

Predicting Real-World Ghosting Using Typical Camera Parameters in ImSym

A Product-Specific Workflow for Accurate Stray Light Evaluation before Hardware is Available

Executive Summary

Predicting stray light accurately during optical design remains one of the most difficult challenges in imaging system development. Although optical simulation can identify potential ghost paths, engineers frequently encounter discrepancies between predicted stray light and what ultimately appears in captured images. The challenge becomes even greater when detailed sensor and ISP characteristics are unavailable during early design.

This application note demonstrates a practical workflow for reproducing real-world ghosting in **ImSym 2026** using only information that is typically available to lens designers and optical engineers. Rather than relying on proprietary camera models or exhaustive parameter characterization, the workflow combines:

- Patent-derived optical models
- Typical CMOS sensor characteristics
- Default ImSym ISP parameters
- Standard atmospheric and solar data

Using this approach, engineers can accurately reproduce the position, color and relative intensity of ghosting observed in a commercial camera photograph, enabling meaningful stray light evaluation long before physical hardware exists.

Engineering Challenge

Designing optical systems for low stray light traditionally presents three major challenges.

1. Evaluating Multiple Imaging Conditions

Ghosting depends on numerous variables, including:

- Field angle
- Light source position
- Scene brightness
- Reflection order
- Camera exposure

Running independent Monte Carlo ray traces for every condition quickly becomes impractical.

2. Bridging the Gap Between Optical Simulation and Camera Images

Many optical simulations evaluate irradiance at the image plane but stop before modelling the complete imaging pipeline. Engineers often encounter situations where optical metrics appear acceptable while objectionable ghosting becomes clearly visible in the final camera image.

3. Limited Access to Sensor and ISP Information

Accurate image reproduction requires detector and image-processing parameters that are rarely published by camera manufacturers. This frequently discourages optical engineers from attempting end-to-end image simulation.

ImSym Workflow

ImSym addresses these challenges through an end-to-end imaging simulation workflow.

The Stray Light Scanner stores stray light information generated across the field of view, allowing engineers to evaluate different operating conditions without repeatedly performing computationally expensive Monte Carlo ray tracing.

The imaging pipeline then models:

- Optical system
- Detector
- Image Signal Processor (ISP)
- Final rendered image

The remaining question is:

How accurate can image prediction become when detailed sensor parameters are unavailable?

This application note demonstrates that readily available reference values are sufficient for realistic ghost prediction.

Reference Measurement

The validation image was captured using:

Component	Specification
Camera	Sony a7C
Lens	50 mm F1.8
Aperture	F2.8
Exposure	1/800s
Environment	Outdoor, early morning
Scene	Sun partially within field of view

The photograph exhibits strong red ghosting in the lower-right corner together with weaker bluish artifacts.

The objective is to reproduce:

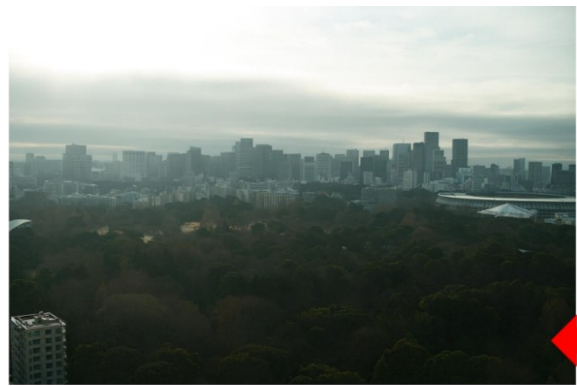
- Ghost location
- Ghost geometry
- Relative intensity
- Spectral appearance

rather than achieving pixel-perfect image reconstruction.

To isolate the ghost contribution, a version of the image with the ghost removed using generative AI is used as the scene input. Since ImSym generates the stray light independently, the precise AI reconstruction is not critical provided that scene brightness and shooting conditions remain representative.



Original image



Input image (ghost removal by AI)

Step 1 – Optical System Modelling

Accurate optical modelling remains the single most important factor affecting ghost prediction.

