Commissioning of a New Diamond Point Turning Capability for STFC

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Introduction

The Central Laser Facility has invested in a new ultra-high precision lathe for the manufacture of high power laser target components and small optical elements for its program. The machine, a Single Point Diamond Turning (SPDT) lathe, is one of the most technically advanced machining centres in the world and is able to machine components with surface roughness's of ~ 1nm Ra. Through an existing and productive collaboration with RAL Space Precision Development Facility (PDF), where the equipment will be located, the CLF will be able to manufacture a new range of ultra-precise components furthering its leading position within the community.

Machine Specification

A Precitech Nanoform X with a B-axis and C-axis (figure 1) was purchased as it enables many geometries to be manufactured including hemi-spherical components and free form elements. This platform was chosen as it was appropriate for laser targets and for small optical components. The system has a high precision air-bearing spindle and a number of software features that stabilize the tool and make the maximum use of the cutting element and reduce tool wear. Able to hold parts up to 200mm in diameter it is capable of manufacturing optical parts for the Gemini laser and small optical elements for Vulcan.

Figure 1 Nanoform X Lathe at Factory Sign Off

Commissioning Results

During factory sign off and on site commissioning a number of parts have been manufactured. A Nickel plated steep part, a Brass spheret and an Aluminum curved form. These parts were measured at the factory and then machined again on site at RAL to ensure that the system was working within specification. Measurement results for the parts were taken and show that the surface roughness that can be achieved by the lathe is almost two orders of magnitude better than currently available within STFC.

1. Nickel Plated Steel Part

The Nickel test part (figure 2) verifies the ultimate surface finish that can be achieved by the machine with the B axis locked. The test part is 12.7mm diameter with a 254mm convex spherical radius and the surface finish is specified as better than 1.5nm Ra. At the factory, there was a sample produced that had a roughness of 0.804nm over an area of ~800um square. When tested at RAL the initial measurement taken gave a roughness of 9nm over an area of ~200um square. This was not within specification and on site investigations showed some contact between the spindle shaft and the brass vacuum tube. A simple skimming of the surface on site and re-machining of the part gave excellent results and achieved a surface finish of 1.388 nm Ra (figure 3)

The Nickel test part was measured using the Target Fabrication Wyko White Light Interferometer. This instrument can give surface roughness data at the nm resolution and can image an area of ~200um x 200um at a 50 x magnification with a 0.55 field of view magnifier.

Figure 2. The Ni Test Piece

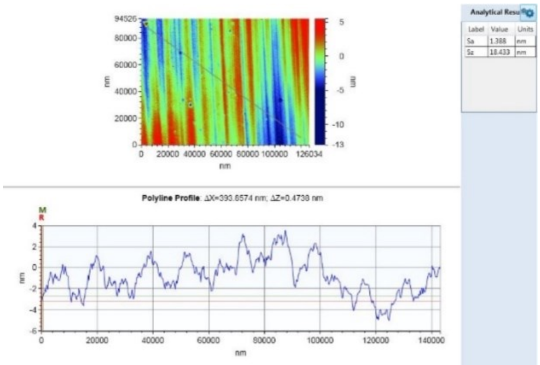

Figure 3. Ni Test Piece Metrology (1.159nm Sa)

2. Brass Spherical

The brass spherical enables the verification of the finish of the part when using the B axis under rotary control. The part is a 20mm diameter 15mm convex radius spherical. It is tested for both form and for finish. When produced on the machine in the factory the metrology data showed that the finish of the parts was 29.471nm PV and 2.379 nm Ra. The form had a PV of 143nm and a Ra of 23nm. When replicated on the system at

RAL the finish was measured at 14.22nm PV and 2.099nm Ra which shows it is within specification (figure 5). The measurement was taken using a Zygo ZeGage TM at Precitech. The form was measured as 128.968nm PV and rms of 14.729 (figure 6) again within tolerance. This measurement was taken using the CLF Zygo interferormer.

