

MOPA Laser Black Annealing Parameter Matrix

Stainless Steel Marking Protocol & ISO/IEC 15415 Grade A Verification Guide

Meenjet Technical Asset
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1. SUBSTRATE PARAMETER MATRIX (MOPA FIBER LASER)

Substrate Grade	Pulse Width	Frequency	Speed	Power Output	Hatch Pitch	Expected Finish & Quality
AISI 304	8 – 15 ns	80 – 120 kHz	120 – 180 mm/s	40 – 55 %	0.003 – 0.005 mm	Deep matte black, non-destructive oxide film. Grade A
AISI 316L	6 – 12 ns	100 – 150 kHz	100 – 150 mm/s	45 – 60 %	0.003 – 0.004 mm	Surgical grade black, corrosion resistant. Grade A
AISI 430	20 – 30 ns	40 – 70 kHz	150 – 220 mm/s	35 – 50 %	0.005 – 0.008 mm	Dark charcoal, moderate oxide layer thickness. Grade A/B
17-4 PH	10 – 20 ns	60 – 100 kHz	100 – 160 mm/s	40 – 50 %	0.004 – 0.006 mm	High-contrast black, requires a grid test. Grade A

* The baseline is configured with a 100mm f-theta lens and a 30W MOPA laser module. Adjust power based on actual substrate surface roughness.

2. PHYSICS OF BLACK ANNEALING & KEY CONTROLS

Pulse Width (ns) Control

- <5 ns: Insufficient heat buildup → Light gray or faint annealing mark.
- 6 – 20 ns: Optimal window for thermal growth of uniform black iron oxide (Fe₃O₄) layer without surface vaporization.
- >50 ns: Excessive heat → Melting, graying & HAZ (Heat-Affected Zone) expansion.

Frequency (kHz) & Hatch Pitch

- High Frequency (80–150 kHz): Keeps single-pulse energy low while maintaining continuous heat accumulation for smooth blacking.
- Dense Hatching (0.003–0.005 mm): Ensures total overlap of microscopic spot tracks to eliminate light leakage under 2D verifiers.

3. ISO/IEC 15415 GRADE A DATAMATRIX OPTIMIZATION

Parameter Tuning for Verification Parameters

- Symbol Contrast: Reduce speed to 80–100 mm/s, or reduce frequency to 50–80 kHz, to boost peak pulse power and produce a deeper black.
- Modulation & Unused Error Correction (UEC): Defocus the beam by +2.0 mm to +3.0 mm (move the laser head further from the surface) to smooth out spot-to-spot overlap and eliminate microscopic hotspots within dark modules.
- Axial Nonuniformity: Calibrate galvo scanner field correction and ensure orthogonal mounting relative to the conveyor belt or fixture.

4. PASSIVATION & CORROSION RESISTANCE PROTOCOLS