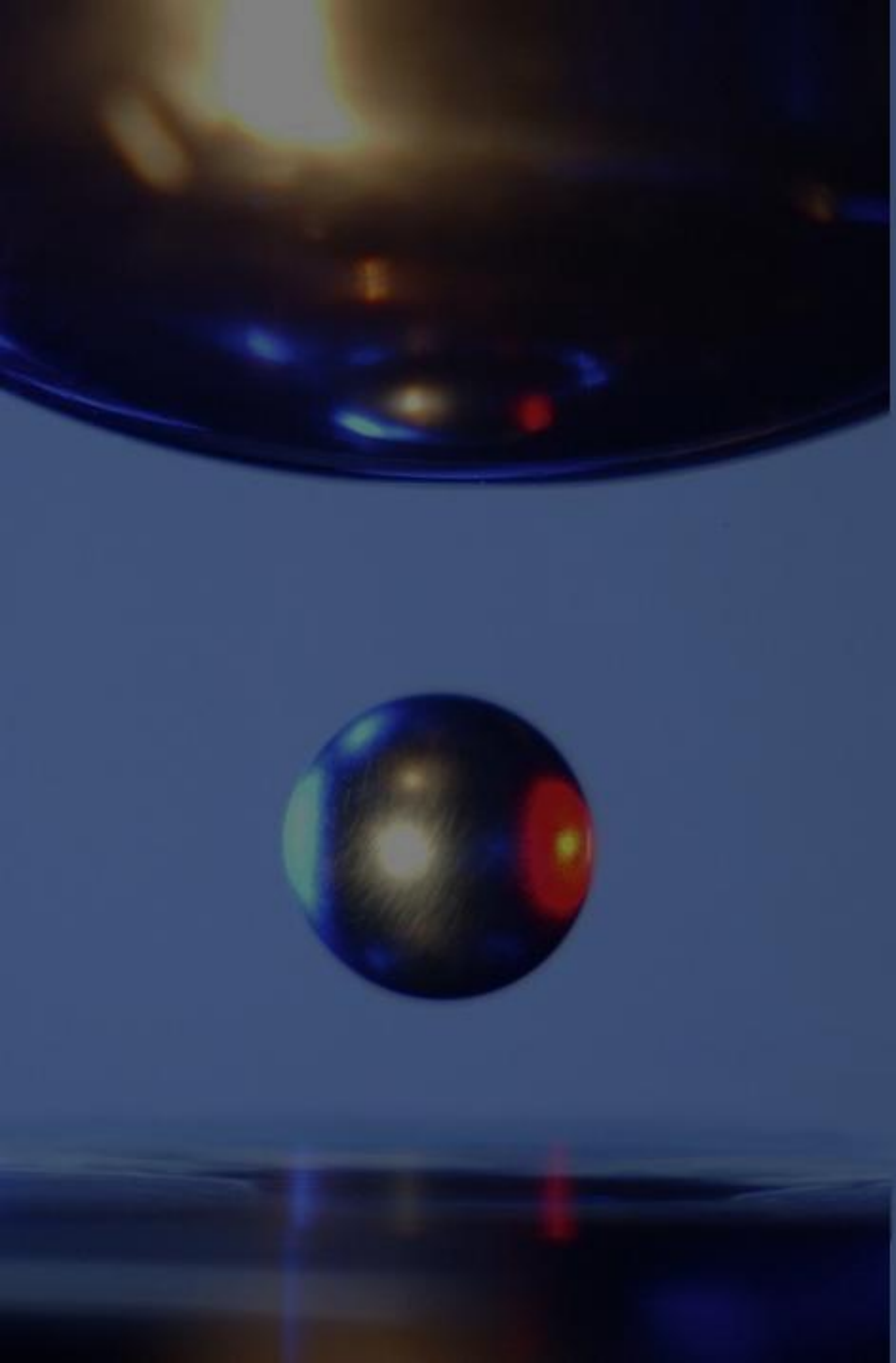


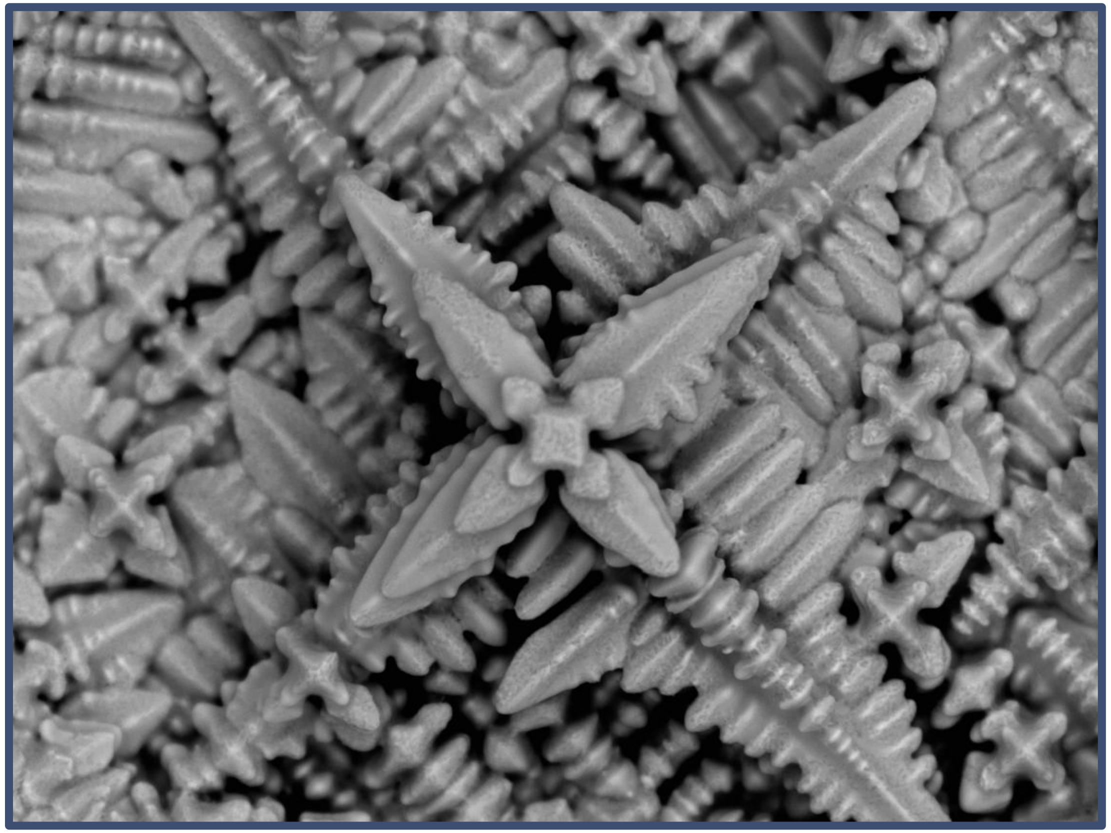
Development of Inconel Analog Alloys

William Cusato – EM31

NASA Tufts

Agenda

- Introduction
- Hypersonic Material Testing
    - Motivation
    - Density of Inconel Analogs
    - Compositional Changes
    - Future Work
- Electromagnetic Levitator Development
    - Hardware Integration
    - Future Work



