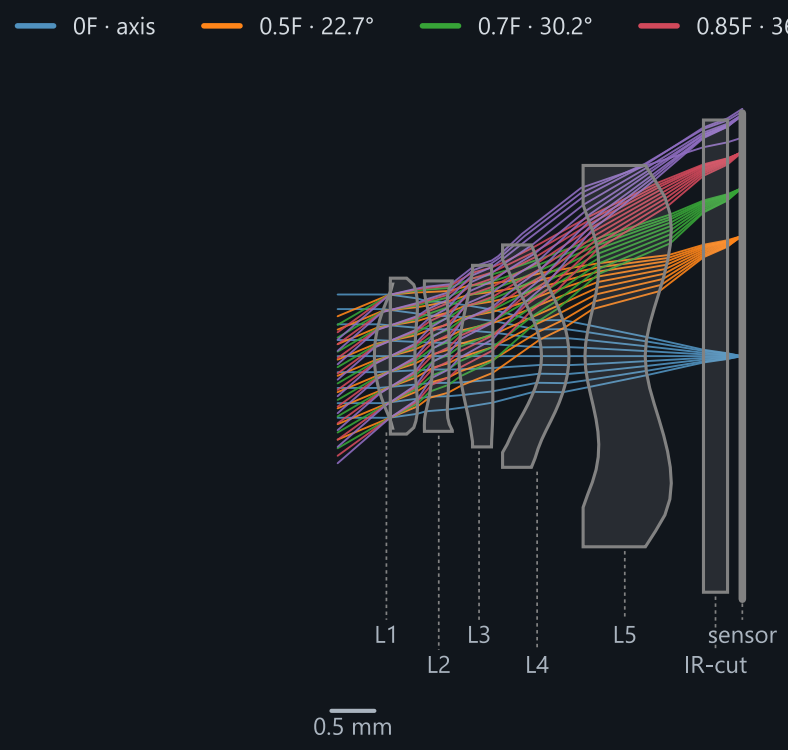
CASE STUDY 3 · FRONT CAMERA MODULE · OPTICS, THIN FILMS, NON-SEQUENTIAL

The front glass decides: flat is invisible, a bent edge is not

A phone's front holds three optical systems under one piece of glass: the selfie camera, the Face ID infrared camera with its 940 nm filter, and the infrared flood that lights the face. This study builds each from a published patent, verifies it against the patent's own numbers, and asks what the cover glass, the filter and the flood each cost.



Selfie lens, five plastic aspheres, rays from axis to the corner.

0.59
selfie MTF on axis at Ny/2 (225 lp/mm), Huygens

108 µm
astigmatism behind a 5 mm cover-glass bend, 10× the depth of focus

29 nm
blue shift of an oxide 940 nm band-pass at 30° AOI; the target is < 12 nm

0.23
flood irradiance min/max over the IR camera's field at 25 cm (σ 0.8)

Paraxial · generic branding · all numbers from saved API responses · summary edition

BACKGROUND 01

Three optical systems share one piece of glass

- **What it is.** The front of a flagship phone carries a selfie camera in a 3.3–3.7 mm punch-hole and, on Face ID phones, an infrared (IR) system: a flood illuminator that lights the face at 940 nm and a global-shutter IR camera that sees it through a narrow band-pass filter. All of it sits under the front cover glass.
- **Who uses it.** Everyone who takes a video call or unlocks a phone by looking at it, at 25–50 cm.
- **The question. Can the published lenses meet a compact-camera-module image spec, what does the 940 nm filter need from the IR lens, how uniform is the flood, and what happens when the camera sits under a curved part of the glass?**
- **Where it fits.** Case study 1 covers the rear main camera, 2 the telephoto and ultra-wide, 4 the environment. This one covers the front of the phone.

