Fabrication of an Active Grating

An active grating based on a novel optical concept with bendable polynomial surface profile to reduce the coma and defocus aberrations has been designed and tested by a prototype. In the prototype design we adopted a 17-4 steel bender and glued it onto a silicon substrate. Due to the difference in thermal expansion between steel and silicon, the prototype distorted after polishing and deblocking. To reduce the thermal deformation of the active grating during the polishing process we replaced the steel bender by an Invar bender. This modification showed good results and the grating is now ready for the next step of grating ruling. In this article we will present the design modification and test results.

In a holographically recorded diffraction grating, the material is usually made of silicon or zerodure glass. The fabrication process starts with polishing of the substrate to flatness of wavelength/10 and roughness of 1-2 Å rms, followed by applying photosensitive coating on the flat surface. Two laser beams are used to produce interference fringes in the photosensitive layer and then the layer is developed and processed. The final processes are vacuum coating and testing. Normally the grating surface profile produced in this way is fixed, but in our new active grating design the profile is bendable. Being a brittle material, silicon is too fragile to be used as the base material of the bender. Thus we designed a metal bender with 17-4 stainless steel and glued a silicon substrate to it. After our test polishing without pitch blocking, the polished profile attained 2.5 μrad rms, however, the surface was relatively rough. In the standard polishing process of the grating manufacturer, pitch blocking is adopted during polishing. The slope error could reach 0.2 arcsec rms as polished, but after pitch deblocking by heating to 60°C the surface profile deformed to about 20 μrad The surface deformation could be due to thermal mismatch between silicon and bender and/or glue deterioration.

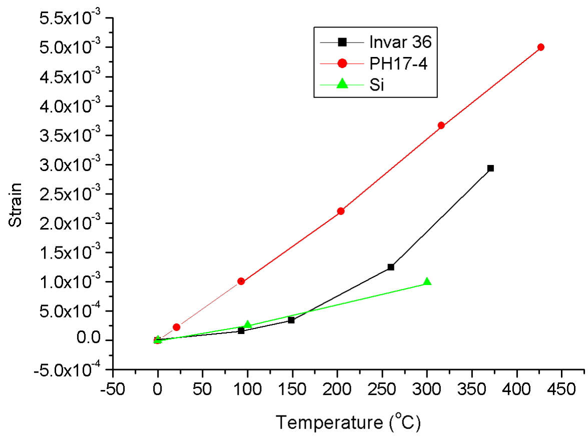

Fig. 1: The thermal strain of three test materials for different temperatures.

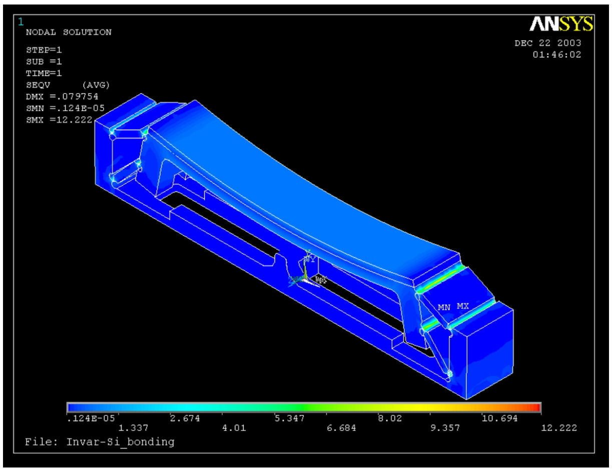

Fig. 2: Finite element analysis of the glue bonding.

According to the information from the grating manufacturer the temperature for pitch blocking is about 60°C; and for ruling (photosensitive layer curing) is about 90°C. To meet the process re-quirement we have to design a new structure with low sensitivity to temperature change and high resistance to temperatures up to about 100°C. After surveying various materials with good thermal match to silicon we chose Invar as the bender material. As shown in Fig. 1, the thermal expansion coefficient of Invar is only slightly lower than that of silicon below 150°C. It is 5 times better than 17-4 stainless steel. For temperatures above 400°C Invar will phase transform and the thermal mismatch becomes worse. Either brazing or soldering above 400°C will easily induce cracks during thermal cycling. We have performed the brazing test and inevitably this phenomenon occurred. Thus a high temperature glue resist up to 120°C would be a reasonable choice. Finite element analysis was performed to simulate the bonding stress after the gluing process. As shown in Fig. 2, the shear strength is well within the peel strength of the glue. Many different thermal cycles were also tested to verify the temperature resistance of the glue aging. No significant profile deformation was found, as can

