EPSRC Centre for innovative manufacturing in ultra precision

www.ultraprecision.org
www.cdt-up.eng.cam.ac.uk

Creation of a control system for plasma delivery

Hui Zhou, Renaud Jourdain, Vincent Serantoni, Jose L. Endrino, Paul Shore, Paul Morantz

Research Motivation

The Cranfield University Precision Engineering Institute team has created a unique plasma figuring capability to correct large optical surfaces at atmospheric pressure.
Research background: Processing capability for large optical components.

Aims :

1. Securing the process determinism and protecting electrical components.
2. Shorting process time dramatically.

Project Objectives:

1. Tuning key electrical components of the radio frequency (RF) network.
2. Monitoring different processing parameters.
3. Adding cooling system.

Large Optical Component Project

European Extremely Large Telescope (E-ELT)

E-ELT will be the largest ground-based telescope in the world.
Optical design: Five-mirror designs;
Three-mirrors on-axis anastigmat;
Two fold mirrors used for adaptive optics.

Diameter. Primary M1: 39 m
(798 hexagonal 1.4 m mirror segments)
Diameter. Secondary M2: 4 m
Diameter. Tertiary M3: 3.75 m
Diameter. M4: 2.4 m

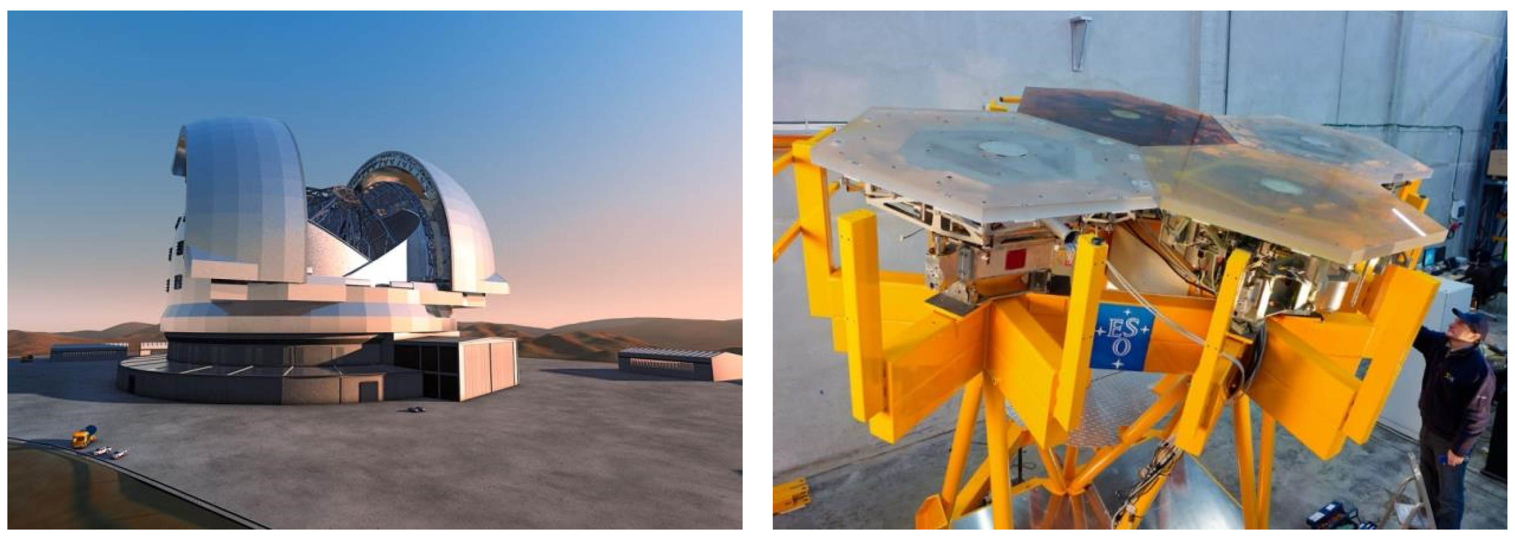

Figure 1. Large optical sample of European extremely large Telescope [1]

