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in Latin America and the Caribbean

UNLIREC

Working Paper

Firearms Marking with Laser Engraving: Technical Insights and Recommendations

Disclaimer

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SUMMARY

Marking is a critical element in arms control, aiding with effective stockpile management, preventing the diversion of firearms into illicit markets, countering illicit trafficking and ensuring the traceability of firearms in criminal investigations.

This paper explores the use of laser engraving technology for firearm marking in accordance with international and regional instruments, including the Programme of Action on Small Arms and Light Weapons, the International Tracing Instrument, the Firearms Protocol, and the Inter American Convention against Illicit Trafficking and Manufacturing of Firearms, Ammunition, Explosives and other Related Materials, as well as best practices for firearms marking outlined in module 05.30 on marking and record-keeping of the Modular Small Arms Control Compendium (MOSAIC).

It provides guidance to States on key technical aspects, including the types of laser engraving machines suitable for firearms marking. It also outlines critical considerations such as the recoverability of obliterated markings, techniques to minimise potential damage to firearms, and safety measures to ensure a safe marking process.

The paper presents findings of experimental research aimed at identifying the optimal applications of laser engraving for marking firearms to prevent, to the extent possible, their obliteration, and to ensure, as far as technically possible, their recoverability. The experiments provide empirical evidence indicating that laser-engraved alphanumeric markings on stainless steel, mild steel and aluminium with a depth greater than 0.2 mm can, to some extent, be restored. The research presented is an important contribution a growing body of research in response to calls by UN Member States to better understand the opportunities and challenges related to laser marking and the recoverability of laser engraved markings.[1]

It should be noted that the research presented in this paper has certain limitations which should be considered when interpreting the results. The sample size was limited in both quantity and quality, preventing the paper from drawing universal conclusions. Only two models of fibre laser engraving machines and only two restoration methods – chemical etching and electromagnetic techniques – were used during the experiments. To strengthen the knowledge on using laser technology for firearms marking, future research should expand the sample size, incorporate a broader range of marking depths and materials, and test additional types of laser engraving machines and restoration methods. This study should therefore be understood as an initial research contribution, while highlighting the need for further research to enable the United Nations and the community of practitioners to develop sound scientifically based arguments regarding the parameters and application of laser engraving for firearms marking.

This paper does not cover the marking of small calibre ammunition. Separate research is recommended to investigate the application of laser technology for ammunition marking, exploring its potential to enhance identification, record-keeping, and tracing processes, in alignment with the new Global Framework for Through-life Conventional Ammunition Management.

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[1] Paragraph 164, *Report of the Fourth United Nations Conference to Review Progress Made in the Implementation of the Programme of Action to Prevent, Combat and Eradicate the Illicit Trade in Small Arms and Light Weapons in All Its Aspects* (A/CONF.192/2024/RC/3).

INTRODUCTION

Marking is an essential element of arms control and is a requirement of various international instruments, including the Protocol against Illicit Manufacturing of and Trafficking in Firearms, their Parts and Components and Ammunition (Firearms Protocol), and the International Instrument to Enable States to Identify and Trace, in a Timely and Reliable Manner, Illicit Small Arms and Light Weapons (International Tracing Instrument).

Marking allows for the unique identification of each firearm[2], which is essential for adequate record-keeping, stockpiling, and the ability to trace firearms throughout their entire lifecycle. It allows to track the history of a weapon from its manufacture to its last legal owner, in both time and geographic space. Adequate marking supports the maintenance of reliable records. As such, when paired with efficient record-keeping and other legislative, regulatory and operational measures, marking enables authorities to maintain oversight of firearms in circulation within their jurisdiction, prevent their diversion and counter illicit trafficking.

During criminal investigations, the markings on a firearm assist firearms examiners and investigators in identifying the weapon. The markings enable national or international tracing processes, which can determine when and how a firearm was diverted from legal to illegal ownership, and potentially may reveal links to its use in criminal activities. The findings of such investigations – facilitated by firearm markings – provide reliable evidence that can be presented during judicial proceedings, supporting an effective criminal justice response to firearms-related crimes. In addition, when seized firearms are systematically traced, the analysis of that data provides valuable information on illicit trafficking trends. These insights can shape effective crime prevention strategies, support investigations and guide counter-criminality initiatives.

There are different methods available to States to mark their firearms, including, among others, stamping, casting, mechanical engraving, laser engraving, and micro-stamping. While the choice of marking method is a national prerogative, the decision should be guided by the ability to ensure that the markings are “conspicuous without technical aids or tools, recognizable, readable, durable and, as far as technically possible, recoverable”[3]. Resource availability and cost considerations may also play a key role in determining the most suitable marking method for each State.

Technological solutions are improving and driving progress in the field by increasing efficiency and precision in the marking process, as well as the capacities to restore obliterated markings. In recent years, laser technology (i.e. light amplification by stimulated emission of radiation) has emerged as a practical alternative to traditional firearms marking methods such as stamping, dot-peen or mechanical engraving. However, its reliability depends, on adherence to best practices and guidelines. Laser engraving offers numerous advantages, ensuring that markings are visible, readable, and durable, and is fast. What has been less established is to what extend laser engravings are more difficult to obliterate and whether the markings can be recovered once obliterated.

