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The Precision–Speed–Cost Triangle

A Process Engineer's Guide to Sourcing Laser Micromachining Services

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Executive Summary

In laser micromachining procurement, three parameters are fundamentally interdependent: Precision, Speed, and Cost.
You can optimize any two. The third is determined by physics and process economics.
This document explains how the triangle operates in practice, provides quantified benchmarks, and identifies the red flags that signal an unqualified supplier.

Chapter 1: The Precision–Speed–Cost Triangle

1.1 The Core Constraint

In laser micromachining, three parameters are interdependent and governed by non-negotiable physical constraints:

- Precision — Geometric tolerance, surface roughness (Ra), and heat-affected zone (HAZ) dimensions.
Driven by pulse duration, beam quality (M^2), and optical system stability.

- Speed — Throughput per unit time, measured in features per second or linear feed rate (mm/s).
Determined by repetition rate, scan speed, and material removal mechanism.

- Cost — Per-part or per-wafer processing cost, inclusive of setup time, yield loss, inspection overhead, and amortized capital equipment.
Scales non-linearly with precision requirements.

The rule is fixed: You can lock in two parameters. The third is derived by the process physics and economics.
A supplier claiming otherwise is either misinformed or misrepresenting capability.

1.2 How the Triangle Works in Practice

Fixed Pair	Typical Outcome	When to Use
Precision + Speed	Cost increases 3–10×Premium source + qualification overhead	High-volume production with tight tolerancese.g., SMT carrier tooling, medical device shims
Precision + Cost	Speed decreases 50–80%Slower feed rates, smaller batch windows	Low-volume R&D, validation batchese.g., prototype optical slits, test sockets
Speed + Cost	Precision relaxed to ±10–20 µmNanosecond sources, mechanical fixturing	Consumer electronics shims, non-critical spacerse.g., speaker grill backing plates

Quantified Examples

Example A: ±5 µm tolerance, 10,000 units/month
- Source: Femtosecond or picosecond laser (ultrafast regime)
- Feed rate: 50–150 mm/s (vs. 500+ mm/s for nanosecond processes)
- Setup: Vision alignment + Cpk qualification (4–8 hours per batch)
- Cost multiplier: 4–6× vs. a ±20 µm baseline process
- Why: Cold ablation requires pulse overlap >80%, reducing effective speed proportionally

Example B: ±25 µm tolerance, 500,000 units/month
- Source: Nanosecond fiber laser (sufficient for thermal ablation at this tolerance)
- Feed rate: 800–1,500 mm/s (high-speed galvo scanning)
- Setup: Mechanical fixturing only (no vision alignment required)
- Cost: Baseline reference — this is the standard production model
- Why: Relaxed tolerance allows lower pulse overlap and higher scan speeds

1.3 When Clients Break the Triangle

The most common sourcing mistake in precision manufacturing is demanding all three vertices of the triangle simultaneously.

If a supplier agrees to ±5 µm tolerance at nanosecond-laser speed at baseline cost, one of three outcomes is inevitable:

1. The supplier does not understand the specification — and will learn at your expense during production.
2. The supplier will deliver out-of-tolerance parts — with yield rates hidden until final inspection.
3. The supplier will absorb unsustainable losses — and either exit the business or renegotiate mid-contract.

A qualified supplier will push back. They will ask which parameter can flex — precision, speed, or cost.
This pushback is not obstinacy. It is a positive signal of technical competence and process honesty.
Suppliers who say "yes" to everything typically deliver on nothing.

Need a Process Review?

Send your specification to our engineering team.
We will map it against the triangle and return a feasibility assessment with quantified throughput and cost targets — no obligation.

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