Plasma Figuring Technology

Plasma Figuring provides a unique rapid surface figuring capability for large optics based on silicon materials. It benefits from a bespoke plasma tool and tool path algorithm.
At Cranfield University, there is a unique plasma figuring machines (Fig. 2) named Helios1200. It combines plasma technology operating at atmospheric pressure and computer numerically controlled (CNC) motion systems. The radio frequency (RF) plasma systems for Helios1200 is equipped with a fixed match RF network [2] .

Figure 2. Helios1200

A RF inductively coupled plasma (ICP) torch is used to atomize the reactive gas and create free radicals [2] . The combined torch, RF network, and signal generator are named Plasma Delivery System (PDS). In Helios1200, a fixed match electrical design was chosen. Here below the original torch assembly and the real torch are displayed [3].

Figure 3. Original Helios1200's torch assembly (left), Helios1200's torch component(right)

Novel Approach for RF Circuit Design

The novel approach aims at maintaining the plasma in stable condition for tens of hours process duration. Thus, temperature increase of the electrical components, environmental perturbations, and process parameter variations will be monitored [4].

Proposed Fixed Match Automation and Control

Through the means of actuators, sensors, and micro controller, the impedance of the load will be adjusted by tuning the values of the two vacuum capacitors (tune and load). Those capacitance values are intended to be changed using stepper motors mounted at the end of cylindrical vacuum capacitors. In addition, the free running RF signal generator will be used to determine finely and rapidly the optimum output frequency. Figure 4 illustrates the motorization of the capacitors.

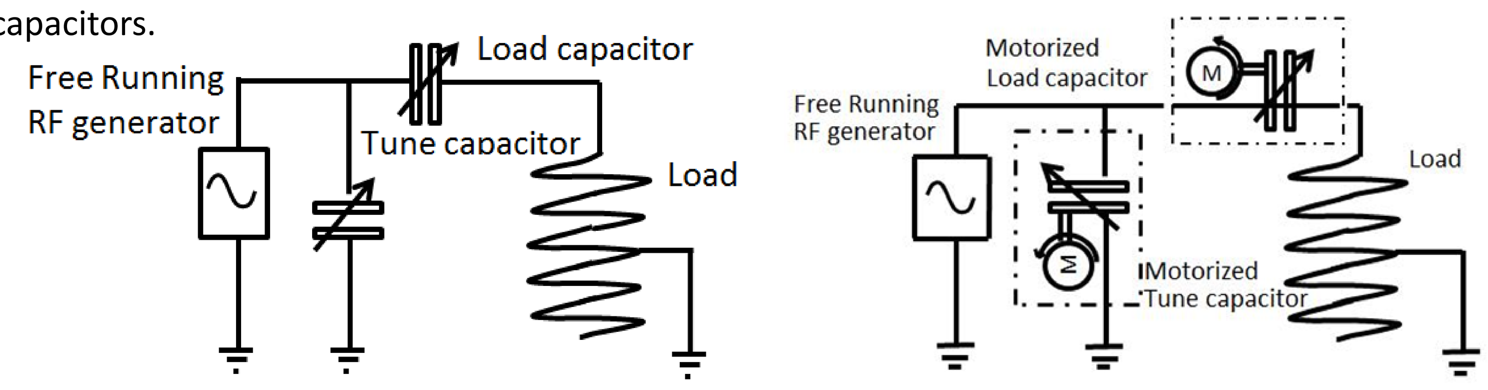

Figure 4. fixed match and Motorized fixed match RF network

Novel Plasma Delivery System Design

The novel features of the control system address three operation phases: ignition, regular operation and critical circumstances. These phases are experienced during regular operations.