Because the commercial lens design was unavailable, the optical system was reconstructed using:

- Patent lens prescriptions
- Estimated lens barrel geometry
- Manufacturing knowledge
- Patent-derived coating structures

Even with this simplified model, the simulation reproduces the measured ghost remarkably well.

Engineers working with proprietary production lens models can therefore expect even greater agreement.

Step 2 – Coating Definition

Surface coatings dominate ghost intensity and color.

The coatings used in this study were modelled from patent information corresponding to the manufacturing period of the lens.

An especially important characteristic is the radial variation in coating performance.

Real deposited coatings exhibit reduced thickness towards the lens edge, producing increased long-wavelength reflectivity at large radii.

If this behavior is ignored and ideal coating performance is assumed across the entire surface, simulated ghost intensity becomes significantly underestimated.

ImSym 2026 includes Python automation that generates this coating scaling directly from coating definitions, greatly simplifying implementation.

Step 3 – Scene Radiance Definition

The input image is converted into a radiometric scene using the **Scene Object** properties.

The most important parameter is:

In-Band Scene Radiance

This value defines the radiance assigned to the brightest pixel (RGB 255).

For outdoor scenes, it may be tempting to use solar radiance directly. However, because the sun occupies only a small portion of the image while clouds are already saturated, this would excessively brighten the remainder of the scene.

Instead, the brightest cloud should be treated as the reference white.

Typical clear-sky cloud radiance values of approximately:

50 W/m²/sr

produce realistic results and correspond to the default value supplied with ImSym.

Spectral content can likewise be defined using the default blackbody daylight spectrum.

Step 4 – Detector Configuration

Only basic camera specifications are required.

For the reference camera:

- Full-frame sensor
- Approximately 24 MP resolution
- Exposure time: 1/800 s

From these values, ImSym requires:

- Exposure time
- Sensor dimensions
- Pixel count
- Pixel pitch

The remaining unknown parameter is the detector well depth.

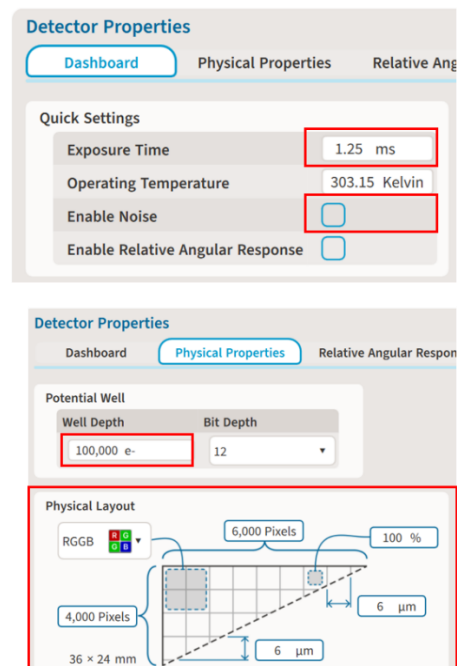
Although manufacturers rarely publish this value, numerous academic studies demonstrate a correlation between pixel size and full-well capacity.

For a modern full-frame sensor of this resolution:

100,000 electrons

provides a realistic approximation.

ImSym 2026 also includes twelve sample detector models covering common sensor categories, allowing rapid configuration without extensive research.



Step 5 – ISP Calibration

Radiometric calibration determines how accumulated detector charge maps to image brightness.

When using real scene images, excellent results are obtained by:

- Setting Saturation Radiance equal to detector well depth
- Setting Reference Radiance to approximately 80% of saturation

This establishes realistic gain without requiring detailed ISP characterization.

Step 6 – Defining the Stray Light Source

The final step is to define the external light source responsible for ghost generation.

Using the camera field of view, the sun position can be mapped directly from image coordinates.

For this example:

- Radial angle: 18°
- Azimuth: 230°

Solar irradiance is estimated from published atmospheric models.

