

# Geometric Control of Glass 3D-Printing Via Thermal Imaging Feedback

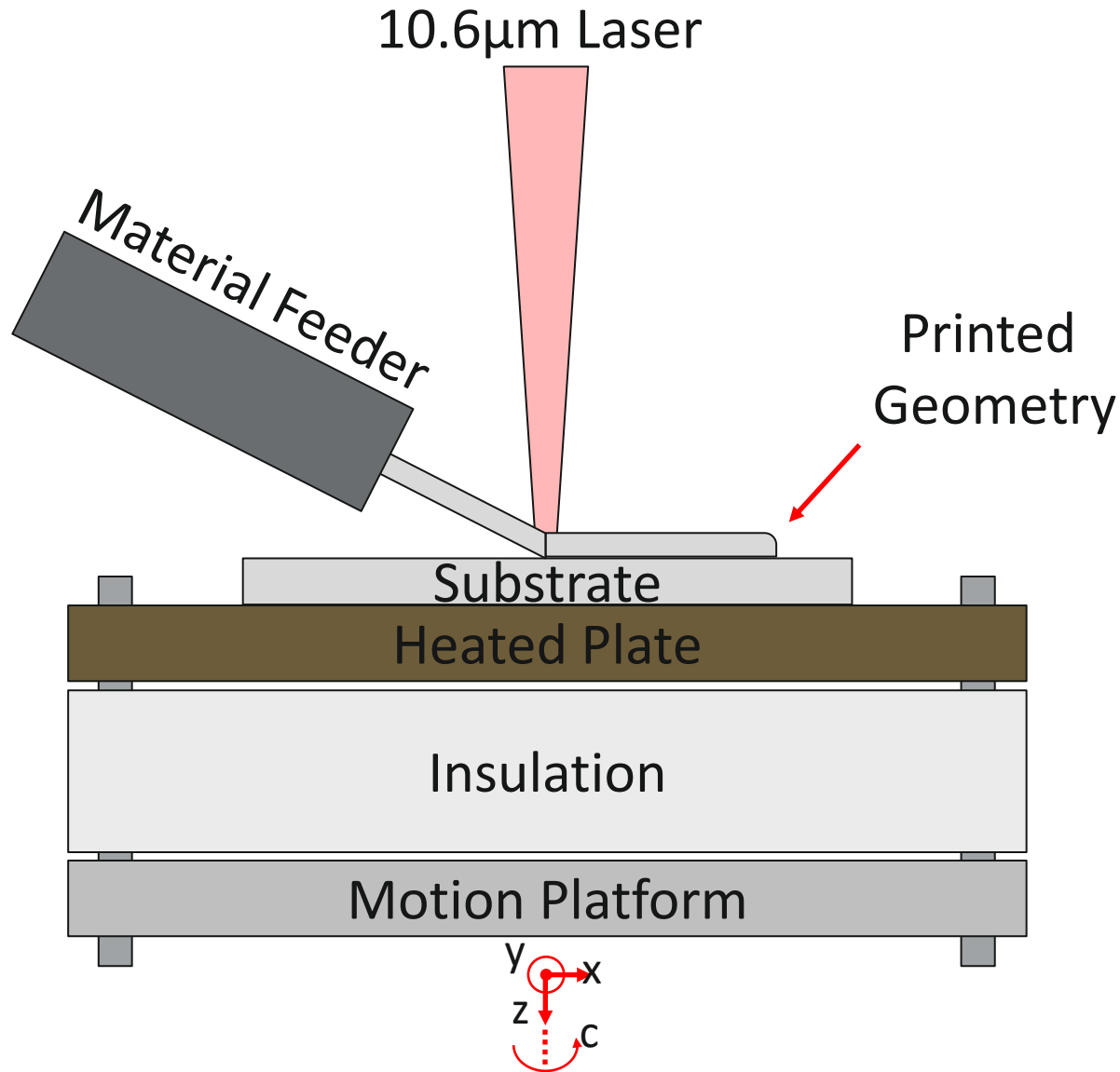
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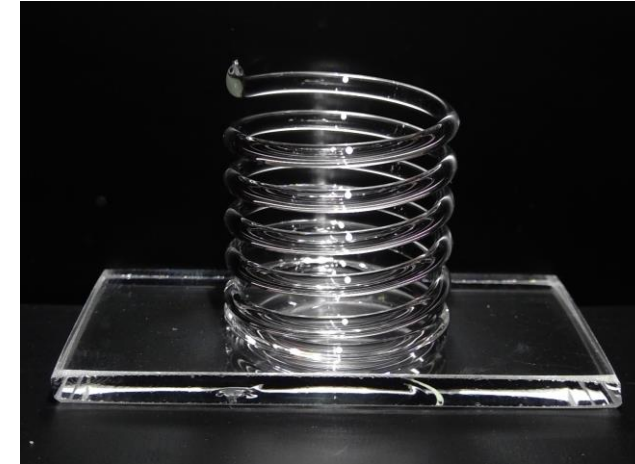
# Overview

- > Overview
- > How are we 3D-printing glass?
- > What is Feedback Control?
- > How does Thermal Imaging fit in?
- > Summary

# How are we 3D-Printing Glass?



Coil Spring  
Daniel Peters, 2018



Single-Layer Wall, 2019



# What is Feedback Control?

- > By varying the system input as a function of both the desired and actual system outputs, many systems may be guided to produce that output.

