Mathematical Modeling Study to Identify Limitations of Optical Dilatometry Technology and Assess their Influence on Contact-less, Absolute Dimensional Change Measurements

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Double beam optical dilatometry is a well-established technology for the measurement of thermal expansion and the optimization of sintering processes. Its main and most significant benefit over other techniques to measure a sample's dimensional changes as a function of temperature is the capability of contact-less and absolute measurements. The lack of contact between the measuring system and the sample prevents artifacts due to mechanical interference, while the use of two independent optical systems to frame the two extremities of the specimen makes redundant and not necessary the method and/or sample-size specific calibrations that are required by other techniques.

As known, along with these advantages come a few limitations and interferences, which impact double-beam optical dilatometry's resolution, linearity and, consequently, reproducibility:

- distortions caused by the changes in the reflective index of air as a function of the temperature can lead to apparent expansion/contraction and non-linearity,
- elongation of the sample's supporting rods as a function of the temperature modifies the distance between the optics and the sample, with the risk of bringing it out of the focal range of the optics,
- measurement's resolution is limited by the wavelength of the light source, which makes it virtually impossible to detect changes smaller than 500 nm.

Though these restraints were known since the development of the double-beam optical dilatometry technique, their influence on measurements for industrial applications were considered negligible compared to the undisputed advantages the technique introduced, hence the have never been studied in depth.

Recent developments in shape and image analysis eventually allowed us to mathematically model their impact, and for the first time discuss their influence. Theoretical models have been developed to estimate the errors related to each factor. Specific experiments were designed to single-out, amplify, and measure the extent of the errors under controlled conditions.