This paper explores the use of laser engraving technology for firearm marking in accordance with international and regional instruments and provides guidance to States on key technical aspects

[2] According to the UN Firearms Protocol, a firearm is “any portable barrelled weapon that expels, is designed to expel or may be readily converted to expel a shot, bullet or projectile by the action of an explosive, excluding antique firearms or their replicas”. Meanwhile, small arms are defined as “any man-portable lethal weapon designed for individual use that expels or launches, is designed to expel or launch, or may be readily converted to expel or launch a shot, bullet or projectile by the action of an explosive”. In this publication, the terms the terms firearms and small arms are used interchangeably.

[3] Paragraph 7 of the International Tracing Instrument. The research and recommendations in this paper are grounded in the objective of ensuring that firearm markings meet these key characteristics.

and considerations relevant to firearms marking. The first chapter outlines the obligations and commitments undertaken by States regarding marking, record-keeping and tracing of firearms, as established under international and regional arms control frameworks. The second chapter explores the application of laser engraving technology for firearms marking. It describes the main characteristics of laser engraving machines, the types of lasers commonly used for metal engraving, and their respective advantages. Special attention is given to the technical aspects of the process, particularly the adjustment of key parameters – such as power, speed, frequency, and loops – according to the properties of the materials commonly used in firearms. The third chapter addresses the forensic recoverability of intentionally obliterated laser markings. It seeks to contribute to the growing body of research examining whether, and under what conditions, laser-engraved markings can be recovered. This chapter presents findings from experimental research and provides empirical evidence on the circumstances under which such markings retrievable. The fourth and final chapter discusses key advantages and limitations of laser engraving for firearms marking. It concludes with a set of recommendations for national authorities and manufacturers on implementing laser engraving systems to ensure effective compliance with international standards.

1. INTERNATIONAL FRAMEWORK

States have acknowledged the importance of marking firearms and standardising their practices, incorporating these principles into various international and regional[4] instruments. Collectively, these instruments create a framework for traceability and fostering cooperation among States to enhance firearm regulation and control. In particular, the following instruments mandate States to implement marking systems for firearms:

- Protocol against the Illicit Manufacturing of and Trafficking in Firearms, their Parts and Components and Ammunition (2001) (Firearms Protocol), supplementing the United Nations Convention against Transnational Organized Crime (UNTOC). This instrument is legally binding for its State Parties[5] and has an international scope.

- United Nations Programme of Action to Prevent, Combat and Eradicate the Illicit Trade in Small Arms and Light Weapons in All Its Aspects (2001) (UN Programme of Action or PoA), which is politically binding and applies to all the UN Member States.

- International Instrument to Enable States to Identify and Trace, in a Timely and Reliable Manner, Illicit Small Arms and Light Weapons (2005) (International Tracing Instrument, or ITI), developed in the framework of the PoA. It is also politically binding and applies to all UN Member States.

- Additionally, at the regional level in the Latin American and the Caribbean, the Inter-American Convention Against the Illicit Manufacturing of and Trafficking in Firearms, Ammunition, Explosives and Other Related Materials (CIFTA) was adopted in 1997 and is legally binding for its State Parties[6].

Table 1 | International framework on firearms

Firearms Protocol	Programme of Action	ITI	CIFTA
Legally binding	Politically binding	Politically binding	Legally binding
Global scope	Global scope	Global scope	Regional scope (Latin America and the Caribbean)

These international instruments not only emphasise the importance of firearm marking but also set specific requirements aimed at ensuring effective traceability and controlling the illicit trade in firearms. The following section delves into the key provisions of these instruments establishing when, where and how firearm markings must be applied.

[4] Given the geographical scope of UNLIREC's mandate, this paper focuses on global instruments and those applicable within the Latin American and Caribbean region. It is acknowledged, however, that other regional instruments are also relevant to other parts of the world.
[5] At the time of writing (December 2024), the Firearms Protocol has 123 States Parties and 52 Signatories.
[6] At the time of writing (December 2024), the CIFTA has been ratified by 31 of the 34 OAS Member States.

1.1. When shall the markings be applied?

According to international instruments, firearms must be marked at the time of manufacture (Article 8, Firearms Protocol; paragraph 8, ITI[7]; Article VI, CIFTA), at the time of importation (Article 8, Firearms Protocol; paragraph 8, ITI; Article VI, CIFTA), and when they are transferred from State stockpiles to civilian use (Article 8, Firearms Protocol; paragraph 8, ITI).

Table 2 | Marking firearms according to international instruments

	Firearms Protocol	Programme of Action	ITI	CIFTA
At the time of manufacture	✓	✓	✓	✓
At the time of import	✓		✓	✓
Confiscated firearms	✓		✓	✓
Firearms transferred from State stocks to civilian use	✓		✓	
Deactivated firearms	✓			
Essential or structural component of the firearm		✓	✓	
Other parts of the firearm			✓	

At the time of manufacture, as specified in the abovementioned provisions, markings must include the name of the manufacturer, the country or place of manufacture and the serial number, or an alternative marking combining geometric symbols with numeric or alphanumeric codes permitting an easy identification by all of States of the country of manufacture (Article 8.1(a), Firearms Protocol; paragraph 8(a), ITI; Article VI.1(a), CIFTA). The ITI also encourages States to include additional markings such as the year of manufacture, type or model and calibre of the firearm. Some resources refer to the markings at the time of manufacture as classical markings.

