Abstract

Optical interference filters, most often consisting of a stack of dielectric layers deposited on a glass substrate, perform essential functions in any current optical system (antireflection, polarizers, selectors, separators, mirrors, equalizers ...). In general, the phenomena of thermal origin in these filters, which appear when they are subjected to laser flux, cannot be neglected. On the one hand, they can be responsible for many problems ranging from the degradation of optical performance of the filter to its irreversible damage. On the other hand, they are at the basis of various methods of characterizing the absorption of filters, such as photo-thermal deflection, common-path interferometry, or Lock-In Thermography.

However, describing these phenomena with precision remains a difficult step. Existing models are often incomplete, based on approximations or are not adapted to the field of interference filters. The objective of this thesis is therefore first to propose theoretical tools to accurately model the photo-induced thermal phenomena in optical thin films, in arbitrary illumination regime (pulsed, clocked, continuous).

These photo-induced processes originate from the absorption of multi-dielectric components, whose bulk density is the heat source responsible for a temperature rise in the component. Thus, the photo-induced temperature is the first thermal phenomenon studied in this thesis and a complete description based on layer and illumination parameters is proposed. It is mainly based on an analogy between optics and thermics, allowing to obtain an analytical model of the temperature. This procedure allows to better target the influence of the different input parameters, and to further address the phenomena of laser damage or self-organization of nanoparticles.

The temperature increase leads to a modification of the thermal radiation of the filter. Very often, the modeling of this radiation in monochromatic illumination regime is reduced to a calculation of emissivity in connection with Kirchhoff's law, which stipulates its equality with the absorption. However, this method is insufficient when we want to go further into the details of the balance of thermal processes (evanescent waves, guided modes by coupling, transient regimes). Thus, in this thesis, we propose a direct modeling of photo-induced thermal radiation. This means that we rely on the various works of statistical physics that allow to link the thermal agitation of particles to volume densities of electric current. These currents are inserted into Maxwell's equations to obtain the electromagnetic field radiated in free space, called thermal radiation. The method of resolution is based on the work related to luminescent microcavities and the volume scattering of light in filters.

The resolution method also allows the design filters that confine and exalt their own thermal radiation in a small spectral or angular bandwidth. More broadly, this opens the way to the control of thermal radiation by multilayer planar structures, which is an important research area in the Defense and Energy sectors. An analytical synthesis method is proposed to generate giant field exaltations in microcavities, with application to thermal radiation.

Finally, this precise analysis of the thermal radiation allows, for the first time, to precisely quantify the part of the photo-induced thermal radiation that is transferred as guided modes to the multi-dielectric structure.

Keywords: optical interference coatings, thermal radiation, photo-induced temperature