Effects of Forced Airflow Cooling on Laser Beam Heating of Volume Bragg Gratings

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Abstract

Volume Bragg Gratings (VBG) are holographic elements recorded in Photo-Thermo-Refractive (PTR) glass. They are relatively new invention of the last decade that has been successfully used for high power and high spectral density laser beam combining [1]. Main application of these beams include laser beam welding and cutting. Further demand for increased output power of these systems implies necessity for higher output powers of each separate laser. This in turn creates higher heat deposition in working optical elements such as VBG's, and leads to thermal deformation of PTR glass plates. These changes of shape or thickness of grating may cause substantial deterioration of output beam quality and even change of spectral transmission range.

In this work we consider one of the cheapest and most efficient ways of reduction of these negative effects by means of cooling the system by forced airflow. This method was recently suggested by Venus et. al. [2]. A realistic model of the setup for this type of cooling is developed and studied using COMSOL Multiphysics®. The schematic of the setup is shown on Fig. 1 for one VBG and a copper holder with slits for air cooling.

Geometric dimensions of the VBG were taken to be 2.2 x 2.2 x 0.274 cm which are typical for many applications. Modeling was conducted for four laser beam intensities of 4.5KW, 6.7KW, 8.9KW, 11KW and seven evenly incremented rates of cooling airflow. Temperature of the incoming flow was taken to be 20 degrees Celsius and corresponded to the ambient temperature in the system. Beam intensity distribution was taken as Gaussian, with beam width of 3mm (FWe^(-2)IM) and its axis perpendicular to face of VBG (Fig 2a).

In our model, we obtained data for spatial mean temperature increase in the VBG along the axis of heating beam and compared it with data obtained from an experimental setup with the same parameters. These results are shown on Fig 3. They indicate that our model is adequate for prediction of behavior of real systems. Discrepancy between modeled and experimental temperature increase was around 15%, with the maximum reaching 27% for some combinations of laser power and rate of air flow. Calculations of the same type were conducted for a model, where airflow was limited by two transparent glass plates, presumably allowing for more efficient cooling at the same rates of airflow as before (Fig 2b). This assumption was proven to be correct both by our modeling and by the experiment (Fig 4). While measurement of each new

parameter of the system in physical experiment requires special arrangements, in our model we obtained information about some of those parameters (airflow velocity distribution, non-axial temperature distribution, etc.) along with computation of main parameters. This substantially contributed to understanding of the system behavior.

To conclude, forced air cooling of VBG proved to be efficient for reducing thermal deformations caused by laser heating. Results obtained within framework of our model are consistent with experiment.

Reference

[1] D. Drachenberg, I. Divliansky, V. Smirnov, G. Venus, and L. Glebov, "High Power Spectral Beam Combining of Fiber Lasers with Ultra High Spectral Density by Thermal Tuning of Volume Bragg Gratings." Proc. of SPIE vol. 7914 (2011).

[2] Brian Anderson, Sergiy Kaim, George Venus, Imtiaz Majid, Julien Lumeau, Vadim Smirnov, Boris Zeldovich, Leonid Glebov. "Forced Air Cooling of Volume Bragg Gratings for Spectral Beam Combination." Proceedings of SPIE 8601, Fiber Lasers X: Technology, Systems, and Applications (2013).

Figures used in the abstract

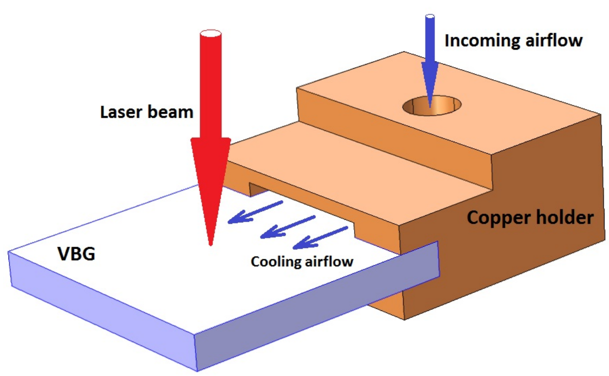

Figure 1: Schematic of VBG cooling setup.

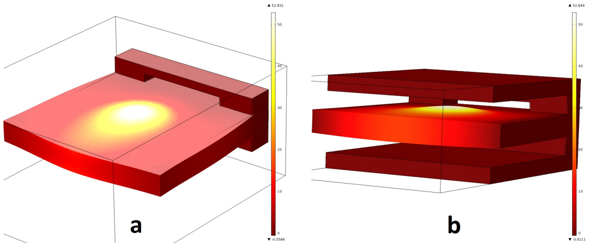

Figure 2: Temperature distributions for VBG illuminated by laser with power of 11KW and cooled with airflow of 1 SCFM. (a) without limiting glass plates; (b) with limiting glass plates.

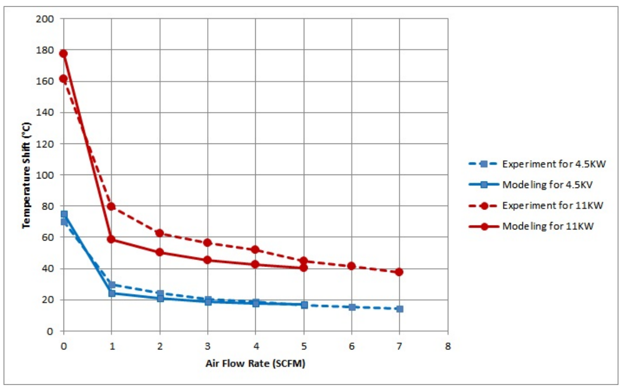

Figure 3: Comparison of modeled and experimental temperature increases for lasers with powers of 4.5KW and 11KW.

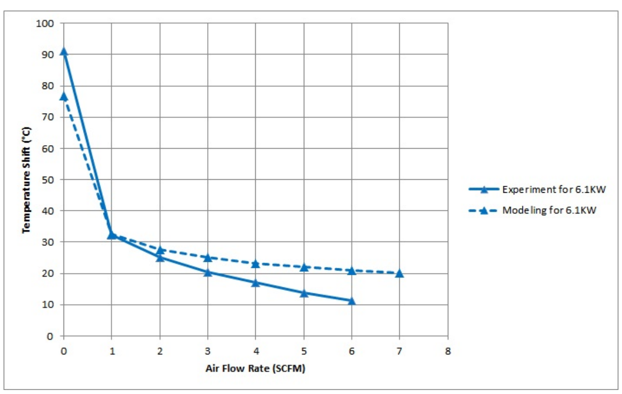

Figure 4: Comparison of modeled and experimental temperature increases for a laser with power of 6.1KW for VBG with limiting glass plates.