EPSRC Centre for innovative manufacturing in ultra precision

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Control System for Ultra Precision Processing

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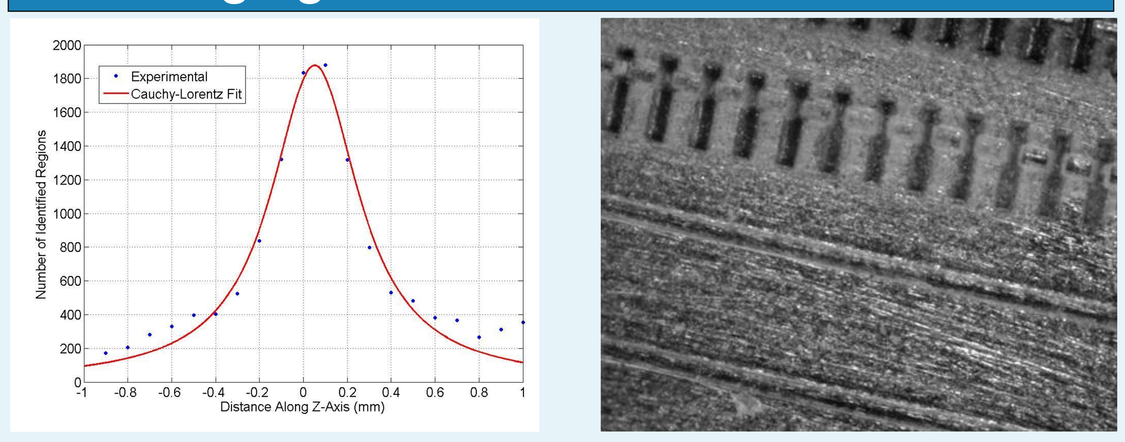
Introduction

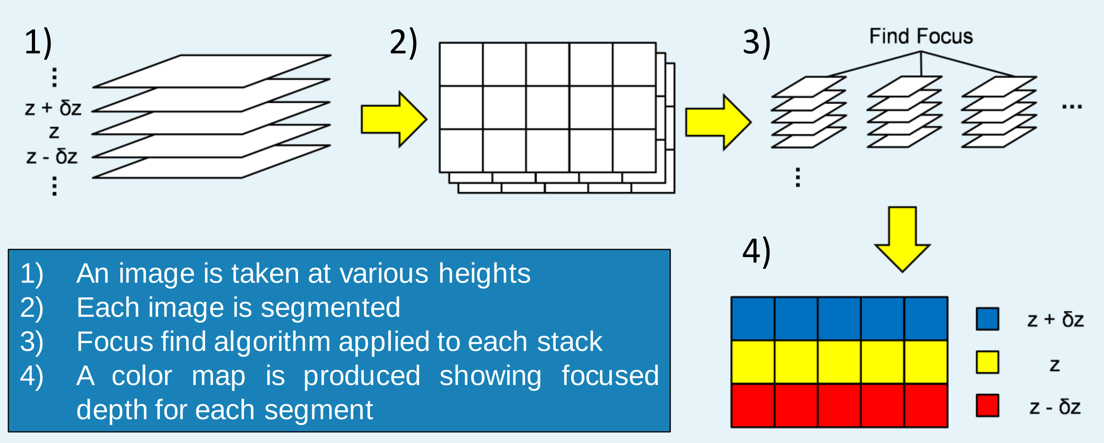
High precision manufacturing of nano- and micro-sized objects has become increasingly prominent given current technological trends. However, while traditional macro-manufacturing systems rely on automatic feedback loops to detect errors and act immediately, this is a more difficult task when scaled down to the single micron or less.

Initialization Control

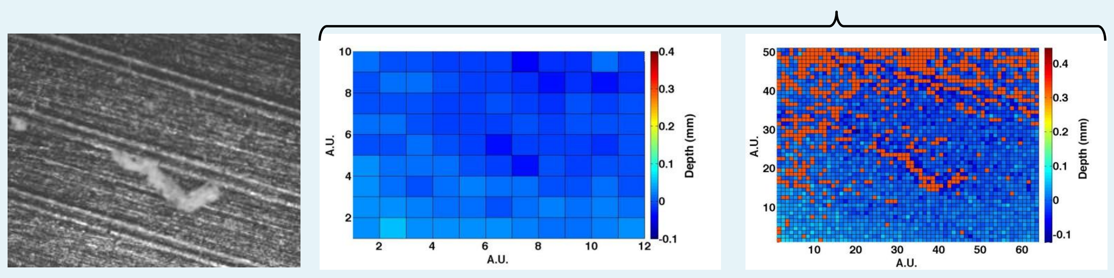
Imaging Focus Find and Tilt Control



Left: Algorithm identifying the in-focus image from stack. Right: Image corresponding to peak of left plot.



