MWL **MANUFACTURING WITH LIGHT**

HANDHELD LASER WELDING FOR U.S. MANUFACTURERS

A Practical Guide to Evaluation, Safety, Process Development, and Implementation

PURPOSE: A shop-floor-oriented starting point for small manufacturers and fabrication shops considering their first handheld laser welding system.

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Safety, Legal, and Regulatory Disclaimer

READ THIS FIRST: Handheld laser welding is high-power industrial laser processing. The open process is generally Class 4 and can cause severe and permanent eye injury, skin injury, fire, and hazardous exposure from direct, reflected, scattered, or transmitted laser radiation. Welding fumes, electrical energy, hot metal, compressed gases, and other non-beam hazards also remain relevant.

This MWL publication is educational and general manufacturing guidance. It is not legal advice, a laser hazard analysis, an engineering design, a welding procedure specification (WPS), an OSHA compliance determination, a product certification, or a substitute for the equipment manufacturer's instructions. It does not replace the work of a qualified Laser Safety Officer (LSO), welding engineer or inspector, industrial hygienist, electrical professional, fire-safety professional, or other competent specialist where those roles are appropriate.**[1][2][6]**

Every employer and facility is responsible for identifying the federal, state, local, contractual, customer, and industry-code requirements that apply to its installation and products. OSHA's laser-safety page identifies applicable workplace regulations and also states explicitly that the ANSI Z136 series consists of national consensus standards and is not, by itself, OSHA regulation. State Plans may impose requirements that differ from or exceed federal OSHA requirements.**[3]**

FDA/CDRH requirements address laser products placed into U.S. commerce. The current FDA radiation-emitting product database defines a laser welder as a high-power laser intended to join materials in an industrial or commercial environment and points to 21 CFR 1040.10 as the applicable performance standard. Product certification and workplace safe-use responsibilities are related but not identical.**[4][16]**

ANSI Z136.1-2022 is the current general U.S. consensus framework for safe laser use. At the time of this edition, the Laser Institute of America's catalog identifies the 2013 manufacturing-specific Z136.9 edition as historical. OSHA's topic page still lists Z136.9 generically among consensus resources. Before relying on any standard, verify its current edition and status directly with the issuing organization.**[3][5]**

Numerical values in this guide are not production settings. Published thicknesses, power levels, wobble widths, line-energy examples, and material observations are included to explain concepts or help screen equipment. A production process must be developed and qualified on the actual machine, optics, material, joint, filler, shielding gas, fixture, and operator used for the work. Applicable product codes and customer requirements control.**[1][7][10]**

COPYRIGHT AND SOURCE USE: The major diagrams in this guide are original MWL concept illustrations derived from referenced technical principles; they do not reproduce copyrighted figures from third-party publications. Manufacturer specifications and claims are identified as manufacturer-published information. Links are provided so readers can inspect the original sources.

Contents

How MWL handled sources

The source hierarchy for this edition is intentional: U.S. government and regulatory sources first for U.S. legal/regulatory context; current standards organizations for consensus frameworks; AWS/IIW/EWF/EWA guidance and peer-reviewed research for handheld-laser-welding-specific technical evidence; and manufacturer documentation for product-specific features and capabilities. Where a manufacturer makes a performance claim, this guide labels it as a manufacturer claim rather than independent proof.

The 2026 publication Considerations About Handheld Laser Beam Welding is the principal handheld-laser-welding-specific synthesis used here. It was prepared by subject-matter experts and is supported by IIW, EWF, EWA, and AWS. It covers equipment, safety, personnel qualification, weld qualification, beam profiling, QC, joint design, heat input, materials, gases, and preparation. Its own disclaimer correctly reminds readers that local and national requirements still control.**[1]**

Terminology note: This MWL guide uses the plain-language term “handheld laser welding” throughout because it is the most natural wording for U.S. shops. Some technical sources use Handheld Laser Beam Welding (HLBW), and AWS has also used Handheld Laser Welding (HHLW). When a source title or quoted source terminology uses HLBW or HHLW, this guide preserves that wording; otherwise, it avoids acronyms unless they add clarity.

> **MWL PUBLISHING RULE:** If a source does not support a universal number, this guide does not invent one. Blank ranges and “machine-specific” statements are deliberate.

Executive Summary: Treat It as a Manufacturing System

Handheld laser welding can be a compelling process for a small manufacturer. Demonstrations show fast travel, narrow welds, comparatively small heat-affected areas, attractive surface appearance, and relatively quick operator learning. Those advantages are real enough to justify serious evaluation. They do not, however, turn a Class 4 industrial laser into a drop-in replacement for a TIG or MIG power source.**[1]**

The practical system boundary is larger than the machine: laser source + beam delivery + welding head + interlocks + controlled work area + LSO + fume control + PPE + trained operator + joint preparation + fixture + qualified procedure + inspection + maintenance records. A weakness in any one of those systems can erase the productivity benefit or create unacceptable risk.

> **THE CENTRAL IDEA:** Do not buy "a laser." Build a safe, documented welding process around representative parts.

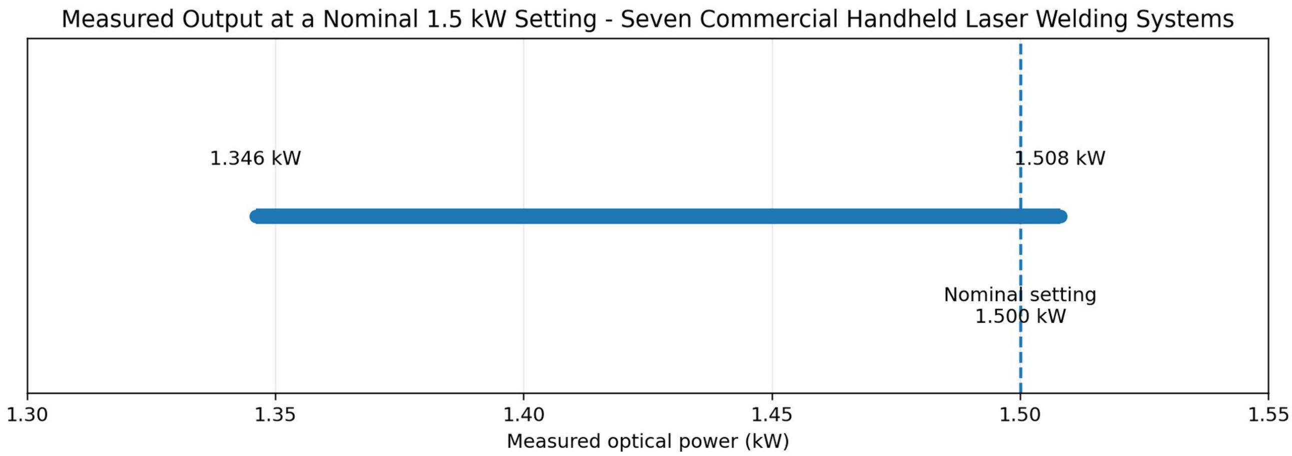
Five questions to answer before you ask for a quote

1. Which three to five real parts are we trying to improve, and what is wrong with the current process?
2. Can their fit-up, joint access, cleanliness, backing, and beam path be controlled?
3. How will the laser energy be contained - including reflections and energy that can pass through the root or a gap?
4. What inspection or test will prove the weld is acceptable?
5. Who will own laser safety, process development, training, maintenance, and quality after the application engineer leaves?

Where the evidence is strongest

A good first handheld laser welding application is usually repetitive or semi-repetitive fabrication with accessible seams, controllable fit-up, and enough value in reduced welding time, distortion, finishing, or rework to justify the safety and process infrastructure. Stainless steel and common steels are often attractive starting points; aluminum can also be successful but demands stronger attention to reflectivity, oxide control, porosity, filler, and parameter window. Copper, brass, titanium, difficult dissimilar joints, very thick multipass work, and code-critical products deserve a more conservative development path.**[1]** **[10]**

The peer-reviewed 2026 comparison of seven commercial handheld laser welding machines is especially important for purchasing and quality. At the same nominal 1.5 kW setting, measured output ranged from 1.346 to 1.508 kW. Beam diameters and profiles varied substantially, and one system showed more than 6 mm of power-dependent focal shift. The authors conclude that optimized settings or a WPS cannot simply be transferred between different handheld laser welding systems.**[10]**



Source: Jahn et al., Welding in the World (2026), DOI 10.1007/s40194-026-02377-3. Seven systems tested; not a market-wide range.

Data Figure A. Measured output range at a nominal 1.5 kW setting across seven tested commercial handheld laser welding systems.

Source note: The range comes directly from the peer-reviewed seven-system comparison. It describes the machines tested, not the entire market.[10]

1. Start with the Manufacturing Problem

A laser-welding demo often starts with the technology: power, speed, wobble pattern, a polished bead. A manufacturer should start somewhere else: the part, the production constraint, and the evidence needed to prove improvement. The process has to solve a manufacturing problem, not merely make a visually impressive coupon.

Good reasons to investigate handheld laser welding

- Throughput is constrained by manual welding time and the joint can be presented consistently.
- Distortion, straightening, grinding, blending, or cosmetic finishing consumes significant labor.
- Thin or precision parts benefit from concentrated energy and smaller heat-affected regions.
- Product mix is too variable for dedicated automation but repetitive enough to justify controlled fixtures and procedures.
- The shop needs a path to more repeatable recipes, parameter records, and quality documentation.
- A supplier or application lab can demonstrate representative parts rather than only ideal showroom coupons.

The 2026 AWS/IIW/EWF/EWA-supported guidance lists faster welding, reduced heat input/distortion, less post-weld processing, shorter operator learning, material versatility, and reduced tooling or design-to-part time among potential advantages. It also lists important limitations: Class 4 safety requirements, manual travel-speed variability, reflection challenges, lower power/penetration than large automated systems, and a still-maturing body of process knowledge. The balanced message is important: handheld laser welding supplements conventional welding; it does not eliminate the need for TIG, MIG, or other processes.**[1]**

Warning signs before purchase

- Large or inconsistent gaps that the planned joint/filler strategy does not control.
- Unknown materials, coatings, oils, paint, plating, or contaminants.
- Highly reflective geometry or an uncontrolled path behind the joint.
- Poor operator posture or restricted access that makes torch angle and working distance unstable.
- A part selected because the machine wattage “sounds high enough” without representative testing.
- No owner for laser safety, ventilation, qualification, inspection, or maintenance.
- A plan that depends mainly on laser eyewear instead of engineered controls and a controlled area.
- A purchase justified only by a vendor speed claim rather than a timed, accepted production trial.

