

Affordable, Compact, Research Single Point Diamond Turning Machine

Allen Bohart, Pat Collins, Scott Faulk, Dr. Craig Halvorson,
Dr. Michael McClellan, Dr. Keith Shillito
Schafer Corporation, Livermore, CA 94550

1. INTRODUCTION

Schafer Corporation's Energy and Environment Division has developed an affordable, compact single point diamond turning machine for production of experimental micro-machined parts. The system has been dubbed "SPRL", an acronym for Schafer Precision Research Lathe. Materials that have been machined with this system include copper, aluminum, polymer foams, aerogel and silicon.

The system was assembled and made operational in about 3 months from readily available commercial off-the-shelf parts, including two Aerotech ABL-2000 air-bearing stages with linear motors, an Aerotech DR-500 amplifier module, and an Aerotech Unidex 600 controller. The controller receives input from a standard Pentium-class PC running Windows NT 4.0 and Aerotech's U600 MMI software. The stages are directly mounted to an isolation table comprised of a 60" x 36" x 10" granite slab, and 4 Newport air isolation mounts. The spindle is an off the shelf 4-inch Blockhead spindle acquired from Professional Instruments, Inc, powered by a Hewlett-Packard 6228B DC power supply. A CoHU video camera with a 10x microscope objective is used for fine placement of the tool with respect to the part. The system is operated in a 12' by 24' clean room environment (Level 1000) to maximize temperature stability (to within $\pm 1/2$ °F) and control airflow. Total expenditures for purchased components (excluding the existent granite slab and Newport isolation mounts) was less than \$70K. The compact design of SPRL, shown in Figure 1, with direct mounting of the slides to the granite slab offers reduced vibration and minimized moment arms for the X and Y axis couplings.

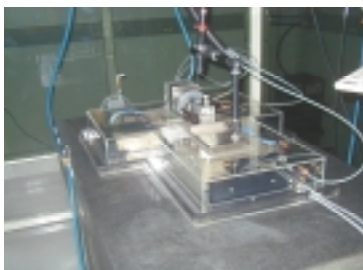


Figure 1. Views of the SPRL Machine

2.0 MACHINE CAPABILITIES

The Schafer SPRL is a single point diamond turning lathe that has exceptional capabilities, considering its affordability and compactness. The machine is capable of 4 nm resolution on both axes, with the ability to produce sub-micron surface finishes. The stages consume only 0.3 cfm of compressed air, allowing the machine to be run with bottled nitrogen, instead of using an air compressor. The machine is programmable in RS-247, 447 CNC programming language and uses standard C libraries. Initial machining results are promising, with no discernible noise or vibration problems.

Typical parts produced on SPRL are copper and aluminum casting molds, foam spheres, and small-scale silicon optics. The casting molds are flats with various surface figures machined into them. Typical surface figures are sine waves and multi-modal sine waves with sub-micron amplitudes, and varying wavelengths. Spheres are machined using approximately 50 mg/cc polystyrene foam. The silicon optics are of varying surface figure, with 40-100 Å rms surface finishes. Samples of the various parts and materials that we have machined are shown in the figures below.

3. PERFORMANCE/EXAMPLES

As a custom designed machine SPRL has been built to produce parts that are required by the Department of Energy for the Inertial Confinement Program. It is capable of producing surfaces with roughness less than 100 Å rms and very detailed surface morphologies.

SPRL is used to produce generally small parts that are approximately 1000µm x 1000µm in area with the following types of features on the surfaces:

Ramps : These ramps range from 10µm to 400µm thickness.

Step: Step size of approximately 100µm.

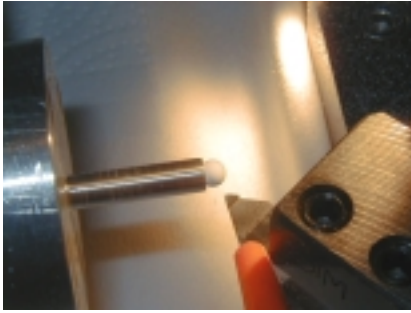
Sine Waves : We have made a wide range from 1µm peak-to-valley, 20µm wavelength, and 20µm thickness to 40µm peak-to-valley, 200µm wavelength, and 20µm thickness.

