White light interferometric profilometry of surface structured glass for high power laser microtargets

H. F. Lowe and C. Spindloe
Target Fabrication Group, Central Laser Facility, STFC, Rutherford Appleton Laboratory, HSIC, Didcot, Oxfordshire, OX11 0QX, UK

Main contact email address **H.F.Lowe@rl.ac.uk**

Introduction

For a recent Astra TA2 experiment investigating High Harmonic Generation, a range of glass targets with average surface roughness from the sub nanometer level to 10µm were requested. The targets were used to study the effects of surface topology on HHG and were produced using a number of methods. The roughest targets were produced by abrading a glass microscope slide with glass paper. In addition, commercially produced glass slabs lapped to a sub nanometer level and to 150 nm were purchased from *Valley Design Corporation*.

Extensive surface characterisation was carried out on these targets, particularly by making use of the *Veeco Wyko NT9300* white light interferometer, depicted in Figure 1.

The *Wyko NT9300* uses while light interferometry to produce a topographical image of the sample under study allowing the operator to measure a number of different parameters. The roughness can then be measured along any line in the x or y axis of the resultant image. The 2D parameters were used as they are better understood than 3D surface parameters as the ISO standard relating to the measurement of 3D surface parameters is yet to be published. The results are limited by the vertical resolution of the *Wyko*, which is <0.1 nm, and the optical (lateral) resolution of 0.55 µm.

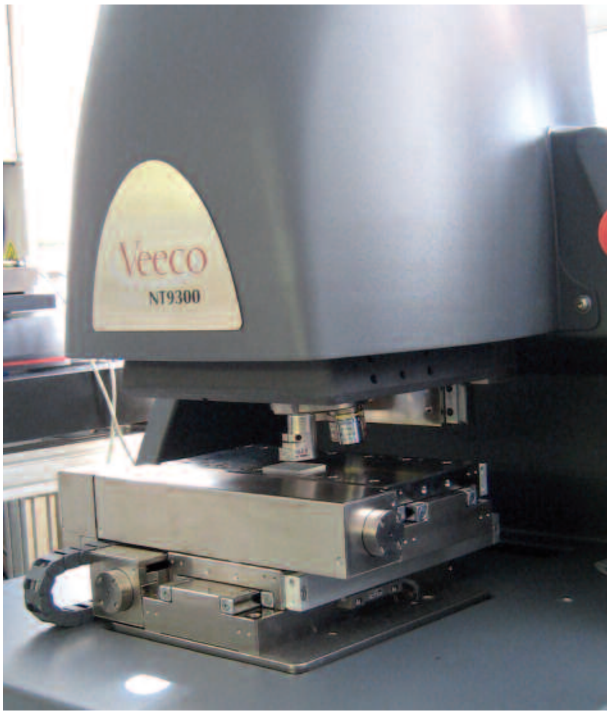

Figure 1. The Veeco Wyko NT9300 White Light Surface Interferometer.

Parameters

In order to perform a surface roughness analysis it is essential to understand the roughness parameters used. Ra is the mean roughness and is complimented by Rq which is the RMS roughness. The difference between the average (Ra) and RMS (Rq) roughness is an indication of the uniformity of the surface as the RMS roughness is more weighted by large values of peak height and valley depth. The RMS value is typically 10%-25% larger than the mean value of roughness depending on the nature of the surface[1].

Rz is the sum of the maximum peak height and the maximum valley depth averaged over the number of sampling lengths contained in the evaluation length[2] and Rt is the sum of the maximum peak height and the maximum valley depth over the evaluation length[2]. If Rt is much larger than Rz, it implies that within the evaluation length there is a particular peak or valley, such as a scratch, that is much larger than the typical features present on that surface.

Rsk denotes the skewness of the profile and is a measure of the evenness of the profile above and below the mean line. A negative value of Rsk implies that the surface under study has deep valleys and shallow peaks, whereas a positive value of Rsk implies that a surface has high peaks and shallow valleys.

