Development of a Segmented Grating Mount System for FIREX-1

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Abstract. A mount system for segmented meter-sized gratings has been developed, which has a high precision grating support mechanism and drive mechanism to minimize both deformation of the optical surfaces and misalignments in setting a segmented grating for obtaining sufficient performance of the pulse compressor. From analytical calculations, deformation of the grating surface is less than 1/20 lambda RMS and the estimated drive resolution for piston and tilt drive of the segmented grating is 1/20 lambda, which are both compliant with the requirements for the rear-end subsystem of FIREX-1.

1. Introductions
High power laser systems have been required for studies such as inertial fusion science and application. [1] A technique of chirped pulse amplification (CPA) has been developed for such high power laser systems. [2] Configurations involving one or two pairs of gratings are widely used in CPA pulse compressor [3] and large gratings are required because of limited damage threshold. For the rear-end subsystem of FIREX-1, a unique two segmented grating arrangement is used for the pulse compressor. [4] If there is deformation of the optical surface and misalignment in setting the segmented gratings, the performance of pulse compressor is degraded (broaden pulse width of a compressed pulse and decreases peak power).

We have developed a segmented grating mount system which has a high precision grating support mechanism and drive mechanism to minimize both the deformation of the optical surfaces and misalignments in setting a segmented grating for obtaining sufficient performance of pulse compressor.

In this paper, the design and analytical performance of the newly developed mount system for segmented grating are described.

2. Segmented grating support and drive unit
Figure 1 shows (a) a photo and (b) functional block diagram of a grating support and drive unit. The unit supports one segment of the grating on the front and drives the grating in five axes including two axes of manual drive mechanism used for initial adjustment. A grating has almost meter-sized
The dimension of 920(W) * 410(H) * 90(D) mm. The unit with the base plate on the rear is attached to the grating mount system that can hold a total of eight segments (two segments of grating per each beam multiplied by four beams). The support frame holds the grating with soft support pads and is suspended by a leaf spring gimbal from a manual drive mechanism attached by base plate.

3. Drive mechanism

The grating support and drive unit has a motorized drive mechanism for piston and tilt x2 (tip/tilt). The drive mechanism consists of a leaf spring gimbal and three actuators.

The leaf spring gimbal has stiffness high enough to counteract the gravitational force of the grating. At the same time, the leaf spring gimbal has low stiffness in the driving direction so that it doesn’t generate strong reaction force to actuator motion. Therefore the actuator doesn’t have to handle a large load that leads to a loss of response and less smoothness. As the leaf spring gimbal is the dominant factor in terms of strength and natural frequency of overall system, we have verified them using structural analysis for the leaf spring gimbal. Figure 2 shows the structural analysis model for the leaf spring gimbal.

![Figure 2. Leaf spring gimbal](image)

![Figure 3. 1st order vibration mode](image)
From the calculation result of strength, the leaf spring has sufficient strength with a safety margin of factor 2 or more for the maximum stroke and earthquake load. Figure 3 shows the calculation result of vibration mode. The 1\textsuperscript{st} order vibration mode has a natural frequency of 5 times higher than the system requirement.

Also, we have developed a high precision vacuum compatible actuator. The actuator consists of a stepping motor, high ratio reducer, bolt and screw type transducer (circular to linear motion). The actuator has the following feature.

• For higher thermal stability, the materials of casing and actuator shaft are carefully chosen taking into account prototype results.
• To lower heat generation, motor electrical current is optimised during drive and shut off after movement.
• Thanks to the leaf spring support, the actuator structure is optimised to the small load and leads to good smoothness.

4. Grating support mechanism
Figure 4 shows the arrangement of soft support pad. Each pad has a following function respectively.
• Grav-\textsuperscript{Y} pads at the bottom receive the gravitational force of the grating.
• Constraint-\textsuperscript{Z} pads fix the Z position.
• For safety during grating handling, other pads hold the grating securely.

![Figure 4. Support pad arrangement.](image)

![Figure 5. Gravitational deformation](image)

We have conducted FEM analysis for the following case.

• Gravitational deformation (1)
• Deformation due to friction force of support pad (2)
• Deformation due to displacement of supporting pad
  • To the normal direction to grating optical surface (3)
  • To the direction within grating optical surface (4)

Figure 5 shows a calculated contour map for the gravitational deformation (1). Fig. 5 (a), (b) and (c) show raw data, component of combined piston, tilt and focus, the deformation after piston, tilt and focus are removed respectively. The deformation after piston, tilt and defocus removed shows 3.6 nm RMS and turned out to be very small.

From the result of FEM analysis for the case from (1) to (4), summation of the deformation shown below is less than 1/20 lambda RMS where lambda is 1053nm.
SQRT( (1) + (2) + (3) + (4) ) = 22.5 [nm] RMS MF (Mirror Figure)

5. Summary
We have developed a segmented grating mount system which has a high precision grating support mechanism and drive mechanism to minimize both deformation of the optical surfaces and misalignments in setting a segmented grating for obtaining sufficient pulse compressor performance. Estimated performance is compliant with the requirement for the rear-end subsystem of FIREX-1. Results of experiment show that deformation of the grating surface is less than 1/20 lambda RMS wavefront from analytical calculation and the drive resolution of the segmented grating is less than 1/20 lambda. The performance of the grating mount system will be verified in an optical test.

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