

System Requirements Document (SRD)

Industrial Laser-Cutting Machine for Metal Fabrication

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1. Document Administration

1.1 Revision History

Rev	Date	Author	Description
1.0	2026-04-15	A. Granot	Initial draft [cite: 3]
1.1	2026-05-15	A. Granot	Top-level requirements [cite: 3]
B	2026-05-16	Systems Eng.	Consolidated SRD merging Architecture analysis, Technical Challenges, and Operational Flows.

1.2 Document Hierarchy & Authority

In cases of conflicting engineering data, requirements follow this descending order of reliability:

1. *sysreq example.odt* (Project Charter) [cite: 3]
2. *Claude-SRD_Laser cutting system design.pdf* (Technical Feasibility) [cite: 1]
3. *ChatGPT-Phase1_Laser-Cutting Machine Design.pdf* (Conceptual Design) [cite: 2]

2. Executive Summary & Critical Feasibility

This document presents the complete system-level design for an industrial laser cutting machine targeting the metal processing industry [cite: 1]. The system must process aluminum and stainless steel sheets up to \$2500 \times 1500\$ mm, with thicknesses ranging from foil (sub-0.1mm) to 15mm plate [cite: 1, 3].

CRITICAL FEASIBILITY FINDING: The combination of a 35μm minimum feature size across the full 15mm thickness represents a fundamental physics conflict due to beam divergence and the heat-affected zone (HAZ) [cite: 1]. The system addresses this through a **dual-regime approach** where 35μm features are specified for thin materials (< 0.5mm), while thickness-dependent specs apply for heavier plates [cite: 1].

3. System Architecture Analysis

3.1 Candidate Evaluations

Three architectures were evaluated [cite: 1]:

- **Arch A: Conventional CW Fiber:** Industry standard. Fails to meet 35μm feature requirement on any thickness [cite: 1].
- **Arch B: Dual-Source Hybrid:** (CW + Ultrafast). Meets precision targets but exceeds target BOM cost by >2x (\$250k - \$350k) [cite: 1].
- **Arch C (RECOMMENDED): Variable-BPP Fiber:** Dynamic Beam Parameter Product (BPP) adjustment. Best balance of capability vs. cost (\$140k - \$165k) [cite: 1].

3.2 Architecture C Recommendation Rationale

- Single laser source eliminates dual-path complexity and maintenance penalties [cite: 1].
- Dynamic mode switching allows bulk cutting (wide BPP) and fine-feature cutting (concentrated BPP) [cite: 1].
- Integrated process feedback (OCT, camera) enables adaptive quality control [cite: 1].

4. Performance & Structural Requirements

ID	Requirement	Specification	Source
PR-01	Metal Types	Aluminum (1xxx-7xxx) and Austenitic Stainless Steel [cite: 3]	[cite: 1, 3]
PR-02	Plate Dimensions	\$2500 \times 1500 \times 15\$ mm (L, W, T) [cite: 1, 3]	[cite: 1, 3]
PR-03	Cutting Speed	\$\geq 125\$ meters of cut per hour [cite: 3]	[cite: 3]
PR-04	System Up-time	> 99.5% (Max 1hr downtime per week) [cite: 3]	[cite: 3]
PR-05	BOM Cost Target	\$150,000 USD [cite: 1, 3]	[cite: 1, 3]

5. Detailed Functional Requirements

5.1 Laser & Optics (OP)

- **Source Power:** 12kW peak power source to support maximum plate thickness [cite: 3].
- **Wavelength:** 1070–1080 nm fiber laser [cite: 3].
- **Power Increments:** 2.5% $\pm$ 0.1% increment capabilities [cite: 3].
- **Beam focus:** Motorized Z-axis focus with 75mm range [cite: 3].
- **Beam DOF:** 15mm for resolution 30lp/mm at MTF > 60% [cite: 3].
- **BPP Range:** Adjustable between 0.8–8.0 mm $\cdot$ mrad [cite: 1].

5.2 Mechanics & Plate Loading (ME)

- **Gantry Accuracy:** $\pm 10\mu\text{m}$ positioning accuracy over full work area [cite: 1].
- **Repeatability:** $\pm 5\mu\text{m}$ bidirectional [cite: 1].
- **Batching:** Support up to 25 plates per raw material batch [cite: 3].
- **Batch Max Height:** 495mm (Calculated: 15mm x 25 + 5mm spacers) [cite: 3].
- **Base Material:** Polymer concrete or mineral cast for thermal stability and natural frequency ≥ 80 Hz [cite: 1].

5.3 Electronics & Software (EL/SW)

- **Update Rate:** CNC interpolation at ≥ 4 kHz update rate [cite: 1].
- **Encoders:** Absolute linear encoders with $\leq 0.1\mu\text{m}$ resolution [cite: 1].

- **Vision Feedback:** Real-time integration with Product-A and Product-B machine-vision modules [cite: 3].
- **CAM Integration:** Automatic nesting layout with $\geq 85\%$ material utilization [cite: 1].

6. Safety & Environmental Compliance

- **Laser Safety:** Class 1 Laser Product with closed covers per IEC 60825-1 [cite: 1, 3].
- **Interlocks:** Redundant SIL-2 rated interlock chain; laser shutdown within 10ms of door opening [cite: 1, 3].
- **Fume Extraction:** $\geq 3000\text{ m}^3/\text{hr}$ with HEPA filtration (99.97% at $0.3\mu\text{m}$) [cite: 1].
- **Noise:** $\leq 80\text{ dB(A)}$ at 1m from enclosure [cite: 1].

7. Operational Flow & Error Handling

7.1 Main Material Flow [cite: 3]

1. Plate loading: one-by-one from the platform via automated pick-and-place.
2. Alignment: Vision-based plate identification and placement verification.
3. Processing: Execution of trajectory with adaptive laser power adjustment.
4. Unloading: Parts retrieval and debris removal to the integrated bin.

7.2 Calibration [cite: 3]

- **Power Auto-Calibration:** Periodic verification against internal power meter.
- **Motors Auto-calibration:** Periodic homing and positioning artifacts verification.

8. External & Internal Interfaces [cite: 3]

- **Electric Interface:** Main power inlet 480VAC [cite: 3].
- **Coolant Inlet:** 3-inch hose, room temperature water at 15L/min [cite: 3].
- **Coolant Outlet:** 3-inch hose, max temperature 74°C [cite: 3].
- **Communication:** OPC UA interface for factory MES integration [cite: 1].

9. Procurement & Vendor List [cite: 1]

- Linear Motors
- CNC Controller

Subsystem	Primary Vendor / Product	Estimated Cost (\$)
Laser Source	IPG YLS-AMB or Coherent FL-ARM (12kW)	\$40k - \$60k
Cutting Head	Precitec ProCutter 2.0 (Zoom Collimator)	\$12k - \$18k
Etel ILF+ or Beckhoff AL8000	\$8k - \$15k	
Beckhoff TwinCAT CX2040	\$5k - \$10k	

10. Requirement Tracking Table (Sample) [cite: 3]

Req #	Title	Source	Status
1.1	Metal type	Product 000-000 #1	Compliant [cite: 3]
2.2.3	Laser Power	Product 000-000 #2	Set to 12kW [cite: 3]
2.4.1	Batch height	Product 000-000 #13	495mm limit [cite: 3]