Measurement-Guided Additive Manufacturing for Quantum Technology Components

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INTRODUCTION

- Additive manufacturing (AM) can play a critical role in fabricating high-precision components for **emerging quantum technologies**.
- Current AM processes lack systematic measurement feedback, leading to **geometric deviations** that compromise component reliability.
- This work proposes a **closed-loop framework** integrating imaging and 3D metrology to improve dimensional accuracy.

PROJECT OBJECTIVES

- Reduce geometric deviations in printed parts
- Enhance repeatability and reproducibility
- Establish a closed-loop QA system

RESEARCH METHODOLOGY — CLOSED-LOOP SYSTEM

1 — Design & Fabrication
CAD → Quantum component design → AM system

→

2 — Advanced Imaging & 3D Metrology
High-res imaging
X-ray CT · CMM scanning

→

3 — Measurement Data Analysis
Surface geometry
Tolerances
Deviation analysis

→

4 — Iterative Optimization
Refine params
Data-driven correction

↺ **PARAMETER ADJUSTMENT FEEDBACK — Closed-loop iterative correction until within tolerance — ↺**

★ **Key Finding: Closed-loop metrology feedback reduced mean dimensional error by 47% (0.19 mm → 0.10 mm) across all printed parts.**

RESEARCH OUTCOMES & VALIDATION

47% error reduction | **0.10 mm** mean accuracy | **3 parts** validated

✓ **Validated Measurement Strategies**
Experimental validation of imaging & 3D metrology methods

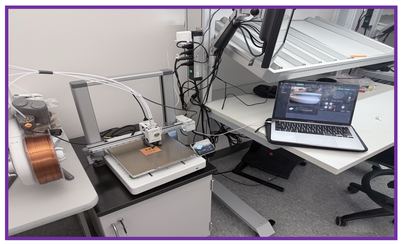
✓ **Improved Dimensional Accuracy**
Quantified deviation reduction via closed-loop feedback

✓ **Manufacturability Assessment**
Constraints evaluated for quantum tech applications

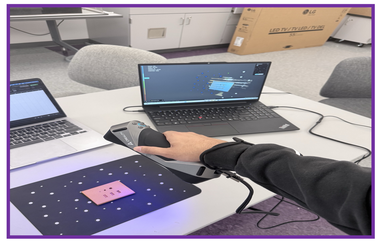
◷ **Enhanced Component Reliability**
Repeatability across multiple part variants

EXPERIMENTAL · MEASUREMENT DATA · RESULTS

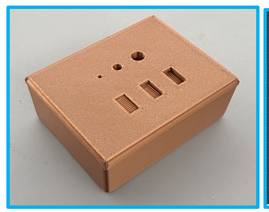
EXPERIMENTAL SETUP

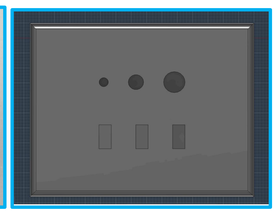


3D Printer (FDM) — Creality — Copper PLA

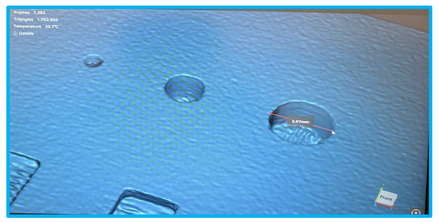


3D Scanner (Handheld) — Creality Raptor Blue Laser





Printed Part (P1) — 3 circles + 3 rectangles



3D Scan Output — CrealityScan 4.2.0

MEASUREMENT DATA — DESIGNED VS. PRINTED

C=Circle dia.(mm) R=Area R1/2/3=rectangle depth(mm) PC/PR=Printed value P=Part no.

Part	C1	PC 1	C2	PC 2	C3	PC 3	Area	R1	PR 1	R2	PR 2	R3	PR 3
P1	3	3.03	5	5.1	7	7.04	4×8	1	0.95	2	2.05	3	3.01
P2	2	1.84	4	4.19	6	5.93	5×10	1	1.05	2	2.1	3	3.05
P3	8	7.94	8	8.07	10	10.13	2×4	1	1.06	2	2.59	3	2.94

CIRCLE DIAMETER DEVIATION HEATMAP (mm)

Part	C1	C2	C3
P1	0.03	0.10	0.04
P2	0.16	0.19	0.07
P3	0.06	0.07	0.13

CONCLUSION & FUTURE WORK

CONCLUSION

A closed-loop measurement framework integrating handheld blue-laser scanning with iterative AM parameter correction can achieve reduction in dimensional error, demonstrating that systematic metrology feedback is both feasible and effective for quantum-device component fabrication.

FUTURE WORK

- Extend validation to metal-SLS and resin-SLA printers for higher-precision quantum components
- Test closed-loop accuracy with 10+ part variants to establish statistical tolerance bounds for quantum fabrication
- Integrate ML-based parameter prediction to automate correction without human-in-the-loop.

REFERENCES

[1] Wang et al. In-situ monitoring & process control in metal-based laser AM. J. Manuf. Proc., 2023.
[2] Delli & Chang. AR, Cyber-Physical Systems & Feedback Control for AM: A Review. IEEE Access, 2019.

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