PRACTICAL TIP: Choose three to five parts that represent the real opportunity. Include normal fit-up variation, real material lots, starts/stops, corners, tack strategy, surface condition, and the actual acceptance test. Ask the vendor to weld those parts.

A sample weld is not a production process

A successful sample answers one question: “Can this combination make a promising weld under these conditions?” Production requires a much larger answer: Can the shop reproduce the result across shifts, material lots, optics wear, operator variation, fixture loading, wire changes, gas changes, and maintenance events - while keeping the beam and fumes under control? That distinction should shape every trial and purchase decision.

2. What a Handheld Laser Welding System Actually Is

Modern handheld laser welding equipment typically combines a high-power laser source, a flexible delivery fiber or beam-delivery assembly, a handheld welding head, focusing and protective optics, beam-oscillation hardware, controls, gas delivery, and often a wire feeder. Cooling may be integrated or separate. The 2026 AWS/IIW/EWF/EWA-supported guidance describes fiber and diode sources, with fiber systems available in single-mode and multimode forms and with continuous-wave or pulsed operation. Its reported typical maximum-power range is roughly 800 W to 3 kW, while more recent research notes continuing development above that range.[1][10]

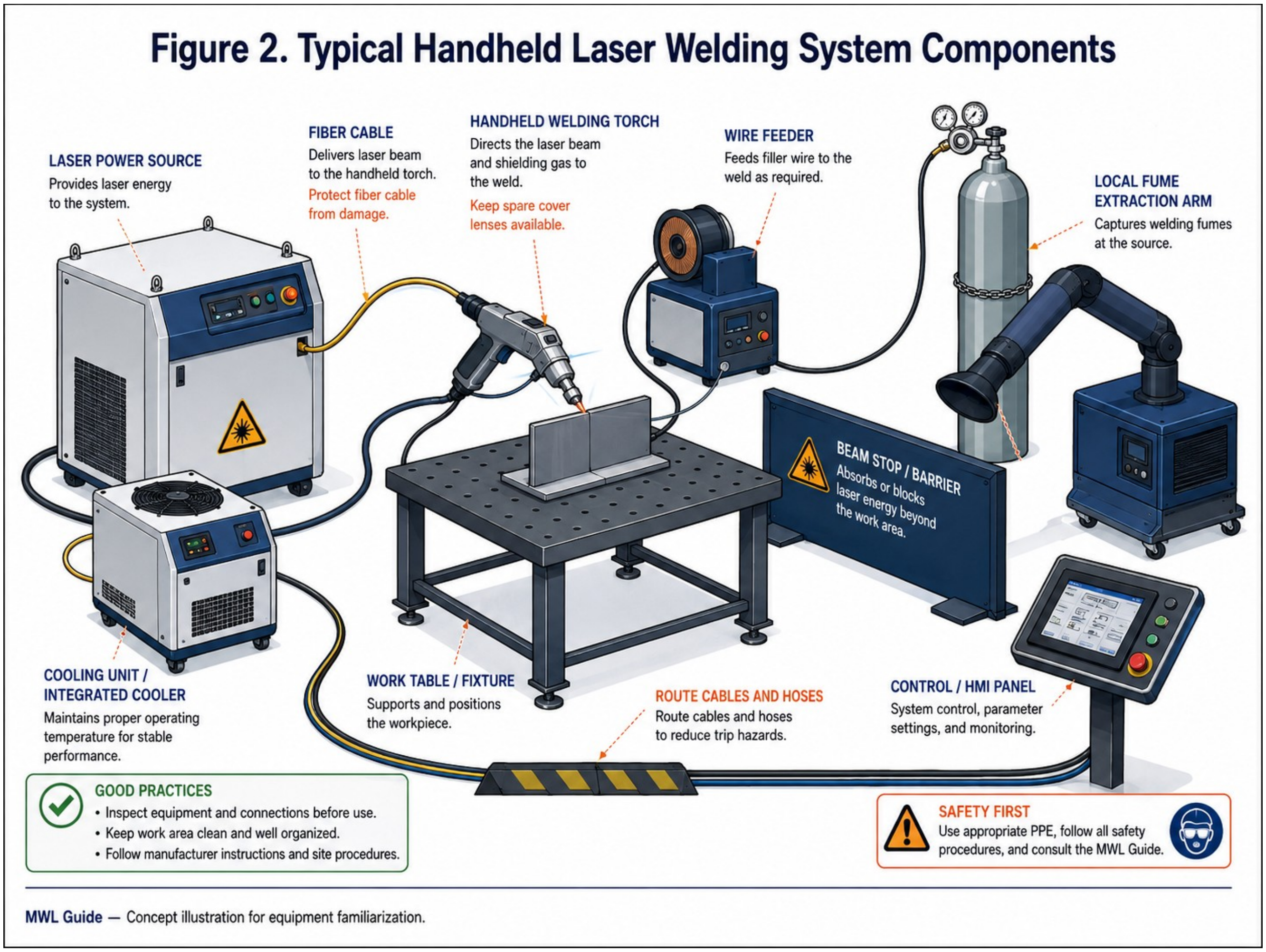


Figure 2. Typical handheld laser welding system components - original MWL concept illustration.

Source note: This conceptual figure synthesizes common equipment elements described in the 2026 guidance, current OEM literature, and peer-reviewed system characterization. Exact architecture varies by model.[1][9][10]

The welding head matters as much as the power source

The handpiece is not just a nozzle. It may contain or control the focusing optics, protective cover window, gas nozzle, wire guide, one- or two-axis galvanometer mirrors, contact sensing, trigger logic, and process monitoring. Its ergonomics affect operator consistency; its optical design determines spot size and working distance; and its safety interfaces can determine whether the system can be integrated into a controlled work area.[1][6]

Single-mode and multimode: what a shop should know

In simple terms, a single-mode source can generally focus to a smaller, higher-intensity spot than a comparable multimode source. That can increase penetration potential, but “single-mode” is not a guarantee of identical process behavior. The 2026 seven-system study measured handheld-system beam diameters from about 40 to 155 micrometers across systems and documented substantial differences in profile, divergence, focus behavior, and delivered power. The practical purchasing question is not only “single-mode or multimode?” but “What beam data and process evidence does the supplier provide for this exact system?”[10]

QUESTIONS TO ASK YOUR SUPPLIER: What is the wavelength? What is the rated and measured delivered power? What is the beam waist/spot size and where is the focus? What is the allowed working-distance range? What changes with power? What verification method is available after optics service?

3. Understanding the Process Without Becoming a Laser Scientist

For a welding supervisor, the useful model is that several variables determine how concentrated laser energy is delivered to the joint: average power, spot size and focus, travel speed, beam oscillation (“wobble”), torch orientation, material absorption, joint geometry, shielding gas, and filler wire. They interact. Changing one knob can alter what another knob does.

Power, focus, and spot size

Laser power tells you the rate at which optical energy is available. It does not tell you how concentrated that energy is at the workpiece. A smaller focused spot can produce a much higher power density than a larger spot at the same wattage. Focus position and working distance therefore become process variables. The seven-system study found some systems with very small focal shift and another with more than 6 mm shift at 1.2 kW - large enough to move the process outside the measured Rayleigh range.[10]

Beam oscillation (“wobble”)

Handheld laser welding systems commonly move the focused beam rapidly across the nominal travel path using one or two galvanometer-controlled axes. Wobble can broaden the bead, help distribute energy across a joint and filler wire, and change sidewall fusion and penetration. Frequency, width/amplitude, pattern, and any position-dependent power compensation should be documented as process variables, not treated as cosmetic bead controls.[1][10]

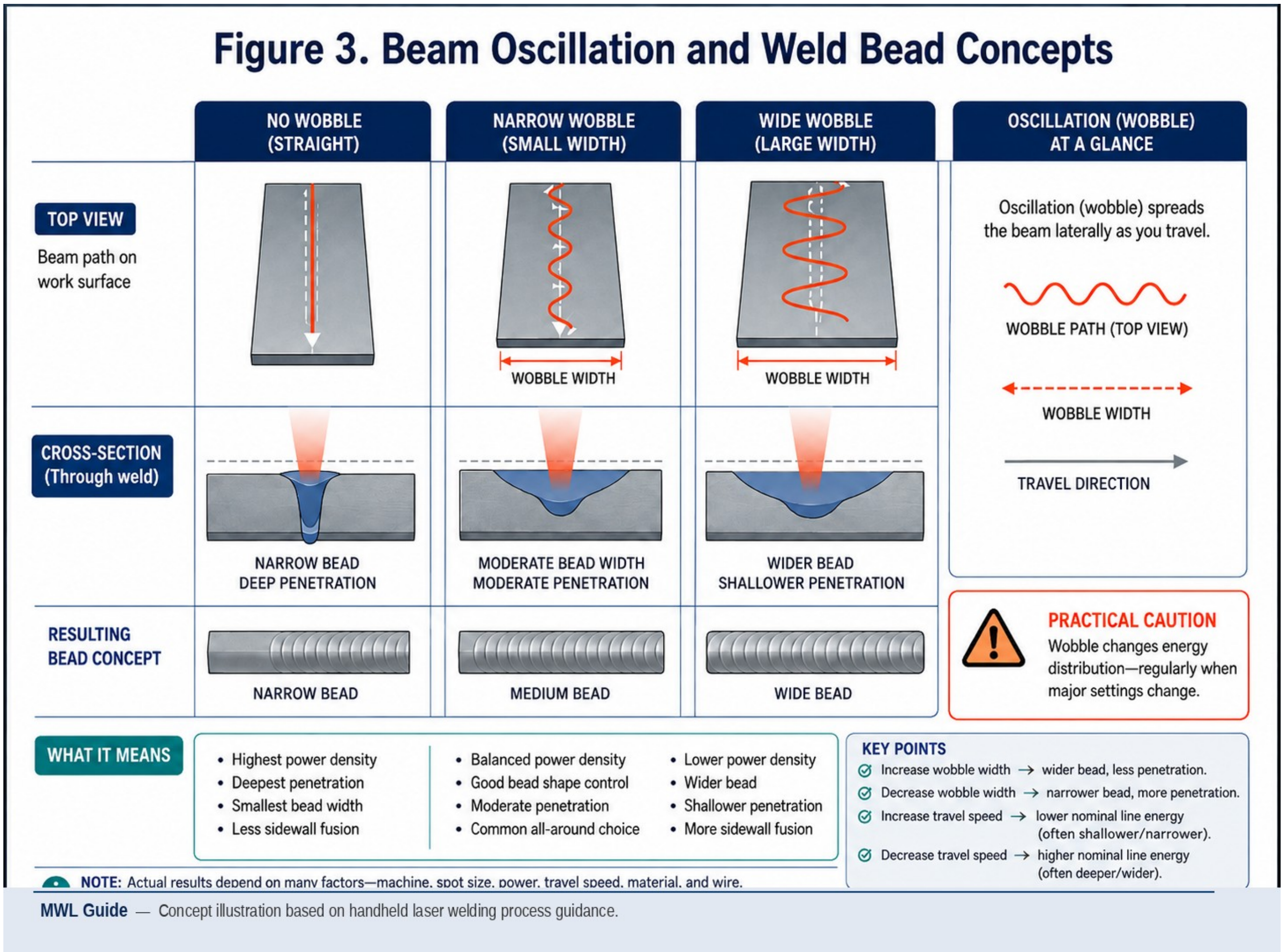


Figure 3. Beam oscillation and weld bead concepts - original MWL concept illustration.

