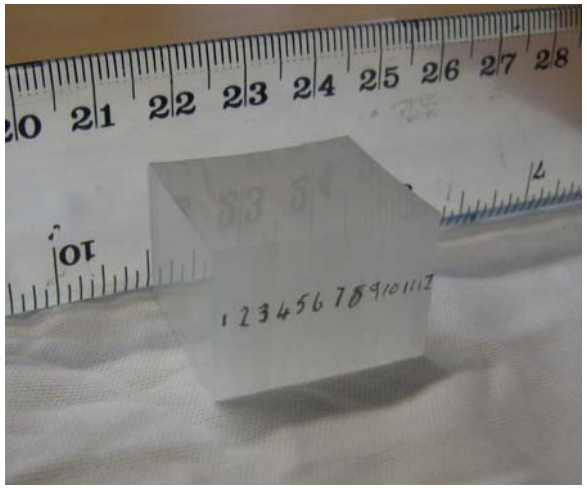
De-bonding of hydroxide-catalysis bonds

S. Rowan describing work by E. Elliffe, S. Rowan, J. Hough as part of collaborative work with the UK Astronomy Technology Centre and Spanoptic Ltd Fife, under a PPARC industrial support grant

Motivation

- De-bonding investigated in Glasgow under a proposal to develop glass integral field units (IFUs) for astronomical spectroscopy
- Individual slices of material (here silica) are bonded together, figured and polished such that the ‘end’ face of the slicer forms an optical ‘mirror’ surface.
- Slices are then de-bonded, displaced relative to one another (such that the foci of the mirror slices are spatially offset) and rebonded.

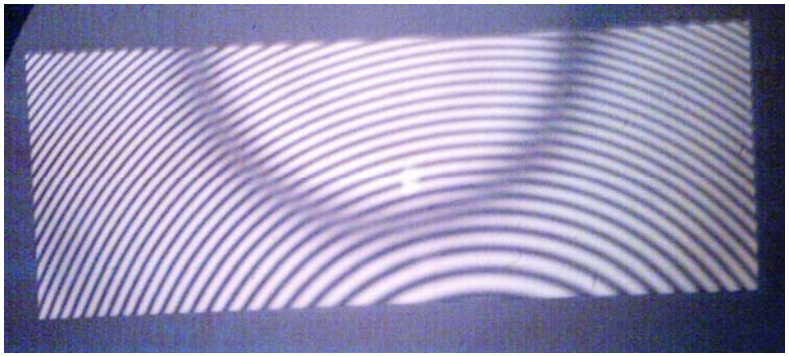


Slicer unit assembled before bonding

Initial studies

- 3 pairs of silica slides were bonded (each ~dimensions of a microscope slide – see below

- First step was to verify the surface global flatness of the bond regions using an LI10 Logitech interferometer with a $\lambda/10$ 4” optic



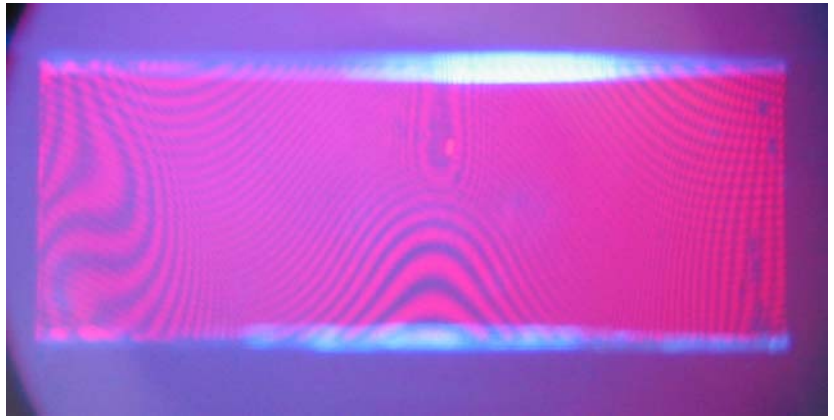
An interference pattern showing the overall global flatness of a silica slice that has yet to be bonded.

Fringe pattern suggests that there is a some curvature of surface.
This result implies that an increase in bonding solution may be required to increase the effective fill factor for the interface figure mismatch. It also suggests that a warping of surface figure may occur upon bonding, as the surface tension of the solution pulls the two globally mismatched surfaces together.

