Athermalization Model - of a Simple Imaging Module

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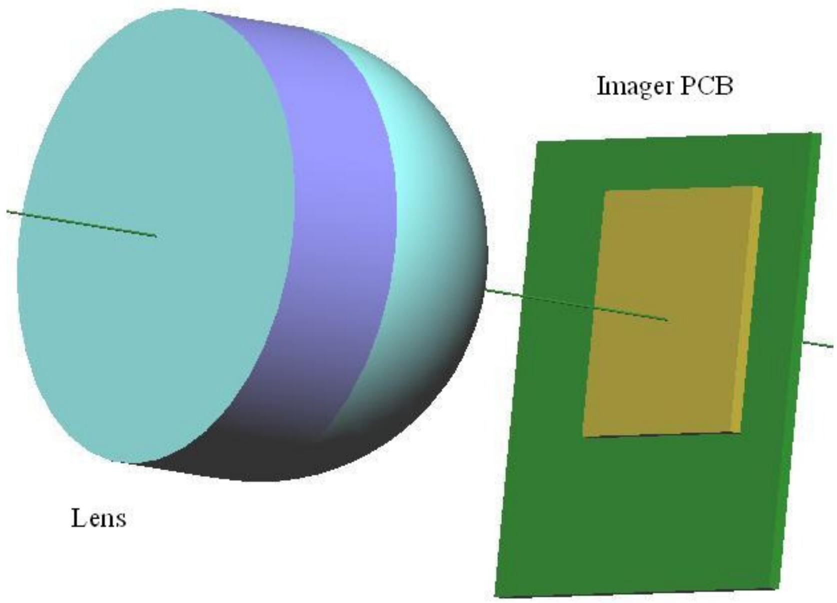

Abstract: The article discusses means to athermalize a PCX lens

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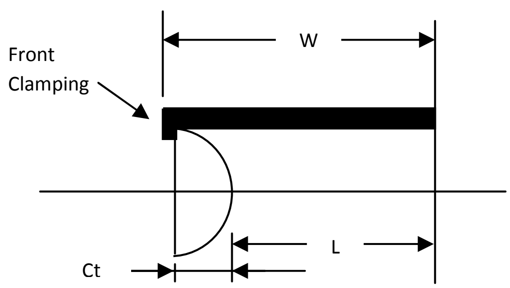
Introduction

Thermal effects can reduce the quality of an optical image, and should therefore be considered in the design process. Thermal changes may affect the focusing as well as positioning drifts that may cause a boresight error. In the following discussion we exemplify one method to athermalize a simple PCX lens.

Athermalization Principle

Consider the following geometry:



W – Distance from detector to lens clamping point
L – Distance from detector to vertex of lens
Ct – Distance from lens clamping point to Vertex of lens

Thermal changes cause:

a) The lens' radius of curvature- R, to increase with temp, causing the *focal distance* to increase
b) The refractive index - "*n*", to decreases with temp, causing the *focal distance* to increase
c) The housing to expand with temperature – causing the image distance to the *focal plane* to increase, thus tending to cancel out the effects of a and b.
d) The distance between the lens' vertex to its clamping point to the housing to increase (if within the central thickness) – causing the image distance to the *focal plane* to increase, thus tending to cancel out the effects of a and b.

In the following analysis we assume that stress effects caused by thermal changes are not dominant. This means that that the lens will expand and contract independent of its outer housing. We will first relate to a front clamping of the lens as in the above figure – then we will derive other cases.

The focus of a PCX lens is given by: $f = \frac{R}{n-1}$

Where R is the radius of the convex surface.

Thus, $\frac{df}{dT} = \frac{dR}{dT}\left(\frac{1}{n-1}\right) - \frac{dn}{dT}\left(\frac{R}{(n-1)^2}\right)$ Or: $\delta f = \frac{dR}{dT}\left(\frac{1}{n-1}\right)\delta T - \frac{dn}{dT}\left(\frac{R}{(n-1)^2}\right)\delta T$

Since $\frac{dR}{dT} = R_0\alpha$ where α is the thermal expansion coefficient and R_0 is the radius at the middle temperature range, we get:

$$\delta f = \left(\frac{R_0\alpha}{n-1}\right)\delta T - \frac{dn}{dT}\left(\frac{R_0}{(n-1)^2}\right)\delta T \qquad \text{(i)}$$

On the other hand: $L = W - Ct$ or: $\delta L = \frac{dW}{dT}\delta T - \frac{dCt}{dT}\delta T = (W_0\alpha_e - Ct\alpha)\cdot\delta T$ (ii)

The overall defocusing effect is the combined effect of (i) and (ii), or:

$$\delta f = \{\left(\frac{R_0\alpha}{n-1}\right) - \frac{dn}{dT}\left(\frac{R_0}{(n-1)^2}\right) - W_0\alpha_e + Ct\alpha\}\cdot\delta T$$

Full athermalization is obtained when $\left(\frac{R_0\alpha}{n-1}\right) - \frac{dn}{dT}\left(\frac{R_0}{(n-1)^2}\right) - W_0\alpha_e + Ct\alpha = 0$ (iii)

Examples

Example 1: An all PC solution
Substituting for PC: α_e=α=6.8E-5 °C^{-1}, dn/dT= -13E-5, Ro=2.77mm, Ct=3.6mm, Wo≈f+Ct
We obtain a defocus of: 1.1µ / °C (a drift of 33µ per 30 °C)

Example 2: Lens from PC and body from PE – lens is clamped near the Aperture
Substituting for PE: α_e = 20x10^{-5} °C^{-1}, α=6.8E-5 °C^{-1}, dn/dT= -13E-5, Ro=2.77mm, Ct=3.6mm, Wo≈f+Ct.
We obtain a defocus of: -0.14µ / °C (a drift of -4.2µ per 30 °C)

Example 3: Lens from PC and body from PE – Lens is clamped around vertex
Substituting: Ct=0, Wo≈L≈f, PE α_e = 20x10^{-5} °C^{-1}, α=6.8E-5 °C^{-1}, dn/dT= -13E-5, Ro=2.77mm,
We obtain a defocus of: 0.46µ / °C (a drift of 13.8 µ per 30 °C)

Conclusions

Athermalization could be achieved in theory, although more degrees of freedom may most likely be involved than in the above simplified example. The design should relate to the packaging materials and to the clamping points in addition to the optical design.