Source note: The figure is deliberately conceptual. Actual penetration and bead shape depend on the complete parameter set and material; it is not a predictor of exact results.[1][10]

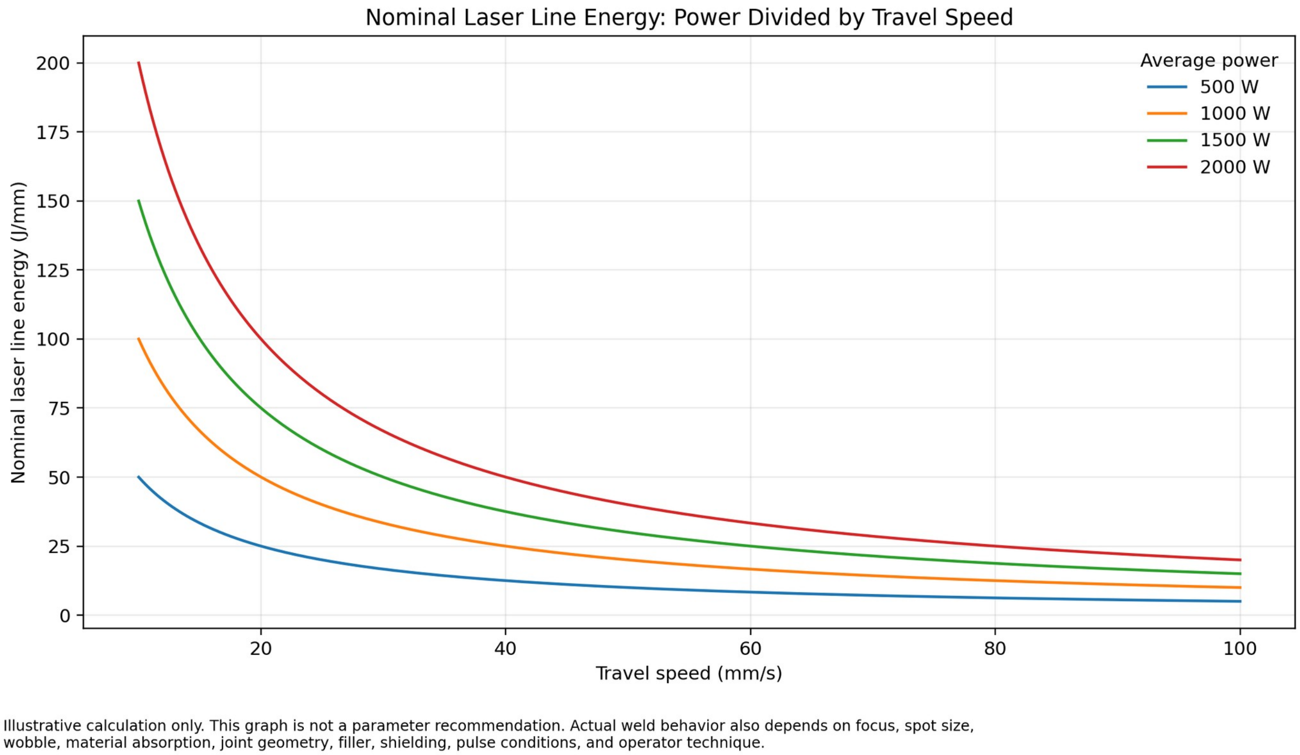
Nominal laser line energy - a shop-friendly comparison number

A useful way to combine average power and travel speed is nominal laser line energy. It answers a simple question: “How much laser energy is available for each millimeter of travel?”

> **SIMPLE EQUATION:** Nominal laser line energy (J/mm) = average delivered laser power (W) ÷ travel speed (mm/s).

A watt is one joule per second. If the laser is delivering 1,000 W, it is supplying 1,000 joules each second. If the torch travels 25 mm in that second, the nominal line energy is 1,000 ÷ 25 = 40 J/mm. Slower travel at the same power increases the nominal energy per millimeter; faster travel decreases it. Raising power at the same speed increases it; lowering power decreases it.

This should not be called the exact “heat input” absorbed by the workpiece. Some energy is reflected or otherwise not coupled into the metal, and focus, spot size, wobble, joint geometry, filler, shielding, pulse behavior, and keyhole stability change how the energy is distributed. Two welds can have the same J/mm calculation and produce very different results. For pulsed or modulated welding, use time-averaged delivered power for this comparison, not peak power - while remembering that pulse duration, duty cycle, frequency, and overlap still matter.[1][10]



Data Figure B. Nominal line energy as a function of power and travel speed.

Source note: This is a mathematical illustration only, not a parameter recommendation. The 2026 AWS/IIW/EWF/EWA-supported guidance reports that CW handheld laser welding with filler wire commonly operates at 50 J/mm or less in the examples discussed; MWL does not treat that observation as a universal target or limit.[1]

PRACTICAL TIP: Use nominal line energy to compare controlled trials on the same machine and setup. Record it with the full recipe. Never accept or reject a weld on J/mm alone.

4. Materials, Joints, Fit-Up, Wire, and Shielding Gas

Fit-up is often the first production limit

Laser welding can be unforgiving of gaps because a tightly focused beam may simply pass through space instead of coupling energy into both joint faces. Autogenous welding - welding without filler - generally rewards near-zero-gap preparation. Filler wire broadens the usable joint family and can help bridge controlled gaps, but it adds wire position, feed speed, alloy, and calibration to the process variables.[1]

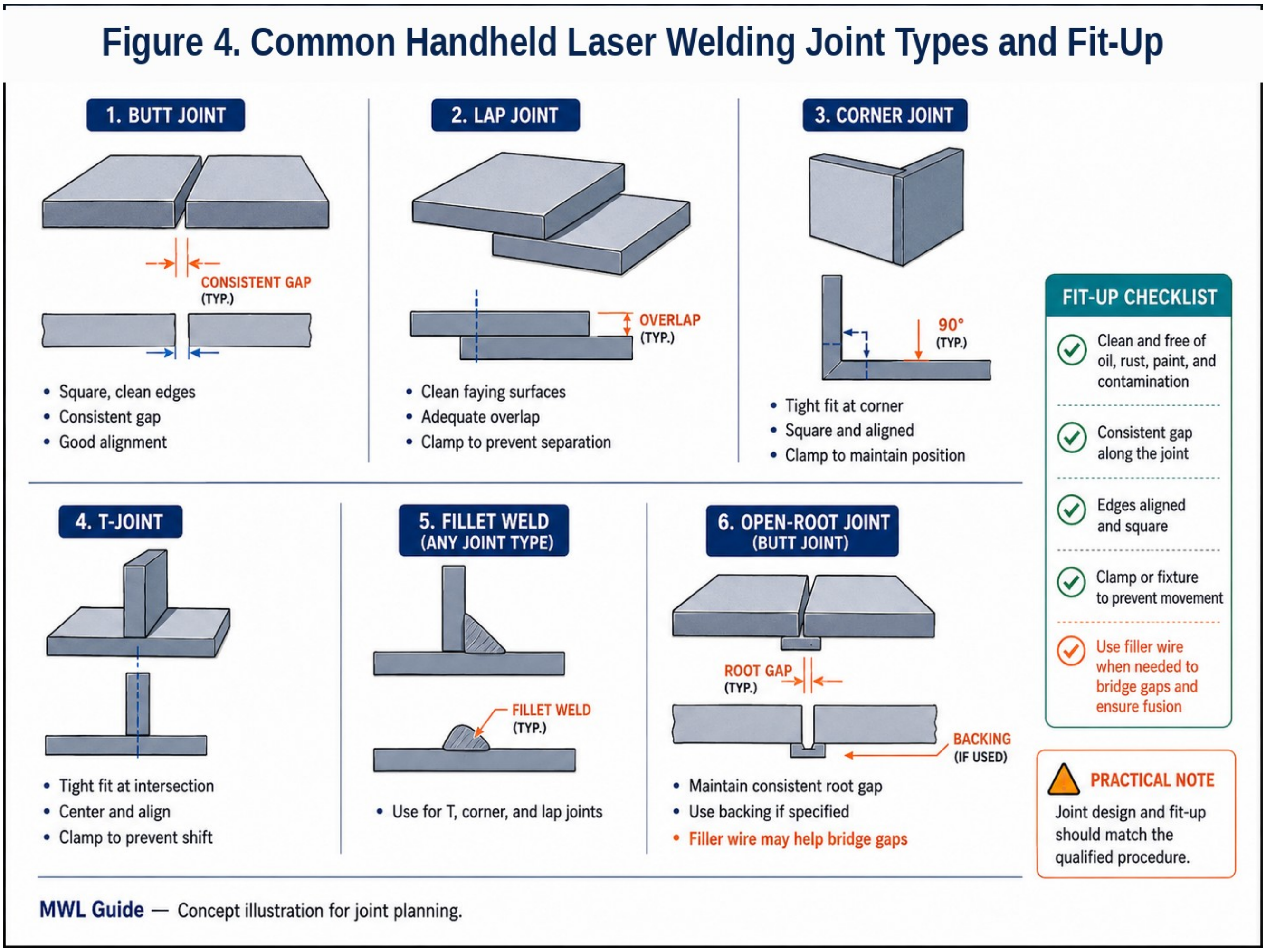


Figure 4. Common handheld laser welding joint types and fit-up - original MWL concept illustration.

Source note: The 2026 guidance documents square butt, corner, T, lap and other joint families, including filler-wire and multipass examples. Joint dimensions must come from the qualified procedure, not this illustration.[1]

Material starting points

Material	Why it can work	Main cautions / development focus
Carbon & low-alloy steel	Strong candidate for many fabrication joints after qualification.	Hardenability, hydrogen-assisted cracking in susceptible grades, material grade, filler condition, shielding, penetration.
Austenitic stainless steel	Often an excellent early handheld laser welding application with good appearance and controllable distortion.	Solidification cracking in susceptible compositions, porosity, gas selection, repeated rework cycles.
Martensitic / PH / duplex stainless	Feasible.	Metallurgy, hardening, heat-treatment condition, phase balance, tighter procedure control.

