Ghost image analysis

Lens Design OPTI 696A

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Ghost images

Lens systems are designed to form an image according to an ideal model. Light that passes through the stop aperture forms the image. However, some light may not contribute to the formation of the intended image and reaches the image plane to degrade the image. This light is known as stray light, flare, veiling glare, and ghost images.

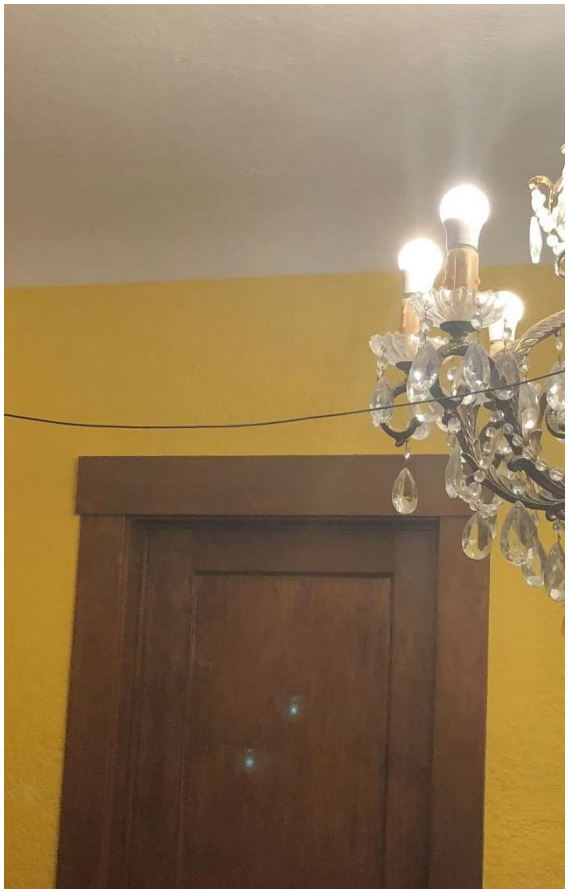
Ghost images of bright objects

Ghost images of the aperture stop

Ghost pupils

Ghost images

Cell phone photo



Ghost pupils

GHOST IMAGE ANALYSIS FOR OPTICAL SYSTEMS

By

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A Dissertation Submitted to the Faculty of the

COLLEGE OF OPTICAL SCIENCES

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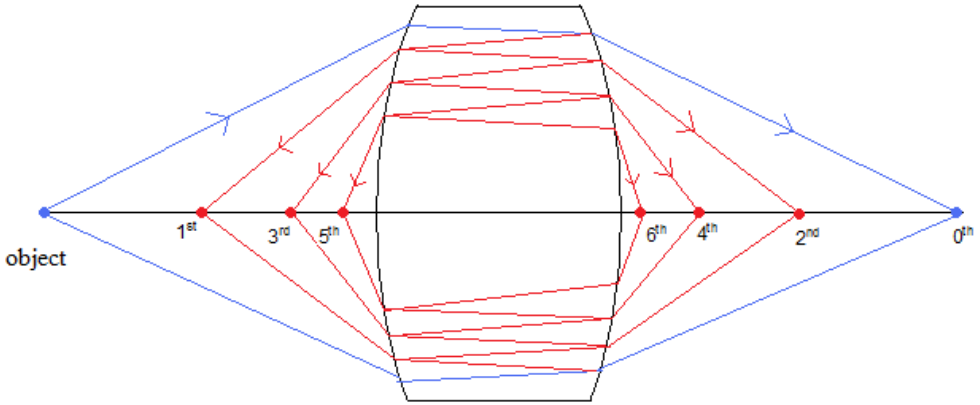
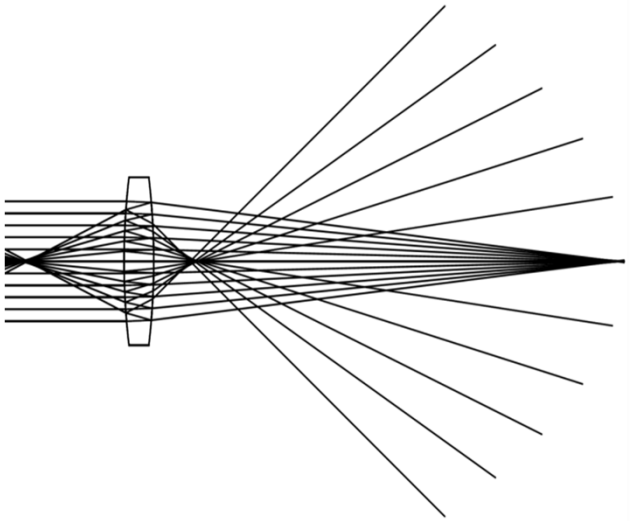
One, two, n bounces



