The Role of Sample Length in Thermal Lensing of Solids: Theory and Experiment

Luis Carlos Malacarne [C, S] and Nelson Guilherme Castelli Astrath
Physics Department, Maringa State University, Maringa, Parana, Brazil
lcmala@dfi.uem.br

Thermal Lens or the wavefront distortion induced by thermal lensing is a key effect in laser engineering and photothermal spectroscopy. The description of wavefront distortion induced by laser absorption in optical elements is fundamental in the design and evaluation of solid state lasers, optical windows and other passive optical components for high power laser systems. In addition, monitoring the dynamic process of optical path difference (OPD) with photothermal methods enables direct quantitative access to many physical properties of a large class of materials. The amplitude of the thermal lensing or its dioptric power is proportional to the OPD between the center and border of the beam, which is proportional to the heat power. This distortion is a result of complex photoelastic effects that characterize the degradation and the propagation of the beam. Due to thermally induced mechanical stress and bulging of end faces of the sample, OPD depends critically on the geometry of the sample. Simple analytical solution is obtained only for low absorbing materials, with the assumptions that the stresses obey either thin-disk or long-rod type distributions. In this investigation, TL measurements were performed as a function of the sample length keeping the same heat power. It is experimentally demonstrated that for materials with positive temperature coefficient of the refractive index the OPD increases typically 30 to 50 % with the decrease of sample length (from long rod to thin-disk geometry). For materials with negative temperature coefficient of the refractive index, this variation is much larger due to the cancelation of the different contributions to OPD with opposite signs. Furthermore, the experimental investigation presented here validates a recently proposed unified theoretical description of the TL effect, ``J. Opt. Soc. Am. B 29, 3355 (2012)", which relates the OPD to the temperature profile in a relatively simple manner for all classes of absorbing optical materials. This generalized model could have significant impact on designing laser systems and has direct application in photothermal techniques in the determination of thermal, optical and mechanical properties of solid materials.