Balancing a pencil uses feedback control



Credit: Mark van Laere

Cruise-control uses feedback control



Credit: Robert Jack, Wikimedia

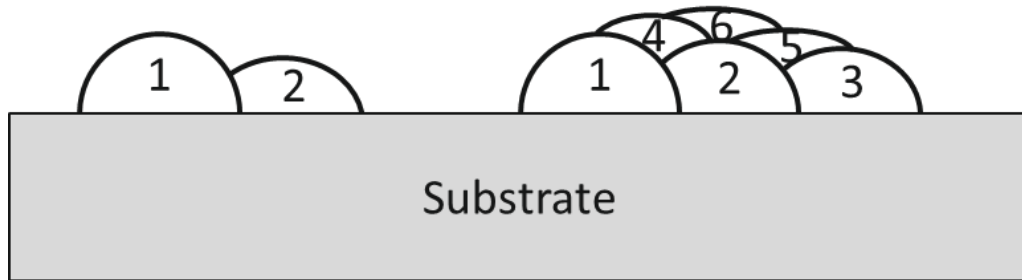
Machining with a robot arm uses feedback control



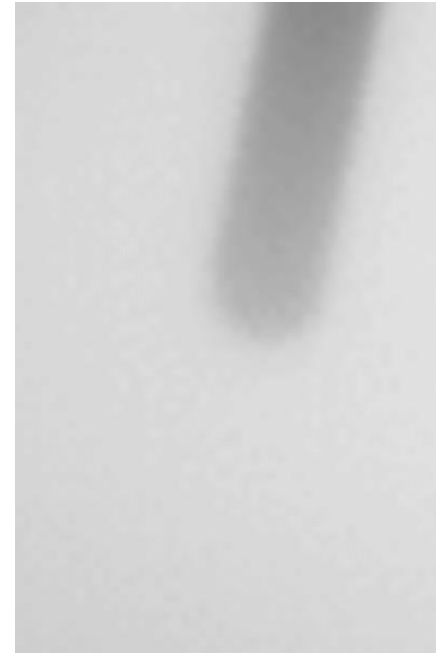
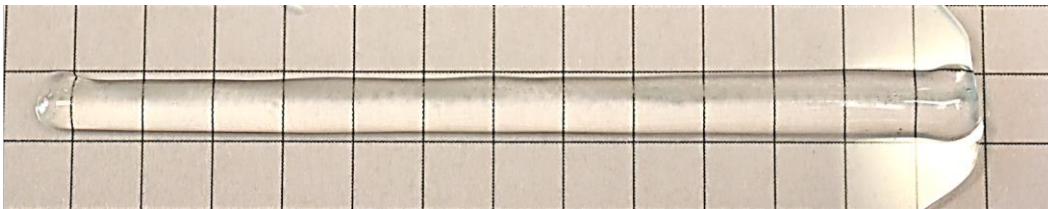
Credit: Joseph Fischer

# How does Thermal Imaging fit in?

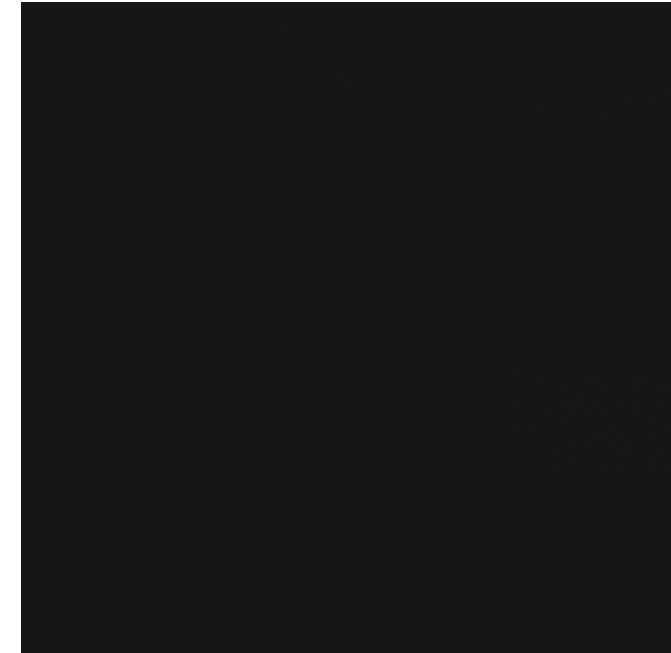
Residual heat causes geometric defects



Inconsistencies in process setup and laser dynamics also lead to geometric defects



Unmodified  
Infrared camera



Visual-spectrum camera  
attenuated by 99.999%

# Summary

- > We're 3D-printing transparent glass by using fully-dense feedstock to maximize optical quality
- > Feedback control adjusts the input based on the measured output
- > We're using an infrared camera and feedback control to keep the width of printed walls constant throughout a print