Laser Cleaning and Surface Preparation

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Lasers with powerful pulsed output provide a simple, versatile tool for removing corrosion, oxides, scale, lubricants, paint, rubber, carbon black, and other contaminants in a single dry step, with no damage to the underlying substrate.

The Growing Need for Surface Cleaning

Across many industries, there is an ever increasing need to clean surfaces, and particularly, metal surfaces. A primary driver for this is the impact of surface composition and quality on downstream processes. For example, the use of aluminum-dipped steel for corrosion-resistant tailored blanks requires removal of the outer aluminum-silicon coating from all locations that will be welded.

Other examples include stripping corrosion from copper “hairpins” in electric motors before welding, and removal of cutting lubricants or other organic materials from gears and other transmission components prior to welding. Plus, in the automotive industry, hang-on parts are increasingly fabricated by welding or brazing sheets of aluminum. Those sheets have a corrosion protection layer or a thin oxide layer that naturally forms on these alloys, which must be removed prior to bonding. In all these cases, the surface must be cleaned to the base metal in order to achieve a brazed or welded joint with the requisite integrity and strength. Contaminants can otherwise act to weaken these joints.

Figure 1. Laser cleaning is ideal for re-usable molds as well as cast metal components.
Just as important, many joining applications are currently based on adhesive bonding, or are switching to this technology. In particular, it is increasingly the method of choice in automotive applications, where it increases the strength-to-weight ratio of assemblies. For example, automobile roof assemblies formerly made extensive use of brazing, but this application may switch to adhesive bonding. The tensile strength of an adhesive bond is negatively impacted by surface contamination, particularly by the presence of organics, such as lubricants, that are commonly used in extrusion, machining or as mold release agents. This relationship is non-linear, with traces of organic materials having a significant weakening effect.

There are other reasons driving a need for surface cleaning, such as restoring parts where long-term rusting or other corrosion has occurred. Similarly, it may be necessary to remove old paint or other coatings. Or, it might be required to remove a protective coating before subsequent handling or processing.

Figure 2. In laser cleaning, the beam is focused to a narrow line or small spot which is swept across the surface. Dirt, rust and other contaminants are blasted away with no effect on the underlying substrate.

Traditional cleaning is based on physical abrasion or chemical cleaning/etching, or a combination of both. These methods use consumable materials, which are often hazardous, requiring regulated disposal. The overarching trend towards more environmentally friendly manufacturing processes is causing many applications to look instead at surface cleaning with lasers, where the only consumable is electricity. At the same time, a new generation of powerful pulsed lasers has been developed based on fiber laser technology. These lasers have the performance and cost of ownership characteristics to make laser cleaning an economically attractive alternative to mechanical or chemical cleaning.
Laser Ablation

When a laser beam is focused to a high intensity on a material, it induces local heating. Above a threshold fluence (power per unit area), a process called ablation occurs, where the laser vaporizes and removes material. For many materials, reaching this ablation threshold requires extremely high power. Depending on the focused spot area, it can require up to a megawatt. For this reason, pulsed lasers are utilized in many industrial applications, including surface cleaning.

Pulsed lasers can deliver the power required because their output is emitted as a fast stream of extremely short pulses – in the nanosecond regime or even shorter. Compressing the laser power into these short pulses results in very high peak power – orders of magnitude higher than the laser’s overall or average power. Furthermore, applying the power in pulses means that the laser can momentarily exceed the ablation threshold of a target material without applying massive amounts of overall power which might damage or even melt the target object.

The key to laser cleaning is material selective ablation: removing the unwanted contaminant layer without damaging the underlying material. Every material has its own ablation threshold. And fortunately, organics such as lubricants, plastics and paint have much lower ablation thresholds than metals. Furthermore, oxides, such as rust and scale, all have significantly lower ablation threshold than aluminum, which in itself has a lower ablation threshold than commonly used steel alloys.

In operation, the laser power and focused spot size for each cleaning application are set so that the laser easily blasts away the surface contamination, but leaves the material underneath in pristine condition. In operation, movement of the part and/or the laser line is used to rapidly “paint” large areas of the surface. The vaporized material (dust) can be easily captured using vacuum, so there is no debris to worry about and no chemicals to dispose of in this dry, one-step process.

Next Generation Laser Tools

Near-infrared laser wavelengths are ideal for cleaning most metal surfaces in this way. Recently, powerful pulsed fiber lasers have become available in this wavelength regime. Fiber lasers are well-established in numerous industrial applications, including welding, case hardening, and marking, because they offer a very attractive power/cost ratio with superior reliability. Moreover,
they generate a round, symmetrical output beam that can be easily shaped to a line or other format.

Until recently, these fiber lasers could not offer the ideal combination of high *average* power required to enable economically viable process speeds for industrial cleaning applications, together with the very high *peak* power needed to ablate tougher materials like AlSi and rust. Fortunately, advances in fiber technology have now solved the technical challenges. A standout example of these new cleaning lasers is the HighLight FL1000P from Coherent | Rofin, based on the same technology and components well-proven in other industrial fiber laser products.

This new laser has been optimized specifically for cleaning applications. It delivers a maximum pulse energy of 100 mJ, at pulse widths between 10 ns and 100 ns, and with repetition rates ranging from 10 kHz to 30 kHz. The beam is also easily focusable; a beam parameter product of typically 20 mm x mrad (for a 400 μm, round core output fiber) enables this power to be effectively concentrated into small focused spot sizes. And, its uniquely high power enables higher throughput than other lasers. Plus, the widely adjustable pulse width enables the output to be exactly matched to a diverse range of cleaning applications.

![Image](image-url)

*Figure 3. The high power and short adjustable pulse width of the HighLight FL1000P enable laser cleaning to be optimized to a wide range of applications, including cleaning leaf debris from railroad tracks.*

The laser can be supplied as a standalone device for OEMs, or with a range of accessories such as scanners and focusing optics. Because the power is fiber-delivered, it is easily integrated into different platforms, including large area scanners and even handheld units. It also available integrated within complete Coherent | Rofin workstations which include part handling, etc. Moreover, where laser welding is required after cleaning, both the cleaning and welding can be
integrated into a complete solution package, including software process recipes carefully developed and proven in our applications laboratory before installation, completely eliminating risk for the end user.