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Concept and Dimensioning of Thin Ceramic High Power Mirrors

Introduction

High power laser processing of sheet metal including cutting, welding and drilling has gained much in importance in recent years. A significant increase of system power and beam quality has enabled the progress in e.g. cutting of thick plates. The beam shaping inside the laser is made either with lenses of large diameters and an optional cooling or massive mirrors that can also be cooled. This work develops a new design for laser beam profile shaping mirrors that is based on thin ceramic wafers with a reflecting surface and integrated piezoelectric zirconat titanat (PZT) actuators. The present work discusses various concepts for thin high power adaptive mirrors and their dimensioning.

Material Selection

The further progress in laser processing will depend heavily on a further increase and tuneability of the system power and on an enhanced beam quality. Laser profiles for material machining are typically shaped as flattop, whereas profiles inside the laser are Gaussian. This leads to an increasing need for high power shaping devices. Such high power adaptive mirrors are constructed by applying piezoelectric layers on the backside of the mirror. The set-up with a single layer piezoelectric material on a passive substrate is already known as monomorph and extensively described analytically [1].

The relative strength c and height a of the substrate to the PZT thick film determines the product of deflection and force of the monomorph (Fig. 1). Thin substrates with a high elastic modulus lead to the highest product of deflection and force. To keep the manufacturing effort low, a screen printing process for the application of a PZT thick film was chosen. Films with a thickness of 80-130 µm were applied on the microelectronic substrates alumina (Al_2O_3), zircon oxide (ZrO_2), low

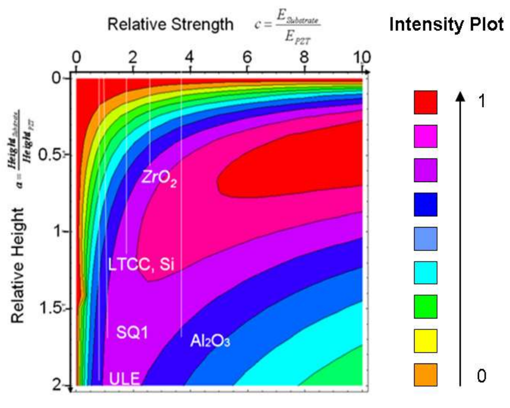

Figure 1: Product of deflection and force depending on relative height a and strength c

temperature co-fired ceramics (LTCC) and silicon (Si) [2].

The material selection for conventional high power mirrors results basically either in a low thermal expansion material (e.g., ULE) or a high thermal conductive material (e.g., copper). In contrast to the established solutions, a thin multilayer material system is proposed and not a massive design. Hence requires more sophisticated material selecting tools.

Multilayer System Concepts for Reducing Thermal Influences on Mirrors

Adaptive mirror systems under a thermal load and based on LTCC substrates were investigated. LTCC was chosen as substrate material because it allows for easy integration of metallizations and thermal vias. A piezoelectric layer with a bottom electrode (15 µm thickness) and a top gold electrode is applied on the back. A metallization as a reflecting surface is applied on the substrates front. The modeled mirror has a diameter of 100 mm and a thickness between 200 and 300 µm, depending on the number of LTCC layers.

Studies on the performance of different reflecting surface metallization materials (copper, nickel- phosphorous, silver) under high thermal laser load (laser beam diameter 30 mm, Gaussian profile,1 W material absorption) were carried out with FEA. It is shown that copper and silver lead to low thermal induced deformation. Three layers of LTCC lead to less deformation compared to two layers of LTCC. An additional inner metallization between two LTCC layers lowers the thermal induced deformation once more. Starting from FEA-Simulations and experimental validations new concepts of LTCC-based high power adaptive mirrors are presented.

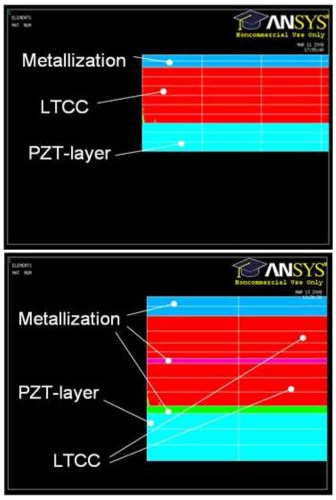

Figure 2 starting design of adaptive LTCC mirror; 2 bottom: new design concept

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