TECHNICAL NOTE

Designing Athermal Optical Systems with CODE V Multi-Environment Coupling

Minimum CODE V version: 2025.03 • Prepared by FOS Optonics

The Athermalization Challenge

Take a lens that focuses perfectly on the bench at room temperature and put it through a thermal cycle, and three things start moving independently: the refractive index of every glass element shifts with dn/dT, the elements and airspaces grow or shrink with their own CTE, and the housing around all of it expands or contracts at its own rate. The mechanical image plane set by the housing and the ideal optical image plane almost never move together by the same amount — in an exaggerated case, a housing alloy with a very high CTE can push the detector away noticeably faster than the optics can refocus toward it, opening a real gap between the two.

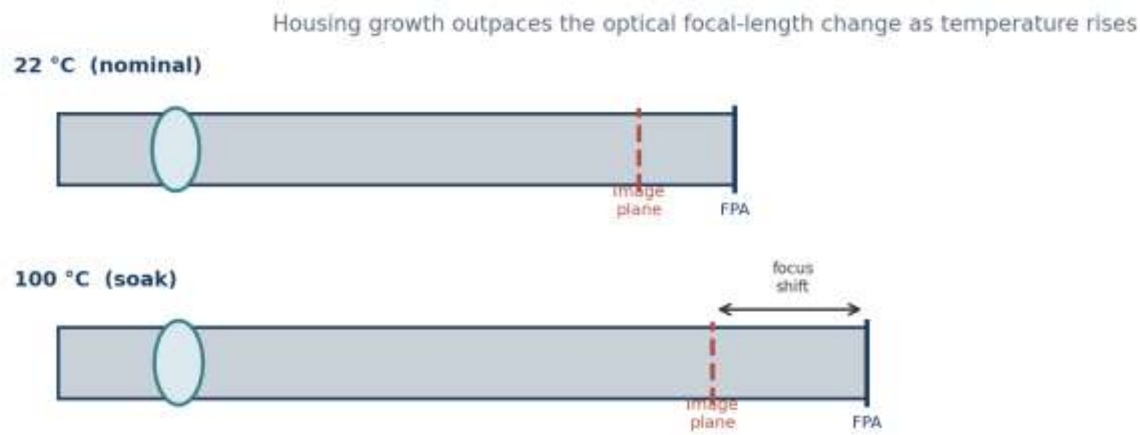

Figure 1 — An exaggerated-CTE example of how housing growth and optical shift can diverge, opening a focus gap between the FPA and the ideal image plane.

Athermalization isn't about eliminating that movement — for most designs that's not physically realistic. It's about designing the optics and the housing together, so the two shifts stay close enough to each other that image quality holds up across the full operating range.

Three Paths to a Stable Image Plane

Every athermalization strategy comes down to some mix of three approaches:

- Active focus adjustment — a mechanism refocuses the system as temperature changes. It works, but it's one more moving part to design, calibrate, and eventually service.
- Passive mechanical athermalization — sleeves or spacers made of different housing materials are combined to produce an effective CTE that offsets the optical shift, with nothing that moves.
- Passive optical athermalization — lens materials, curvatures, and airspaces are chosen so the optical image shift itself tracks the mechanical shift, without any extra hardware.

Most rugged designs lean on the second and third approaches together, and reserve active compensation for the range that materials alone can't cover.

How CODE V Models the Environment

CODE V has offered ways to bring environmental effects into a design for a long time, and there are now four of them. Each still has its place, but the guidance for new work is fairly clear-cut:

Method	Best suited for	Notes
ENV	Fast, approximate thermal analysis	Available in CODE V for decades; not built for optimization-driven athermalization
ThermPik	Legacy projects	Builds on ENV; largely superseded but still available
ENVPIK	Seat-based mounting	Available for a few years; a solid choice when every element seats directly on the housing
MECo	Seat-based, spacer-based, or a mix of both	The option Keysight now recommends by default, regardless of mounting scheme

MECo is the one to reach for on new designs, because it couples optics and housing for any mounting approach — seat-based, spacer-based, or a mix — inside a single lens model, significantly reducing the need to manually maintain pickup relationships between configurations.