Initial Experimental Procedure

For the glass slabs with a nominal surface roughness of 150 nm, an arbitrary area of the glass sample was scanned at magnifications of 20 to 100 times over evaluation lengths in the range of 50 µm to 300 µm. The roughness of the sample was then analysed from each scan. This roughness was from unfiltered 2D data as the sample scan length was shorter than the standard 5 sample lengths required by the ISO standard to use a Gaussian filter.

Analysis

Figure 2 is a topographical image of the glass at a magnification of 100 times obtained from the *Wyko*, where the variation in colour represents the variation in height. Figure 3 is a 2D section of the scan in the x direction from which the roughness parameters were computed at this magnification.

Figure 4 shows the roughness parameter values obtained from the scans taken over different evaluation lengths.

For the initial investigation (Figures 2 and 3) of the nominally 150 nm roughness sample, the values of mean roughness vary from 160 nm to 180 nm which is in the expected range. In this case, the RMS values are consistent across the four different evaluation lengths, ranging from 200 nm to 220 nm and are an average of 27% higher than the corresponding Ra values.

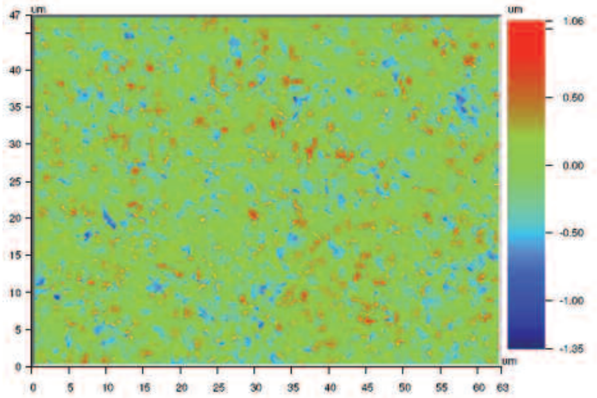

Figure 2. Wyko image of the glass surface at a magnification of 100 times over an evaluation length of 65 μm.

Figure 3. 2D lineout from the Wyko image of the glass surface at a magnification of 100 times over an evaluation length of 65 μm.

Evaluation length	65 μm	125 μm	225 μm	310 μm
Ra/μm	0.17	0.18	0.16	0.17
Rq/μm	0.22	0.22	0.20	0.22
Rz/μm	0.88	1.04	1.11	1.23
Rt/μm	1.30	1.41	1.54	1.64
Rsk	-1.21	-0.24	0.01	-0.12

Figure 4. Surface roughness values for the glass sample lapped to 150 nm.

The Rz values range from 0.88 μm to 1.23 μm while the Rt values range from 1.30 μm to 1.64 μm. These values are affected by the change in scan length as this may include or omit defects that have high or low points on the sample.

Referring to Figure 4, Rsk is negative over three of the evaluation lengths. This implies that the surface has deep valleys and shallow peaks[1]. Rsk was 0.01 when taken over an evaluation length of 225 μm, in which case the surface profile was almost symmetrical about the mean line.

It can be seen that the unfiltered data gives results that agree well over the range of evaluation lengths that are achieved using the different magnifications. Although the Rt and Rz values are higher for longer scan lengths, this is expected as it is more likely that there will be scratches and defects over a larger area of the surface which would dominate the Rt and Rz values.

Filtered Data Analysis

A filter is a mechanical, electronic or computational means of selecting only features with a wavelength above or below the filtering cut off to be included in the filtered profile. Filtering a surface profile is intended to separate the waviness profile from the roughness profile[2].

As the roughness values obtained from the unfiltered data agree at high and low magnification, it was decided to carry out measurements on both the glass lapped to a sub-nanometer level and the glass lapped to 150 nm using the stitching algorithms on the *Wyko*. These algorithms allow an area of larger than 4 mm to be scanned, which is the minimum evaluation length required by the ISO standard to apply the necessary filter with a cut off of 0.8 mm. This allowed the use of computationally executed Gaussian filters on the primary profiles obtained in order to give ISO standard measurements for the surface parameters.