THE JOB 02

A compact-camera spec, a filter spec and a working distance

WHAT THE JOB NEEDS	SPECIFICATION	WHY
Selfie format	`12 MP, 1.12 µm, 4.48 × 3.36 mm`	2025 flagship class (research R3 [4])
Selfie lens	`EFL 3.3 mm, f/2.2, 80° DFOV`	R3 §1.1; 26 mm equivalent
Selfie image quality	`MTF axis Ny/4 > 0.70, Ny/2 > 0.40; to 0.8F > 0.55 / 0.30`	12 MP CCM spec (Steinich & Blahnik, R1 [25])
Selfie geometry	`distortion < 3 %, RI > 35 %, CRA < 30°, lat. colour < 3 px`	same CCM spec
IR camera	`1.4 MP, 2.8 µm, 940 nm, global shutter`	TechInsights die analysis (R3 [21])
IR field	`60–70° DFOV (assumption)`	R3 assumption 2: face plus margin at 25–50 cm
940 nm filter	`passband shift < 12 nm at 30° AOI`	Materion low-shift NBP (R3 [36])
Flood	`VCSEL + diffuser, 25–50 cm, Class 1`	R3 §2.1–2.3
Cover glass	`0.6 mm, n ≈ 1.51, bend R ≥ 5 mm`	R3 §3.1–3.2 (thickness, index: assumptions)

WHY IT IS HARD 03

Small pupils, steep rays and thin glass

- **Field against telecentricity.** An 80° selfie field puts chief rays on the sensor at up to 33°, and the IR lens puts its rays on the filter at up to 34°: a thin-film band-pass shifts blue with angle.
- **Narrow band against angle.** A narrower filter rejects more sunlight but loses its own signal sooner as the angle grows.
- **Industrial design against optics.** Curved glass edges look good; under a camera they are a cylindrical lens of a few millimetres radius.
- **Lighting against crosstalk.** The flood shines through the same glass the IR camera looks through; glass guides light sideways.