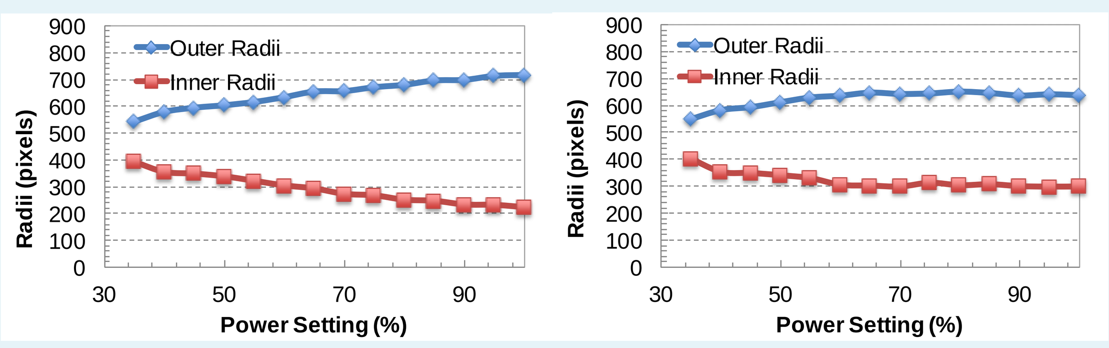
1) An image is taken at various heights
2) Each image is segmented
3) Focus find algorithm applied to each stack
4) A color map is produced showing focused depth for each segment



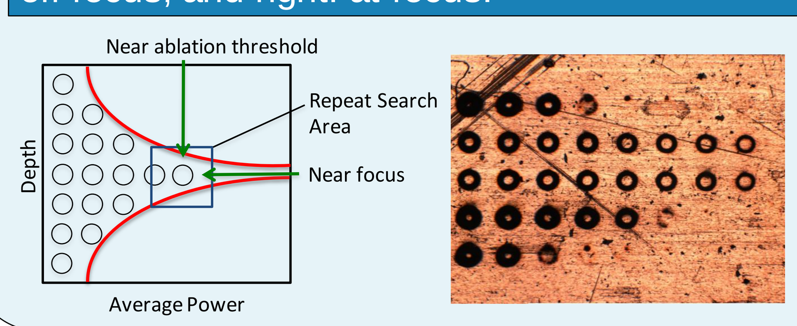
Left: In focus image. Middle: Large segmentation tilt control output showing sample tilt from bottom left to top right. Right: Small segmentation output showing structural information.

Processing Focus Find and Tilt Control

Ring shapes are cut at varying power and focal depth to find the focus and tilt of the sample relative to the processing beam. An image recognition algorithm is used to identify the rings and find their radii.



Inner and outer radii of the rings for varying power at left: 50 μm off focus, and right: at focus.



Left: Theoretical, and right: experimental focus find patterns.

