UV Fiber-to-Lens Collimation Design Notes

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Design notes for coupling a UV fiber source through a Ø7.1mm fused silica plano-convex lens (PFG Precision Optics, R=7.00mm convex) into a collimated beam reflecting off a fixed mirror.

Lens specs (PFG Precision Optics drawing)

Spec	Value	Meaning
Part	UV FS 7.1mm PL/CX	Plano-convex, fused silica
Material	Corning 7980, Standard UV Grade 2-F	UV-transmitting fused silica
R (S2, convex)	7.00 mm	Radius of curvature — sets focal length, not a physical size
OD	Ø7.100 mm (+0/−.010)	Physical part diameter, radius = 3.55 mm
Center thickness (t)	10.00 ± .05 mm	S1 to S2
Clear aperture (CA)	Ø5.0 mm (radius 2.5 mm)	Guaranteed usable optical zone; smaller than OD by design margin
S1 figure	½ fr P-V (flat), 45° x 0.2mm bevel	Surface figure tolerance, not an aperture spec
S2 figure	1 fr irregularity, DO NOT BEVEL	Convex edge left sharp, unbeveled

The ~1 mm gap between CA (2.5mm radius) and OD (3.55mm radius) is manufacturing/mounting margin — edge polish rolloff, bevel allowance on S1, and cell clamping clearance — not a hard optical ceiling.

Focal length vs. wavelength

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f = \frac{R}{n - 1}
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With one flat surface, EFL is exact (thickness term vanishes) and does not depend on which side faces the source.

Narrowband source (217–240 nm), R = 7.00 mm (as-drawn lens):

λ (nm)	n (approx.)	f = EFL
217	~1.531	13.18 mm
230	~1.520	13.46 mm
240	~1.513	13.65 mm

Optimal single f ≈ 13.4 mm (midpoint); chromatic spread ~0.4mm.

Broadband (200–400 nm), R = 7.00 mm:

λ (nm)	n (approx.)	f = EFL
200	~1.551	12.70 mm
300	~1.488	14.34 mm
400	~1.470	14.90 mm

Minimax compromise f ≈ 13.8 mm; chromatic spread ~2.2mm (much larger — fused silica dispersion is steep in deep UV).

Narrowband (217–240 nm) with steeper custom R = 5.65 mm:

λ (nm)	n (approx.)	f = EFL
217	~1.531	10.64 mm
230	~1.520	10.87 mm
240	~1.513	11.01 mm

Optimal single f ≈ 10.8 mm (midpoint); worst-case defocus ±0.2mm.

n values are approximate (Sellmeier-based); confirm against Corning's published dispersion data for final design.

Fiber source and collimation geometry

Source: FVP600660710UVM fiber (600µm core / 660µm clad / 710µm buffer), 0.22 NA → half-angle = arcsin(0.22) ≈ 12.7°.

System: fixed mirror 5mm from the lens's plano (S1) face. Collimation — not focusing onto the mirror — is the right goal here: a collimated beam is insensitive to the mirror's exact distance, and on reflection it refocuses back onto the fiber tip (cat's-eye retroreflector). Focusing a point source to a real image closer than ~6.9mm past S1 isn't achievable with this lens anyway, which conflicts with the 5mm mirror gap.

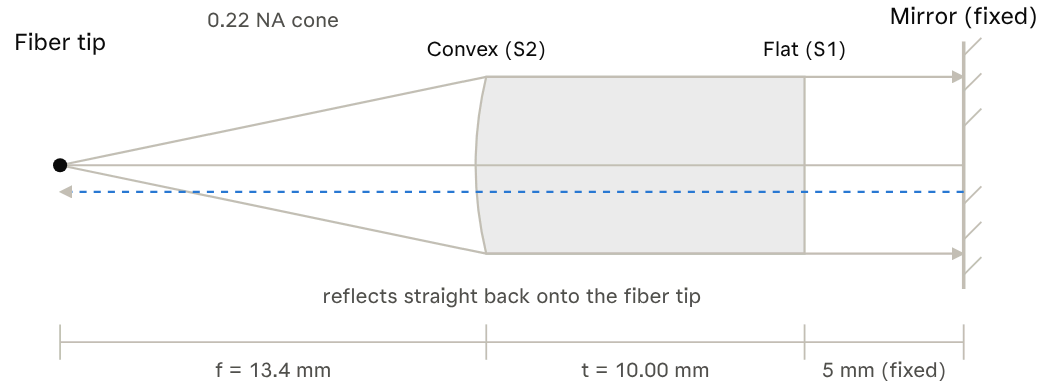
Orientation for collimation: convex (S2) side faces the fiber, flat (S1) side faces the mirror. With this orientation, the front principal plane coincides with the convex vertex, so:

Fiber-to-convex-face distance = f (EFL), exactly — no t/n correction needed (that correction only applies in the opposite orientation, flat-side-first).