THE SELFIE CAMERA 04

The selfie lens is sharp to 0.85F; its corner and chief-ray angle are not

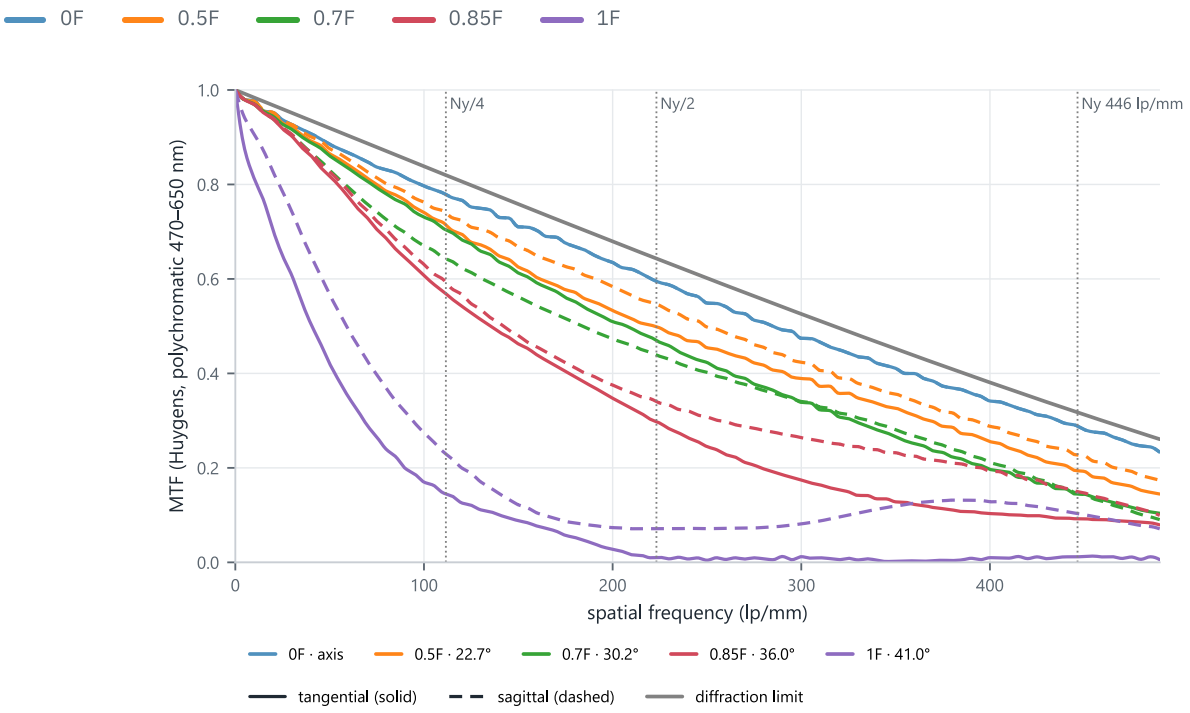


Figure 1. Polychromatic Huygens MTF (470–650 nm, weights 1/2/3/2/1), 64 pupil samples on a 256 grid; the half-sampling run differs by at most 0.025. Ny = 446 lp/mm for 1.12 µm pixels. FFT MTF differs from Huygens by up to 0.11 (comparison only).

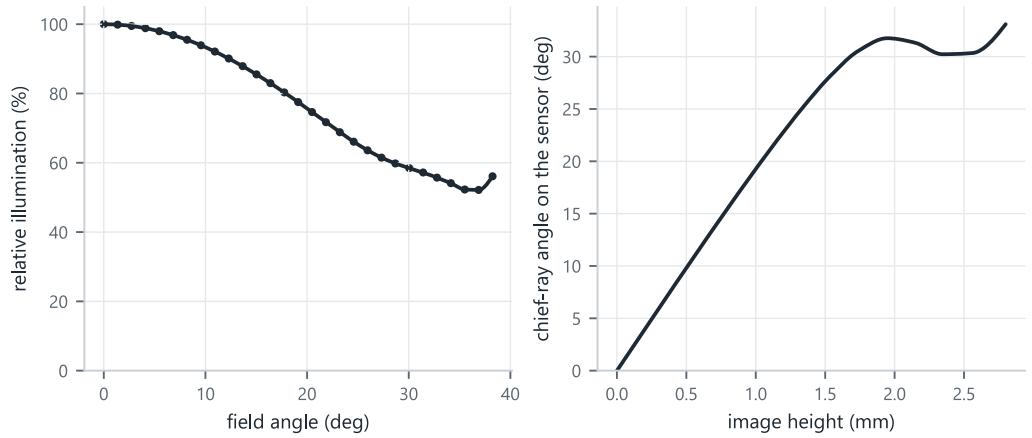


Figure 2. Relative illumination (4000-ray grid, cos⁴ and vignetting) to 38.2° and chief-ray angle on the sensor. The API's value at the very corner (41.0°) is 2.39, above 1, with every sampling tried (2.66, 2.51, 2.39); it is not plotted.

> **Finding.** On axis the lens gives 0.78 at Ny/4 and 0.59 at Ny/2. At 0.85F it holds 0.57 / 0.29; the 1.0F corner falls to 0.15 at Ny/4. The chief-ray angle peaks at 33.1° against the CCM's 30°, and distortion reaches 2.39 %.