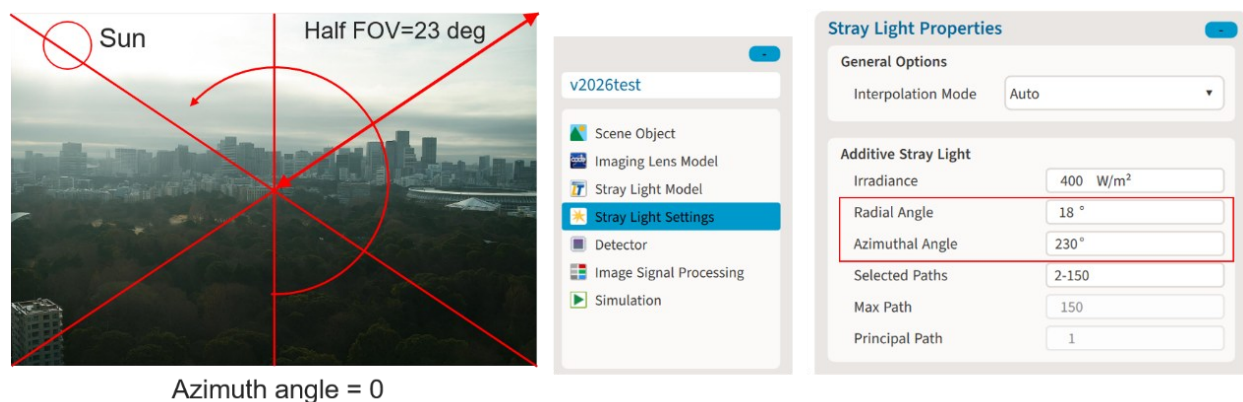
Considering:

- Early morning sunlight
- Thin cloud cover
- Atmospheric transmission

an irradiance of:

400 W/m^2

provides a realistic input and is entered using ImSym's **Additive Stray Light** settings.



Simulation Performance

Using ImSym 2026, this complete simulation requires approximately:

10 seconds per rendered image

on a modern workstation. This enables rapid iteration while evaluating different optical design options.

Results

The simulated image reproduces the key characteristics of the measured photograph:

- Dominant red ghost
- Secondary bluish ghost
- Correct ghost position
- Comparable relative intensity
- Similar overall visibility

The objective is not photographic duplication but engineering prediction of stray light behaviour before hardware is available.

Why Optical Modelling Matters More Than Sensor Modelling

Additional simulations were performed to investigate parameter sensitivity.

Replacing the patent-derived multilayer coating with a simple single-layer coating dramatically altered the ghost color, producing unrealistically strong blue ghosts.

Similarly, using a multilayer coating while ignoring radial performance degradation caused the dominant red ghost to nearly disappear.

These comparisons demonstrate that coating definition has a significantly greater influence on ghost prediction than modest uncertainty in detector or ISP parameters.

Typical detector values and default ImSym ISP settings remain sufficient for evaluating ghost visibility in many engineering applications.

Engineering Recommendations

For engineers seeking realistic stray light prediction during early development:

- Model lens geometry as accurately as possible.
- Invest effort in coating characterization, particularly radial coating variation.
- Use representative outdoor scene radiance rather than solar radiance as the image white reference.
- Estimate detector well depth from published reference data when manufacturer specifications are unavailable.
- Use ImSym default ISP calibration unless measured calibration data exists.
- Define solar position and irradiance using standard atmospheric models.

This workflow provides a practical balance between modelling effort and predictive accuracy, enabling meaningful evaluation of ghosting before physical prototypes are available.

Conclusion

This study demonstrates that realistic prediction of ghost visibility does not require complete knowledge of proprietary camera hardware.

Using readily available optical information together with typical detector characteristics and ImSym's default ISP settings, engineers can accurately reproduce the location, color and relative intensity of ghosting observed in commercial imaging systems.

The results also reinforce a key engineering conclusion: accurate optical modelling—particularly lens coatings and their real manufacturing behavior—has a much greater impact on ghost prediction than precise detector or ISP characterization.

By combining these practical modelling techniques with ImSym's end-to-end imaging simulation, engineers can evaluate stray light performance confidently during the design phase, reducing design iterations and identifying imaging issues before hardware is built.

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