Initial studies

- Three bonds were made from the six flats provided. Prior tests using microscope slides of similar bond area and flatness suggested that 10μl of bonding solution should be used for each bond made. Bonding solution used was1 part sodium silicate solution (27% NaOH, 14% SiO_2) to 4 parts water.
- Monitoring the global flatness of the pairs of silica slides when bonded (ie looking at fringe patterns of the bonded pairs) showed that there was significant distortion see below. This was to be expected as the surfaces pulled together and distorted the thin (~1.5mm thick) slides.
- Each of the three bonded pairs showed a similar effect.

Interference pattern showing the overall global flatness of two silica slices bonded together.



Initial studies

- The three bonds were then de-bonded (1 day, 5 days, 14 days) in a 10% solution of micro 90 in an ultrasonic bath
- Table below shows the time each bond was cured for at room temperature and the corresponding time taken for each bond to de-bond in a 10% ‘micro 90’ (commercial glass cleaning detergent) solution.

Curing time	De-bonding time
1 day	~ 0 hrs 30mins
5 days	~ 8 hrs 16mins
14 days	~ 8 hrs 45mins

- Micro 90 is an alkaline solution and therefore contains a fraction of OH- ions that will slowly etch the silica surface.
- At a pH less than 11, this process is usually insignificant over short timescales of ~ 1hour,
- For samples which spent >8hrs in solution – etching is a possibility (not found at a significant level here)

Initial studies

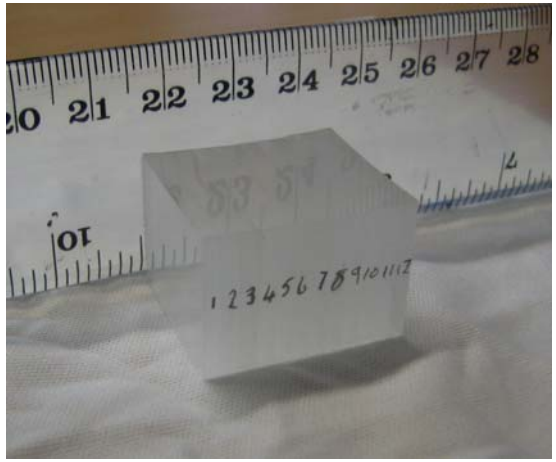
- Characterisation of the global flatness after de-bonding showed that the flatness did not change significantly and the pieces could be successfully rebonded.

Further work

- Further experiments showed debonding was possible after much longer post-bonding time intervals.
- For a solution of 1 part sodium silicate solution (27% NaOH, 14% SiO_2) to 6 parts water de-bonding could be carried out more than 28 days after initial bonding.
- This particular bonding solution was used to fabricate the slicer units discussed below .
- The resistance of a bonded structure to grinding and polishing was then tested and it was found that the grinding motion combined with the alkaline pH (pH = 9) of the grinding fluid provided an ideal de-bonding environment.
- This presented a potential problem. In principle this might have been overcome by changing the type of grinding fluid used but this was not an option for the specialist machines in use at our collaborating company who were polishing the units.
- Instead it was decided to carry out the coarse grinding and polishing using wax to hold the slices together, and use hand grinding and polishing to finish the figuring when the slices were silicate bonded.

Further work

- Thicker slices were used - 12 slices of dimensions 2.3 mm by 25 mm by ~20 mm.
- The increase in slice thickness over that of previous slices allowed a flatness of approximately lambda/2 to lambda to be achieved.
- To allow the pieces to be precisely placed before initial bonding the slices had one side polished and the other with a ground finish.
- Bonding solution could then be ‘wicked’ in to bonding surfaces.



Slicer unit assembled before bonding

Final prototype slicer unit mounted in measurement setup after bonding, de-bonding and re-bonding

Experiences with ‘ear’ debonding

- GEO attachments were bonded by Helena Armandula, Sheila Rowan and Jim Hough at Stanford
- In one case, the bond looked unsatisfactory shortly (~20 mins) after bonding.
- This ear was de-bonding (in less than ~1 hour) after bonding using a nominally identical technique to that described above.
- Flat on side of optic was set resting on Teflon rods such that the ear attachment and the flat were –just- submerged in an ultrasonic bath.
- Ear was detached after a few minutes of ultrasonic action