THE IR CAMERA AND ITS FILTER 05

The IR lens is fine; the filter is what limits the edge of the field

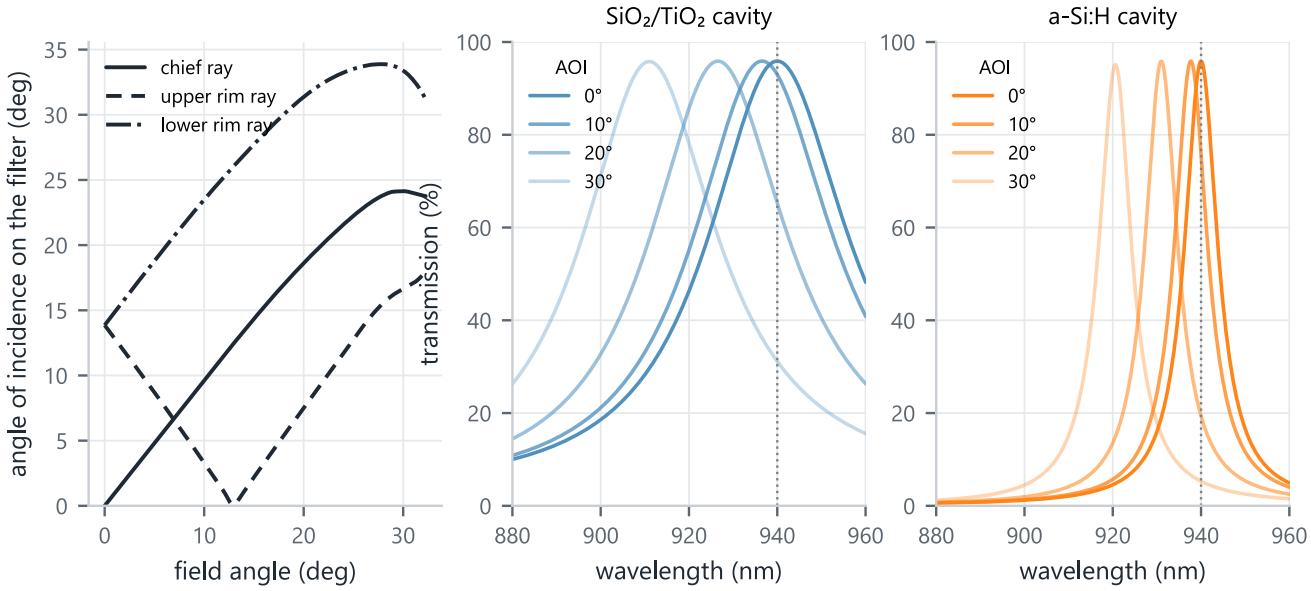


Figure 3. Left: angles of incidence on the filter's front face (API single-ray traces, 31 fields). Middle and right: transmission of two single-cavity 940 nm band-pass stacks from the API's transfer-matrix thin-film engine, at 0–30° AOI. Oxide: SiO_2/TiO_2, FWHM 39 nm. a-Si:H: the same sequence with n = 3.3 high-index layers (assumption), FWHM 9 nm.

Finding. The chief ray reaches the filter at up to 24.1° and the rim rays at 33.9°. At 30° the oxide passband moves 29.0 nm and the a-Si:H one 19.4 nm, both beyond the 12 nm target. At the sensor corner the mean 940 nm throughput over the chief and rim rays, relative to the axis, is 53 % (oxide) and 15 % (a-Si:H): the narrower filter loses more of its own signal.

Decision. Pair the narrow a-Si:H filter with a lens whose image-side ray angles stay under about 10°, or move the coating to where the beam is near-collimated (in front of L1), or keep the wider oxide band and accept less ambient-light rejection.