Table 3 | Information of the markings at the time of manufacture

Marking at the time of manufacture	Firearms Protocol	PoA	ITI	CIFTA
Country or place of manufacture	Required	Required	Required	Required
Name of manufacturer	Required	Required	Required	Required
Serial number	Required	Required	Required	Required
Geometric symbol plus (alpha)numeric code	Accepted as alternative		Accepted as alternative	
Year of manufacture			Encouraged	
Calibre			Encouraged	
Type or model			Encouraged	

[7] Additionally, outcome documents adopted at Biennial Meetings of States and in Review Conferences of the PoA have included references to applying measures aligned with the ITI provisions on marking. In the final report adopted in the Fourth Review Conference of the PoA (RevCon4, 2024), States reiterated "to apply the marking requirements specified in the International Tracing Instrument" (para. 143, A/CONF.192/2024/RC/3).

When imported, firearms must also include the country of import and, where possible, the year of import (Article 8.1(b), Firearms Protocol; para. 8(b), ITI). Moreover, a unique marking should be applied if the firearm did not bear it. The CIFTA requires markings that permit the identification of the importer's name and address (Article, VI.1(b), CIFTA).

In some cases, when firearms are produced for export, the importing country may require the manufacturer to include the import markings at the time of manufacture, ensuring both the manufacture and import markings are applied simultaneously during manufacture. In such instances, the importing country may specify to the manufacturer the characteristics of the import marking and the method to be used, in line with its national regulations and protocols. This good practice helps save time and resources, as organising a marking process at a later stage can be time-consuming, and marking certain areas of the firearm with traditional methods like stamping is difficult once fully assembled.

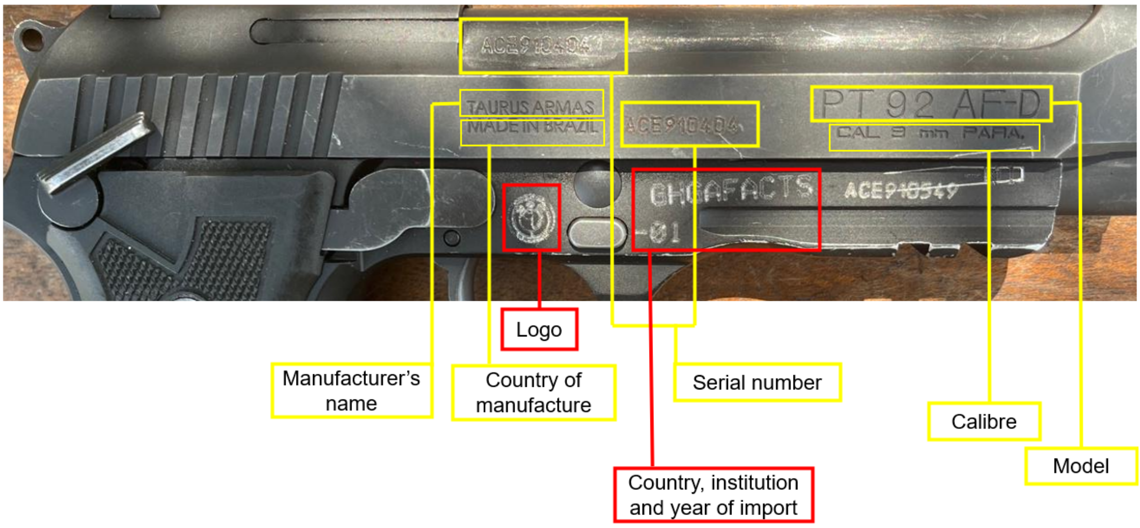
Table 4 | Information of the markings at the time of import

Marking at the time of import	Firearms Protocol	ITI	CIFTA
Country or place of import	Required	Required	Required
Importer		Required	Required
Year of import	Where possible	Where possible	
Unique marking (if serial number is missing)	Required	Required	

Additionally, the ITI establishes that States shall mark and securely store all the illicit firearms found in their territory, or destroy them, as soon as possible (para. 9, ITI). Similarly, according to the Firearms Protocol, firearms that are permanently deactivated by the State should also be marked at the time of such actions for verification purposes by the relevant authorities (Article 9(c), Firearms Protocol), or otherwise disposed with official authorisation after seizure (Article 6.2, Firearms Protocol). Meanwhile, the CIFTA requires State Parties to mark any confiscated or forfeited firearm retained for official use (Article VI.1(c), CIFTA).

This set of marking practices enhances the efficiency of tracing operations by allowing the identification of the manufacturing country or the last known country of legal import, thereby indicating where to direct tracing requests.

Figure 1 | Example of markings at the time of manufacture and import marking



Pistol Taurus PT92 AFS-D model. Calibre 9mm. Manufactured in Brazil. With serial number ACE910404. Imported in Ghana by Ghana Armed Forces. ECOWAS logo also marked at the time of importation. Marking at the time of manufacture with stamping method. Import marking applied with dot-peen method. Markings applied on metal parts of the firearm, including the barrel, the slide and the frame.