The lapped sub-nm glass was scanned over an area of 5 mm × 5 mm and the stitched data is shown in Figure 5.

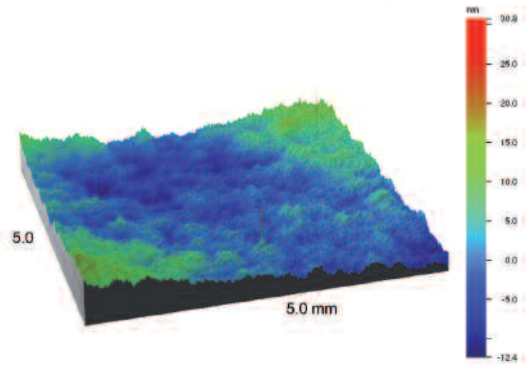

Figure 5. Unfiltered stitched 3D height data of the nominally sub-nm roughness glass.

Using the ISO standard filtering rules, an 80 μm filter was applied and the resulting roughness parameters are shown in Figure 6.

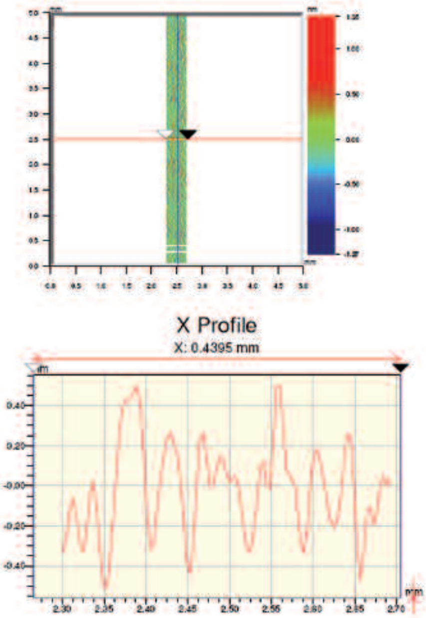

Figure 6. Topographical image of the filtered data and 2D filtered profile of the nominally sub-nm roughness glass.

The same process was carried out for the nominally 150 nm roughness glass over an area of 7 mm × 7 mm.

In this case, using the ISO standard filtering rules, an 800 µm filter was applied. The results are shown in Figures 7 and 8.

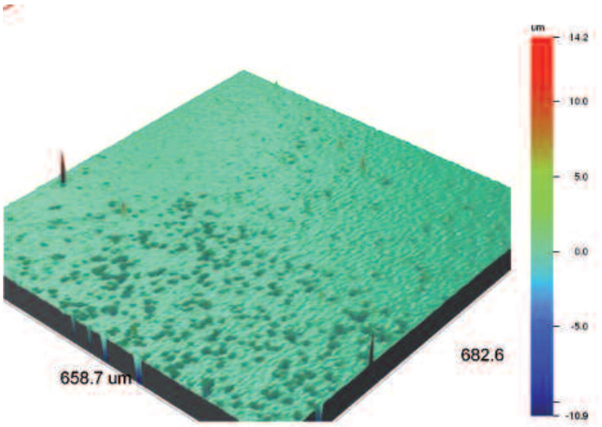

Figure 7. Unfiltered stitched 3D height data of nominally 150 nm roughness glass (zoomed in to 600 µm × 600 µm).

