63
6	Grating calibration: $a = 100 \pm 3 \mu\text{m}$ (10 lp/mm con- firmed)	79
6	50% duty cycle confirmed (even orders suppressed)	67
6	Frequency doubling observed in Case (f): $m = \pm 1$ only	72
6	Abbe criterion: Case D (126.6 units) vs Case B (47.2 units)	76
7	B3 Gibbs overshoot: 23.4%, 10.4±6%, 11.7±6% for $m_{\text{max}} = 7, 5, 3$	91
7	Phase object: dark-field contrast = 0.84 (best tech- nique)	101
7	χ^2/DoF : Case A = 1.533; Cases B/C ≈ 0.02 (model fits)	102
7	Fitted parameters: $\lambda = 525 \pm 86$ nm, $f = 202.2 \pm 0.1$ mm	79

Summary

Sessions 1–3 established the Köhler illumination optical train, diagnosed and corrected lens orientation errors causing non-uniform illumination, and verified 12.5 lp/mm resolution with $M \approx 1.6$ magnification. Sessions 4–5 completed Setup 2 by adding beam splitter and secondary Fourier camera arm, resolved image doubling through condenser lens realignment, and measured $f_{\text{eff}} = 139$ mm with resolution tests on 26 and 50 lp/mm gratings. Sessions 6–7 demonstrated spatial filtering techniques including low-pass, high-pass, dark-field, and Schlieren filtering on amplitude and phase objects; calibrated the grating period ($a = 100 \pm 3 \mu\text{m}$) with χ^2/DoF analysis confirming model validity; quantified Gibbs ringing ($\Lambda_{\text{ring}} = a/m_{\text{max}}$, overshoot 10–23%); and confirmed dark-field (contrast = 0.84) as optimal for phase object imaging.