Advanced Additive Manufacturing: Development of a Multiple-Material Selective Laser Melting Machine

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Introduction

- Additive Manufacturing (AM) parts are fabricated from the ground up, in a layer-by-layer process versus conventional manufacturing, which is subtractive or formative [1]
- Current traditional AM machines are limited to producing single-material components [2]
- Multiple-Material (MM) is economically favorable and permits the integration of various useful functions: lightweighting, conductive pathways, embedded components, optimization of material properties [2], [3], [4].
- Current MM methods developed yield varying degrees of contamination, dimensional inaccuracies, and some do not produce true multi-material capability [1], [3]
- Deliver a benchtop/research-grade, customizable Multi-Material Selective Laser Sintering (MMSLM) machine that is lacking in the current research space

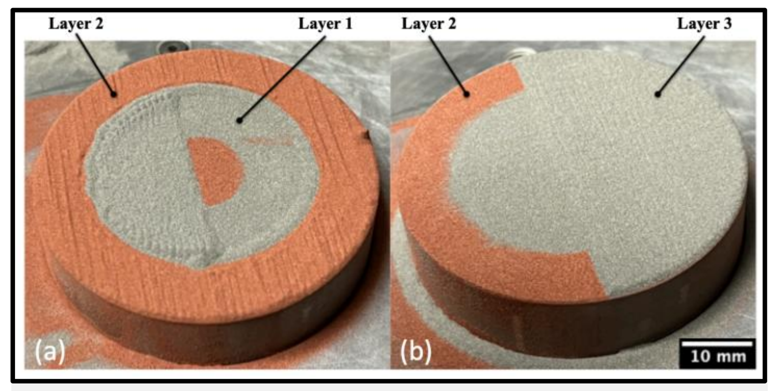

Figure 1. A sequential layered view of the multi-material powder bed, (a) Layer 2 over Layer 1; (b) Layer 3 over Layer 2 [1]

Objectives

Develop a benchtop, research use Multiple-Material Selective Laser Melting (MMSLM) machine to:

- Fabricate fully dense, three-dimensional, multi-material prototype parts.
- Enable researchers to study material interfacial properties, component properties, AM signatures, and process optimization, including laser scan strategies, powder deposition characterization, FGM transitions/material blending, contamination reduction, and material-specific machine parameters.

Methods

- Continued dissertation work of Scott Snarr, PhD., innovating upon his prior MM machine
- Design, assembly, FEA in Autodesk Inventor CAD
- Literature review and analysis of common commercial metal machines (EOS M280, Renishaw AM400)

Figure 2. Commercial AM machines: a) EOS M290 (SLM); b) Renishaw AM400 (SLM); Craftbot Plus Pro (material extrusion)

MMSLM Machine Process

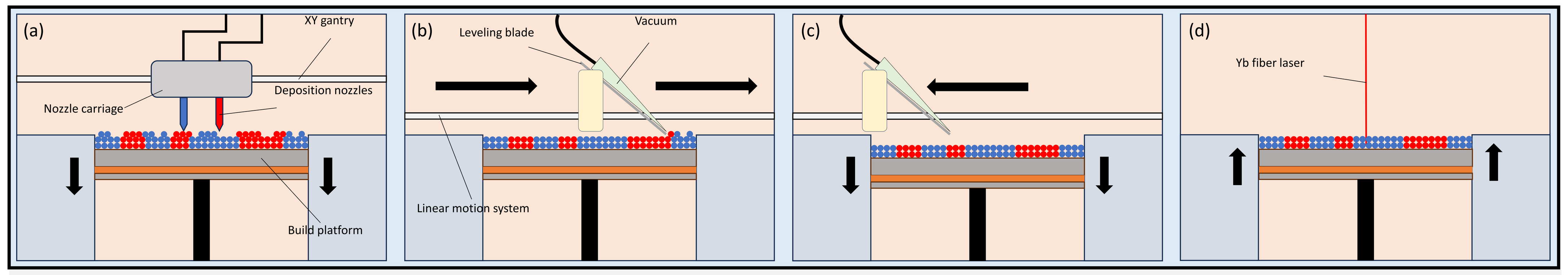

Figure 3. MMSLM process diagram: (a) build plate lowers one layer thickness, nozzles selectively deposit powder; (b) leveling blade smoothens out powder bed and vacuum removes excess loose powder; (c) build plate lowers one layer thickness and leveling blade retracts back to origin; (d) build plate raises one layer thickness, then selective lasing of powders commences