Inside MECo: What the Model Captures

- **Environmental zooms** — each temperature and pressure case sits as its own zoom position inside one lens file, so every condition gets analysed and optimized together instead of living in separate models.
- **Housing links** — the coupling between an optical surface and the mechanical structure. A spacer's expansion feeds straight into the airspace between two elements; a seat contact instead tracks the housing's growth at the surface edge, so the same airspace can behave quite differently depending on which mounting scheme is in play.
- **Contact-point control** — exactly where a seat touches an element is defined by two parameters: SEC (how far out from the axis) and SEC FEZ (how far along the axis from the surface itself). The same pair of settings can represent **a simple seat, a notched seat, a flange, or an edge-bonded joint** — whatever the real mount looks like, MECo just needs to know where contact happens.

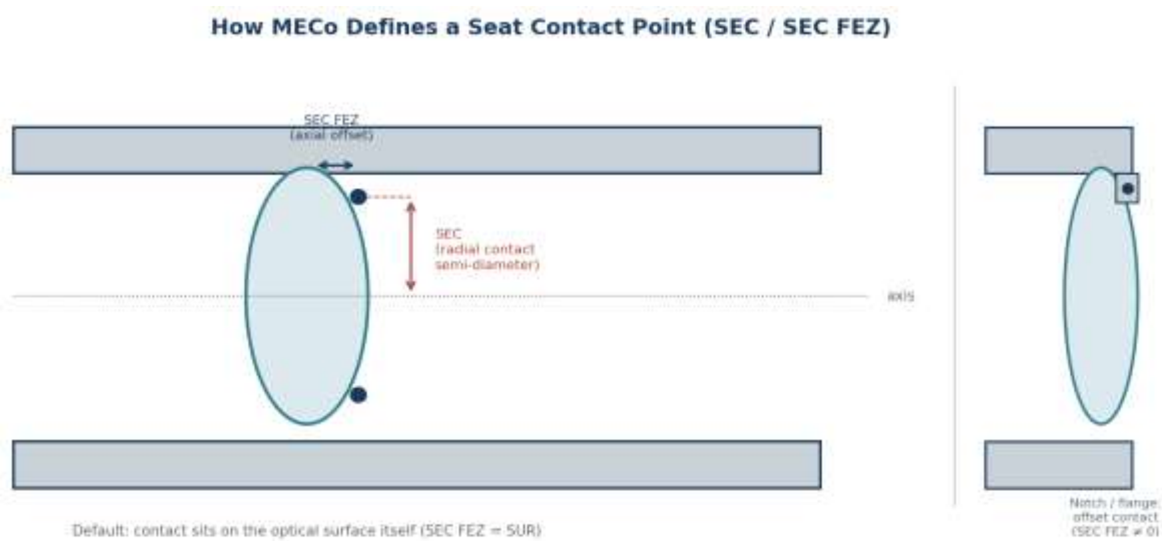

Figure 2 — A seat contact point is defined by its radial position (SEC) and its axial offset from the surface (SEC FEZ); the same pair of settings covers on-surface seats as well as notched or flanged variants.

- **Material handling** — catalog glasses and housing alloys are built in, and any custom material — a special aluminium alloy or a glass melt — can be entered with its own CTE and dn/dT coefficients.
- **3D visualization** — housing links can be rendered in three dimensions before a single mechanical drawing exists, which is a good point to catch mounting assumptions before they go further.
- **Full data listing** — every environmental parameter in the model can be listed for review (the ELI command), which gives a design review something concrete to check against.