Note: MOSAIC 05.30 provides an example of the recommended format for markings applied at the time of manufacture and at the time of importation, aligning with the obligations and recommendations outlined earlier.

- Example of alphanumeric marking at the time of manufacture:

Country of manufacture (2-digit ISO country | **Year of manufacture (2 numbers)** | **Serial number**

XX XXXX 00 00 00000 00

Manufacturer's name or code | **Type/model code** | **Caliber**

- Example of alphanumeric marking at the time of importation:

Country of manufacture (2-digit ISO country | **Serial number (only if the weapon was inadequately marked)**

XX 00 00000

Year of importation (2 numbers)

1.2. Where shall markings be applied?

Another important consideration for marking is its placement. This is particularly relevant for the purposes of this paper, as this determines the materials involved and the accessibility of the surface which will be marked. These factors are critical when choosing the most suitable marking method, particularly after the firearm has been fully assembled.

The ITI provides more detailed guidance on this matter, specifying that "markings should be applied to an essential or structural component of the weapon where the component's destruction would render the weapon permanently inoperable and incapable of reactivation, such as the frame and/or receiver" (paragraph 10, ITI).

The ITI also encourages additional markings on other parts of the firearm, such as the barrel, slide, or cylinder, to facilitate the accurate identification of these parts or the firearm as a whole. For the purposes of recordkeeping and tracing, the marking on the frame or receiver shall be the main reference point for identifying a firearm (paragraph 10, ITI).

For marking considerations, these parts and components are normally made of metal, and in some cases polymer. When the frames are made from polymers, the markings should be applied to a metal plate permanently embedded in the material of the frame in a way that it cannot be easily removed and removing it would damage or destroy parts of the frame.[8]

1.3. How should the markings be applied? The importance of the recoverability of the marks

Both the ITI and the Firearms Protocol emphasise the importance of the recoverability of marks on firearms. Paragraph 7 of the ITI stipulates that the marks must be "as far as technically possible, recoverable", while Article 8(2) of the Firearms Protocol requires States Parties to "encourage the firearms manufacturing industry to develop measures against the removal or alteration of markings". Moreover, during the Fourth Review Conference of the PoA, States resolved to take advantage of technological developments for enhanced marking, record-keeping and recovery of obliterated markings (paragraph 145, RevCon4 Final Report).

While the choice of marking method remains within the prerogative of the States (paragraph 7, ITI), the following criteria should guide this decision: (i) it does not damage the performance or technical quality of the weapon; (ii) the marking is legible, practically indelible, durable, difficult to falsify, and preferably recoverable through a restoration process; (iii) it should be practical to apply; (iv) it can be applied to several parts of the firearm; and (v) the cost per unit produced is affordable.[9]

Since the advent of laser engraving technology, this method has attracted much attention due to its capacity to mark different materials and surfaces, to adapt to the forms and thickness of different parts and components reducing potential damage to the weapon, and its high precision ensuring legibility of the marks. Speed, practicality, and cost-effectiveness per unit (after the initial imbursement), are also additional advantages of laser marking compared to other marking methods. Please refer to the next section for a detailed overview of the advantages and disadvantages of laser engraving machines for laser marking.

In general, permanent marking methods (such as stamping, dot-peen, mechanical engraving or laser engraving) cause a deformation in the crystalline structure of the material in the marked

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[8] United Nations Office for Disarmament Affairs. *MOSAIC 05.30* (2022). 5.2.1.1.4 "Non-metallic frames".

[9] This recommendation was highlighted by the Secretariat of the Conference of the Parties to the UNTOC in the background note for the Working Group on Firearms, titled "Good practices, gaps and challenges in countering the illicit manufacturing of and trafficking in firearms, their parts and components and ammunition, and measures to facilitate the implementation of the Firearms Protocol" (2012), CTOC/COP/WG.6/2012/3.

area, including below the visible mark, which may enable the recovery of the marks if they are obliterated on the visible surface by applying specialised techniques. While the recoverability of the marks on firearms cannot always be guaranteed, this is more effective with metals marked with methods that apply pressure, causing permanent deformation and resulting in more pronounced and permanent changes to the material.

Considering the above, MOSAIC 05.30 recommends applying the stamping method on essential components (usually made of metals), at a depth of *at least* 0.2mm (clause 5.2.1.1.6) at the time of manufacture; and import markings should have a depth of *at least* 0.1mm for metals and 0.2mm for polymers (clause 5.3.4), recommending any marking method, including laser engraving.

The next section explores how laser engraving technology works, its impact on the engraved materials, and its use for marking firearms. It is followed by an examination of the effectiveness of recovery techniques for laser-engraved markings to help identify best practices.

2. USE OF LASER ENGRAVING TECHNOLOGY FOR FIREARMS MARKING

Laser engraving technology works based on the principles of light amplification by stimulating emissions of radiation to remove material from the surface of an object using heat by passing the laser beam several times over a surface. The precision of the laser makes it ideal for engraving detailed and accurate designs, and its versatility allows it to be used on a wide range of materials, from metals to plastics, wood, and even glass.