Material	Why it can work	Main cautions / development focus
Aluminum	Good applications exist and current OEMs publish meaningful thickness capability.	Reflectivity, high thermal diffusivity, hydrogen porosity, oxide removal, Mg/Zn evaporation, solidification cracking, HAZ softening.
Titanium	Laser weldable but advanced for a first small-shop implementation.	High-purity inert shielding, protection of cooling weld metal, contamination/embrittlement; do not use nitrogen shielding.
Copper	Possible on demonstrated equipment.	Strong near-IR reflection before coupling, high conductivity, beam-path hazard, narrow process window on some systems.
Brass	Development application.	Zinc evaporation, keyhole instability, porosity/spatter, composition change, fume considerations.

Source note: Material guidance is a practical synthesis, not a universal weldability ranking. Grade, temper, thickness, filler, joint and product acceptance criteria control.**[1][10]**

Shielding gas: do not automatically copy the TIG bottle

Shielding gas can materially change handheld laser welding quality and metallurgy. The 2026 guidance includes a 316L stainless example in which high-purity nitrogen produced substantially less porosity than argon while the other stated variables were held constant. The authors discuss possible mechanisms but do not claim a definitive universal explanation. The safe lesson is not “always use nitrogen”; it is “treat gas type and flow as qualified process variables.”**[1]**

Titanium is a clear exception to casual gas substitution: the guidance states that nitrogen should not be used because nitrogen pickup can contribute to brittle titanium nitride formation. Titanium and other gas-sensitive materials require high-quality inert coverage of both the molten pool and the cooling weld bead. **[1]**

PRACTICAL TIP: When a gas change is proposed on an established handheld laser welding procedure, treat it like a process change that deserves weld-quality review and, where applicable, requalification.

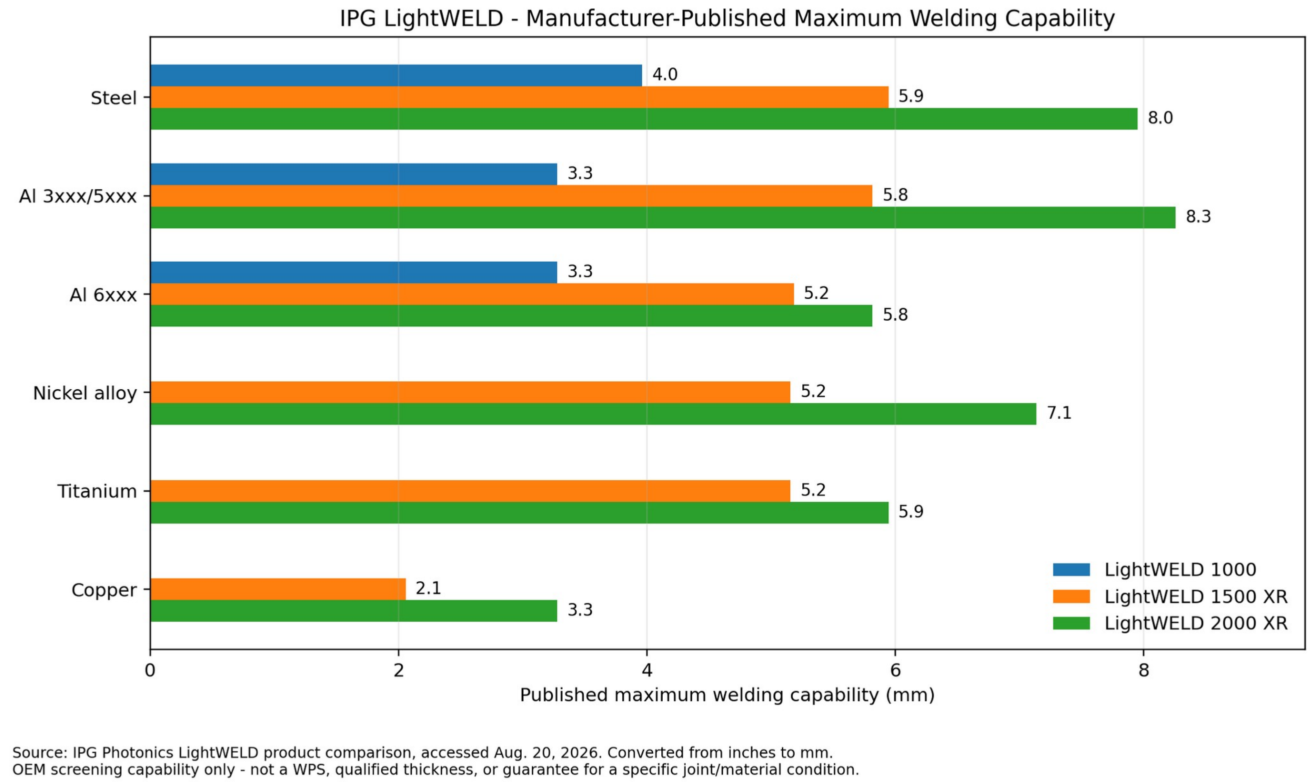
Cleaning is part of welding

Surface preparation affects absorption, porosity, inclusions, and repeatability. Some handheld laser welding systems include a laser-cleaning mode, but the 2026 guidance cautions against assuming laser cleaning automatically replaces conventional oxide or contaminant removal. Incomplete aluminum-oxide removal and surface melting that traps impurities are examples of why cleaning methods should be validated on the actual material.**[1]**

NEVER BYPASS A SAFETY INTERLOCK: The 2026 guidance specifically warns against defeating workpiece-contact safety interlocks to make laser cleaning easier. A cleaning mode remains Class 4 laser processing and requires its own approved hazard controls and operating procedure.

IPG Photonics capability data: useful for screening, not qualification

IPG currently publishes model-specific maximum welding capability for its LightWELD 1000, 1500 XR, and 2000 XR systems. Those numbers are useful when deciding which model is worth trialing, but they are OEM-published capability limits, not a WPS or guarantee for a particular alloy, joint, gap, position, surface condition, or acceptance criterion.[9]



Data Figure C. IPG LightWELD manufacturer-published maximum welding capability, converted to millimeters.

Source note: Source values are IPG-published. IPG also publishes up to 0.200 in. (~5.1 mm) wobble width and wire-welding capability on all three listed models. Product availability and configuration can change.[9]

5. The Class 4 Safety Challenge

The most important mental shift for a traditional welding shop is this: the hazardous laser beam may be invisible, may reflect in a direction the welder does not expect, and may remain hazardous after it passes through the weld root or a gap. Standard arc-welding habits do not automatically control those paths. AWS describes handheld laser welding equipment as high-power Class 4 laser equipment and identifies direct and reflected beam exposure as serious hazards.[6]

Direct, specular, diffuse, retroreflection, and through-beam paths

A shiny metal surface can produce a specular reflection - a mirror-like beam path. Multiple surfaces can create more complicated paths, including energy returned toward the torch/operator. Even when a stable keyhole reduces reflection into the surrounding area, the initial interaction, changing part geometry, a lost keyhole, starts/stops, corners, and reflective materials can change the hazard geometry. Full penetration or an open root adds another route: energy leaving the back of the joint.[1][6]

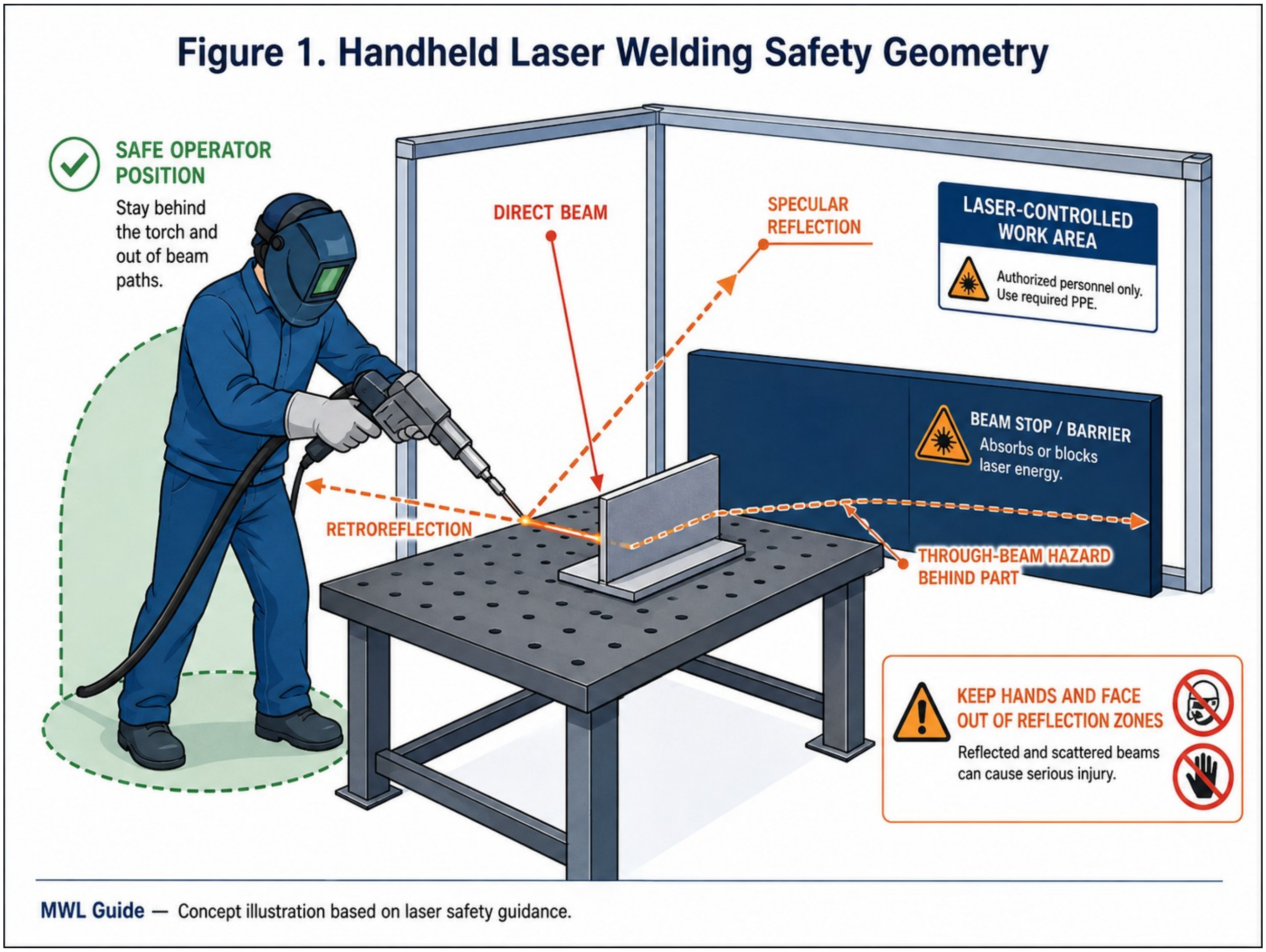


Figure 1. Handheld laser welding safety geometry - original MWL concept illustration.