Ramp/Sine Wave: 2µm peak-to-valley and 20µm wavelength on 10µm thick to 20µm thick ramp.

Several examples of the types of products we have machined are shown below.



Figure 2. Copper Sphere Process Development for Polymer Foam Spheres

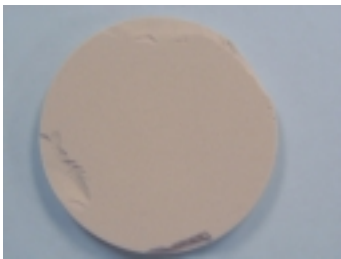


Foam machining in-process on SPRL

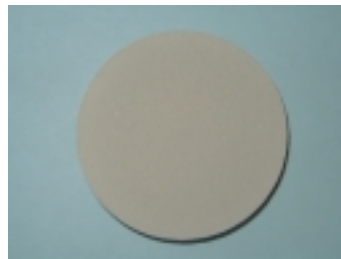


Completed sphere (4.5mm diam.,40mg/cc)

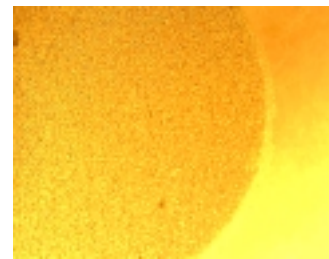
Figure 3. Polystyrene Foam Sphere



Original cast surface.



SPDT facing cut.



Fine pore structure.

Figure 4. Face cut of SiO₂ Aerogel (< 5 mg/cc density)

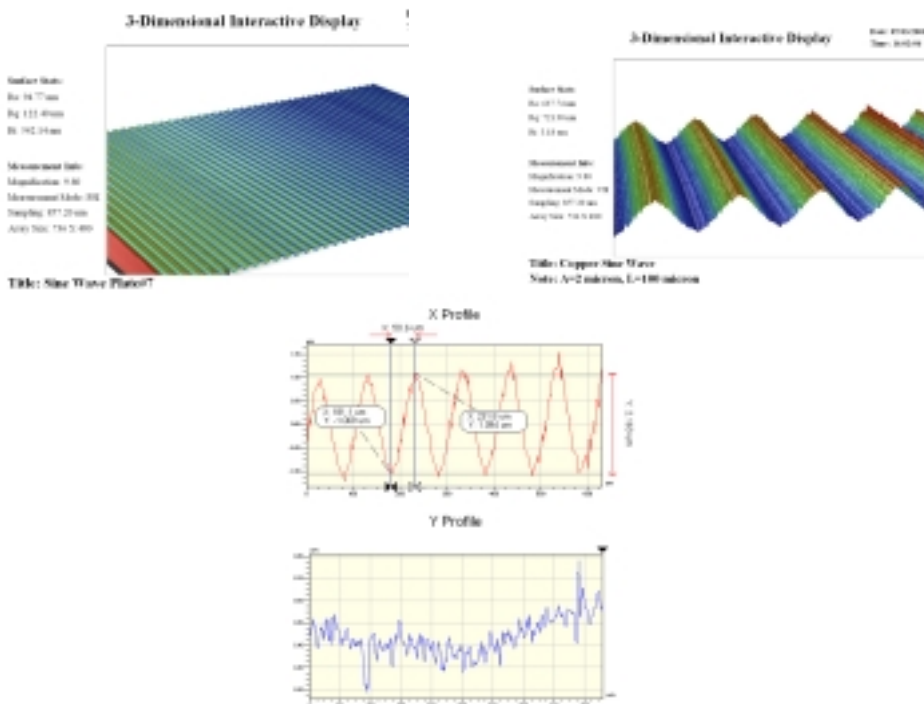


Figure 5. Copper Sine Wave Plate, Amplitude: 2 μ m , Wavelength: 100 μ m. Characterizations using VEECO White Light Interferometer.