Problem

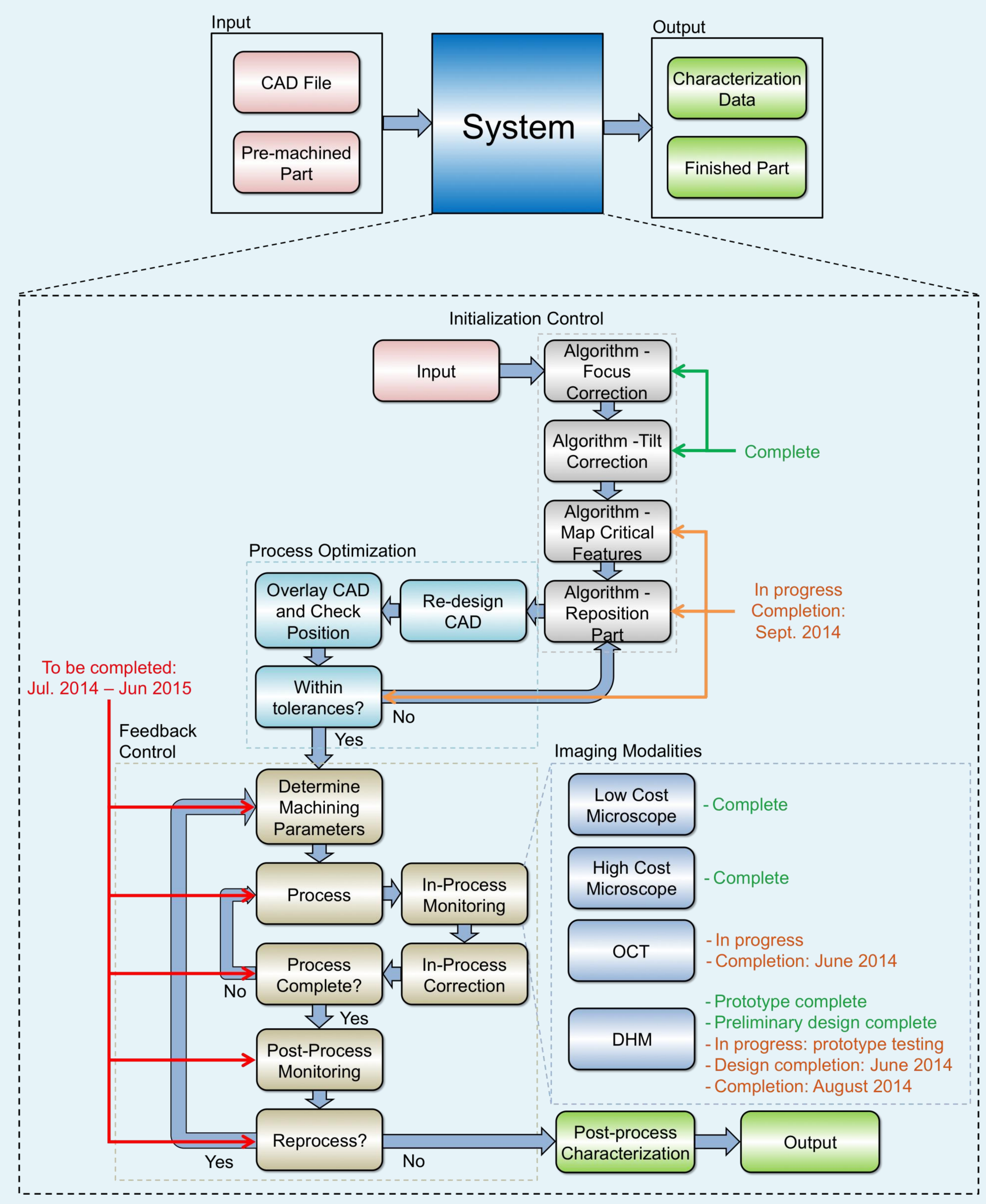
Ultra precision laser processing is inherently unstable and very sensitive to environmental effects (e.g. temperature, vibrations). Thus, the lack of an in-process monitoring and feedback system makes efficient production difficult.

Solution

The aim for this project is to create a closed loop system capable of delivering automated high-precision rapid prototyping and batch production with limited user guidance. The work can be broken down into two components: Imaging systems and control systems.

Control Systems

The control system will be universal to the imaging techniques and can be broken down into three sections: initialization, process optimization, and feedback control.



Control flow diagram for proposed system.

Conclusion

Miniaturization represents a driving force for the development of technology. However, rapid prototyping and mass manufacturing of these ultra precision devices is hindered by a lack of in-process control that traditional macro manufacturing benefits from.

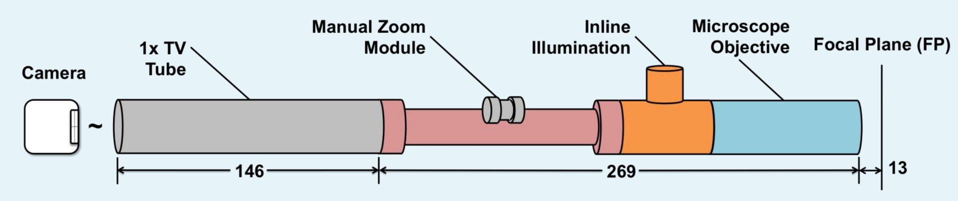
The proposed system seeks to overcome this gap and present a solution to automate ultra precision processing.

Imaging Systems

Due to the complexity of ultra precision processing and varying needs of industry, multiple imaging solutions will be utilized with specific monitoring purposes.

The three chosen techniques are: 1) optical microscopy for large field of view and low cost systems, 2) optical coherency tomography (OCT) for high speed point inspection, and 3) digital holographic microscopy (DHM), for in-process 3-D monitoring.

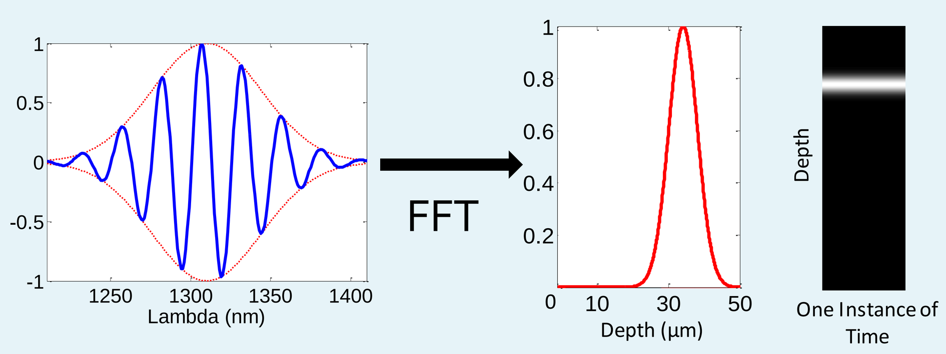
Optical Microscopy



Resolution: 0.56 – 1.9 μm (adjustable). Speed: 6 fps.