It should be noted that laser technology can be used not only to engrave but also to anneal or etch. Laser annealing utilizes the heat of the laser beam to modify the item's surface by hardening it or altering its colours, without removing material, resulting in superficial marks and a smooth surface with no depth. Laser etching creates raised marks by melting the surface with the heat of the laser beam. Laser engraving, meanwhile, uses the laser beam to mark the surface by removing material through sublimation and carving the mark into the item, creating depth in the engraving. For the purposes of this paper, when discussing the use of laser technology for firearms marking, focus will be placed on the laser engraving process.

How does laser-engraving work? Laser engraving machines generally consist of a laser generator, a laser head, a control system (computer software), and a surface to place the items to be engraved. The laser head has a cavity with an active medium (frequently made of CO_2 gas, fibre, or crystal). The laser generator then provides energy to excite the atoms or molecules in that active medium. This stimulation causes them to emit photons (light particles) in the active medium. The energy in the medium intensifies as the photons bounce through the laser's cavity. That energy is then concentrated using a series of lenses, creating a highly focused, intense beam of light. Different active mediums create beams of light with different wavelengths. Directed by the control system, the beam is then focused onto the surface of the item to be engraved.

When the item's material absorbs that high concentration of light, it reaches extremely high temperatures (typically between thousands to tens of thousands of degrees Celsius). This intense heat is capable of sublimating (converting from solid to gas) the material at the point of contact, which results in removing part of it and leaving a mark on the surface. As the laser beam moves through the surface of the item, guided by the design programmed with the control system, it creates a groove. When a mark is engraved in a material, the metal below the groove is annealed, changing its crystalline structure.

The depth and width of the engraving can be regulated by adjusting the laser's power, speed, and the number of passes (loops) – which will depend mainly on the laser's wavelength, the machine's power, and the material's capacity to absorb light.

Laser Parameter Adjustment to Material Properties

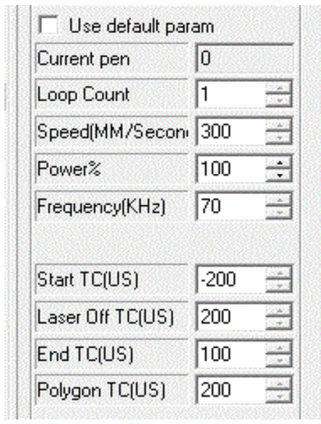
The parameters of the laser machine such as power, speed, frequency, and loops should be adapted to the material's density, thermal conductivity, and reflectivity, as these properties influence how the material absorbs and interacts with laser energy.

- **Power**. The laser power determines the energy delivered to the material per unit time. Reflective materials, such as metals, require higher laser power because a significant portion of the laser energy is reflected rather than absorbed for heating. Denser materials also require higher power because a greater number of molecules must be heated above the threshold temperature to sublimate and engrave a mark. Additionally, materials with high thermal conductivity dissipate heat quickly, requiring more laser power to achieve sufficient heating for engraving. In contrast, materials of low reflectivity, low density or low thermal conductivity would require less power, as heat is retained longer.

- **Speed**. The speed at which the laser beam is set to move when marking determines the exposure time of the material to the laser beam. As such, hard materials require slower speeds to ensure sufficient time to absorb energy to heat and effectively engrave the marks. Conversely, softer materials like polymers require higher speeds to prevent excessive heating, burning or melting. Similarly, materials with high thermal conductivity like aluminium would require also lower speed to concentrate sufficient heat for engraving, whereas low conductivity like polymers require high speed as the heat does not dissipate quickly.

- **Frequency**. The frequency refers to the number of laser pulses emitted per second. It impacts the smoothness and detail of the engraving. Higher frequencies are normally required for hard, dense or reflective materials, such as metals, to ensure that the laser pulses overlap and produce a smooth, continuous marking. On the other hand, lower frequencies are more suitable for soft, porous or heat-sensitive materials, like polymers, to reduce the risk of burning or excessive melting.