THE COVER GLASS 06

Flat glass costs nothing; a bent edge is a cylinder lens

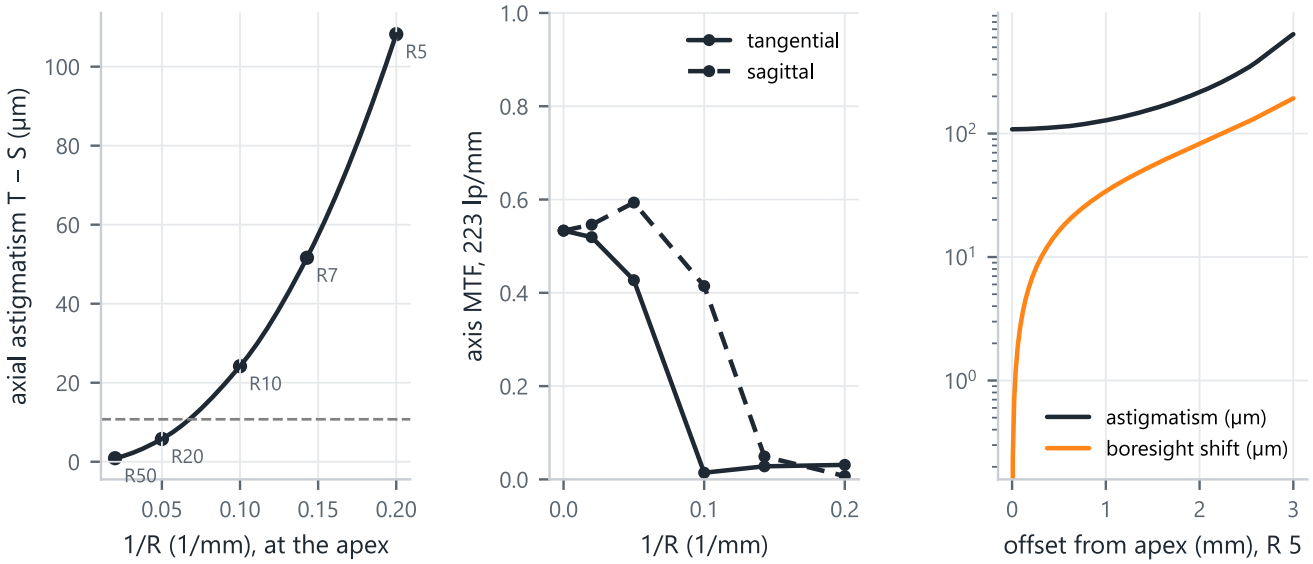


Figure 4. Selfie lens behind 0.6 mm of cover glass (n 1.51), refocused midway between the axial T and S foci. Left: axial astigmatism against bend curvature, camera at the apex; dashed = the full depth of focus $4\lambda N^2$ = 10.7 µm (555 nm, f/2.2). Middle: on-axis Huygens MTF at Ny/2. Right: R = 5 mm, camera moved off the apex.

Finding. Flat glass adds 0.00 µm of astigmatism and moves focus by -0.0 µm: invisible. Bent glass at the apex adds 108 µm at R = 5 mm; the depth of focus is used up at R ≈ 16 mm. Off the apex it grows to 638 µm, with the line of sight moved 193 µm (172 pixels), at 3 mm. This is why front cameras sit under the flat part of the glass.

