Thermal Management of Large Scale Optical Systems

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We consider the thermal problems appearing in the practical use of large optical systems, e.g. of an airborne camera. A cold lens is brought into a warm environment: how can the heating up needed to reach specifications be accelerated by active heating? We present analytic solutions for idealized heat conduction problems and some of their consequences for the problem at hand.

1 Introduction

Large format lenses as used in airborne photogrammetry must be athermalized in a relatively broad thermal range to comply with the stringent specifications for optical resolution and for mapping geometry, like camera constant and distortion. In case of rapid thermal changes, e.g. when a cold lens is brought into a warm environment, thermal gradients unavoidably occur in the glass material, leading to variations of the refractive index and, consequently, to optical aberrations. If lenses with large diameter are involved, it can take several hours of diffusion time to reach the stationary state. The optical system must therefore be robust enough to keep the optical quality always within specifications, requiring a complicated and expensive optical design.

One attractive and economic possibility to shorten the thermal diffusion process is to heat each lens individually. This requires a thermal management system, consisting mainly of a microprocessor controlling the current in heat bands winded around each lens. The control parameters (heat current and heat duration) depend on the lens geometry and the glass material, on the mechanical mounting structure, and on the thermal boundary conditions. The parameter evaluation is rather complex and needs a detailed 'finite element modeling' of the optomechanical system, elaborate optical ray tracing through gradient lens segments, and finally extensive experimental verification.

2 Our Approach

To find first estimates for the optimal parameters and thermal strategy, we decided to concentrate on the underlying diffusion process and model it in closed analytical form, however under simplified geometrical assumptions. Dependent on the chosen boundary condition, like constant mounting temperature or constant heat flow or a combination of both, the results can be presented in a material and scale invariant form, adaptable to a large variety of similar applications. Besides the heat problems mentioned above we have also analyzed the thermal load problem of a Lidar telescope for a planned space mission, see Fig. 1.

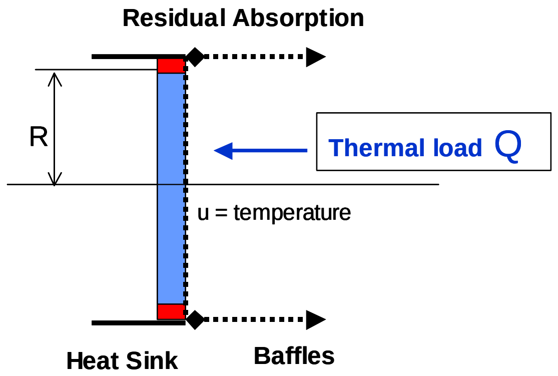

Fig. 1 *Most thermal radiation hitting the telescope aperture is reflected back to space. Some unavoidable absorption occurs in the heat shield coating. The absorbed heat is guided to the heat sink.*

3 Results

The results are summarized in two parts:

a) The *handouts* of a presentation given at the annual meeting of the German society for applied optics, DGaO, June 2004.

b) A *summary* of five idealized heat conduction problems with their analytic solutions and with links to downloadable Matlab programs for their computation.

Full details of the underlying physics and mathematics can be found in the forthcoming paper [1].

Reference

[1] B. Aebischer: „Heat Conduction in Lenses“, submitted to *American Mathematical Monthly* (2004)