Formation and Removal of Flammable/Explosive Laser Dust – Challenges and Solutions

Preface

In industrial laser processes, the processing waste products often pose a significant challenge for assessing explosion hazards. This topic concerns both operators and manufacturers.
Operators are responsible for conducting a risk assessment for dust extraction systems in their installation areas. They must prepare an explosion protection document in accordance with the German Hazardous Substances Ordinance and review the effectiveness of the measures taken.
Conversely, manufacturers are required to submit a safety concept in accordance with the Explosion Protection Directive. They must inform operators about the intended use, residual risks, and the protective measures taken. The following article discusses the necessary framework for this.

Formation of laser dust

During laser material processing, fine dust often arises because the laser heats the material intensely and breaks it down into small particles. Depending on the laser settings – i.e., the power level, how small the laser spot is focused, and how quickly the laser is moved over the material – dust particles of varying sizes and quantities are created. The material also plays a role: metals, plastics, and ceramics behave differently. For continuously operating lasers, such as fiber lasers, the following applies: Metals can produce very small, high-energy particles—up to 100 nm in diameter—while plastics tend to form larger, fibrous particles or even burn completely.

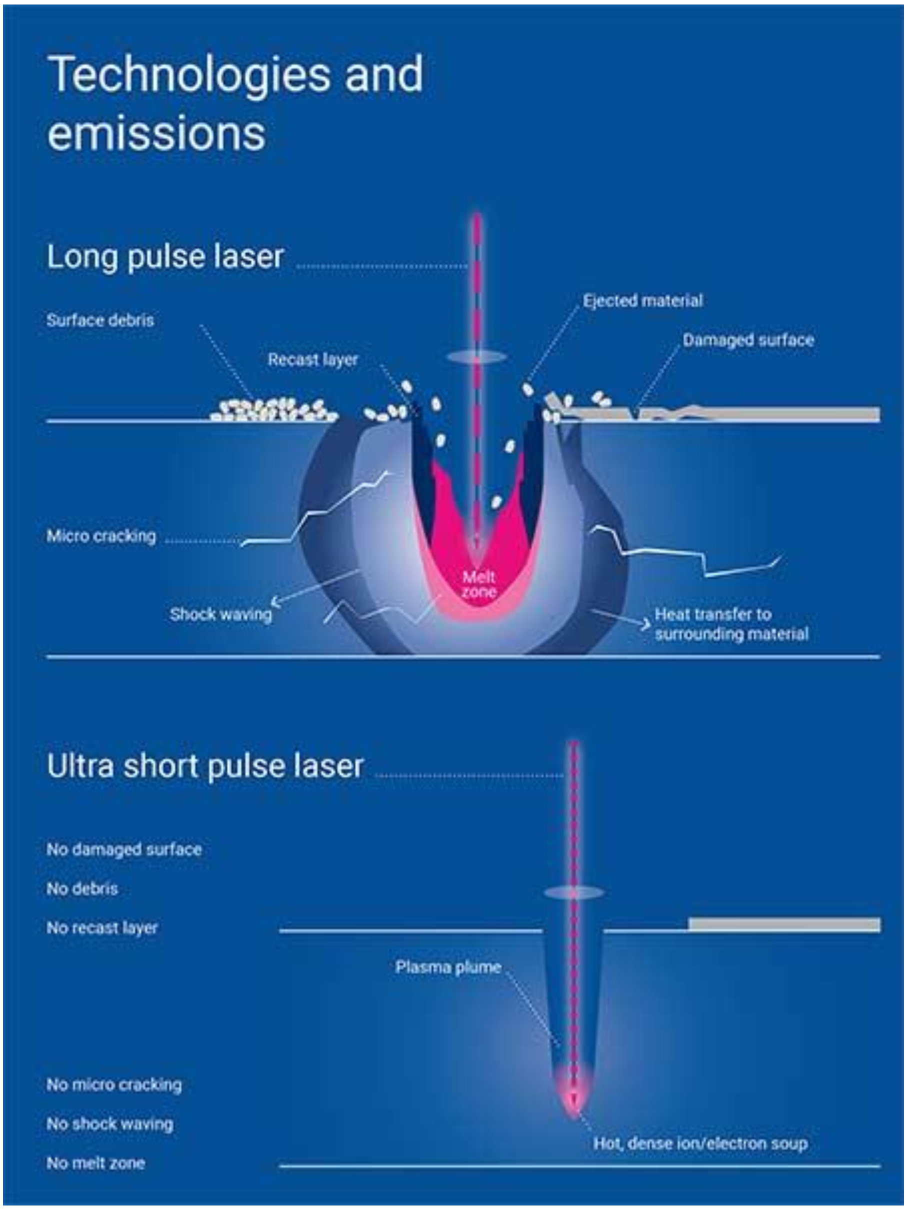

Image 1: Comparison of long-pulse vs. short-pulse processes and respective particle formation ©ULT