$$R = \left(\frac{n-1}{n+1} \right)^2$$

Number of two-bounce ghosts



A singlet lens can have a single two-bounce ghost, a two lens system can have six, two-bounce ghosts, a three lens system can have 15 two-bounce ghosts, and the number of two-bounce ghosts increases as

$$k(k-1)/2$$

where k is the number of optical surfaces

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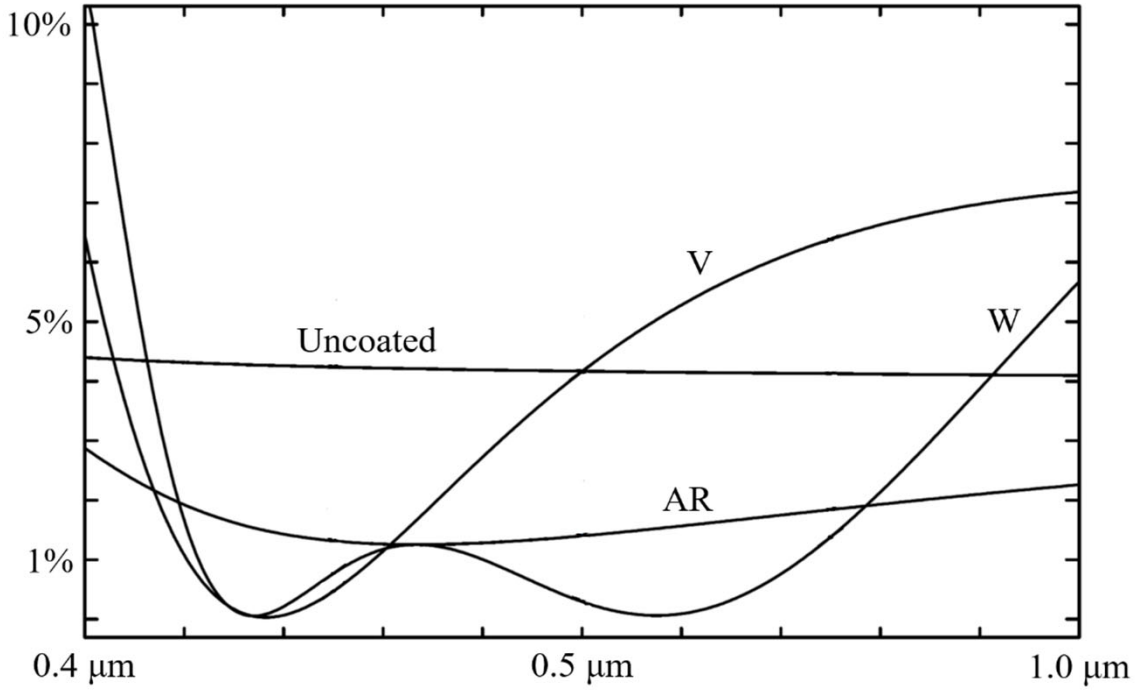
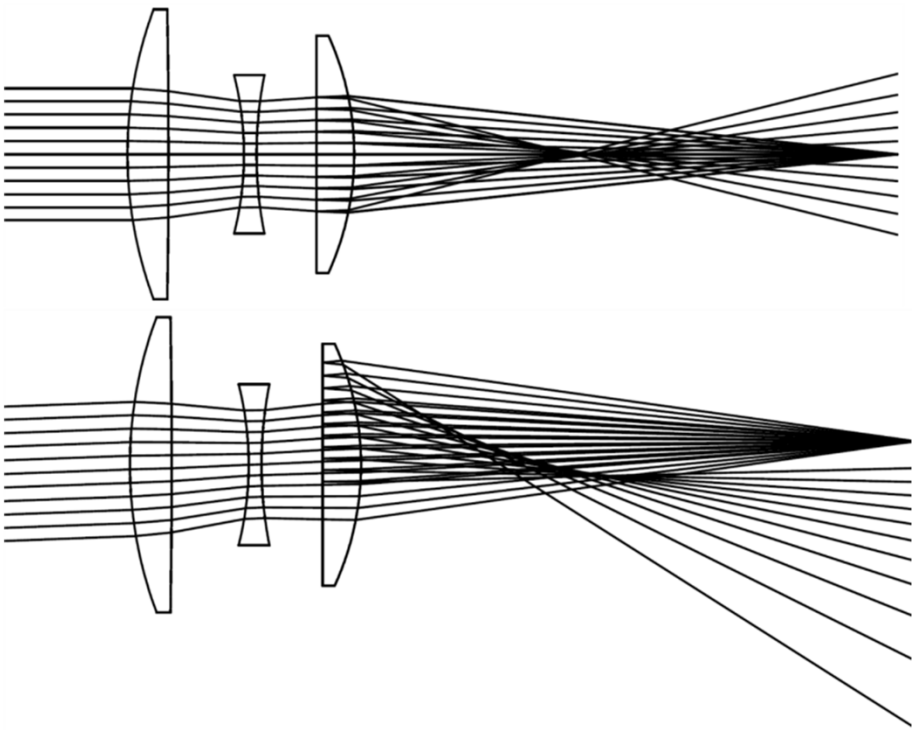
Anti-reflection coatings