Backscatter Image of MAT-2569 – QA718-Nb at 1000x

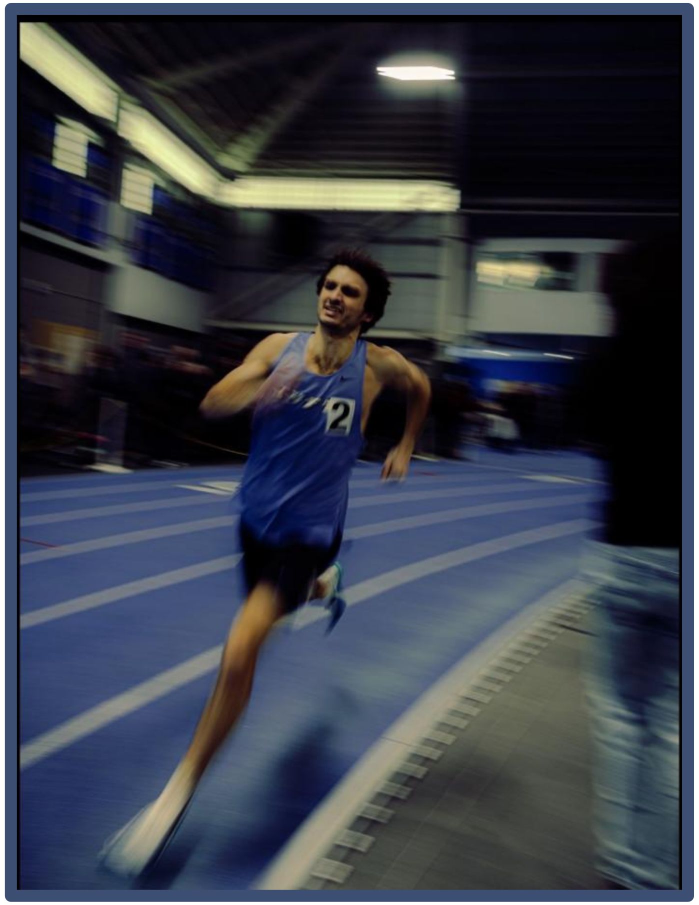
Introduction

- From Upstate NY
  - Albany / Schenectady

- B.S. ME – Tufts
  - Class of 2026
  - Research with Doug Matson and LevLab
  - Undergraduate Thesis

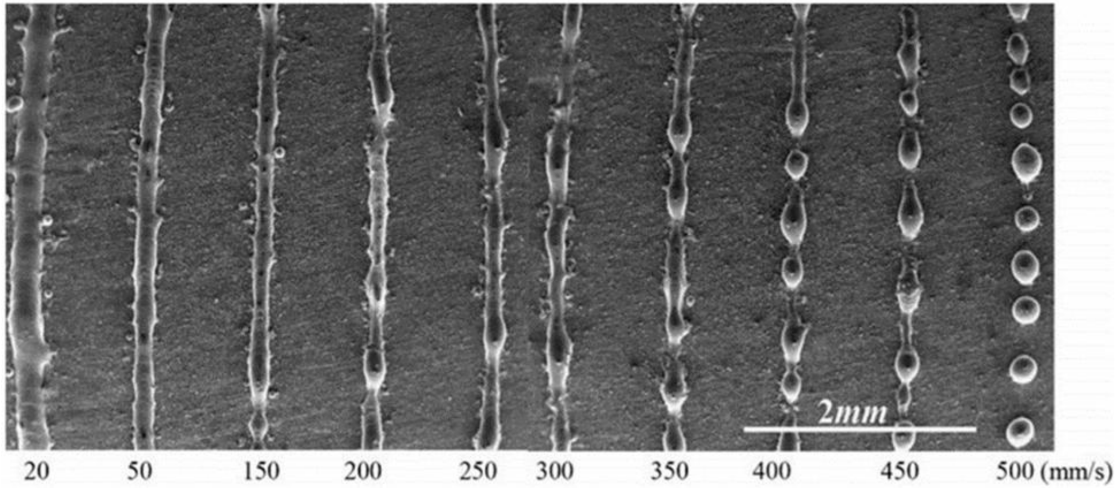
- M.S. MSE – Stanford
  - Sometime in 2028
  - Thesis track

