SF data analysis notes B2/B3

February 1, 2026 8:21 PM

- Some data sets had a different period shift/translation
- Some data sets seemed to have a very slightly different period size
- Most data sets had different amplitude stretches and noise levels

1. Abbe Minimal Criterion (Case D: 0, +1)

Your data shows:

D (orders 0, +1): Range = 126.6 intensity units with clear spatial variation
B (order 0 only): Range = 47.2 (mostly noise, no true spatial structure)
Explanation: The Abbe minimal criterion states that to resolve a periodic structure, you need at least the zeroth order AND one first-order diffraction component. Order 0 alone carries no spatial frequency information—it's just the DC (average) intensity. Case D transmits 0 and +1, which allows interference between these orders, producing a cosine-like intensity pattern at the fundamental spatial frequency. This is the minimum information needed to detect periodicity.

2. Dark-Field Filtering (Cases A vs J)

Your data shows:

A (all orders): mean = 74.9, std = 78.6, contrast = 1.05
J (all except 0): mean = 37.9, std = 17.3, contrast = 0.46
Explanation: Blocking the zero order removes the DC component (background illumination), leaving only the oscillating (edge/detail) information. This produces "dark-field" or "edge-enhanced" contrast because:

Uniform regions (no edges) contribute only to order 0 → appear dark

Edges/transitions scatter light into higher orders → appear bright
The result is an image where edges "glow" against a dark background.

B3: Order Cutoff and Gibbs Ringing
Measured Overshoot Amplitudes:

mmax	Orders	Overshoot (%)
All	0,±1,±3,±5,±7...	23.4%
5	0,±1,±3,±5	10.4%
3	0,±1,±3	11.7%

(Note: A shows higher overshoot likely due to noise and experimental variability)

Ringing Period (theoretical):

P = 58.6 pixels (grating period)
mmax=3: ringing period ≈ P/6 = 9.8 pixels
mmax=5: ringing period ≈ P/10 = 5.9 pixels
Why increasing mmax sharpens edges but doesn't eliminate ringing:

The Gibbs phenomenon is fundamental to truncated Fourier series—it's not an artifact of finite sampling. Even as mmax → ∞, the overshoot approaches a fixed value of ~9% of the step height.
Increasing mmax:

Sharpens edges by adding higher-frequency components
Reduces ringing period (oscillations become faster/finer)
Does NOT eliminate overshoot until infinitely many terms are included
The 9% overshoot limit is a mathematical property of the Fourier series at discontinuities.

Describe and explain what you see in all cases:

(a) Bright Field (unmodified diffraction pattern):

The phase grating is weakly visible with modest contrast (0.42)
Some visibility occurs because the object may have slight amplitude modulation or is slightly defocused
Pure phase objects at perfect focus would be invisible in bright field
(b) Phase Contrast (λ/4 plate on zero order):

Improved visibility (0.47) compared to bright field
The λ/4 retardation plate shifts the zero-order phase by 90°, converting phase variations into intensity variations through interference
This is the principle of Zernike phase contrast microscopy
(c) Dark Field (zero order blocked):

Highest visibility (0.84) - the grating lines are most clearly visible
By removing the zero order (DC component), only the diffracted light from edges/phase gradients reaches the image
Background appears dark; grating features appear bright
(d) Schlieren (one side of Fourier plane blocked):

Lower visibility (0.35) but produces directional contrast
Phase gradients in one direction appear as intensity differences
Useful for visualizing flow or gradients in a specific direction
Which technique is best for observing phase objects, and why?

Dark Field (c) produces the highest contrast for this phase grating because:

It completely removes the uniform background (zero order)
Only light scattered by phase gradients/edges is transmitted
This maximizes signal-to-noise for features that would otherwise be invisible
However, Phase Contrast (b) may be preferred when you need to preserve information about the sign of phase variations (positive vs negative), which dark field cannot distinguish.

Why is a pure phase object normally invisible?

A pure phase object changes only the phase of the transmitted light, not its amplitude. Since detectors (including eyes and cameras) respond only to intensity ($|E|^2$), uniform phase shifts are undetectable. The object becomes visible only when:

Phase variations are converted to amplitude/intensity variations (via filtering)
The light is slightly defocused (converting wavefront curvature to intensity)
Note: Your data shows some visibility even in bright field, likely due to:

Slight defocus