Case	Recommended fiber-to-convex-face distance
217–240nm, R=7.00mm (as-drawn)	~13.4 mm
200–400nm, R=7.00mm (as-drawn)	~13.8 mm
217–240nm, R=5.65mm (custom)	~10.8 mm

Fiber at f = 13.4 mm collimates the beam before the mirror

217–240nm band, convex-side orientation (as-drawn lens, R = 7.00mm)



ray sketch · fiber at f=13.4mm, convex-first orientation

Marginal rays diverge from the fiber tip, hit the convex face, and exit the flat face parallel — the collimated beam then travels on to the mirror regardless of the 5mm gap, and reflects straight back onto the fiber tip.

Clear aperture clipping — problem and solutions

At f ≈ 13.4mm (as-drawn lens, 217–240nm), the fiber's 0.22 NA cone has grown to a diameter of 2 × 13.4 × tan(12.7°) ≈ 6.0mm by the time it reaches the lens — larger than the 5.0mm clear aperture, clipping roughly 30% of the power at the cone edge.

Max distance for zero clipping at CA=5.0mm: d_max = 2.5 / tan(12.7°) ≈ 11.1 mm (wavelength-independent).

Three options (OD fixed at 7.1mm):

1. **Request larger CA on the same R=7.00mm prescription.** Needs CA ⩾ ~6.15mm (narrowband) or ~6.7mm (broadband, likely too tight for a 7.1mm OD). Ask the shop what P-V figure tolerance they can hold at the larger CA — don't assume the original ½ fr P-V carries over for free; the right ask is the CA number itself, not the P-V spec.
2. **Custom steeper curvature, same OD and CA=5.0mm.** R ≈ 5.65mm (narrowband, f≈10.6–11.0mm) or R ≈ 5.10mm (broadband, f≈9.3–10.9mm). Fully captures the NA with margin; sag increase is modest (~0.13–0.2mm over the as-drawn lens).
3. **Keep the current lens, accept the ~30% edge clipping.** No part change; collimation of the captured light is still fine, just reduced throughput. Workable if return power isn't critical.

Sag

Sagitta: depth a curved surface departs from flat, at the edge of a given aperture radius y.

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\text{sag} = R - \sqrt{R^2 - y^2}
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Matters for manufacturability (more sag = more grinding/polishing, more edge figure risk), mounting depth, and spherical aberration (more sag at a given aperture = more aberration).

At y = 2.5mm (half of 5.0mm CA):

R	Sag
7.00 mm (as-drawn)	0.453 mm
5.65 mm (narrowband custom)	0.585 mm
5.10 mm (broadband custom)	0.658 mm

Even the steepest custom option only deepens the curve by ~0.2mm vs. the as-drawn lens — a modest, easily manufacturable increase.

Why n changes with wavelength (dispersion)

1.458 is the index at one specific wavelength (near 1064nm/633nm), not a single fixed value — every transparent material's index varies with wavelength (dispersion), a real physical effect.

Light's E-field drives bound electrons (Si–O bonds in fused silica) into oscillation; their re-radiation, phase-shifted relative to the drive, is what we experience as refraction. Electrons respond most strongly as the light's frequency approaches the material's natural resonances — for fused silica, strong electronic absorption bands below ~160nm (deep UV), plus vibrational resonances further in the IR. The closer the light sits to a resonance, the stronger/more retarded the response, and the higher n rises.

UV light (200–400nm) sits much closer to fused silica's deep-UV absorption edge than 1064nm IR does — hence n ≈ 1.51–1.53 in the 217–240nm band vs. ~1.458 near 1µm.

Captured quantitatively by the Sellmeier equation:

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n^2 - 1 = \sum_i \frac{A_i \lambda^2}{\lambda^2 - \lambda_i^2}
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which rises sharply as λ approaches a resonance λ_i from above — the source of every chromatic-focus-shift number in this doc.