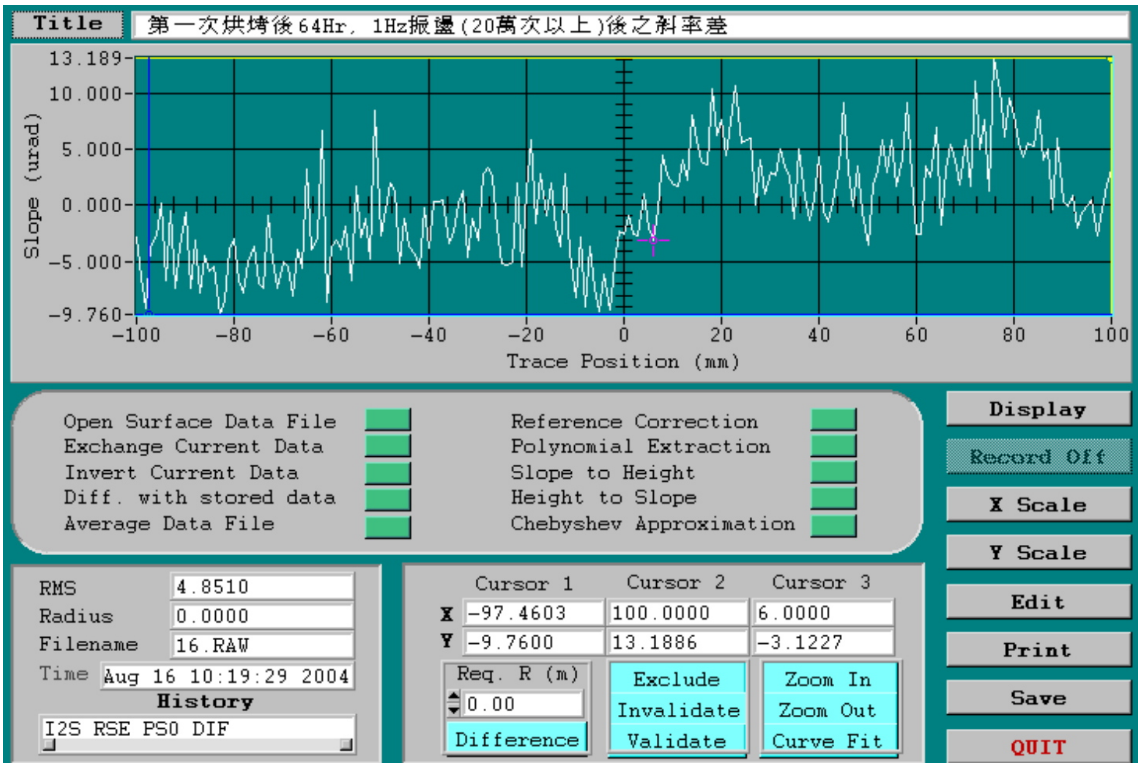

Fig. 3: Thermal cycle test of the silicon substrate glued onto an Invar bender.

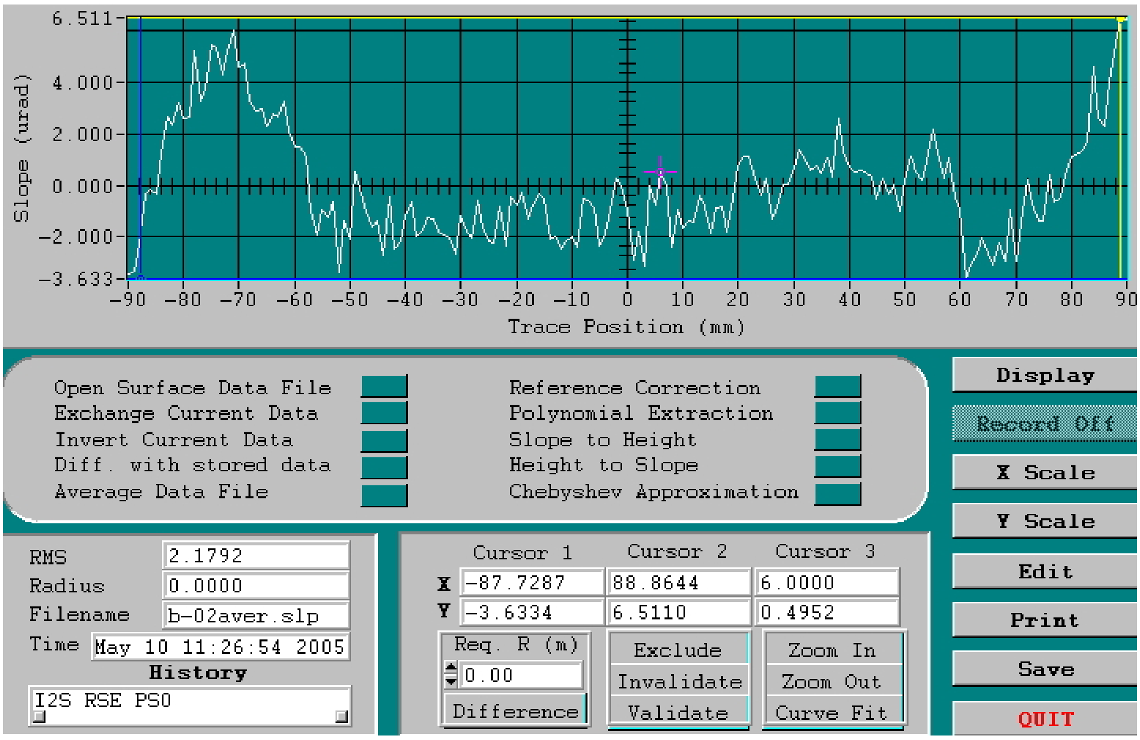

Fig. 4: Slope error of the polished profile of the new design version.

be seen in Fig. 3. The polished profile of the new design version is shown in Fig. 4, in which the slope error is about 2 μrad rms after subtracting the second and third order terms.

In summary, a novel bendable active grating has been polished by the manufacturer with satisfying result. To reduce thermal deformation of the active grating during the polishing process, we designed a new version, which uses an Invar bender and a glued-on silicon substrate. This bender/substrate assembly will be ready for the next step of grating ruling.

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