MEMS Mirror for High Power, Large Angle, 2D Laser Steering

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A MEMS mirror has been developed for large angle, 2D steering of high power laser beams. Besides space applications, such mirrors can also be used for laser scribing and other laser patterning methods.

Within the JEM-EUSO project [1], a MEMS mirror for 2D laser steering has been developed, with the following key specifications:

- optical actuation angle: +/- 30° in both directions
- maximum settling time: 100 ms
- laser source: 355 nm (tripled Nd-YAG), 20 mJ, 15 ns pulses

The short wavelength of the laser source, combined with the high energy of the pulses, requires the mirror surface to have a minimum size in order to prevent laser-induced damage to the mirror surface. The mirror material chosen was coated quartz. The quartz itself is transparent to the laser light, so it cannot be damaged. Very good, high reflectivity coatings (> 99%) are available on this material. The laser source will be spread over a 2.4 mm diameter beam, so that the energy density of the light will remain below 1 mJ/mm^2. The mirror surface should have a diameter of at least 3 mm to be able to reflect all light from the laser in all possible directions.

The mechanical actuation angle of the mirror is half the optical actuation angle: +/-15°. The laser will impinge on the mirror at a 45° angle. As a result, the mechanical actuation angle in the actuation direction perpendicular to the plane of incidence of the laser light should be +/-21° in order to achieve the +/- 15° actuation in this direction.

The flexible material chosen for the suspension of the mirror is silicon. Silicon, when properly machined, has excellent mechanical and fatigue properties, which make it, therefore, well suited for space applications. Furthermore, it can be machined in batch processes with high precision.

The design of the flexible structure has been inspired from the work on a robotic arm actuator [2] and is depicted in Figure 1. In this figure, the mirror is transparent and will be clamped between two silicon holders in the middle of the structure. Each holder is connected by three spiral beams to a frame. The spiral beams are rigid with respect to lateral motion and are flexible for out-of-plane bending movements. Therefore, when the two frames are laterally displaced with respect to each other, a tilting of the mirror occurs. This can be understood by the fact that the spiral beams are stiff for a lateral motion, so that the lateral movement of the frame results in an almost identical lateral movement of the mirror holder. This lateral movement can only be accommodated by an out-of-plane rotation of the mirror. This rotation is possible because the spiral beams are flexible for out-of-plane movements.

The design has been simulated extensively using the Comsol finite element package. The actuation force can be as high as 1 N and the relative movement of the frame will be around 1 mm. Only magnetic actuation can deliver this amount of force over such a distance. Therefore, actuation voice coils from BEI Kimco will be used for actuation, with the goal of replacing these coils with a custom solution in the future.

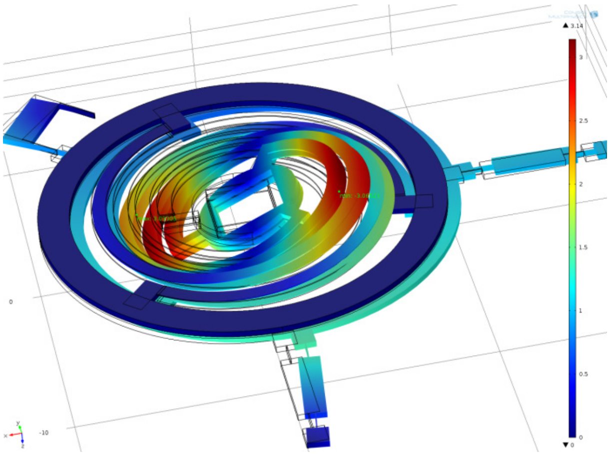

Figure 1: The actuation mechanism for the MEMS mirror.

It has been found that the structure exhibits a small piston movement that needs to be dampened. This damping is achieved by making the side of the mirror conductive and placing a permanent magnet below the mirror. The piston movement of the mirror relative to the magnet induces Eddy currents in the conductive layer around the mirror, and these Eddy currents are converted into heat by the resistivity of the layer, thus absorbing the energy of the piston movement.

The launch conditions were also simulated, and the vibrations in the mirror risk breaking the spiral beams. A clamping mechanism was therefore designed to fix the mirror in place during launch. The resulting structure is depicted in Figure 2. The fabrication of this structure is foreseen for 2016.

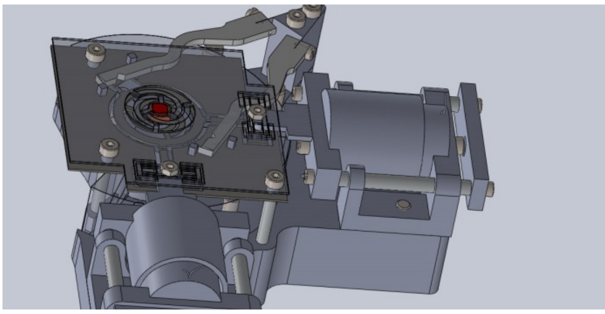

Figure 2: The complete MEMS mirror with actuation and clamping.

[1] T. Burch, *et al.*, "A Platform for a MEMS-based Laser Pointing System with Position Feedback", this report page 96

[2] L. Rubbert, "Conception de mécanismes compliants pour la robotique chirurgicale", Ph.D. Thesis, University of Strasbourg, 2012