- Big fan of running, hiking and music critique



Inconel Analog Processing - Motivation

- **Precise thermophysical data for quaternary alloys are scarce, yet critical for accurate manufacturing process models**
- **Studying simplified Ni-Cr-Fe-Nb ternary analogs isolates key elemental interactions in Inconel 718**
- **Wetting and the balling defects are governed by the interplay of density and surface tension**



Visualization of the balling defect at different AM scan speeds [1]

TA718-Ni Composition		
Ni	Cr	Fe
60.10	20.19	19.71

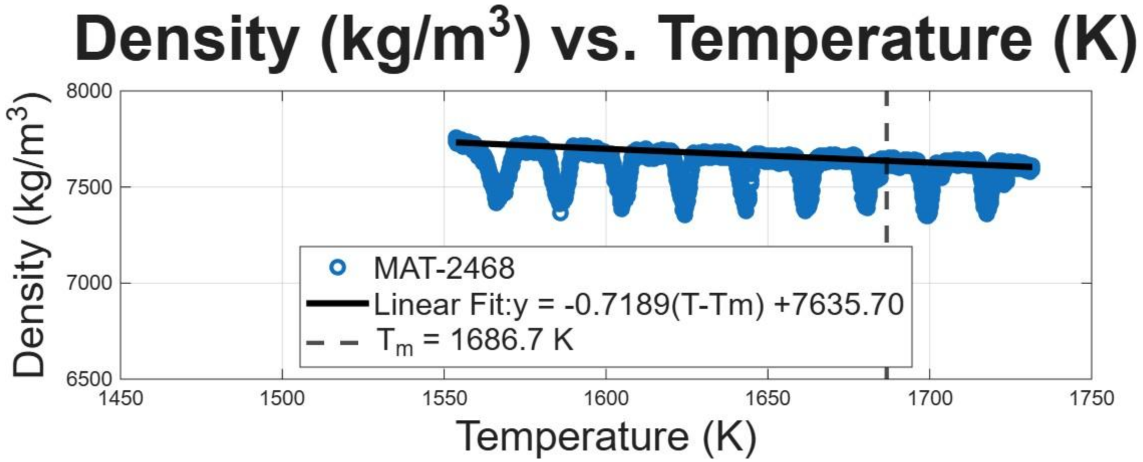
TA718-Fe Composition		
Ni	Cr	Fe
49.85	16.56	33.59

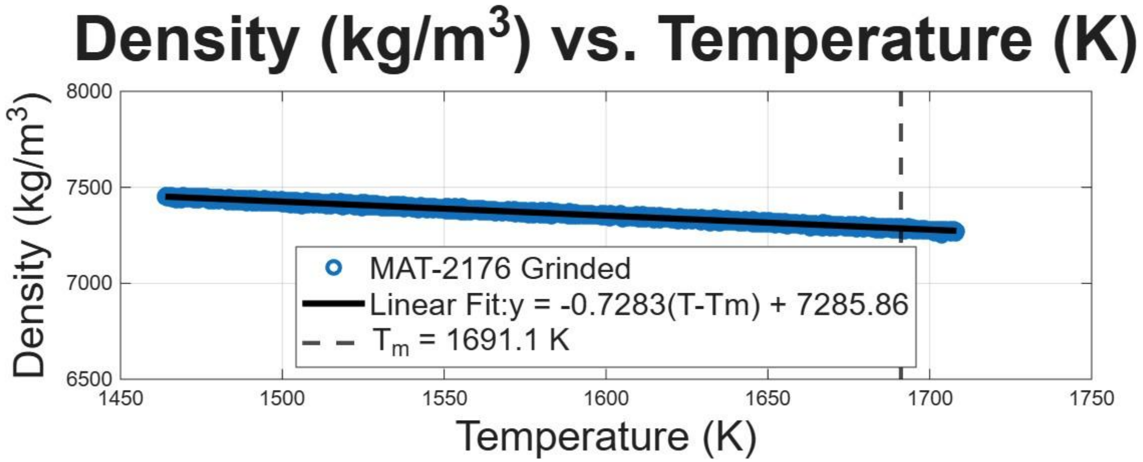
Composition of TA718-Ni and TA718-Fe in Weight Percentage