First-order analysis

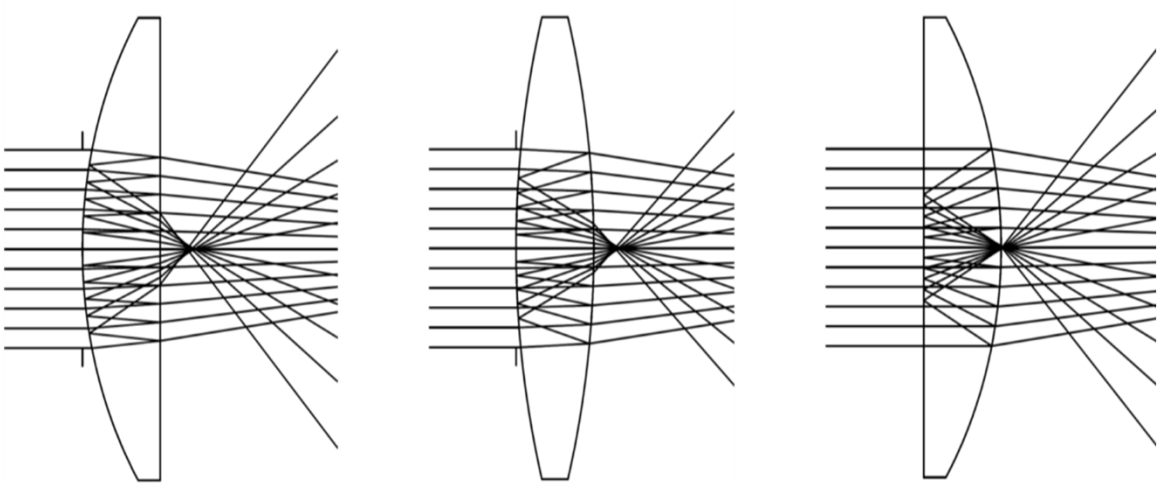
First-order ghost analysis for a Cooke triplet lens			
Reflection Surfaces	Distance to ghost pupil in mm	Distance to ghost in mm	F/#
2-1	-53.6	-54.7	0.98
3-2	-73.8	-58.9	1.42
3-1	-276.9	-65.63	1.32
4-3	-54.5	-61.1	0.75
4-2	-75.8	-87.5	1.23
4-1	160.1	-34.7	1.43
5-4	49.9	-34.9	1.4
5-3	-60.6	-64.8	0.98
5-2	-86.1	-101.4	2.26
5-1	-32.6	-43.6	1.25
6-5	-28.3	-40.4	0.66
6-4	-40.1	-51.6	0.97
6-3	-70.5	-53.7	0.91
6-2	-180.2	-74.9	0.95
6-1	-49.8	1556.9	103.8
7-6	-52.5	-51.4	0.97
7-5	-27.9	-23.4	2.4
7-4	-34.9	-38.4	1.28
7-3	-70.1	-67.6	1.43
7-2	-166.7	-122.4	4.7
7-1	-49.5	-47.2	1.45