Best-Practice Workflow

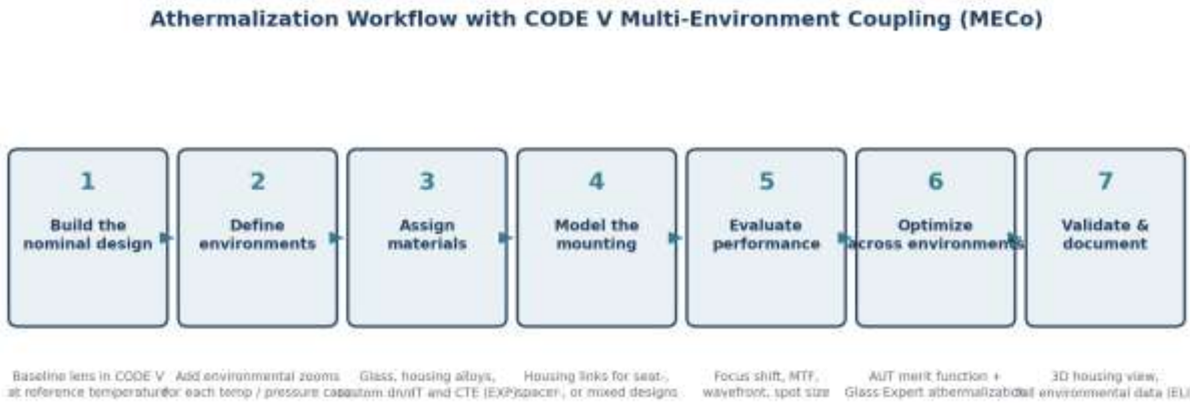

Figure 3 — A typical MECo-based athermalization workflow, from nominal design to validated, documented results.

One thing worth flagging at step 5: because each environment traces rays slightly differently once temperature and pressure are applied, **vignetting factors should be re-checked once environments are added** — otherwise MTF and spot-size comparisons across zooms can be misleading.

Applied Example: A Seat-Based Triplet Across a 200 °C Range

Here's how the workflow plays out on an actual case: an aspheric triplet mounted on Al6061 seats, required to hold its performance from –80 °C to +120 °C. Lens 1 seats on its rear surface, Lens 2 on its rear flat, and Lens 3 on its front surface. In the LDM, the surfaces tied to environmental conditions are flagged automatically, so it's easy to see at a glance which parameters MECo is now driving:

Lens Data Manager (LDM) — Triplet, Seat-Based Mounting

Illustrative surface table — the "E" flag marks values MECo now drives automatically across environments

Surface	Role in this design	Zoomed by MECo	Material	CTE / dn-dT linked
S1	Lens 1 - front	—	NLAK12_SCHOTT	
S2	Lens 1 - rear (seat)	E	NLAK12_SCHOTT	E
S3	Lens 2 - front	—	SF11_SCHOTT	
S4	Lens 2 – rear (seat)	E	SF11_SCHOTT	E
S5 / SS	Aperture stop	E	—	
S6	Lens 3 – front (seat)	E	NLASF31A_SCHOTT	E
S7	Lens 3 - rear	—	NLASF31A_SCHOTT	
S8 / Si	Image plane	E	—	

Figure 4 — Illustrative LDM layout for the triplet: surfaces flagged "E" are the ones MECo now drives automatically across the -80 °C / +120 °C environments.

For the housing links, there's more than one way to wire the three seats together. Rather than tying each seat straight to the image plane, this example routes all three seats to the stop and then the stop to the image plane — which leaves the door open to using a different housing material on that longer stop-to-image run than on the shorter links between lenses:

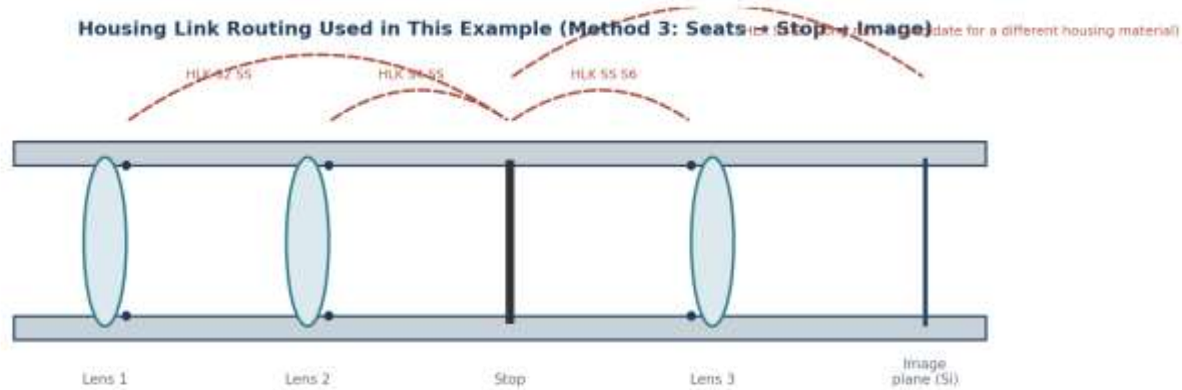

Figure 5 — Housing link routing for this example: each seated surface links to the stop, and the stop links to the image plane.