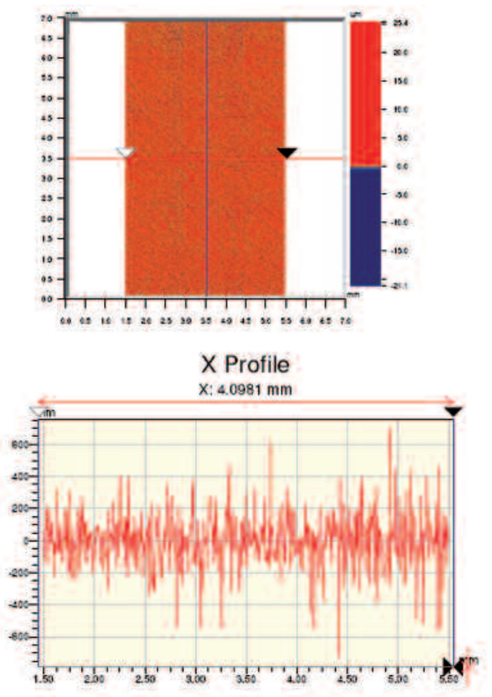

Figure 8. Topographical image of the filtered data and 2D filtered profile of nominally 150 nm roughness glass.

The data obtained from theses measurements is collated in Figure 9.

For the sub-nm glass, the Ra value of 0.19 nm is well within specification, although an Rq value of 0.24 nm, which is 26% higher than the Ra value, suggests that the surface is not entirely uniform. An Rz value of 0.70 nm shows that over 5 sampling lengths, the average maximum peak heights and valley depths are still sub-nm. An Rt value of 1.01 nm is close to the Rz value, which suggests that there are no particularly large scratches in the evaluation length but the feature or features that are in the order of 1 nm have given rise to the Rq value that is large in relation to Ra.

Sample	Sub nm lapped glass	150 nm lapped glass
Filter	0.08mm	0.8mm
Ra/nm	0.19	110
Rq/nm	0.24	150
Rz/nm	0.70	1,030
Rt/nm	1.01	1,400
Rsk	-0.08	-0.22

Figure 9. Filtered surface roughness values for the two glass types.

For the glass lapped to nominally 150 nm roughness, the roughness parameter values are slightly different under filter application from the initial investigations. This can be put down to the fact that the sample was scanned in a different region, but also because the filtered data is over a larger area. An Ra value of 110 nm is within specification. The Rq value of 150 nm is 36% higher than the Ra value. This implies that there is considerable variation in the heights of the features and this sample was less uniform than the glass lapped to sub-nm roughness. However the Rq value of 150 nm meets the specification.

The Rz value of 1.03 µm is of similar magnitude to the Rt value of 1.40 µm, which indicates that the larger features contained in the evaluation length are fairly uniform. However, these larger features are up to 10 times the average roughness of 110 nm and have given rise to the high Rq value in relation to Ra.

The Rsk value for both the sub-nm lapped glass and the glass lapped to 150 nm is negative but fairly small in magnitude which implies that there are slightly deeper valleys and shallower peaks on both surfaces but that they are fairly even about the mean line.

Conclusion

From the roughness parameter values obtained for the nominally 150 nm roughness lapped glass over various evaluation lengths, the lapped glass surface has an Rq value 27% higher than the Ra value which implies that there are several peaks and valleys contained in the surface that are larger than the average 0.16 µm to 0.18 µm. In addition, the closeness of the Rz and Rt values implies that there are no exceptionally large features contained in the area under study but the largest peaks and valleys on the surface are up to 10 times the average value at 1.64 µm. The valleys on the surface are also predominantly deeper than the peaks.

From the filtered data, it can be seen that both targets are within specification with the sub-nm glass being particularly smooth with no large scratches. For the 150 nm glass, although the Ra and Rq are within specification, other parameters indicate a large number of scratches on the surface that are out of specification.

This characterization data was made available to the group carrying out the experiment into High Harmonic Generation to assist them with assessing the affect of the surface topography of the glass targets on HHG.

References

1. D. Whitehouse, *Surfaces and Their Measurement*, Ch. 3, Hermes Penton Science, 2002.
2. R. Leach, *NPL Measurement Good Practice Guide No.37: The Measurement of Surface Texture using Stylus instruments,* 2001.