Real ray tracing analysis

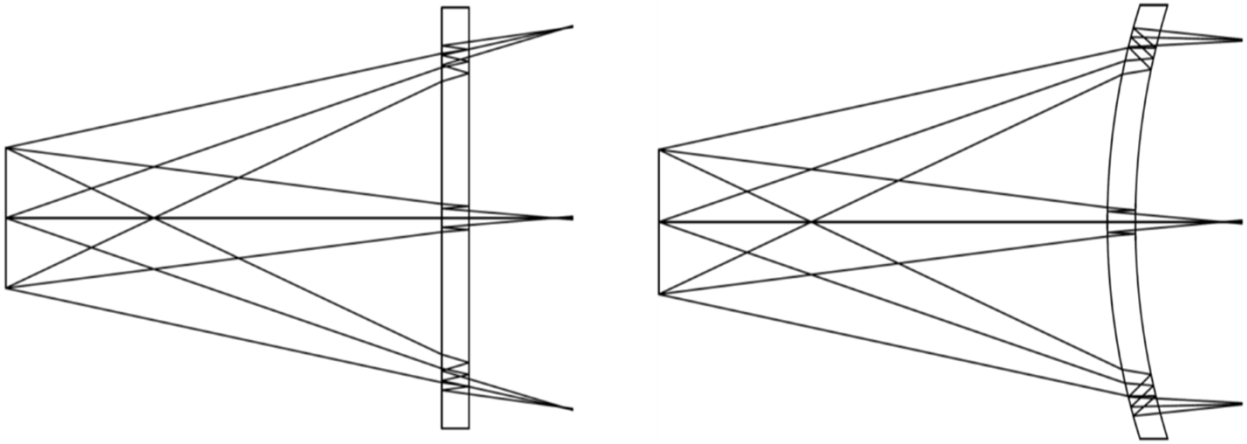


Thin lens ghost images

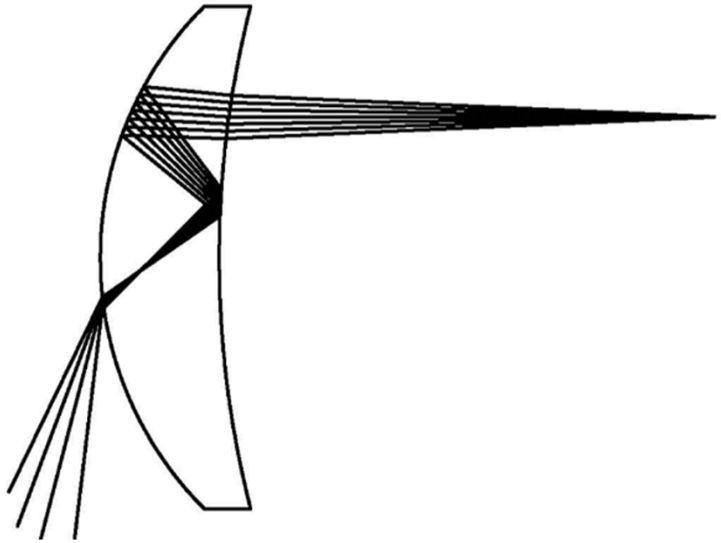
$$u' = -\phi y\left(3 + \frac{2}{n-1}\right) \approx -7\phi y$$