Running the ray-aberration analysis at both temperature extremes before touching anything shows a strongly tilted trend across the field — the signature of defocus dominating the error budget, at both -80 °C and +120 °C. From there, **Glass Expert** is used to reselect materials while the color correction is optimized at the same time, rather than solving thermal and chromatic performance one after the other. The pattern that typically follows optimization looks like this:

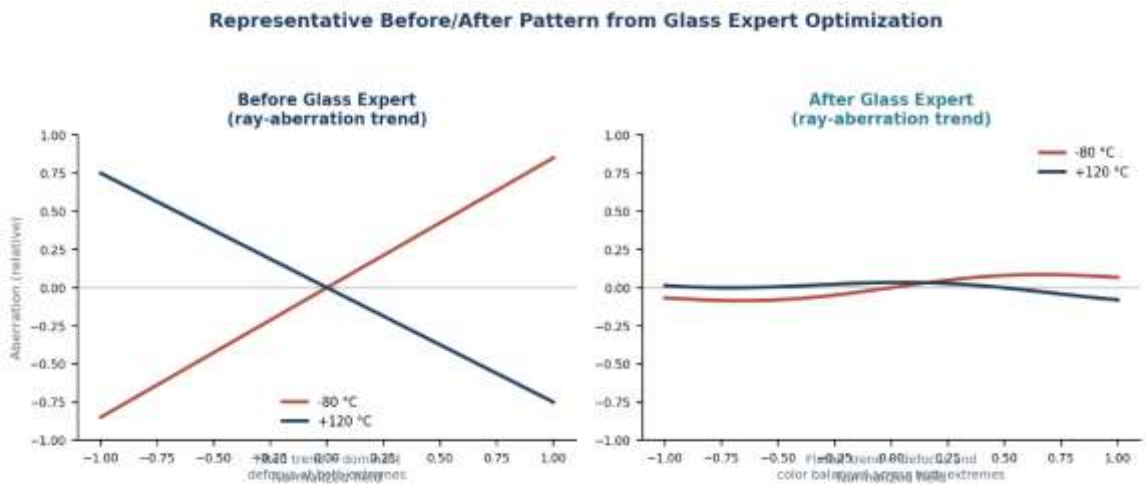

Figure 6 — Representative before/after pattern: a strong linear (defocus) trend at both temperature extremes flattens out once Glass Expert has run. Curve shapes are illustrative, not measured data from a specific run.

It's also worth remembering that this result is tied to the seat-based mounting chosen here — a version of the same starting lens optimized around spacers instead would land on a different material selection, and one design being athermalized doesn't automatically mean the other is.

Engineering Best Practices

- Confirm the contact-point semi-diameters (SEC / SEC FEZ) match what the opto-mechanical team intends to machine — this is the most common gap between simulation and hardware.
- Re-check vignetting after adding environments; each zoom traces rays slightly differently.
- Enter true CTE and dn/dT coefficients for any non-catalog material rather than approximating with a nearby catalog entry (the FIT_EXP and FIT_DNC macros can fit these coefficients from measured data).
- Use Glass Expert to screen for combined color and thermal sensitivity, not thermal sensitivity in isolation.
- Visualize housing links in 3D before finalizing the model, to catch mounting-topology assumptions early.
- Keep an ELI environmental data listing with every design release for traceability.
- If a design needs to move from seats to spacers (or vice versa) later, treat it as a re-optimization, not a like-for-like swap.

> *Also useful: ABR_VS_T, RWE_VS_T, and MTF_VS_T plot aberrations, RMS wavefront error, and MTF as a function of temperature, and ENVSENS runs a sensitivity analysis of wavefront error against fabrication-temperature changes — handy for turning a MECo model into a tolerance discussion.*

Where This Matters

- Automotive ADAS — cameras and sensors that must hold focus across a wide underhood and exterior temperature range.
- Aerospace & Defence — optics qualified across extreme soak temperatures and changing altitude or pressure.
- Industrial machine vision & metrology — keeping measurement repeatability intact as factory-floor temperatures drift.
- Medical imaging — systems that need to survive sterilization thermal cycles and stay reliable over years of use.

Planning a thermally robust optical design? Discuss your application with us and explore CODE V's environmental modeling capabilities to identify the workflow best suited to your application. Simply reply to this email to arrange a technical discussion