UNC CHARLOTTE
The WILLIAM STATES LEE COLLEGE *of* ENGINEERING

Senior Design Project Description for Fall 2016 Project Title: Replication System for Production of Freeform Optics from Toroidal Substrates (UNCC_FFRP)

Supporter: UNCC Charlotte, Center for Freeform Optics

Supporter Technical Representative: ASSIGNED

Faculty Mentor: __X__ ASSIGNED _____ TBD (check one)

Single Team __X__ Dual Team _____ (check one)

Personnel (EN/ET): _____ E, _____ Cp, _____ Cv, __2__ M, _____ SE

(Complete if the number of students required is known)

Expected person-hours: (250 per student)

Description of Project:

Freeform optics allow the near arbitrary redirection of light in three-dimensions. They are poised to revolutionize optical systems for both imaging and non-imaging applications replacing centuries of optical designs based on axial symmetry (flats, spheres, aspheres) with freeform designs. Among the potential advantages of freeform optical systems are: (1) drastically reduced size; (2) reduced sensitivity to positioning errors; and (3) the ability to perform entirely new optical functions. Freeform optics affect both imaging optics such as cameras and telescopes and non-imaging optics such as solar concentrators and freeform reflectors for energy-efficient lighting. One roadblock to the widespread application of freeform optics is the necessity for a cost effective path to production. This project addresses that need.

Many freeform optics have a small deviation from a base spherical shape and often an even smaller deviation from a base toroidal shape. To capitalize on this a project is underway in the Center for Freeform Optics (CeFO, http://centerfreeformoptics.org/) a collaborative NSF I/UCRC between UNC Charlotte and the University of Rochester and 15 non-academic members. The project examines whether it is possible to cost-effectively manufacture a class of freeform otpics for imaging applications by beginning with a base toroidal substrate that has been validated by new measurement technology and using a freeform stamper to apply a UV-cured replicant to the toroid that corrects it to form the desired freeform shape. Initially we target reflective optics and so the desired freeform generated by replication must also be amenable to post application of a reflective coating. For the UV-coating and curing either the stamper or the substrate toroids must be UV-transparent. Thus the project encompasses four main thrust areas: (1) fabrication and metrology of the base toroidal shapes; (2) fabrication and metrology of the freeform stamper; (3) identification of materials for the base toroids, the stamper and the UV curable replicant; (4) construction of the mechanical replication system; and (5) completion of the replication tests. This senior design project focuses on (4) but students will interact with UNC Charlotte graduate students and advisors, graduate students and faculty at the University of Rochester, and members of the CeFO industrial advisory board to complete their work in concert with the other parts of the project.

Initial Project Requirements (e.g. weight, size, etc.):

Some changes to the specifications may be allowed based on early interactions with the optical design team at the University of Rochester and the CeFO mentors.

Volume/Dimensions: 0.5 meter cube or less. Stamper and base-toroid dimensions: 50 mm diameter required with 100 mm diameter desired. System may utilize separate mechanical alignment and

UV-curing chambers or the two may be integrated together.

Mass: < 10 kg (moveable by one person)

Positioning accuracy of stamper to substrate: Cartesian: ±5 micrometers overall; Clocking: 0.25 mrad; tilt: 0.25 mrad.

Environment: System must operate in moderate vacuum while replicating (< 5 Pa) to remove air prior to replication.

Stamper/Base-Toroid Materials: After curing replicant must adhere to the base-toroid and release from the stamper. One possible material combination is: diamond turned electroless nickel stamper; fused silica base toroid; UV Cure Epoxy, Summer Laboratories J-91[1].

UV Curing: An integrated or separate UV curing chamber capable of curing the replicant in approximately 10 minutes is required. System should be capable of applying force to accomplish mechanical alignment during curing and be capable of applying a release force after curing (~ 20 N maximum estimated).

Minimum/Maximum feature replication size: 50 nm/200µm required; 10 nm/500µm desired.

Automated Control: Desired but not required.

Expected Deliverables/Results:

The deliverable is a replication system capable of replicating a freeform optic on a base toroid with the specifications listed above.

List here any specific skills or knowledge needed or suggested (If none please state none):

Machining; Ability to learn CNC Machining; SolidWorks (or equivalent) Design; Finite Element Analysis; Ability to learn precision machine design.

Reference

1. Sohn, A. and Dow, T.A., 1999. Removal of Form Error in Replicated Optics. In ASPE Spring Topical Meeting on Precision Fabrication and Replication (Vol. 19).