Figure 4. The Brass XZB test part

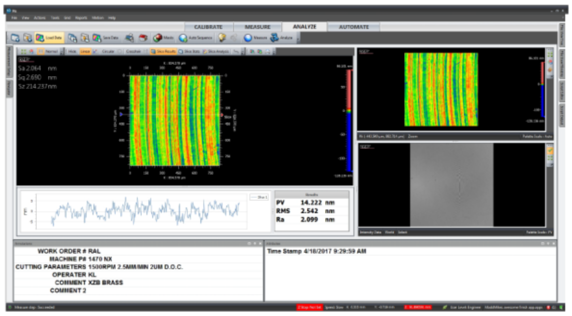

Figure 5. Surface finish of the Brass XZB test part

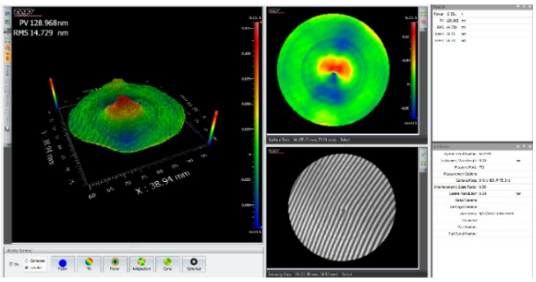

Figure 6. Form measurement of the Brass XZB test part

3. Aluminum Spherical

Form accuracy with the XZ axis and the B axis locked is verified by the cutting of an Aluminium test part (figure 7). It had a 76.2mm diameter with a 254mm convex spherical radius. The tolerance was 0.15um PV over the full aperture. When machined in the factory the part was measured as 55nm PV and with a rms of 8nm; when replicated at RAL, and measured using the CLF interferometer over the full aperture using a f/3.3 transmission sphere, the system achieved a PV of 105.176nm PV and 0.013λ which is the equivalent of 8.23nm (figure 8).

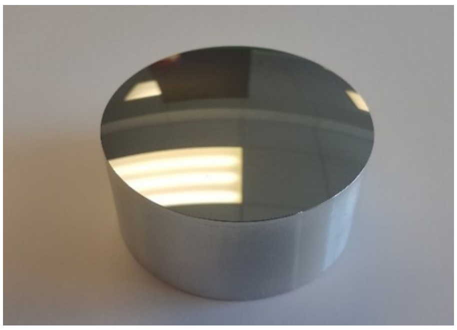

Figure 7. The Aluminium test part

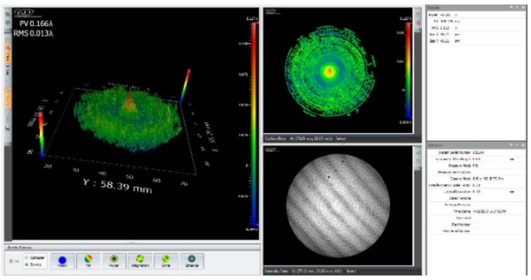

Figure 8. Form and Finish measurement of the Al spherical

The tests all show that the machine is commissioned within specification. There is a final test to be performed in the future to verify the XZC plano part to verify the slow tool servo and this is being planned in the schedule.

Example Target Projects

Over the coming months there are a number of example targets that we will manufacture to verify processes and to train staff members in the manufacture and metrology of the parts. Some recent examples of diamond turned parts that have been used as target components are discussed below. We will aim to replicate these and develop our processes to be able to offer a full service to the user community.

1. Structured Sine Wave Targets

To investigate the seeding of instabilities, such as Rayleigh–Taylor instability which is a key factor when compressing ICF targets, sine wave targets with periods and amplitudes from 200nm to 20um have been previously requested and fabricated using external sources. Such targets have been fielded on the Vulcan Petawatt laser system and in LULI and will be key target components for experiments on fusion scale facilities such as the Laser MegaJoule (LMJ).

2. Hemispherical Proton Focusing Targets

Using SPDT it is possible to manufacture mandrels that have surface roughness of less than 5nm Ra. These parts, when machined to a hemisphere, can then be coated using either standard PVD or by electroplating to deposit a thin (usually 25um gold) metallic layer on the mandrel. The mandrel can then be re-machined to give a good external finish to the plated part and then etched away to leave a high precision hemispherical form. These target components can be used for proton focusing in high power laser experiments because the protons are ejected normal to the target surface and consequently the focal point of the hemi will be a point to where some of the protons are focused.

Conclusions

A single point diamond turning center has been successfully purchased, sited and commissioned by STFC. The capability is now available to produce components with surface finishes that are at least an order of magnitude better than anything available at the moment at RAL. The CLF and RAL space are embarking on a program to develop the capability further and to integrate the metrology and machining to enable the highest specification parts to be made.