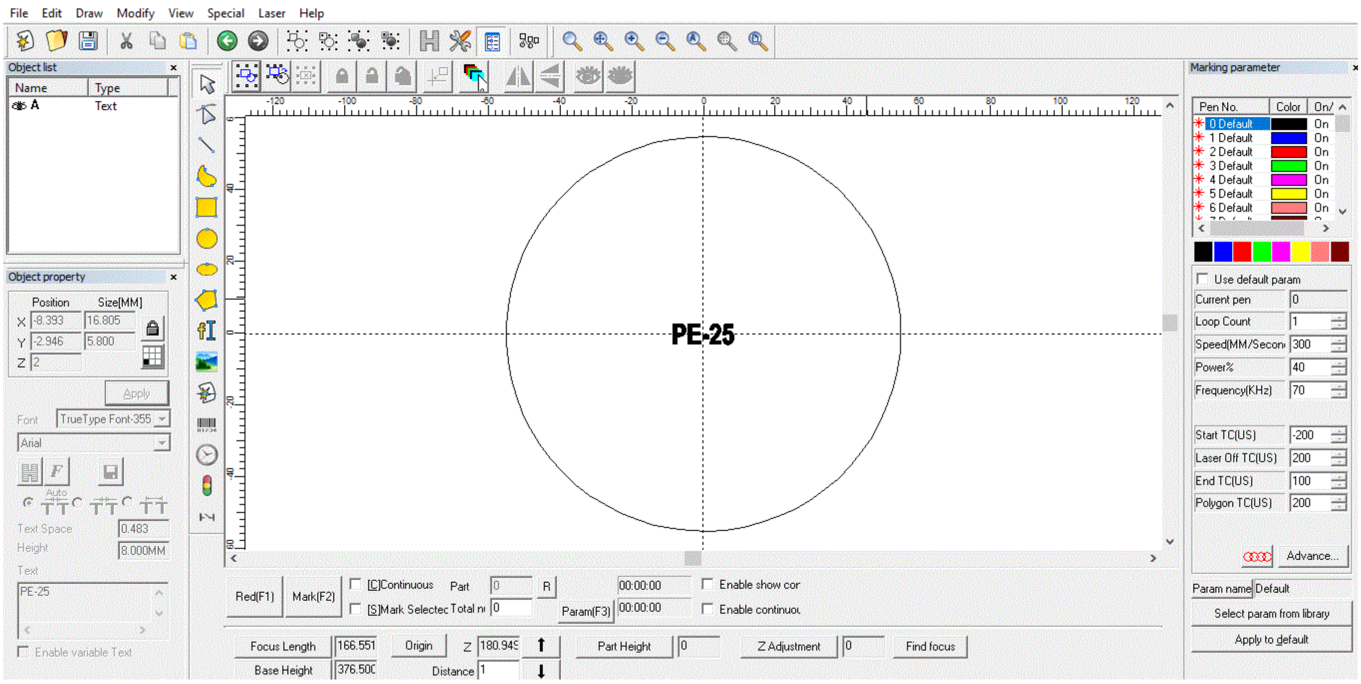
Figure 2 | EZCAD2 interface 1



- **Loops**. The loops refer to the number of passes the laser makes over the same area, affecting the depth and clarity of the engraving. Hard, dense or reflective materials, like stainless steel, would typically require higher number of loops to achieve depth. In contrast, soft, porous or heat-sensitive materials would need fewer loops, as they are more easily engraved and additional passes may cause damage or degrade the quality of the engraving.

A computer and specialised software typically control the movement of the laser beam or the material. Most systems use computer programmes based on the Ezcad2.V2 software, although some manufacturers have created their own dedicated software. The machine's software permits the adjustment of the parameters, and it oftentimes allows for the creation or import the design of the marking or the alphanumeric code to be engraved, which then translates it into a series of movements for the laser.

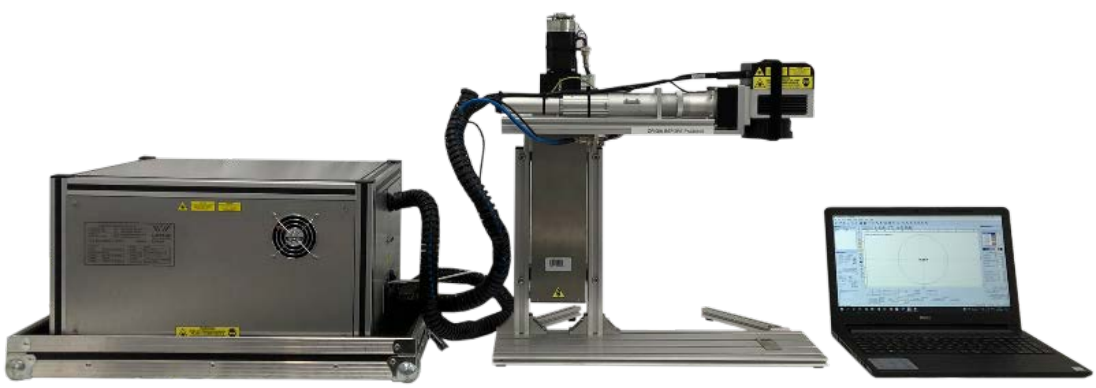
Figure 3 | EZCAD2 user's interface



On older systems, the workpiece is typically placed on a flatbed, which can move in the X and Y directions, while the laser head can also move in the Z direction to adjust the focus. Together, these movements ensure the laser can reach any point on the material's surface. More modern systems move the laser beam over the workpiece which is stationary.

Many laser systems are equipped with a cooling system to prevent overheating and ensure consistent performance. During the process, fumes and particles are generated. An exhaust system removes these from the work area to maintain a clean and safe environment.

Figure 4 | Lotus Laser Systems – Model I-Meta



Types of Lasers Commonly Used for Engraving Metals

Laser engraving allows for marking with extreme precision, including areas that would be inaccessible to other marking instruments. It is also faster than other marking methods. There are three main types of lasers suitable for metal processing, although not all of them perform equally well. What follows is an explanation of these three main lasers and a comparison of their advantages and disadvantages for firearms marking[10].