THE IR FLOOD ILLUMINATOR 07

The diffuser sets the flood; the IR ink sets the crosstalk

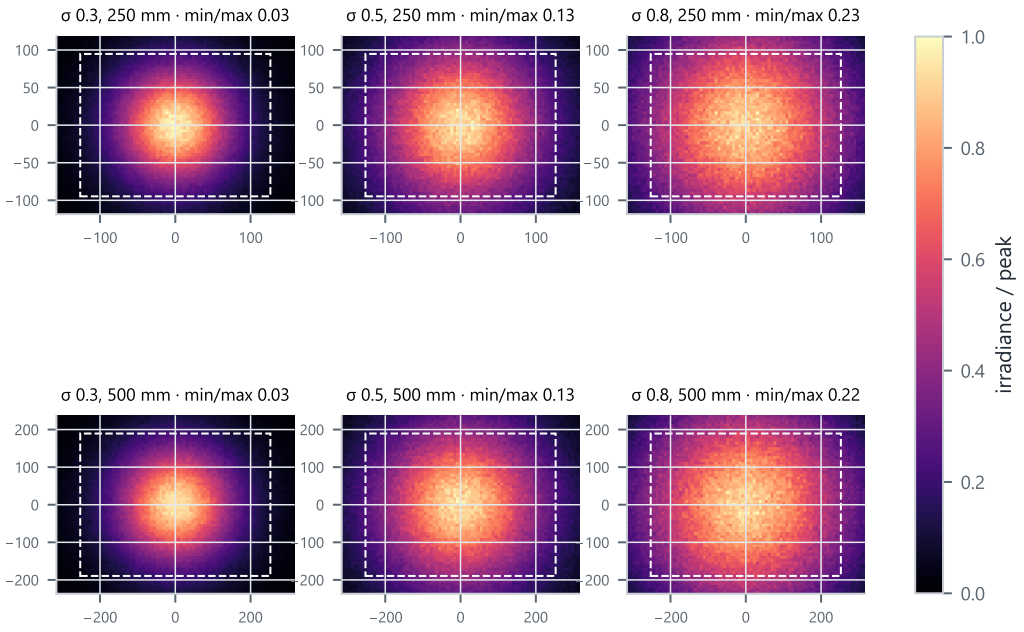


Figure 5. Flood irradiance (normalised) on a plane at 250 and 500 mm for three diffuser scatter widths σ. Dashed: the IR camera's field. Each map is the mean of 13 seeded traces (seeds 42 on), 1.95 M launched rays per case.

Finding. Through smooth IR ink, 0.0023 % ± 0.0003 % of the flood power reaches the IR camera's window 10 mm away; with rough (ABg-scattering) ink it is 0.0019 % ± 0.0002 %, a ratio of 0.84: the two differ by less than twice their combined error. The light reaching the window travels inside the cover glass.

Decision. Eye safety (IEC 60825-1 Class 1) is a system-level classification set by drive power, pulse timing and interlocks; this study does not certify it. The diffuser raises the apparent source size, which raises the allowed emission.

THE RESULT 08

Status against the job

REQUIREMENT	TARGET	RESULT	STATUS
Selfie EFL	3.3 mm	3.300 mm	✓ Met
Selfie diagonal FOV	80° (2025 flagship)	82.0°	✓ Met
Selfie MTF axis, Ny/4	> 0.70	0.78	✓ Met
Selfie MTF axis, Ny/2	> 0.40	0.59	✓ Met
Selfie MTF 0.85F, Ny/4	> 0.55	0.57	✓ Met
Selfie MTF 0.85F, Ny/2	> 0.30	0.29	✗ Not met
Selfie distortion	< 3 %	2.39 %	✓ Met
Selfie RI (0.95F)	> 35 %	56 %	✓ Met
Selfie chief-ray angle	< 30°	33.1°	✗ Not met
Selfie lateral colour	< 3 px	2.32 px	✓ Met
NBP shift at 30° (oxide)	< 12 nm	29.0 nm	✗ Not met
NBP shift at 30° (a-Si:H)	< 12 nm	19.4 nm	✗ Not met
Bent cover R 5 mm: astigmatism	< 10.7 µm (DOF)	108 µm	✗ Not met
Flat cover: astigmatism	< 10.7 µm (DOF)	0.00 µm	✓ Met

- **Next steps.**
- Re-optimise the selfie lens for chief-ray angle ≤ 30° and the corner, now that the patent form is verified.
- Design the IR lens and filter together: an image-space-telecentric NIR lens, or the filter in front of L1.
- Measure the real ink's scatter (BSDF) and the window spacing; both set the crosstalk number.
- Run the CS4 thermal cases on the IR filter: a band-pass also shifts with temperature.

METHOD 09

How the numbers were made

Every number is a saved Paraxial API response or simple arithmetic on one, and every status is computed from it. Both lenses are published patent designs, checked against the patents' own tables and used without re-optimisation; cover-glass thickness and index, the a-Si:H index and the ink scatter are assumptions, and eye safety is not assessed. The full report adds the patent checks, field curvature, distortion, focus against distance, the IR lens MTF, the cover-glass and flood tables, the sampling, scripts, run times and prescriptions.