Epsilon ONE – Optics Package Selection

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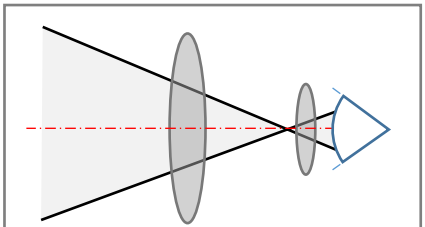
Precision Telecentric vs Conventional Entocentric Optics

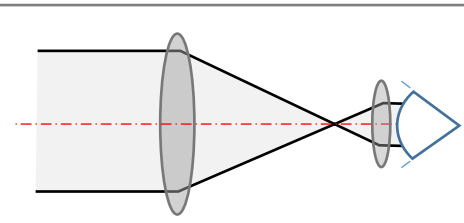
An important factor in selection of an optical extensometer is the choice of either *Precision Telecentric* (ONE-PT-xx) or *Conventional Entocentric* (ONE-CE-xx) Optics systems.

What are Telecentric and Entocentric Optics?

All consumer products use *Conventional Entocentric* lens design, where image magnification depends on object distance. *Telecentric* lenses are a special type of lens design, where *objects appear to be the same size regardless of distance.* Most readers have never seen a telecentric lens.



Conventional Entocentric Lens



Precision Telecentric Lens

Why is this significant? Sensitivity to Out-of-Plane Motion.

Measurement errors due to out-of-plane motion are *scaling* errors caused by changes in the distance between the extensometer and specimen, ***errors which can exceed the yield strain of most materials***. They affect ***all*** optical extensometers which use Conventional Entocentric lenses. The measurement error (indicated strain) due to out-of-plane motion is easily calculated by the change in Working Distance (WD):

$$\epsilon_{indicated} = \epsilon_{actual} + \frac{\Delta_{WD}}{WD}$$

Example: 250mm WD, CE lens, specimen elongates 0.2% and moves out-of-plane by 0.25 mm (0.01"). Indicated strain is 0.2%+0.25/250=0.3%, ***an error of 50%.***

Conventional Entocentric systems are smaller, less expensive and yield a larger Field of View, but they are *much* more susceptible to out-of-plane measurement errors; *all conventional systems have similar out-of-plane sensitivity, regardless of the vendor.* Precision Telecentric systems have a negligible out-of-plane sensitivity; Epsilon is one of the few vendors who offer this special type of lens. Be sure to consider and understand the *Out-of-plane Sensitivity* specification when purchasing any optical extensometer.

How can I tell which type of lens an optical extensometer uses?

Precision Telecentric lenses are always larger in diameter than the Field of View and are longer (>8"). If an optical extensometer is not explicitly referred to as "Telecentric", it is probably an Entocentric system. Most laser-scanning and stereoscopic optical extensometers, while not technically telecentric, have out-of-plane sensitivity similar to telecentric systems. *Mechanical clip-on extensometers are intrinsically insensitive to this movement* as they translate freely with the specimen.

Out-of-plane motion errors are often the largest error source in non-contact strain measurement, ***but they are not challenged by extensometer verification standards ASTM E83 or ISO 9513.***

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What causes out-of-plane motion and errors?

- Insufficient axial preload*
- Self-alignment of the load train due to loose, misaligned, or self-aligning (e.g. U-joint) load trains**
- Straightening of nominally flat specimens having slight bends or curvature*
- Imperfect positioning and alignment of the specimen within the grips*
- Slight eccentricity or asymmetry of specimens*
- Misalignment of an optical extensometer relative to the test axis
- Changes in specimen thickness

* With conventional entocentric optics, out-of-plane measurement errors are generally larger than *real* bending and shear strains which degrade test results, share similar causes and are difficult to distinguish.

** Load train considerations are among the most common causes of poor-quality and nonlinear stress-strain curves. Nevertheless, it is extremely rare for clients to self-report alignment problems; many users underestimate the significance of subtle problems. See related *Epsilon Tech Notes.*

How bad is Out-of-Plane Sensitivity? What effect will it have on my measurements?

The out-of-plane sensitivity of any *Conventional Entocentric* optical extensometer is easily calculated as *1/Working Distance*. E.g., if the working distance is 250mm, the out-of-plane sensitivity is 0.4%/mm: *An out-of-plane motion of 1mm will cause an indicated strain of 0.4%.* When choosing an optical extensometer, consider the amount of motion which could be accepted without degrading the results.

Out-of-plane errors typically affect measurements from 0-1% strain. Elastic Modulus and yield strain measurement errors of 10%-50% are not uncommon with *Conventional Entocentric* optics.

Notes on Calibration and Verification

Out-of-plane motion errors are not currently measured or challenged by extensometer verification standards ASTM E83 or ISO 9513. However, we can calculate the amount of out-of-plane motion which would cause enough strain measurement error to exceed the allowable limits (or any limit):

Example: ASTM E83 class B-1: Strain error limit = 0.0001 mm/mm
250mm WD CE lens: Out-of-plane sensitivity = 0.4%/mm.

Maximum out-of-plane motion within B-1 limits = 0.0001/0.4%/mm= 0.025 mm (0.001")

Out-of-Plane Sensitivity:	*ONE-PT-xx: <0.01%ε/mm (100με/mm)* *ONE-CE-xx: 0.40%ε/mm (4000με/mm)*
Allowable out-of-plane motion for ISO 9513 Class 0,5 @15mm GL and ASTM E83 Class B-1 (<0.01%ε):	*<1000μm (0.040") for ONE-PT-xx* *<25μm (0.001") for ONE-CE-xx*
Typical out-of-plane motion of flat tensile specimens:	*50-500 μm (0.002"-0.020")*

Can I get good results without a Telecentric Lens?

Yes, good test results can be obtained with conventional entocentric optics *if* the out-of-plane motion can be controlled within the allowable calculated based on the application's accuracy requirements.

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