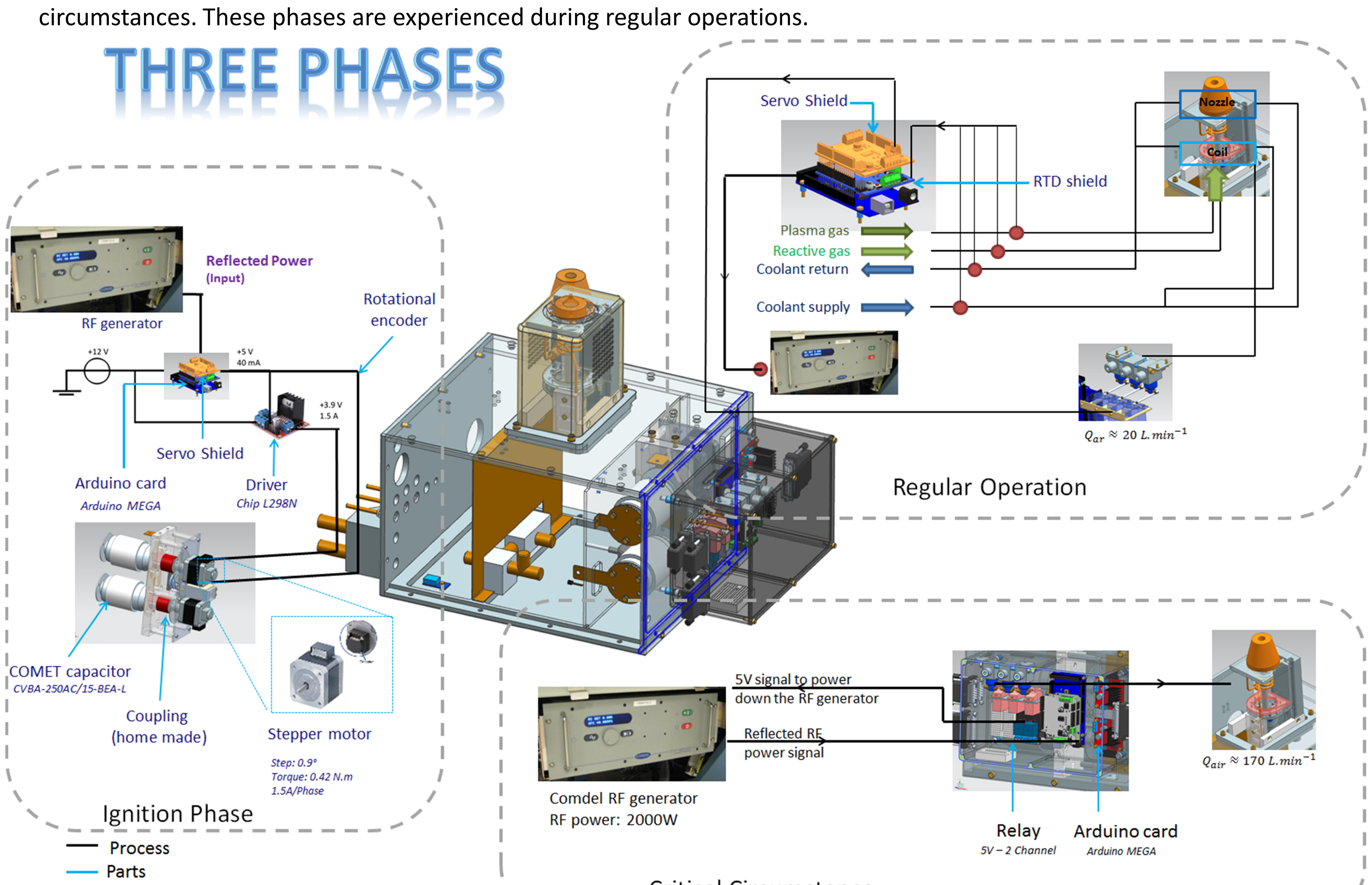

Figure 5. The conception design of PDS

Result

Two technical aspects of the design work were completed: electrical and mechanical design (Fig. 6).