MMSLM Machine Design

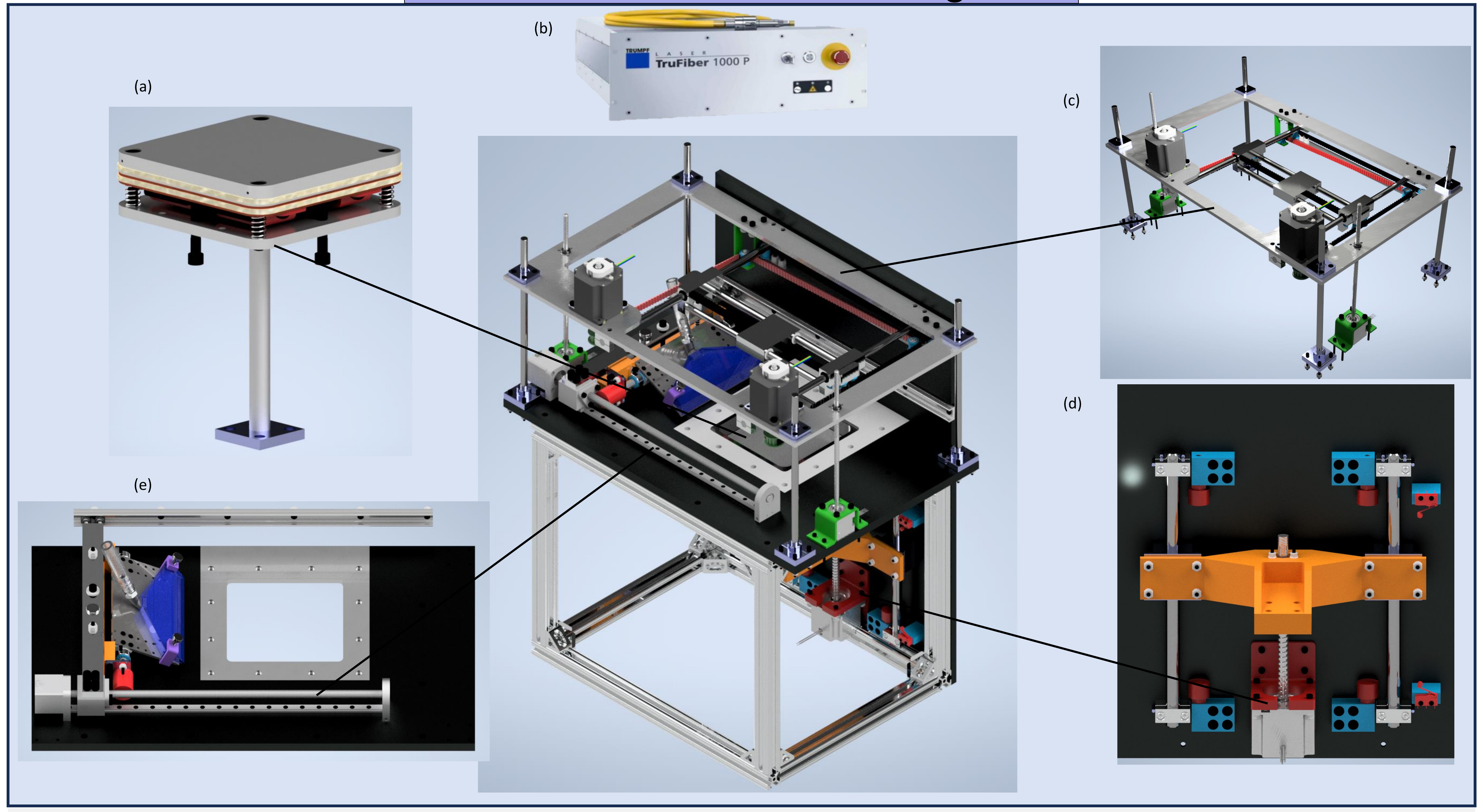

Figure 4. Current assembly of the MMSLM machine and detailed sub-assembly views, clockwise from the top-left: (a) build plate system; (b) TRUMPF TruFiber 501P laser and optics system; (c) gantry and pulley-drive system; (d) linear drive system; (e) powder leveling system

Design Requirements

- Minimum 5"x5"x4" build volume
- Minimum 10 µm layer resolution
- Heated, swappable build plates with powder leveling capability
- XYZ gantry system with nozzle-based method to selectively deposit distinct metal powders
- Has a high degree of modularity/user customization and will allow eventual implementation of Functionally Graded Material (FGM) capability
- Ability to remove excess powder and form consistent layers with minimal contamination
- Enclosed system that can pull a high vacuum
- Inert chamber and a continuous argon flow across the build surface
- Laser and optics: TRUMPF TruFiber 500 laser

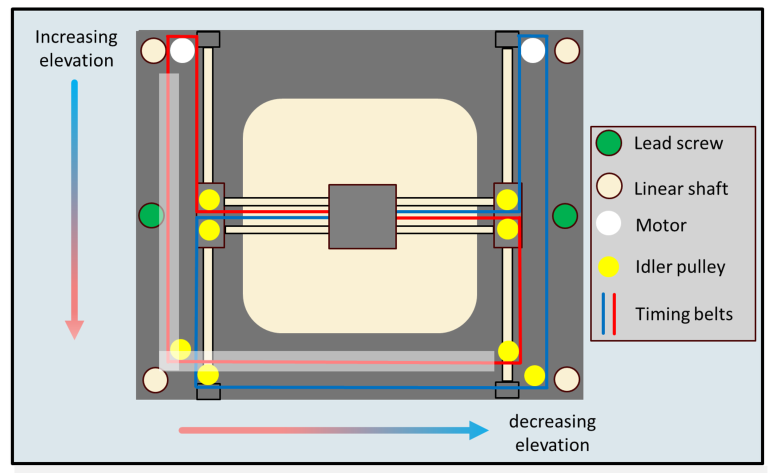

Figure 5. Detailed schematic for the pulley-drive system

Next Steps

- Machine assembly, integration with laser/optics module, controls programming
- Experimental process characterization to determine standoff height, vibration amplitude, translation speed, deposition rate, lasing parameters, etc.
- Research and analysis on material interfacial characteristics
- Advancements in nozzle research; integration of FGM capabilities and increased powder deposition efficiency

Conclusions

- This machine implements a novel angle-adjustable leveling blade with a vacuum attachment for powder removal, and powder deposition via multiple nozzles
- MMAM can deliver highly specialized parts more suitable for the end-user, enhancing the effectiveness of nuclear safety measures
- This benchtop, research-use machine will directly allow researchers to innovate materials science, manufacturing techniques, and investigate metal MM signatures
- Directly contributes to further development of secure, robust, and innovative solutions that reinforce efforts in nuclear non-proliferation

Acknowledgements

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