- **CO_2 Lasers**: Based on the principles of laser engraving machines previously explained, these lasers have a mixture of gases as active medium in the laser cavitation. These gases, when excited by an electric discharge, emit light at a wavelength of 10.6 nm, in the far-infrared range. The laser beam is then focused on the item to be engraved, which would react differently to the laser depending on its material. For example, in some polymers or coated metals, it sublimates small amounts of the material, creating a groove in the surface and leaving a permanent mark; in certain organic materials it can cause carbonisation leaving a darkened mark; and in other materials it can cause a chemical reaction that changes the colour of the affected area leaving a coloured mark, without removing material. It is effective on certain materials that strongly absorb its light like wood, leather, polymers and some metals if coated or treated. However, CO_2 lasers are significantly less effective for metals without surface treatment, hence less fit for firearms marking.
- **Nd:YAG Lasers**: These lasers have as active medium in the laser cavitation a solid crystal of yttrium aluminium garnet (YAG), which is doped with neodymium ions (Nd^{3+}) and then excited or pumped by a diode laser or a lamp to generate the laser beam. The wavelength of the light beam is usually of 1.064 nm, and it is often used for material processing on ceramics, metals, and other hard materials, as well as medical procedures.
- **Fibre Lasers**: These lasers use an optical fibre as active medium, instead of a gas, typically made from glass. That fibre is then doped[11] with rare-earth elements (often, ytterbium, Yb) and excited or pumped by an external source, usually a diode laser, to generate the laser beam. The light is emitted at shorter wavelengths than CO_2 lasers, typically between 1.06 nm and 1.08 nm (near-infrared range), interacting differently with the materials to engrave. These shorter wavelengths are more readily absorbed by metals (especially on stainless steel, aluminium and titanium) and plastics, where the heat can sublimate the material also leaving a groove and permanent mark, ensuring high energy efficiency and precision. This type of laser is therefore highly efficient for engraving on metals and polymers and, since most of the essential parts of firearms to be marked are made of these materials, fibre lasers are one of the preferred technologies for this aim.

When marking firearms, achieving precise depth while avoiding damage to the functional systems is paramount. Since each material reacts uniquely to laser energy based on its inherent properties, it is crucial to consider what materials will be engraved when choosing a type of laser machine, and when configuring its optimal settings each time that is being used, to ensure accurate and damage-free marking.

In that regard, most firearm components – such as the frame, receiver, barrel, slide, and cylinder – are typically made from various metals and, in some cases, polymers. The standard materials (in order of hardness) most frequently used in the manufacture of firearms are steels between

[10] For additional information, please refer to N. Papageorgiou. (2023). "Types of lasers used in metal processing". *International Scientific Journal Machines. Technologies. Materials*.
[11] Doping refers to the process of adding small amounts of elements into the optical fibre to change its properties.

4140 and 4150, aluminium alloys 6082 and 7075, and polymer[12]. As such, two laser options are most suitable for the marking of firearms: fibre lasers and diode-pumped Nd:YAG lasers, with fibre laser as a better choice in the long term.

Table 5 | Comparison table of types of lasers for firearms engraving[13]

	Fiber laser	Diode-pumped Nd:YAG laser	CO_2 laser
Absorption by metals	Excellent	Excellent	Fair
Beam quality	Excellent	Fair	Good
Reliability	Excellent	Poor	Poor
Portability	Excellent	Fair	Poor
Initial cost	Good	Good	Excellent
Maintenance	Excellent	Poor	Poor
Longevity	Excellent	Poor	Poor
Energy efficiency	Good	Fair	Poor

Nd:YAG lasers, are suitable for engraving text, logos, and designs on a wide range of materials, including metals and plastics. The beam quality, however, is generally lower than that of fibre lasers, affecting the precision and, while they offer a relatively lower initial cost, their lifespan is significantly shorter, of approximately 15,000 hours.

Fibre laser machines, while requiring a higher initial investment compared to the Nd:YAG lasers, offer significant long-term advantages. These include a more compact design and easier to be transported, less need for periodic maintenance, lower risk of internal damage, and a substantially longer lifespan of between 50,000 and 100,000 hours, depending on the model. Additionally, fibre lasers consume less energy while providing greater power output and offer higher reliability. These features make fibre lasers an especially appealing choice as new solution for firearms marking.

[12] Some of the polymers that can often be found in firearms include a nylon-based synthetic polymer (Glock polymer), Zytel polymer, inter alia.
[13] Table based on N. Papageorgiou. (2023). “Types of lasers used in metal processing”. *International Scientific Journal Machines. Technologies. Materials;* and EVLaser (2024). “From the CO2 Laser to the Fiber Laser, we discover the most popular types of lasers”.

3. RECOVERABILITY OF OBLITERATED LASER-ENGRAVED MARKINGS

Markings allow firearm examiners and investigators to trace firearms back to their origin, owners, or criminal use. For that reason, criminals tend to obliterate the serial numbers and other firearm markings to hamper identification. As such, restoration of obliterated markings is a crucial tool in criminal investigations. Sometimes a visual examination using a stereomicroscope along with gentle polishing reveals erased markings. If that is not sufficient, firearm examiners can apply specialised forensic techniques to restore the obliterated markings, facilitating their identification.

According to the Association of Firearm and Tool Mark Examiners (AFTE), obliteration can be conducted through various methods, such as grinding, drilling, engraving, peening or punching, scratching, over-stamping or overpunching, welding or other heating processes, rusting, and reapplication of original finish. When criminals remove serial numbers, they most commonly use grinding and most often this is only done to just below the point of the original stamping.