Properties and Characterization

Particles produced by laser processing can have various shapes—spherical, fibrous, or irregular. These shapes depend on the respective laser process and its impact on the processed material. The chemical composition of occurring dust can also vary and influences how hazardous dust is. Methods such as EDX (energy dispersive X-ray spectroscopy) help to determine the chemical composition of the dust. The fine particles often aggregate to form larger agglomerates. Metal particles are particularly critical. Even though the laser is a thermal process, not all particles are necessarily burned or oxidized. Various suboxides – for example, from tool steel – can even be self-igniting.

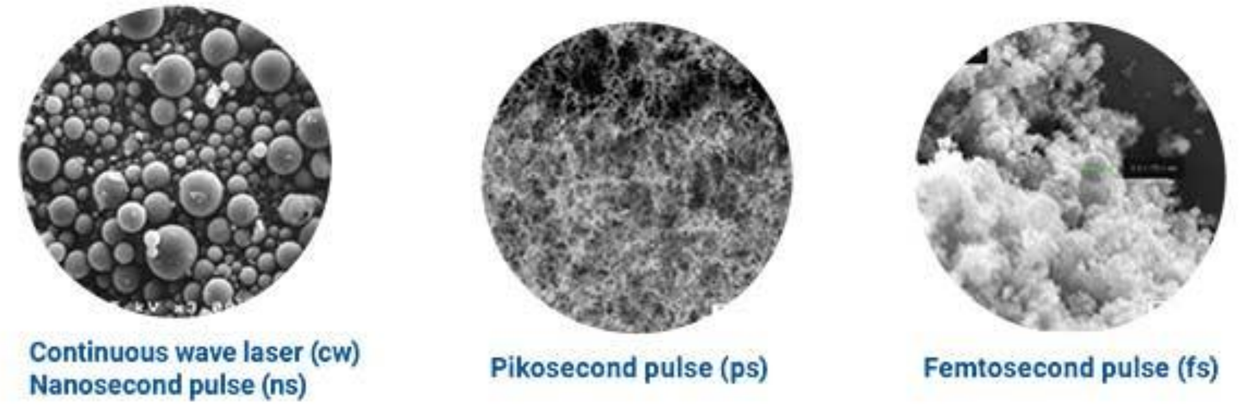

Image 2: Particle shapes after processing with various laser techniques ©ULT

Ignition mechanisms

Once the size and composition of the dust are known, ignition source types must be assessed.

These include:

- Hot surfaces: Surfaces that are heated due to the process or the machine. For example, some machines have a built-in heater, e.g., to achieve the preheating required for the process. Heated sensors should also be evaluated critically.
- Flames and hot gases: The laser is a thermal tool, so it is very likely that flames or hot gases may be generated during the process. Such assessments should be conducted particularly thoroughly. Flames can occur very quickly, especially when processing flammable materials such as plastics.
- Ignition sources caused by mechanical friction, impact, and separation processes: Such hazards arise, for example, when larger particles are entrained and could generate sparks in the filter system. Particular attention must be paid to the cleaning mechanisms within the filter system.
- Electrical systems: All electrical components that may come into contact with explosive dust-air mixtures must be explosion-proof. In many cases, this means achieving effective encapsulation.
- Electrical equalizing currents, cathodic corrosion protection.
- Static electricity: This includes the electrostatic charge of people and surfaces. Any spark caused by contact can act as an ignition source and must be eliminated.
- Lightning strike.
- Electromagnetic fields in the frequency range from 9 kHz to 300 GHz.
- Electromagnetic radiation in the frequency range from 300 GHz to 3000 THz or wavelengths in the range from 1000 µm to 0.1 µm (optical spectral range).
- Ionizing radiation.
- Ultrasound.

- Adiabatic compression, shock waves, flowing gases.
  Chemical reactions: Special attention must be given to this form of ignition source, as some substances are considered pyrophoric.

Spontaneous combustion: In this case, a substance ignites when heat is generated on all sides in the presence of air without any other ignition source. This occurs due to oxidation processes. Substances that spontaneously ignite in small quantities after a short time in air at room temperature (approx. 20 °C) are considered pyrophoric. Spontaneous combustion is essentially limited to solids with a large surface area (e.g., dust), where self-heating initially occurs. However, spontaneous combustion is also possible in low-volatility organic liquids.