Parallel and concentric surfaces



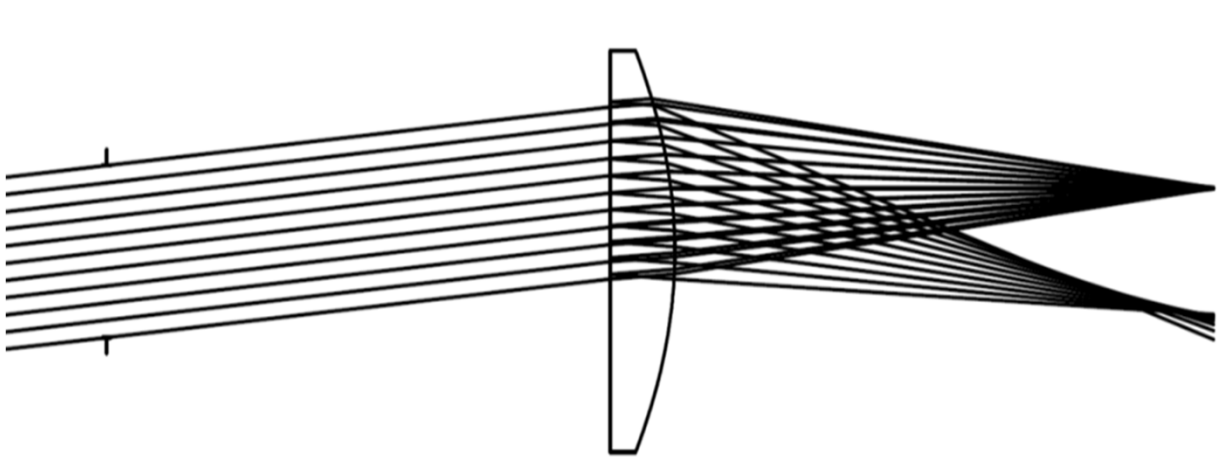
Total internal reflection ghost



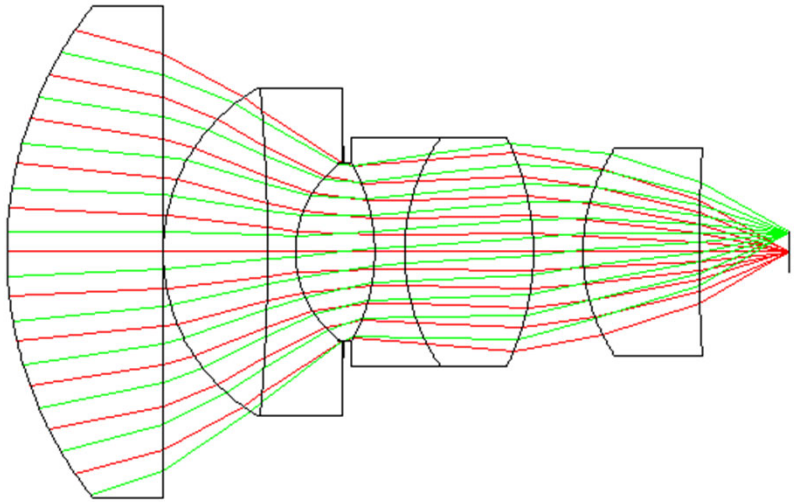
- TIR
- One reflection on the barrel
- On retaining rings

Narcissus retro-reflections

Yni=0



Narcissus retro-reflections



Surf	YNI
1	1.12615
2	-0.70035
3	0.91647
4	-1.14828
5	0.65152
6	-0.21530
7	-0.54348
8	0.61637
9	-0.43814
10	0.16971
11	-0.19229

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