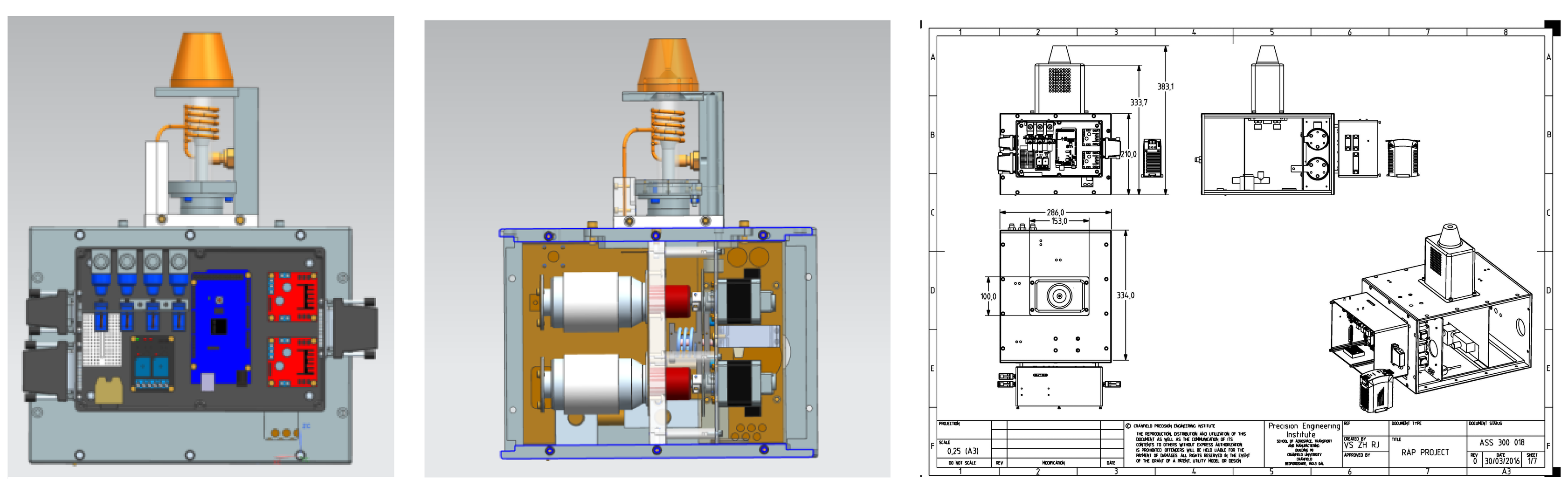

Figure 6. Electrical components (left), Mechanical components (middle) and Assemble engineer drawing(right)

From an electrical viewpoint, the control system hardware is defined and secured. The control system will be programmed using an open-source language based on Arduino technology. That controller will manage inputs and outputs. The mechanical design addressed capacitor motorization, shielding of the electrical components from electromagnetic fields, and securing the position of all sensors.

Conclusion

The design of a novel control system for an ICP torch was completed. A pioneering approach is being explored to enhance the processing capability of plasma delivery systems used in CNC machine tools created for high-end optical fabrication. A highly reliable and deterministic plasma processing system is expected to satisfy the needs of ultra-precision applications. Next step will focus on the fabrication and testing of this control system.

References
[1] E-ELT European Extremely Large Telescope
[2] Jourdain R, Castelli M, Shore P, Sommer P and Proscia D 2013 *Production Engineering* 7(6) 665-673
[3] Jourdain R, Shore P, Proscia D and Subrahmanyan P 2009 *JEOS conference* Munich
[4] Serantoni V, Jourdain R, Yu N, Shore P, Morantz P 2015 *Internal document*

info@ultraprecision.org
cip-admin@eng.cam.ac.uk

Cranfield UNIVERSITY
EPSRC Pioneering research and skills
UNIVERSITY OF CAMBRIDGE