

Large-Area Projection Stitching in Vat Photopolymerisation: Registration, Dose Overlap, Seam Formation and Qualification

A metrology-led framework for tiled exposure fields

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Abstract

Projection vat photopolymerisation can enlarge its build area by translating or multiplexing a finite optical field. Every tile boundary then becomes a coupled geometric and photochemical interface. Registration error creates steps or duplicated features; irradiance non-uniformity changes local conversion; overlap adds dose; gaps subtract dose; resin and machine drift make a calibration unstable over time. A seamless image on a calibration target is therefore not sufficient qualification evidence.

This review defines qualification of large-area projection stitching. It separates stage geometry, optical distortion, radiometric response, temporal sequencing and cured-part outcome. It requires boundary-oriented artefacts, field-wide uncertainty, endurance tests and non-compensatory gates. No universal overlap width, blend function, correction map or seam tolerance is supported.

Keywords: vat photopolymerisation; projection stitching; registration; dose overlap; seam; large area; qualification

1. Significance and scope

Scanning projection stereolithography demonstrates that a projected field can be translated to create objects beyond one static image [1]. The enlarged working area is obtained only by controlling the interfaces between exposures.

ER-249 owns registration, dose blending, seam formation and qualification for tiled or scanned projection fields.

1.1 Corpus boundary

ER-010 retains general dimensional metrology; ER-035 cure-depth interpretation; ER-088 surface-roughness metrology; ER-174 optical imaging; ER-203 radiometry; ER-241 feed-forward exposure-pattern compensation; ER-242 intentional spatial dose modulation; ER-243 pixel and projected-feature geometry; ER-245 thermal control; ER-246 level control; ER-248 top-down architecture; and ER-250 support-removal effects. ER-249 consumes qualified correction, modulation, pixel-geometry and roughness-metrology outputs only at the tile boundary; it does not redefine those incumbent subjects. ER-203, ER-245, ER-246, ER-247, ER-248 and ER-250 are roadmap neighbours; none is used as authority here.

2. Define the stitching architecture

Document the number of projectors or field positions, exposure order, stage axes, overlap policy, focus surface and coordinate transforms. Distinguish simultaneous multi-projector stitching from sequential stage scanning because temporal and mechanical errors differ.

3. Establish coordinate traceability

Calibrate projector pixels, stage motion and build coordinates against an independent artefact. State uncertainty and environmental conditions. Do not infer registration from commanded positions.

4. Map optical distortion

Measure distortion across every field, including corners and overlap zones. Fit and freeze a correction model, retain residuals, and verify it on independent points. Zhou, Chen and Waltz provide single-field mask-image projection optimisation evidence that is relevant to image-correction practice but does not itself establish stitching performance [2]. A low global mean can hide a local boundary error.

5. Map irradiance and dose response

Record field-wise irradiance and temporal stability. Convert overlap into delivered dose only with a validated resin response. Dose is not necessarily additive after inhibition, bleaching, conversion or heating changes.

6. Define overlap and blend functions

State overlap width, weighting function, exposure timing and clipping rules. Challenge flat, ramped and geometry-aware blends where relevant. The selected method must control both undercure gaps and overcure ridges.

7. Control stage motion

Measure positioning error, backlash, straightness, pitch, yaw, settling and thermal drift in both scan directions. Repeat after reversals and long travel. Registration must be qualified under the same payload and timing used for printing.

8. Control timing

Sequential tiles can experience different induction, dark reaction, oxygen recovery and thermal histories. Record exposure separation and order. Randomise or reverse order during qualification to expose hidden temporal bias.

9. Measure seam geometry

Use artefacts with lines, holes, walls and surfaces crossing boundaries at several angles. Measure step, gap, ridge, width change, roughness and local warpage. Wen, Chen, Chen, Zhang, Cheng, Yi, Jiang and Huang report structure-optimisation compensation for projection-stereolithography microstructure accuracy [3]; this is single-field geometric-correction evidence, not stitching evidence. Include features narrower than the nominal overlap.

10. Measure seam material state

Assess conversion or a validated proxy, hardness, green strength and final mechanical response across the seam. Geometric continuity does not prove homogeneous cure.

11. Challenge orientation and feature phase

Move identical features through field centres, edges, corners and crossing points. Vary their phase relative to the tile grid. This detects periodic defects hidden by one favourable placement.

12. Include layer-to-layer propagation

Seam errors can repeat vertically or shift with compensation maps. Test straight walls, inclined surfaces and internal channels over many layers. Evaluate whether periodic dose accumulation creates visible or mechanical planes.

13. Control resin and temperature state

Absorption, inhibition, viscosity and kinetics affect seam response. Qualify the correction across the declared resin, temperature and age range. A geometry map cannot compensate a changed photochemical response.

14. Detect projector mismatch

For multi-projector systems, compare wavelength, irradiance distribution, focus, polarisation where relevant, temporal output and pixel scaling. Match cured response, not only nominal hardware settings.

15. Drift and endurance

Run the longest credible sequence and remeasure registration and radiometry at intervals. Challenge warm-up, restart and maintenance states. Define map validity and recalibration triggers.

16. Scale-up

Additional tiles increase boundary length and compound stage, optical and temporal uncertainty. Qualification must cover internal boundaries, outer-field distortion and intersections where more than two correction zones meet.

17. Change control

Requalify after projector, lens, stage, mount, firmware, blend map, exposure sequence, vat, resin, temperature range or build-height change. Store correction-map hashes with build records.

18. Non-compensatory qualification matrix

Gate	Required evidence	Shortcut prevented
Geometry	Independent field and stage registration	Trusting commanded coordinates
Radiometry	Field-wise dose and temporal stability	Treating overlap pixels as dose proof
Cure	Seam conversion or validated proxy	Accepting geometry alone
Artefacts	Multi-angle boundary features	Testing one favourable line
Endurance	Warm and long-run drift	Freezing a cold calibration
Traceability	Map, firmware and raw-data hashes	Uncontrolled correction updates

Failure of any gate rejects the stitched operating point.

19. Minimum reporting set

Report architecture; projector and lens identifiers; wavelengths; pixel scale; stage model and calibration; coordinate transforms; distortion residuals; irradiance maps; overlap width and blend function; timing and tile order; resin and temperature; artefact geometry and placement; metrology method and uncertainty; seam geometry and cure endpoints; drift results; correction-map and firmware hashes; qualified build domain; and change triggers.

20. Knowledge boundary

Lee and colleagues provide full-text evidence for scanning projection stereolithography beyond one static field and explicitly report stitching projected images over a large area [1]. Zhou, Chen and Waltz address optimisation of mask-image projection in a single field [2]. Wen, Chen, Chen, Zhang, Cheng, Yi, Jiang and Huang address structure-optimisation compensation for microstructure geometric accuracy in projection stereolithography [3]. References [2] and [3] therefore inform correction and geometric-evaluation methods but are not evidence that a stitched seam has been qualified. None of these sources establishes a universal overlap, seam tolerance, blend function or transferable correction map.

21. Limitations

Reference [1] was examined at full-text depth. References [2] and [3] were examined at publisher-abstract depth. Architectures and resins differ, and no cited study validates every multi-projector or moving-stage implementation.

22. Conclusions

Large-area projection is a chain of coordinate, optical, radiometric and photochemical transformations. Qualification must test cured boundaries across position, orientation, time and material state. Seamlessness is an evidence claim tied to a declared operating envelope, not a property of the stitching algorithm alone.

References

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