Source note: Conceptual beam paths are based on the reflection and through-beam hazards discussed by AWS and the 2026 AWS/IIW/EWF/EWA-supported guidance. The exact hazardous zone requires an installation-specific evaluation.[1][2][6]

What U.S. sources actually say

OSHA's laser topic page lists applicable general-industry PPE requirements and identifies the ANSI Z136 series as national consensus standards. Importantly, OSHA states that these consensus standards are not OSHA regulations. OSHA's Technical Manual provides detailed laser-hazard guidance, including Class IV control concepts, biological effects, ventilation, entry controls, beam termination, and LSO responsibilities.[2][3]

FDA/CDRH focuses on the product entering U.S. commerce. The current product code RFF identifies industrial/commercial laser welders and links them to 21 CFR 1040.10. A buyer should ask for the product's required identification/classification/certification information and applicable U.S. documentation rather than accepting vague “FDA approved” language.[4][16]

Safety features to interrogate during procurement

AWS identifies a key switch, emergency stop, and external interlock connection as important built-in Class 4 product features, and it describes additional handheld laser welding safeguards including a two-stage trigger, plasma detection, a workpiece-contact circuit, and fiber-integrity monitoring. The exact architecture can differ among machines, but these functions provide a practical benchmark for buyer questions.[6]

> **IPG EXAMPLE - MANUFACTURER SPECIFIC:** IPG currently lists a key switch, E-stop, delivery-integrity interlock, two-step trigger, nozzle-contact requirement, automatic power shutoff if no welding plume is detected, laser-specific helmet/glasses, and door-interlock circuits on the LightWELD product page. Those are useful examples, not universal substitutes for an LSO review or engineered containment.

Source note: Current IPG product-specific safety feature list.[9]

6. Facility, Controlled Area, PPE, and Fume Control

Laser Controlled Area: plan the room before the machine arrives

A controlled work area is not just tape on the floor. The 2026 guidance recommends a light-tight laser-blocking area or enclosure with controlled/interlocked access, warning indications, restricted trained access, and suitable materials. OSHA's guidance similarly emphasizes restricted access, beam termination, appropriate protection for openings/windows, and Class IV entry controls. The final design belongs to the site-specific hazard evaluation and applicable standards.[1][2]

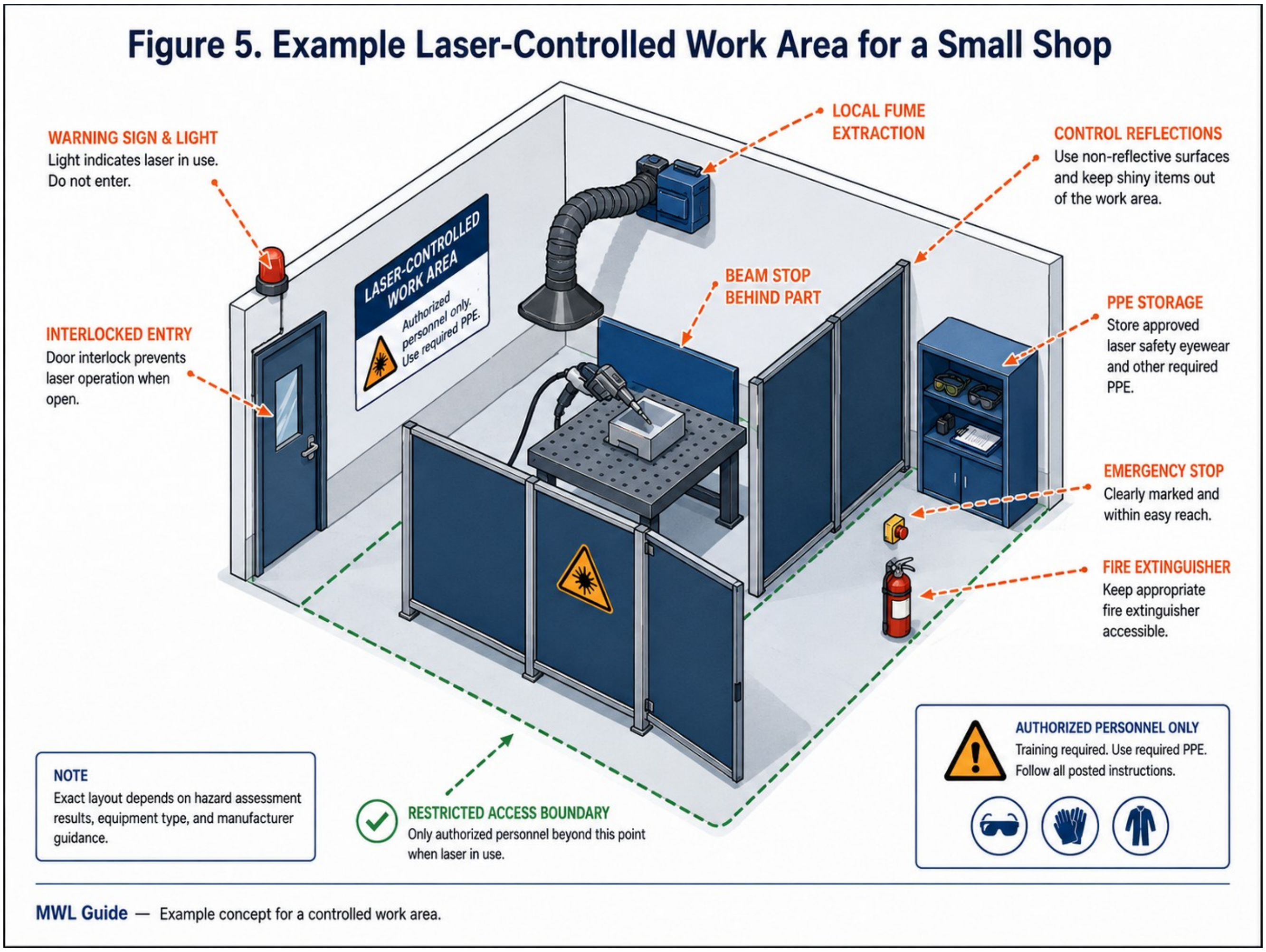


Figure 5. Example laser-controlled work area for a small shop - original MWL concept illustration.

Source note: This is a planning concept, not a compliant design drawing. Barrier rating, roof/opening treatment, viewing windows, interlock architecture, and beam stops must be selected for the actual system and hazard assessment.[1][2][3]

The LSO role

OSHA's Technical Manual describes the Laser Safety Officer as the person with authority to evaluate and control laser hazards. Typical responsibilities include hazard evaluation, approving controls and procedures, selecting PPE, signs and labels, training, and facility-control decisions. The 2026 guidance likewise calls for a qualified LSO and a documented laser-safety program for organizations using high-power handheld laser welding equipment.[1][2]

SMALL-SHOP REALITY: The LSO does not necessarily have to be a full-time laser engineer. In a small organization, a trained internal person can own the program with competent outside support. What cannot be part-time is the authority to stop unsafe operation.

PPE is a layer, not the enclosure

Laser eyewear must be selected for the actual wavelength and required optical density or LB rating, and it must be compatible with the complete face/skin protection needed for the process. Standard shop safety glasses and ordinary welding helmets alone are not adequate for laser hazards from handheld laser welding. Manufacturer-specific PPE values should never be copied to a different wavelength or laser without validation by the LSO/hazard assessment.[1][2][6]

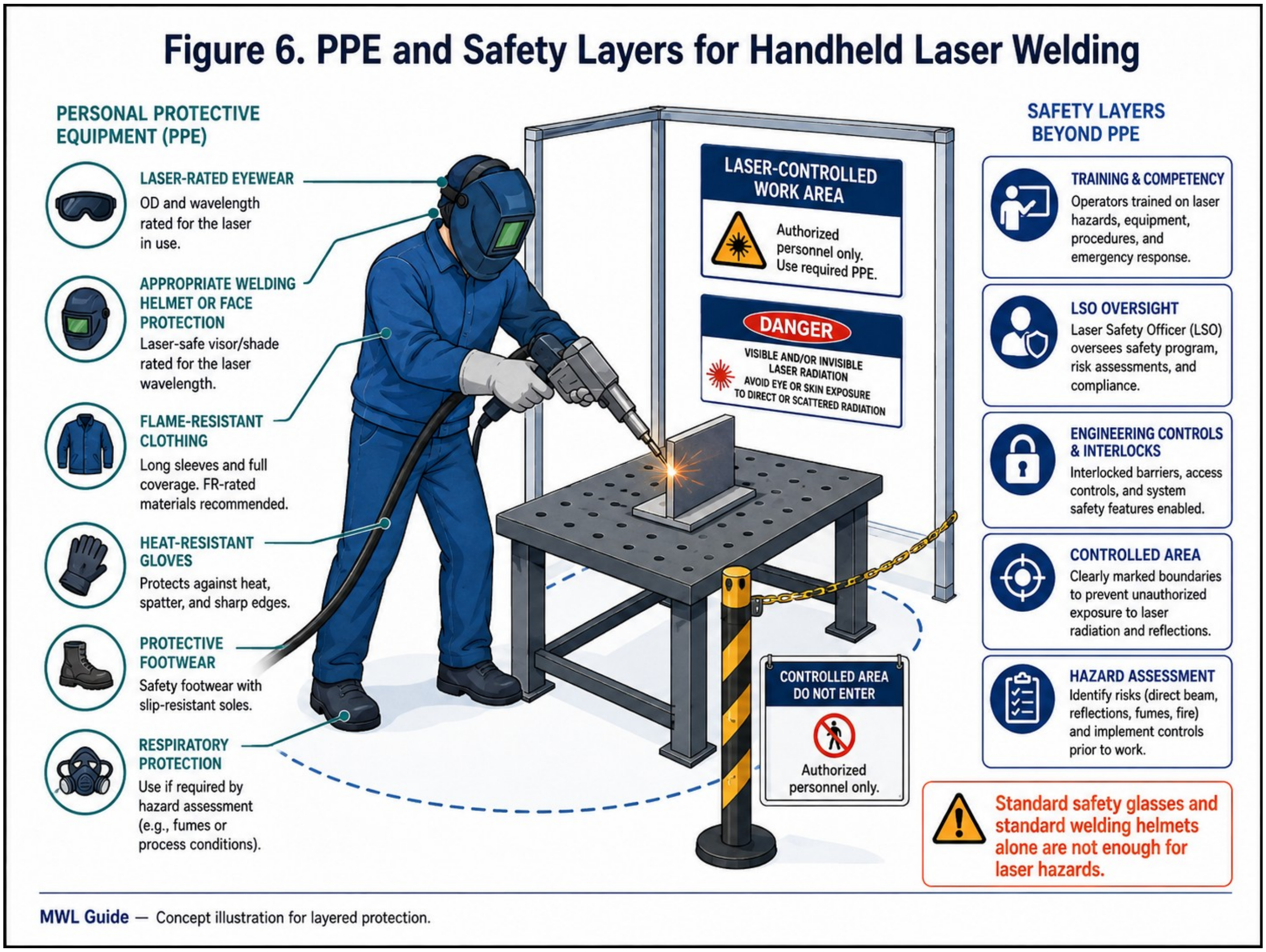


Figure 6. PPE and safety layers for handheld laser welding - original MWL concept illustration.