TA718 Density Results

TA718-Ni	
ρ at T_m	$7635.70 \frac{kg}{m^3}$
$\frac{d_\rho}{d_T}$	$-0.7189 \frac{kg}{m^3 K}$

TA718-Fe	
ρ at T_m	$7285.86 \frac{kg}{m^3}$
$\frac{d_\rho}{d_T}$	$-0.7283 \frac{kg}{m^3 K}$

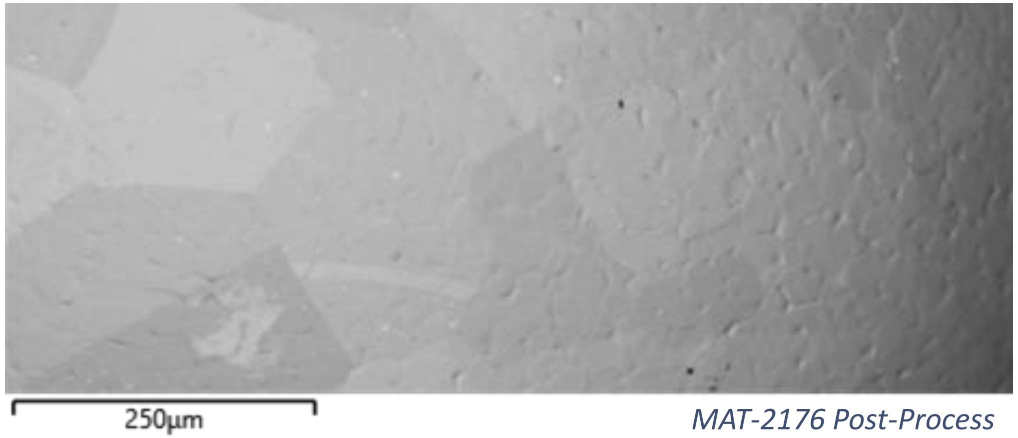




Compositional Changes

MAT-2176, TA718-Fe			
Element	Pre-melt	Pre-processing	Post-processing
Ni	54.89	44.11	55.37
Cr	20.62	16.09	9.77
Fe	18.10	39.80	34.86

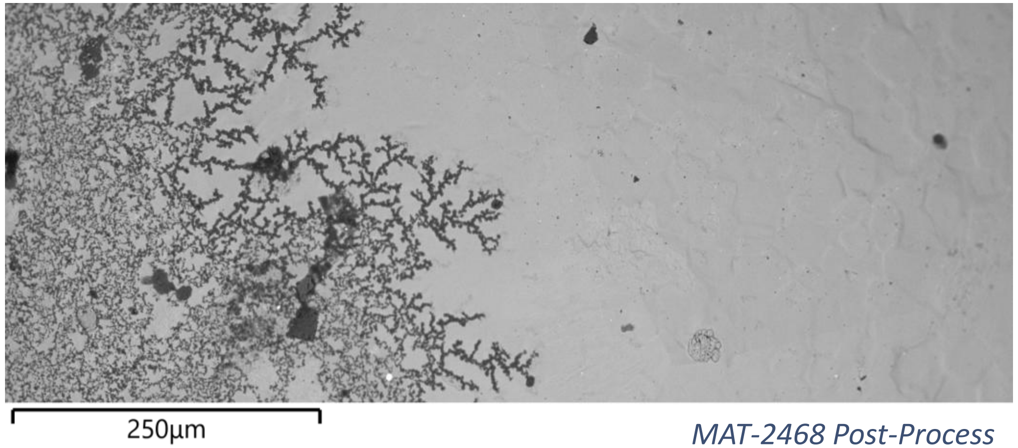
Composition of MAT-2566 in Weight Percentage



