Lightweight Aluminum Mirror with Duplex Layers

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Abstract: We designed a lightweight aluminum mirror structure including duplex layers and triangular ears. Based on the structural analysis, we confirmed that the surface deformation is negligible by optimizing physical dimensions to minimize the deformation. © 2021 The Authors

1. Introduction

Recent advances in ultraprecision technology, e.g., single-point diamond turning, can make high-imaging quality aluminum mirrors. If we would directly mount the aluminum mirror on the aluminum housing structure, the whole optical and optomechanical units can be simple, light-weighted, and sturdy. Besides, this CTE (Coefficient of Thermal Expansion) matching single material mirror-housing structure makes the imaging performance to be independent of the thermal expansion.

Mounting the aluminum mirrors using screws is the simplest and straightforward method. The surface shape of the mirror, however, is very sensitive to the stress induced by the tensile force of bolt fastening and the gravitation force applied to its mirror weight. Since the deformation of the mirror surface degrades optical performance structural design of the aluminum mirror should consider these aspects [1].

To reduce the effect of the stress by the screw, some mirror designs adopt round-shaped ear structures on the rim or backside of the mirror [2,3]. However, in the case of cylindrical plate shape mirrors, the bolting point at the rim affects the surface shape. Also bolting at the rim increase the physical size of the mounting structure which relates to the size/volume of overall optomechanical components or subsystems. We introduce a new concept of the aluminum mirror structure including duplex layers and triangular ears. We performed a Finite Element Analysis (FEA) to find the optimized structure and physical dimensions of the mirror [4,5].

2. Lightweight Aluminum Mirror Design

We designed a simple round shape mirror with an aperture diameter of 174 mm (see Figure 1). The optical layer has a reflective optical surface on the front side (green). For the light-weighting, the backside of the optical layer has isogrid triangle pockets. The assembly layer on the backside of the mirror includes the three triangular ears with screw threads at the edges. The triangular shape can distribute the stress uniformly to the cylindrical neck and minimize the stress on the mirror surface.

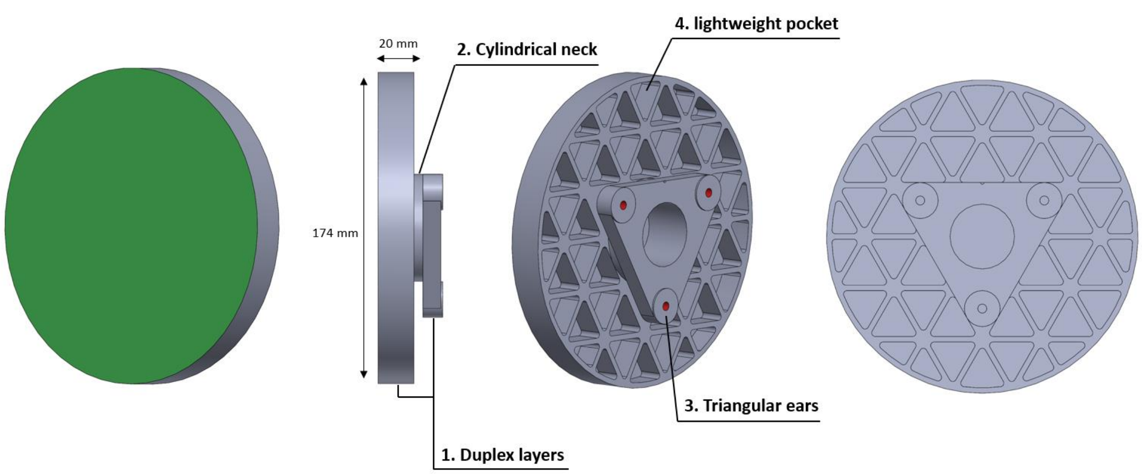

Fig. 1. Design of the 174 mm diameter aluminum mirror structure including duplex layers and triangular ears.

3. Finite Element Analysis and Optimization

We performed the FEA to investigate the robustness and characteristics of the duplex layered aluminum mirror. For checking the characteristics, we analyzed the mirror with two condition cases: load types (gravity and bolt torque), inclinations (0˚−180˚). In the former case, we focused on the pattern of the surface displacement following the external loads. In the latter case, we checked the variation of the error level related to the inclination.

We also varied the values of several key structures (wall thickness, face sheet thickness, etc.) to see which structures were most relevant to optimize the surface distortion. Critical structures were the thickness of the optical layer and a radius of a center hole. These two structural parameters affect the surface more than others and we find values to minimize the surface displacement in Z-axis (i.e., optical axis). Based on the FEA result, the mirror has been optimized at the maximum level of the surface deformation of 14 nm (see Figure 2).

Furthermore, we compared the structural characteristics of the duplex design against a general mirror design using ears at the rim of a single layer through FEA. According to the result, the surface displacement pattern of the duplex design case was less sensitive to the screw tightening than that of the single-layer case and the overall mirror was less shifted from the nominal origin position.

From these FEA investigations and optimization results, we confirmed that the duplex layer mirror design is sufficient to be applied to imaging application systems and units.

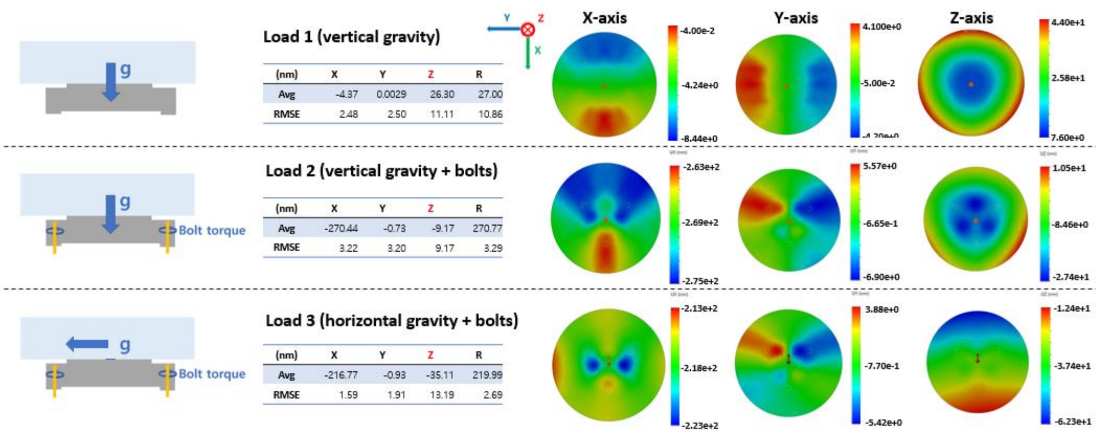

Fig. 2. Surface displacement of the optimized aluminum mirror due to the external loads. The contours show the displacement of each axis. In this simulation, Z-axis RMSE is directly related to the optical wavefront performance.

We plan to fabricate two prototype mirrors and measure their surface shape deformation to verify the simulation result and effectiveness of the optomechanical mirror design. Based on the measurement data we will demonstrate the experimental effectiveness of the mirror design and the numerical accuracy of the FEA process.

4. Acknowledgement

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