Source note: The hierarchy shown intentionally places engineering controls, training, LSO oversight, and hazard assessment around PPE. Exact PPE specifications remain machine- and site-specific.[1][2][6]

Fume extraction: less visible smoke does not mean harmless

OSHA's Technical Manual states that adequate ventilation should reduce hazardous fumes and vapors from laser welding, cutting, and other target interactions to appropriate exposure limits. The 2026 AWS/IIW/EWF/EWA-supported guidance notes that fume generation can be lower than some arc processes, but it also emphasizes that hazards remain and fume generation increases with laser power. A 2024 occupational-hygiene study compared fume-generation/emission behavior across welding processes and reinforces the need to distinguish “less fume mass” from “no health risk.”[1][2][12]

NIOSH data from an arc-welding field evaluation is useful only as a control lesson: portable local exhaust near the source materially reduced measured fume concentrations. Those arc-welding numbers should not be used to predict handheld laser welding exposure. For handheld laser welding, the practical approach is to capture the plume close to the weld, avoid disrupting shielding gas, evaluate the specific alloy/coating/production duty cycle, and add general ventilation or respiratory protection when the hazard assessment shows they are needed.[11]

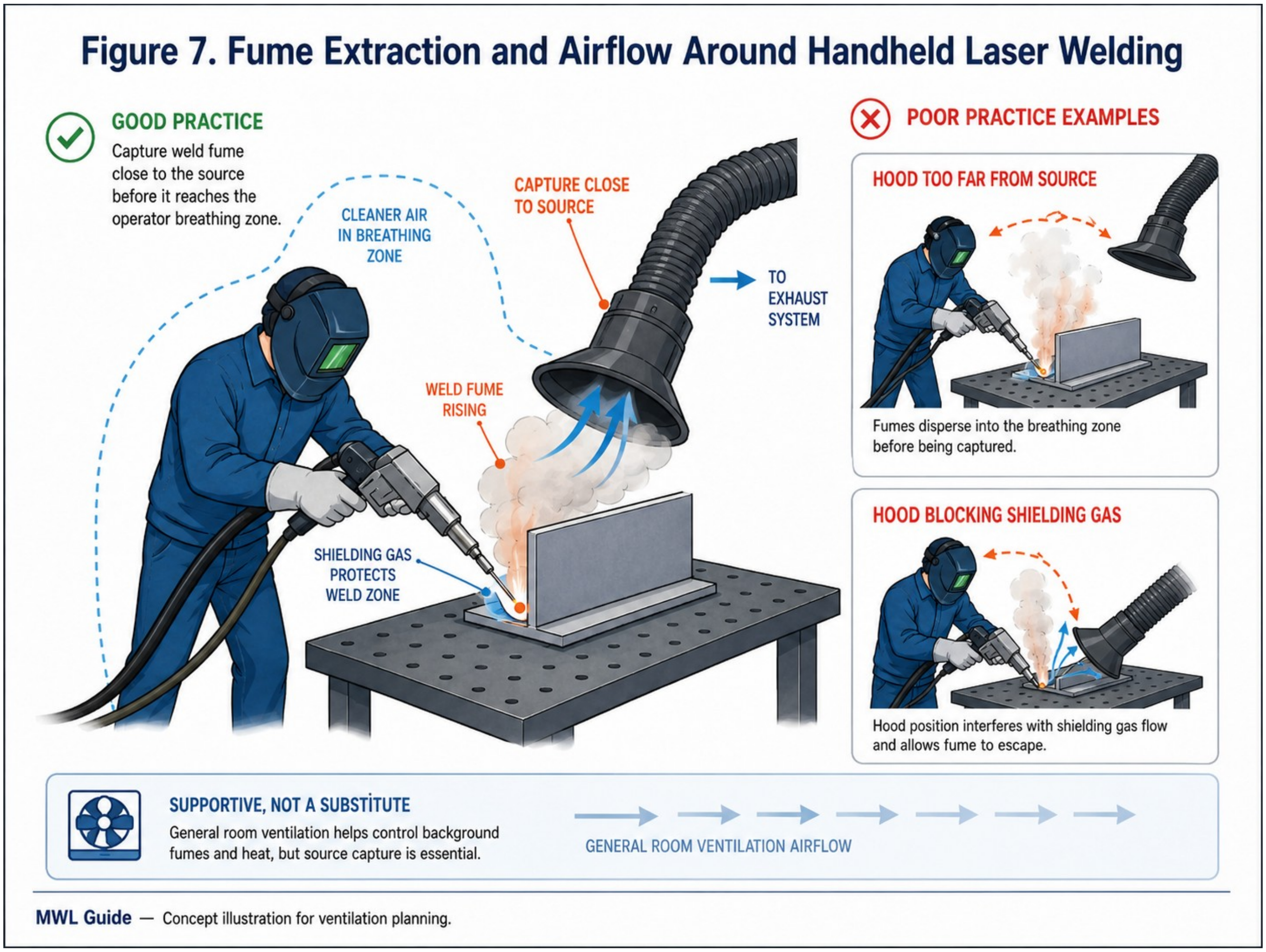


Figure 7. Fume extraction and airflow around handheld laser welding - original MWL concept illustration.

Source note: Source capture should be engineered to the specific fume, hood geometry, flow, shielding gas, enclosure airflow and operator breathing zone. The drawing is not a ventilation design.[1][2][11]

7. Selecting Equipment: What to Ask Beyond Wattage

A shop can easily compare headline wattage and price. Those are two of the least complete measures of whether a system will become a reliable production asset. Beam characteristics, safety architecture, serviceability, parameter access, optics, wire/gas integration, validation capability, training, and U.S. support can matter more than a modest difference in nameplate power.

Minimum procurement questions

Procurement topic	What MWL recommends asking for	Why it matters
U.S. product documentation	Model/serial traceability; identification/classification/certification labeling; U.S. manual; applicable FDA/CDRH documentation.	Helps separate documented product compliance from vague marketing.

Procurement topic	What MWL recommends asking for	Why it matters
Safety interfaces	Key control, E-stop, external area interlock, trigger logic, contact sensing, process/plume safeguard or equivalent, fiber integrity as applicable.	Layers reduce unintended emission and support controlled-area integration.
Beam data	Wavelength; rated/actual power; optical configuration; spot/waist; focus/working distance; beam-profile information if available.	Different handheld laser welding machines do not behave identically at the same nominal power.
Output verification	OEM-approved power check, process-validation method, or access to beam characterization.	Front-panel percentage alone may not prove delivered beam condition.
Protective optics	Easy inspection/replacement; spare cover windows/lenses; contamination criteria.	Contaminated optics can alter spatial power distribution without a large total-power change.
Wobble controls	Axes, width, frequency, pattern, compensation behavior, recipe control.	These are process variables and should be documented.
Wire and gas	Supported wire sizes, feeder calibration, gas regulator/flow control, nozzle options.	Wire and gas can materially change gap tolerance and weld quality.
Service and training	U.S. technical support, spare parts, turnaround, formal laser-safety/process training, application lab access.	Downtime and process support become part of cost per part.
Software/data	Recipe naming/versioning, password levels, export or traceability options, alarms and maintenance records.	Documentation prevents “mystery settings” and unauthorized process drift.

Source note: This checklist synthesizes AWS handheld laser welding guidance, the 2026 multi-machine beam study, and current OEM feature sets.[6][9][10]

What IPG data is good for

IPG is a valuable primary source for LightWELD specifications and safety features because the manufacturer knows its own product. IPG currently publishes 1,000 W, 1,500 W and 2,000 W LightWELD models, up to 0.200 in. wobble width, wire-welding capability, air cooling, and 100 welding/cleaning presets. It also publishes “4x faster than TIG” as a product claim. MWL treats that speed statement as an IPG manufacturer claim, not a universal productivity statistic. A shop should verify speed, quality and finishing savings on its own representative parts.[9]

PRACTICAL PURCHASING RULE: Rank demonstrated welds on your parts, safety architecture, beam/optics information, serviceability, recipe control, qualification support, consumables, and local support ahead of a simple wattage race.

