Athermalised Lens Design

PRECISION-OPTICAL ENGINEERING

OSE 003

Application Note

Introduction

Lens materials for applications in 8 - 14 micron region of the spectrum exhibit properties which are significantly temperature dependent. Of particular importance is the dependence of refractive index on temperature, since as this changes, so does the focal length of the lens. This means that refocusing is required as the temperature rises or falls. The process of compensating for this is known as athermalisation, and can be achieved in its simplest form by a manual refocusing. For many lens systems, however, this is not practicable, especially as compensation may have to range over temperatures from -20 to +80 degrees C, so mechanical systems have been devised, as illustrated in Figure 1

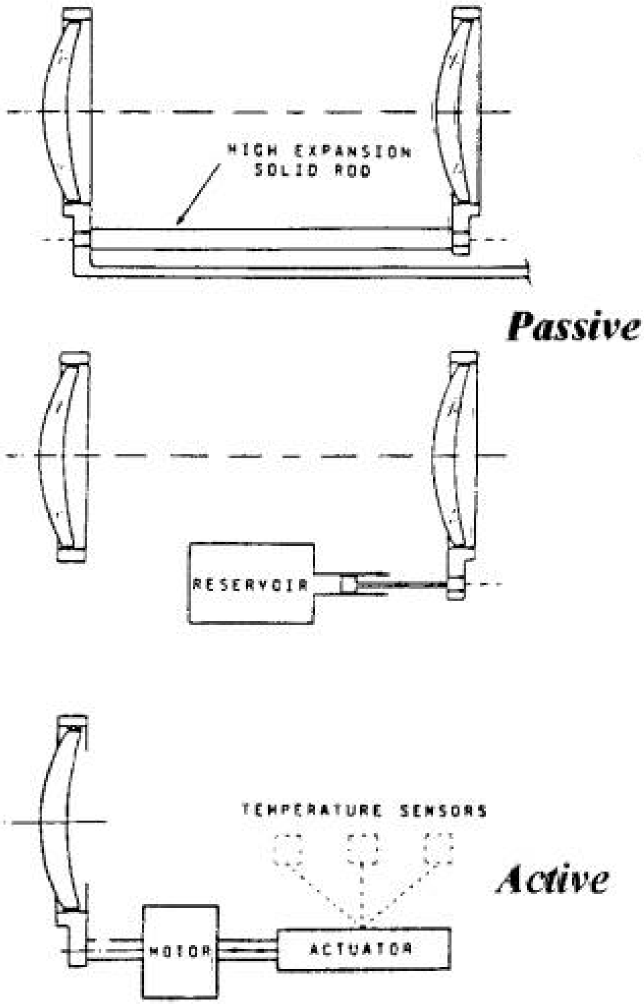

Figure 1. Mechanical Passive and Active Athermalisation Methods

In passive athermalisation systems, compensation is achieved by adjusting the position of the lens using materials with an appropriate coefficient of expansion, which will move the lens by the required amount as the temperature changes. More precise correction can be achieved using an active system, where servos can be used to make the adjustments needed in a precise way. The major problem with these systems is that they add weight as well as cost to the lens system. However the use of diffractive optics allows lens systems which are self athermalising to be produced.

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Diffractive optics for self athermalisation

By choosing materials which have different rates of change of refractive index with temperature (dn/dt), it is possible to construct lens systems which are self athermalising. Key to the process is the use of diffractive optics, produced by single point diamond machining on the non-spherical lens surface to produce hybrid refractive- diffractive lenses. Typical materials used in these lens systems are germanium and zinc selenide. Germanium has the larger dn/dt. Whilst the choice of lens materials stabilises operation over a wide temperature range, the diffractive surface controls the resulting longitudinal chromatic aberration. This is an extremely important part of the design. Figure 2 shows a design for a simple self athermalising lens system.

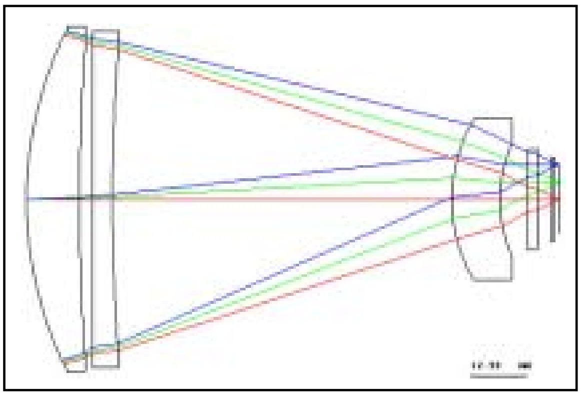

Figure 2

The three lens elements (from the left) are manufactured from zinc selenide, germanium and germanium. Figure 3 shows the axial modulation transfer function (MTF) as a function of temperature for just the refractive and for the hybrid.

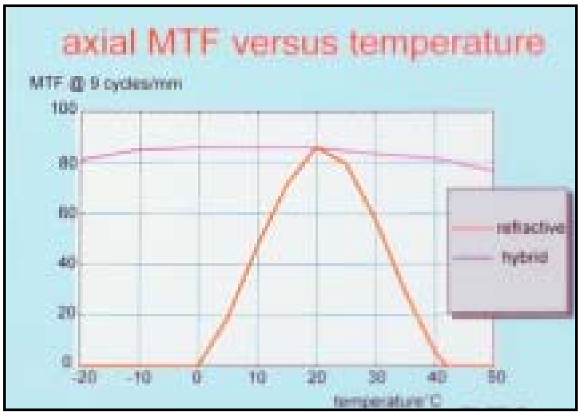

Figure 3

The hybrid shows a consistent MTF across a 70 degrees C temperature range compared to the rapid drop-off with the refractive lens. For some applications, the use of diffractive surfaces with many more zones than would normally be required for chromatic aberration correction can directly compensate for thermal defocus.

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