Risks and regulations

Laser dust can pose an explosion risk if present in unfavorable concentrations with oxygen and can also be harmful to health if inhaled. There are various regulations determining the handling of such dust, for example the ATEX guidelines for explosion protection.

ATEX Directive 2014/34/EU: This European directive regulates the requirements for equipment and protective systems used in potentially explosive atmospheres. This is particularly relevant for installation in zones (20/21/22). Equipment must be certified accordingly and bear the ATEX mark.

DIN EN IEC 60079 series: This series of standards deals with the classification of potentially explosive atmospheres and the requirements for electrical and non-electrical equipment.

- DIN EN IEC 60079-0: General requirements for equipment.
- DIN EN IEC 60079-15: Equipment with type of protection "n" for use in Zone 2 (partially also relevant for Zone 22).
- DIN EN IEC 60079-31: Protection by enclosure "t", specifically for Zone 21 and Zone 22.

DIN EN 1127-1: This standard describes general concepts and methods for explosion protection. It contains basic safety requirements for preventing ignition sources and limiting the effects of explosions.

Important points:
• Device category: Only devices in category 3D may be used in Zone 22 (according to the ATEX directive).
• Marking: Marking of the machine according to ATEX (e.g. II 3D Ex tc IIIB T135°C Dc for Zone 22).

Challenges for extraction and filtration technology

Three levels of explosion protection are identified for extraction and filter systems:

- Primary explosion protection: Avoidance of explosive atmospheres. This can be achieved, for example, by exchanging substances or limiting the quantity.
- Secondary explosion protection: Avoidance of effective ignition sources. Here, attention must be paid to the appropriate selection of materials, often conductive materials or materials that prevent sparking.

- Tertiary explosion protection: If these two measures are not effective, explosions are limited or mitigated to a level that is harmless to humans and the environment. This can include, among other things, pressure-shock-resistant construction, explosion suppression through suitable and rapid extinguishing systems, explosion pressure relief, or explosion isolation of zones, for example, through emergency-closing flaps and rotary valves.

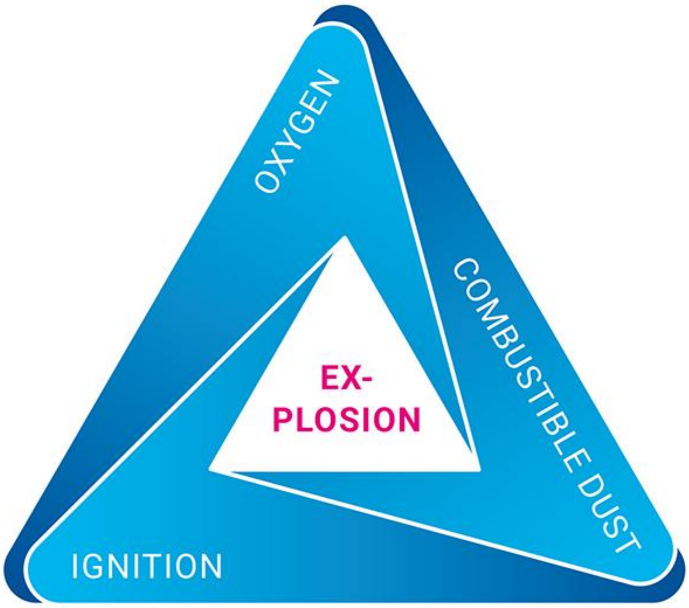

Image 3: Explosion triangle – if all three components are present, there is a risk of explosion ©ULT

Extraction and filtration technology faces various challenges from a design perspective. A filtration device should be designed to remain safe under every conceivable condition. The LAS 260 H/Ex device from ULT is an example of such a solution. It is constructed without ignition sources, has high filtration efficiency and a robust design, and, above all, features integrated safety mechanisms that ensure safe handling of laser dust. It is also ensured from the outside that the device always remains conductive and leak-proof.

Image 4: LAS 260 H/Ex – Extraction and filtration system for explosive laser dust ©ULT

The ignition-source-free design eliminates all system-related risks. If no ignition sources are drawn in or chemical reactions are generated, this device meets the necessary requirements for ATEX certification. The additional sealed construction also tightly encapsulates the electrical compartment, preventing the ignition of dust-air mixtures outside the device. This also allows installation in a potential ATEX Zone 22. However, the operator is always advised to install as few or as few systems as possible in zones where explosive dust-air mixtures may occur.

Conclusion

In summary, laser dust can pose a significant risk to both health and safety in the workplace. Therefore, appropriate protective measures and careful extraction and filtration technology are essential. However, with the right technology, these challenges can be overcome and safe working conditions can be created.

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