Optical microscope for low cost *ex-situ* optimization control and characterization.

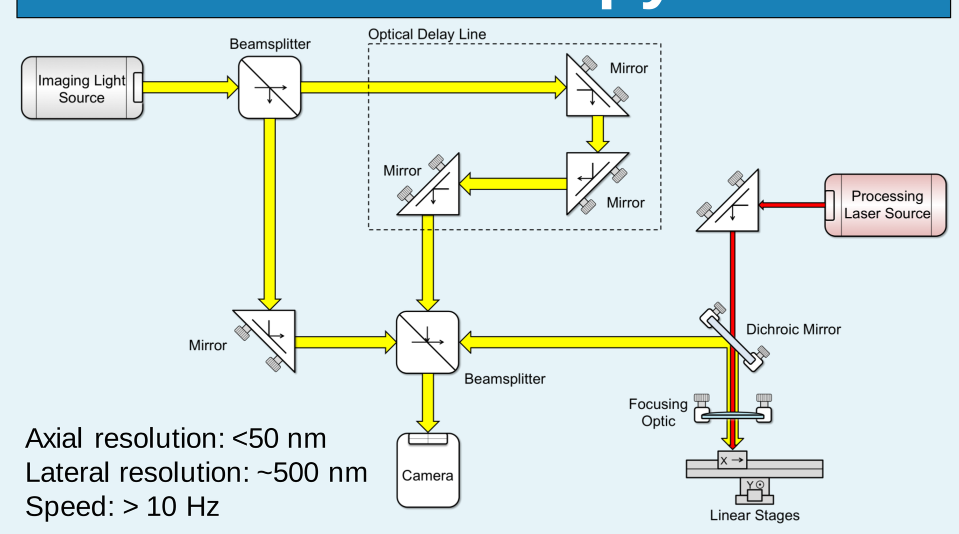
Optical Coherence Tomography



Resolution: 7.5 μm axial, 4 μm lateral (typical).
Depth of Field: >4 mm. Speed: > 100 kHz.

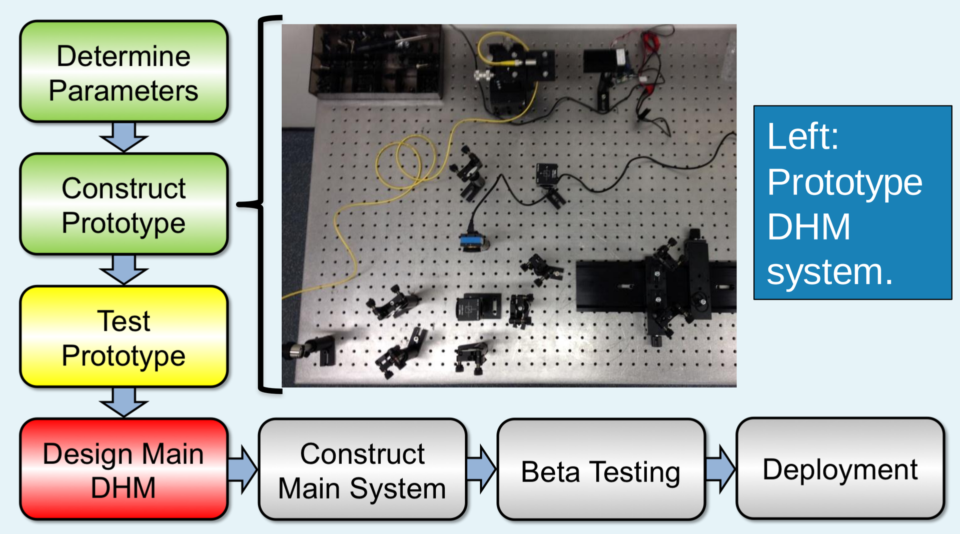
OCT obtains single point depth information by using a broadband interferometer and applying an FFT to the interference pattern. Image to the right shows an OCT A-line, i.e. depth taken at a single instance in time.

Digital Holographic Microscopy



Axial resolution: <50 nm
Lateral resolution: ~500 nm
Speed: > 10 Hz

DHM obtains 3-D information from the phase of the signal. Top: Proposed in-process DHM system.



Left: Prototype DHM system.

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