8. Building a Qualified and Repeatable Welding Procedure

A vendor preset is a starting point. A controlled production procedure is the result of deliberate development, testing, documentation, acceptance criteria, and operator qualification. AWS C7.4/C7.4M is the formal laser-beam-welding process/operator qualification specification to investigate when applicable to the work; AWS describes it as covering safety, fabrication, quality examination, equipment calibration/maintenance, approval, and delivery of laser-welded work.[7]

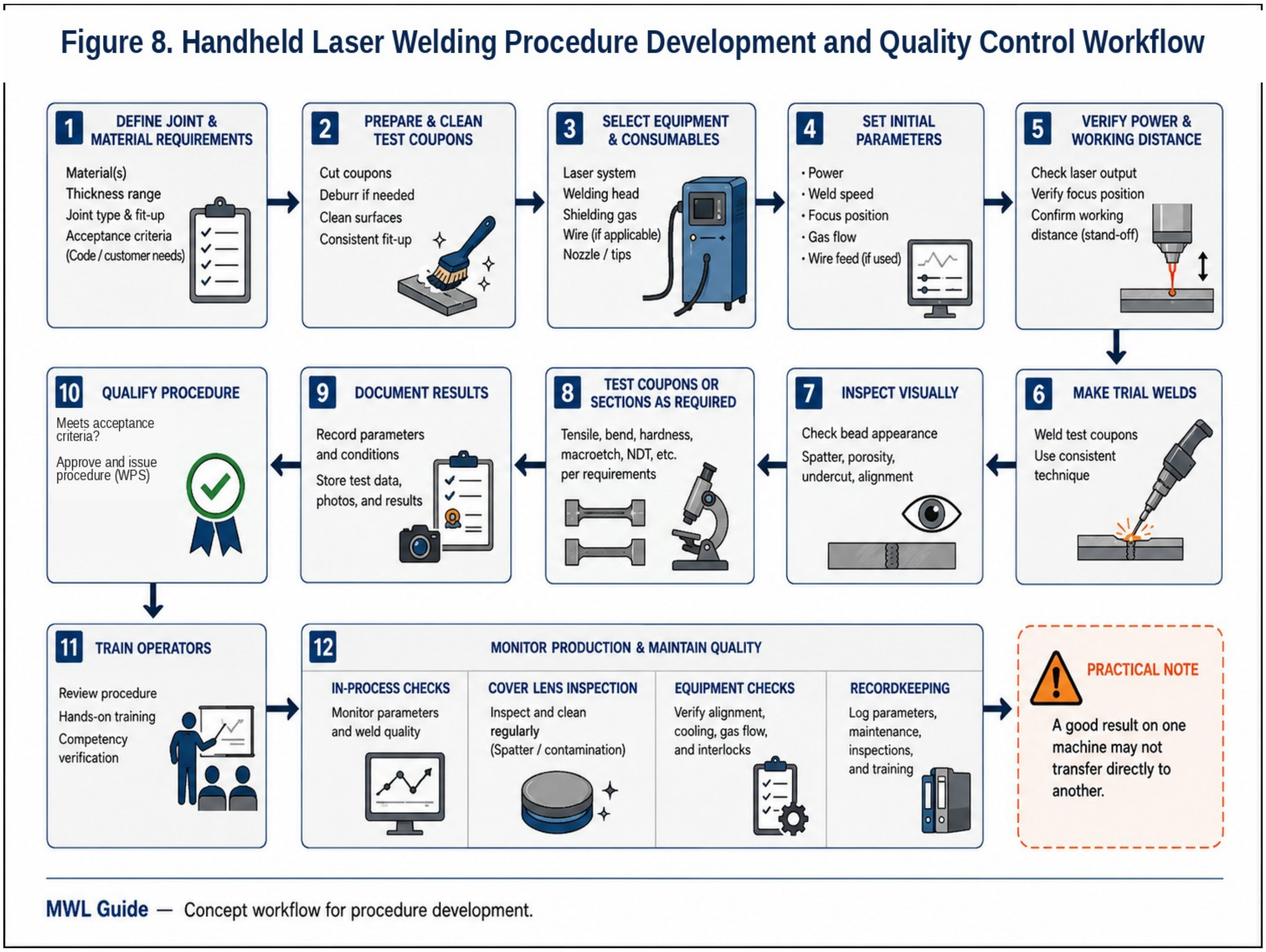


Figure 8. Handheld laser welding procedure development and quality-control workflow - original MWL concept illustration.

Source note: The sequence is a practical synthesis, not a substitute for the code/customer procedure that governs a product.[1][7][8]

Minimum handheld laser welding procedure data

The 2026 AWS/IIW/EWF/EWA-supported guidance recommends capturing enough information that the welding condition can actually be reproduced. At minimum, document the following when relevant:[1]

- Base material specification, thickness/dimensions, joint geometry and allowed fit-up/tolerance.
- Filler specification, diameter, wire feed setting and wire-feed verification method.
- Cleaning/surface preparation and allowed preweld condition.
- Fixture, clamping, backing/beam stop, and part orientation.
- Shielding gas type, flow setting and verification method.

- Exact laser machine, source/model, optical configuration, welding head/nozzle and protective optic.
- Power or machine setting, CW/pulsed/modulated mode, and the method used to verify delivered power.
- Spot size/focus or qualified working-distance band.
- Wobble axes/pattern, width/amplitude, frequency, and any power-compensation mode.
- Operator travel direction, technique, start/stop method, and qualified travel-speed requirements.
- Recipe revision number, acceptance criteria, inspections/tests, and stop-work limits.

A beautiful bead is not qualification

Surface appearance is useful but incomplete. Depending on the product, qualification and production checks may include cross-sections/macroetch, bend tests, tensile tests, hardness, leak tests, dimensional inspection, visual criteria, or nondestructive testing. Use the applicable code, drawing, customer specification, or engineering acceptance criteria. AWS provides free sample qualification forms, including laser-welding equipment qualification material, that can help a shop understand the type of documentation expected.**[8]**

PRACTICAL TIP: Create an approved reference coupon and photo set for operators, but pair it with the hidden-property evidence that matters: penetration, fusion, porosity/cracking limits, dimensional requirements, leak performance, or mechanical properties as applicable.

9. Quality Control, Optics, Output Verification, and Maintenance

Why a power meter is not enough

One of the strongest practical findings in the 2026 beam study involved a dirty protective cover slide. With the laser set to a fixed 300 W, the researchers measured 310.8 W with a clean optic and 310.1 W with the contaminated optic - nearly the same total power - while the spatial power distribution changed substantially. A simple power check could therefore miss an optical condition that changes weld behavior. **[10]**

The same research documents substantial machine-to-machine differences in beam profile and thermal focus shift. That supports a layered verification strategy: visual inspection of protective optics, controlled working distance, power verification, startup coupons or a validated process check, and periodic beam characterization when appropriate for the quality risk.**[10][13]**

A practical verification hierarchy

When	Check	Purpose / stop condition
Before use / shift	Torch/nozzle, contact system, fiber/hose, protective window, gas/wire, interlocks, recipe revision.	Stop for damaged fiber/torch, dirty or damaged optic, failed interlock, wrong recipe or material.
Startup / changeover	Representative coupon or approved process check; compare bead and required penetration/acceptance evidence.	Detect process drift before production parts.

When	Check	Purpose / stop condition
Scheduled / after optic service	OEM-approved power verification and working-distance/focus check.	Confirm output and optical setup after changes.
Periodic / after unexplained drift	Beam profile/caustic characterization where practical; supplier/application-lab support may be used.	Find spot-size, focus, divergence or distribution changes that total power alone may miss.
Production audit	Recipe, material/gas/wire traceability, inspection results, consumable history and maintenance log.	Supports root-cause analysis and controlled change.

Source note: The need for machine-specific beam verification is strongly supported by the seven-system study and the 2026 handheld laser welding characterization literature.[10][13]

Cover lens/windows are process consumables

Spatter and contamination on protective optics are not merely maintenance nuisances. They can reshape the delivered beam, create local heating, shorten optic life, and change weld quality. Make protective-window inspection part of the pre-use routine, stock known-good replacements, and define who is authorized to replace optics and what verification is required afterward.[1][10]

STOP-WORK TRIGGER: Unexpected reflection, unexplained weld drift, optic damage, fiber damage, interlock fault, or a suspected laser exposure is a reason to stop and investigate - not a reason to bypass a safeguard or “turn it up a little.”

10. Vendor Trials and Acceptance Testing

Send the vendor the hard parts, not the easy coupons

A useful vendor trial reproduces the production challenge. Send representative drawings, material specifications, actual or representative parts, normal fit-up variation, surface condition, expected joint access, desired cycle time, filler/gas constraints, and the acceptance test. Ask the supplier to record the machine, optics, power, wobble, wire, gas, working distance, travel method, and inspection results used for the trial.

Questions the trial should answer

1. Can the system make the required weld on the real joint and thickness?
2. What joint gap and alignment window was demonstrated, and how was it measured?
3. Was filler needed? Which wire alloy/diameter and feed conditions were used?
4. What gas and flow were used, and what happens if the shop changes gas?
5. What inspection proved fusion/penetration and the product-specific acceptance criteria?
6. How sensitive is the result to travel speed, torch position, working distance, starts/stops, and corners?
7. What protective optic life/inspection routine did the trial assume?
8. What beam and power verification is available on the delivered machine?
9. How will the system integrate with the shop's interlocked area and emergency-stop architecture?

10. What training, application support, spare parts, service response, and software/recipe controls are included?

Acceptance test: make the sales demo reproducible

Before final acceptance, agree on a small set of representative welds and objective acceptance criteria. Repeat them on the actual delivered system using the production accessories and safety interfaces. Record recipe revision, gas, wire, material, operator, optics condition, and inspection results. The goal is not to prove the machine can weld everything; it is to establish a traceable baseline that both buyer and supplier understand.

> **BEST SUPPLIER BEHAVIOR:** A strong supplier is comfortable discussing limitations, unsafe use, representative application testing, parameter documentation, optics maintenance, and what the system should not be used for.

11. A Small-Shop Implementation Roadmap

Figure 9. Small-shop handheld laser welding implementation roadmap - original MWL concept illustration.

Source note: The roadmap converts the source evidence into a staged implementation sequence for a small U.S. manufacturer.**[1][2][6][7][10]**

Stage 1 - Screen the application

- Select representative parts and define the manufacturing problem.
- Get baseline cycle time, labor, rework, distortion, scrap, finishing, and quality data.
- Identify the acceptance test before making coupons.
- Do an early beam-path/facility screen so an otherwise attractive part is not impossible to contain safely.

Stage 2 - Run controlled vendor trials

- Use real materials and fit-up variation.
- Record the full process state, not just "70% power."
- Section/test coupons as required.
- Request data needed for safety and process verification.

Stage 3 - Design safety and facility controls

- Assign/qualify the LSO role.
- Complete the laser hazard evaluation and controlled-area design.
- Integrate door/access interlocks, warning indication, beam stops, E-stops, and machine interfaces.
- Select source capture and address material-specific fumes.
- Establish PPE based on the actual wavelength/hazard evaluation.

Stage 4 - Qualify and document

- Develop/qualify the WPS or internal controlled work instruction required by the product.
- Qualify operators and train supervisors/maintenance personnel.
- Create pre-use, maintenance, cleaning-mode and incident/nonconformance procedures.
- Set recipe access levels and revision control.

Stage 5 - Pilot, review, then scale

- Start with a controlled pilot lot.
- Measure quality, cycle time, finishing, scrap, consumables, optics, extraction filters, downtime, and support needs.
- Review at roughly 30, 60, and 90 days or another schedule appropriate to production.
- Expand only after the process demonstrates stable capability and the safety system is being followed.