MAT-2176 Post-Process

MAT-2468, TA718-Ni			
Element	Pre-melt	Pre-processing	Post-processing
Ni	54.92	58.08	68.15
Cr	20.66	22.66	11.02
Fe	17.98	19.26	20.84

Composition of MAT-2568 in Weight Percentage

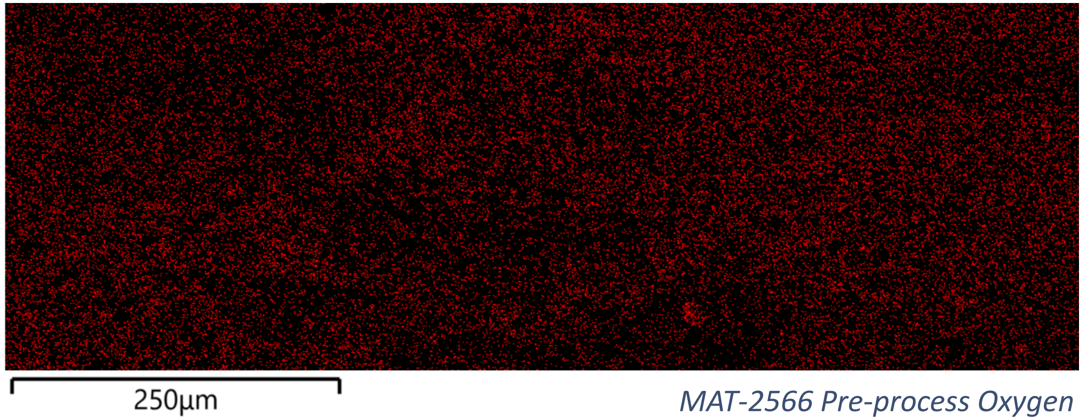


MAT-2468 Post-Process

Inconel Analog – Looking Forward

- Extension to quaternary systems
  - Addition of either Nb or Mo to sample composition
- Extension of ternary and quaternary experiments to viscosity and thermal diffusivity
- Faced challenges processing due to significant oxide presence on sample
- Sample grinding was employed to mitigate these issues