12. Building the Business Case

The machine price is not the business case. The economic comparison should include the complete system and the complete manufacturing route. A laser that welds faster but requires a new enclosure, extraction, training, fixtures, qualification, optics, service, and a long changeover may or may not beat the existing process. Conversely, modest machine speed gains can be very valuable if the process eliminates hours of straightening, grinding, blending, or rework.

Cost categories to include

Category	One-time / startup	Recurring / per-part or periodic
Laser system	Machine, feeder, accessories, installation	Electricity, optics/consumables, service

Category	One-time / startup	Recurring / per-part or periodic
Safety	Hazard assessment, LSO training/support, enclosure/barriers, interlocks, signs, PPE	PPE replacement, audits, refresher training, barrier/window maintenance
Fume control	LEV/extraction equipment, ducting, IH evaluation	Filters, maintenance, sampling as required
Process	Vendor/application trials, fixtures, procedure qualification, test coupons	Wire, shielding gas, coupon checks, requalification after applicable changes
Quality	Test method development, gauges/NDT setup, reference samples	Inspection labor, destructive tests/NDT, records
Production	Programming/recipes, work instructions, operator training	Welding labor, loading/fixturing, changeover, finishing, scrap/rework
Downtime risk	Spare optics/nozzles, backup process plan	Service response, parts lead time, unplanned downtime

Use measured shop data, not a brochure multiplier

IPG publishes “4x faster than TIG” on the current LightWELD product page. That is a manufacturer-published performance claim and may be achievable in some applications, but it should not be dropped directly into an ROI spreadsheet. Time the complete process on your part: loading, tack/fixture work, welding, repositioning, cleaning, inspection, finishing, rework and changeover. Then compare accepted parts per labor hour, not raw torch travel speed.[9]

A SIMPLE ROI TEST: If the business case only works when every weld runs at brochure speed and the enclosure, extraction, qualification, maintenance and learning curve cost zero, the business case is not ready.

Five Rules Worth Posting Above the Machine

1. Class 4 until proven contained. PPE does not replace a controlled area and engineered beam containment.
2. The invisible beam can reflect or pass through the part. Protect the front, sides, fixtures, table openings, and rear of the joint geometry.
3. Never bypass an interlock or enabling control. A nuisance shutdown is a fault to solve.
4. Do not copy settings between machines. Verify the exact machine, optics, delivered output, working distance, and qualified recipe.
5. A beautiful bead is not a qualification test. Verify the penetration and properties required by the drawing, code, customer, or engineering plan.

Source note: These rules synthesize the recurring safety and quality themes in OSHA, AWS, handheld-laser-welding-specific guidance, OEM documentation, and the 2026 multi-machine beam research.[1][2][6][9][10]

Appendix A - Pre-Use Checklist

SCOPE: This checklist assumes the machine, controlled area, PPE and production procedure have already been approved. It is not a substitute for the site SOP/WPS.

Stage	Operator / supervisor check	Stop-work condition
Authorization / PPE	Training current; correct machine-specific laser eyewear/helmet and required clothing/PPE.	Wrong, damaged, missing PPE; unauthorized person in controlled area.
Controlled area	Barriers/windows/doors intact; interlock and warning indication normal; beam stop/backside containment in place; housekeeping acceptable.	Open/unprotected path; failed interlock; unreviewed reflective item/backing in likely beam path.
Machine	Torch/nozzle/contact system, fiber/hose, protective window, work lead and E-stop condition; correct recipe revision.	Fiber/hose damage; dirty/damaged optic; interlock fault; unauthorized recipe.
Fume control	LEV running and positioned close enough to capture plume without disturbing shielding.	Extraction failed; unknown hazardous coating/material; poor capture.
Gas / wire	Correct gas, flow verification, wire alloy/diameter/feed and alignment.	Wrong gas, lost flow, contaminated wire, unstable feed.
Part / fixture	Correct material/thickness, clean joint, qualified gap, clamping, safe reflection geometry and root-side termination.	Wrong material; uncontrolled gap; open path behind joint; unsafe reflective geometry.
Startup coupon	Required check made with controlled recipe and compared to approved acceptance evidence.	Unexplained bead/penetration/process change.
Welding	Qualified working distance/technique; hands/face out of anticipated reflections; monitor plume/wire/gas.	Abnormal reflection, lost plume, unstable wire/gas, unexpected penetration/spatter, safety shutdown.
After weld	Inspect to product/WPS criteria; log traceability as required; inspect optic after abnormal process event.	Appearance is good but required penetration/NDT evidence is missing.
Shutdown	Disable emission, key-control machine, secure torch, service extraction as SOP requires, record defects.	Damaged equipment remains locked out until approved service/verification.

Appendix B - Vendor Question List

- What laser wavelength, source type, rated power, and beam profile/spot data apply to the exact model?
- How is delivered power verified? Is there an OEM-approved method after optics replacement or service?
- What is the qualified or recommended working-distance range and how is it checked?
- What wobble patterns, width/amplitude, frequency and power-compensation functions are available?

- What safety functions are built in: key, E-stop, external interlock, two-stage trigger, contact circuit, plume/plasma detection or equivalent, fiber integrity?
- How does the system integrate with an interlocked controlled area or enclosure?
- What U.S. product labeling/certification documentation is supplied?
- What wire sizes/alloys, feeder speeds, calibration methods and nozzle arrangements are supported?
- What shielding gases are recommended for the specific material, and what evidence supports the recommendation?
- What consumables are expected to wear? What should be stocked? What are current lead times?
- How is the protective window inspected and replaced? What verification is required afterward?
- Can your application lab run our real parts with normal fit-up variation and provide the complete parameter record?
- What test data will you provide: cross-sections, bend/tensile/leak/NDT as applicable?
- What training is included for operators, supervisors, maintenance personnel and LSO/safety integration?
- Who provides U.S. service, what is the response process, and what service events require re-verification?
- Can recipes be password protected, versioned, backed up, exported or traced to production lots?
- What changes when cleaning mode is enabled, and what additional safety review does the manufacturer require?
- Which applications or materials does the supplier recommend we *not* start with?

Appendix C - Minimum Process Development Record

Use this as a starting worksheet. The governing code/customer specification may require additional variables or formal forms.

Record field	What to capture
Part / requirement	Part number/revision, drawing/customer requirement, acceptance criteria, intended production volume.
Base material	Specification/grade, condition/temper, thickness, lot/heat if relevant, coating/plating.
Joint / fit-up	Joint type, edge prep, gap/tolerance, alignment, access, start/stop/corner details.
Preparation	Cleaning method, abrasives/solvents, oxide removal, allowed surface condition.
Fixture / beam path	Clamp/nest, backing, beam stop, table/openings, part orientation, reflection/through-beam controls.
Laser system	Manufacturer/model/serial, source type, wavelength, optics/head/nozzle, protective-window status.
Beam / working position	Verified power method/result, spot/waist data if available, focus/working distance, torch orientation.
Mode / power	CW/pulsed/modulated mode, average delivered power or machine setting, pulse variables where applicable.
Wobble	Axes, pattern, width/amplitude, frequency, position-dependent compensation state.

Record field	What to capture
Travel	Direction, speed/range or controlled technique, positioner/guide if used, starts/stops.
Filler	Specification/alloy, diameter, feed speed, calibration/verification, wire position.
Shielding	Gas type/purity where relevant, flow setting, verification method, nozzle/shield arrangement.
Nominal line energy	Calculated Pavg/v value when meaningful; label as comparison metric, not absorbed heat.
Inspection / tests	Visual, dimensional, cross-section, NDT, bend/tensile/hardness/leak as applicable; results and photos.
Disposition	Pass/fail, approved parameter window, required changes, re-test, authorized approver.
Control	Recipe name/revision, operator qualification link, effective date, change history, requalification triggers.

References and Source Notes

Links below were selected so readers can inspect the source context directly. Standards and product pages change; verify current editions and manufacturer specifications before implementation. Access date for current web-source checks in this edition: August 20, 2026.

[1] AWS/IIW/EWF/EWA, Considerations About Handheld Laser Beam Welding (HLBW), 2026, DOI 10.29391/2026.hlbw.001

[2] OSHA Technical Manual, Section III, Chapter 6 - Laser Hazards

[3] OSHA, Laser Hazards - Standards

[4] FDA/CDRH Radiation-Emitting Product Code RFF - Laser Welder

[5] Laser Institute of America (LIA), ANSI Z136 resources

[6] American Welding Society, Handheld Laser Welding Safety, Welding Digest, January 2025

[7] AWS C7 Committee - AWS C7.4/C7.4M:2017-AMD1, Process Specification and Operator Qualification for Laser Beam Welding

[8] AWS Free Resources - sample welding and laser-welding qualification forms

[9] IPG Photonics, LightWELD Handheld Laser Welding & Cleaning Systems

[10] Jahn, S. et al., Laser beam characteristics of handheld laser beam welding systems, Welding in the World, 2026

[11] NIOSH Engineering Controls Database - Welding Operations: Local Exhaust Ventilation Systems

[12] Khaligh, M. et al., Emission factors and fume generation rates of particles from various welding processes, Annals of Work Exposures and Health, 2024

[13] Pigozzo, I.O. et al., Handheld Laser Beam Welding Characterization: Caustic Profiling and Power Metering, Welding Journal, 2026, DOI 10.29391/2026.105.006

[14] ISO 11553-1:2020 - Safety of machinery - Laser processing machines - Part 1

[15] ISO 11553-2:2007 - Safety of machinery - Laser processing machines - Part 2: hand-held laser processing devices

[16] 21 CFR Part 1040 - Performance Standards for Light-Emitting Products

[17] American Welding Society, Getting a Grip on Handheld Laser Safety, Welding Journal, January 2026

Notes on attribution

The handheld-laser-welding-specific safety, qualification, materials, gas, joint and process-variable discussion in this guide owes substantial credit to the authors of the 2026 AWS/IIW/EWF/EWA-supported guidance [1]. Rather than republishing their figures, MWL created original concept illustrations and points readers to the source publication for the authors' original examples and microscopy.

IPG Photonics information is used as primary manufacturer documentation for LightWELD specifications, safety features and capability screening [9]. Those statements are identified as IPG-published information and should not be generalized to other brands. The independent seven-system study [10] is used to explain why machine-specific verification matters.

OSHA sources [2-3] are used for U.S. workplace context; FDA/CDRH [4,16] for laser-product context; AWS [6-8,17] for welding-specific safety/qualification context; NIOSH [11] for local-exhaust control evidence. Paid consensus standards and codes should be obtained from their publishers in the editions applicable to the shop and product.

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