MAT-2566 Pre-process



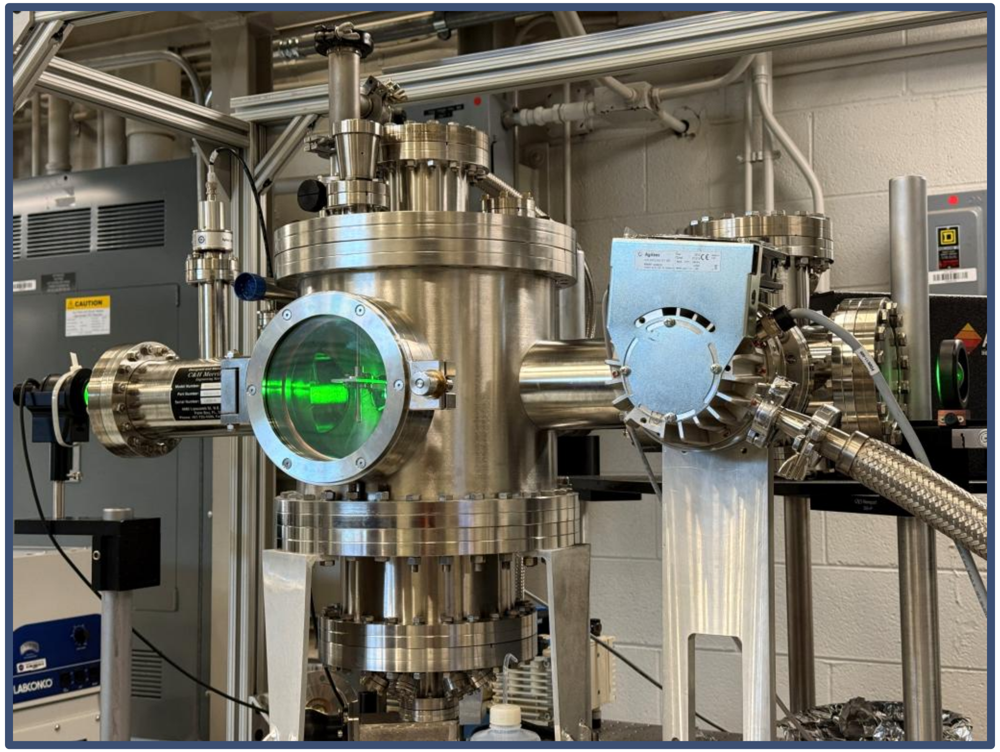
MAT-2566 Pre-process Oxygen Content

EML - Motivation

- Initial hypersonic materials efforts were placed into Molybdenum-Chromium binary alloys

- Challenging due to Molybdenum's and chromium's melting point difference

- These challenges are well suited for electromagnetic levitator use



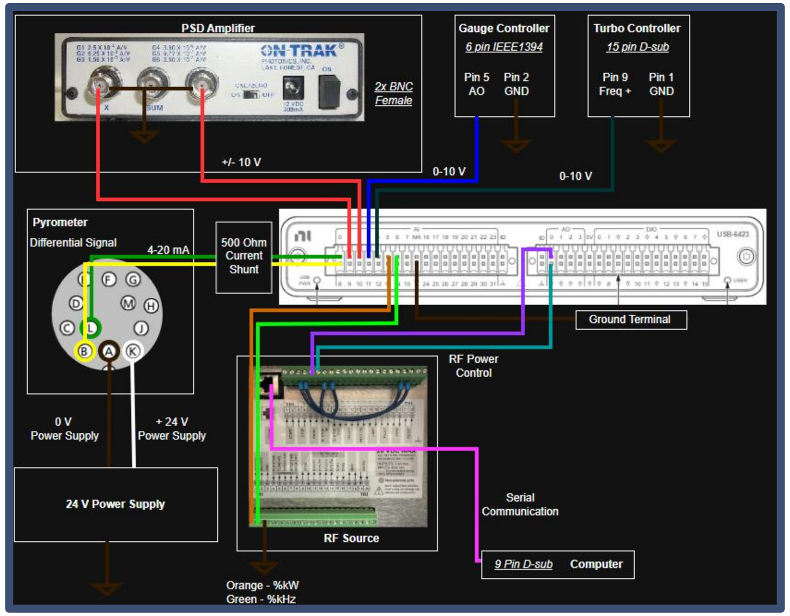
Electromagnetic Levitator (Left) and Levitated Sample (Right)

EML - Hardware Integration and Future

- EML equipped and wired with five different instruments that monitor and control levitation, vacuum, etc.
- EML close to operational state. Current LabView code needs to be updated to showcase newer functionality

Instrument	Purpose
Pyrometer	AO: Reads sample Temp
PSD	AO: Read sample location
IMG Vacuum Gauge	AO: Reads Chamber Pressure
Turbo Pump	AO: Reads turbo pump freq.
Ambrell RF Source	AO: Flow Monitoring AI: RF Power
Sample Loading	DO: Stepper motor control for sample carousel and stem

EML Instrumentation



Wiring Schematic for EML






Introduction to Doug Matson

- Research Professor and Professor Emeritus at Tufts University
- PI with LevLab for 24+ years
- Associate Editor of npj Microgravity
- Research focus on aerospace materials (Inconel, Invar) and uncertainty propagation for more robust ICME

References

[1] Wang, W., Ning, J., & Liang, S. Y. (2021). Analytical prediction of balling, lack-of-fusion and keyholing thresholds in powder bed fusion. *Applied Sciences*, *11*(24), 12053. https://doi.org/10.3390/app112412053