The restoration process exploits the fact that marking methods, such as stamping or laser engraving, cause permanent deformation of the material beneath the surface. This deformation alters the crystalline structure of the material, leaving behind a hidden imprint even if the surface has been obliterated and the marks are no longer visible. Criminals could obliterate the markings so deeply that the altered crystalline structure is unrecoverable, but if that is not done, firearm examiners may be able to restore them entirely or partially.

Restoration methods

The main restoration methods are chemical etching, electromagnetic techniques and ultrasonic cavitation. Chemical etching and electromagnetic methods are the most used techniques for restoring obliterated markings due to their effectiveness, versatility and, in the case of electromagnetic, non-destructive nature. Successful restoration is dependent on the method and focused application by the firearms examiner, the depth that the serial number has been removed, as well as the material and the marking method applied, and as such results can be variable.

Chemical etching involves applying an etching solution over the area in question after it has been polished to a mirror finish. There are several etching solutions available, most of which are acid based, with different formulations used for different metals. For ferrous metals, such as steel and stainless steel, common etching solutions include Fry's reagent and 10% nitric acid, whereas for aluminium and its alloys, typically used solutions include 10-20% sodium hydroxide and 10% nitric acid, among others.

Once applied on the polished surface, the solution etches and eats away the disordered metal more quickly than the sound metal around it, allowing the serial numbers to slowly come into view. Sometimes, if necessary, to speed up this process an electrical current (electrochemical etching) can be applied. This method is widely used for all metals and certain other materials, and it is effective when the deformation extends below the obliterated surface; it is, however, a destructive method.

The electromagnetic or magnetic particle inspection method works by magnetising the firearm or the component, which produce ripples of magnetic forces that identify where the metal had been disordered by the marking process. The area in question is then sprayed with an oil containing coloured iron particles. These particles settle in the places where the metal is disordered and therefore reveal the obliterated serial number. This method is particularly effective and non-destructive, although it is only suitable for ferrous metals that are magnetic or paramagnetic (i.e. steel, mild steel, steel alloys, or stainless steel).

Another non-destructive method is the **magneto-optical sensor.** It uses a sensor that is placed onto the surface where the markings have been obliterated and uses the Faraday effect (the interaction between light and a magnetic field) to detect the subtle magnetic differences in the material crystalline structure created when the markings were applied. The sensor projects light onto the metal and measures how the reflected light is polarised. These different reflections are then interpreted by the equipment and translated into a visual representation of the original serial numbers.[14]

Ultrasonic cavitation is another method whereby the firearm is placed in a special ultrasonic bath of water which inundates it with super high frequency vibrations. When these vibrations produce tiny bubbles along the surface of the metal the cavitation process begins to work. With repeated exposure the process of cavitation eats away the metal in the places where the metal is disordered restoring the serial number. This method is not commonly used due to equipment complexity, lower resolution and being destructive.

It is worth highlighting that most serial number restoration methods involve polishing the surface to achieve a mirror-like finish. When the markings and their underneath imprint are shallow, they can be easily erased during the surface preparation process required for the etching method. In the case of laser engraved marks, since the depth of the deformation of the crystalline structure is generally not as deep as with stamping, special care must be taken during the polishing phase, not going that far so as not to remove the imprinted layer.

When markings are obliterated on polymer materials, firearm examiners can employ methods such as **solvent treatment** and **heat treatment** to attempt restoration of the obliterated marks. For solvent methods, the surface where the marking was removed should first be polished as smoothly as possible, and then a solvent (commonly acetone for polymers) is applied. For heat treatment, after polishing, heat is applied using a hot air gun set to approximately 250°C. During both the solvent and heat treatments, the obliterated markings may become visible for a short period before the polymer begins to melt. It is important to note that the effectiveness of these processes is generally lower compared to methods used for metals, and both approaches are destructive to the material.

Effectiveness of restoration methods in relation to the marking method

The recoverability of obliterated markings depends not only on the restoration method and the competence of the firearm examiner, but also on how the markings were originally applied and subsequently obliterated. For the restoration to be effective, the material's crystalline structure beneath the surface must have been altered during the marking process. Therefore, the marking method and the depth of the applied markings on the firearms are critical factors that States must carefully consider.

Of the various marking methods, those applying cold pressure (such as stamping and dot-peen) have proved as the most recoverable. These methods mark the material through compression, there is no loss of mass of the material, it causes a plastic deformation altering the crystalline structure of the material under the markings. As a consequence, if the marks have been applied

[14] National Institute of Justice, Office of Investigative and Forensic Sciences, Office of Justice Programs. (2015). "Forensic Technology Center of Excellence: Validation and Evaluation of Magneto-Optical Imaging Technology for Recovering Obliterated Serial Numbers in Firearms".

at a certain depth (ideally >0,2mm), restoring obliterated markings becomes relatively easier because there is a significant deformation of the material underneath. Stamping, the most used technique for marking metal, induces the most significant permanent deformation of the material's crystalline structure. This deformation can extend to depths as much as six times greater than the depth of the stamp itself,[15] depending on the material and the marking depth. These structural changes make stamped markings relatively recoverable, even after obliteration. Studies suggest that obliterated stamped markings can be successfully restored in approximately one third of cases.[16]

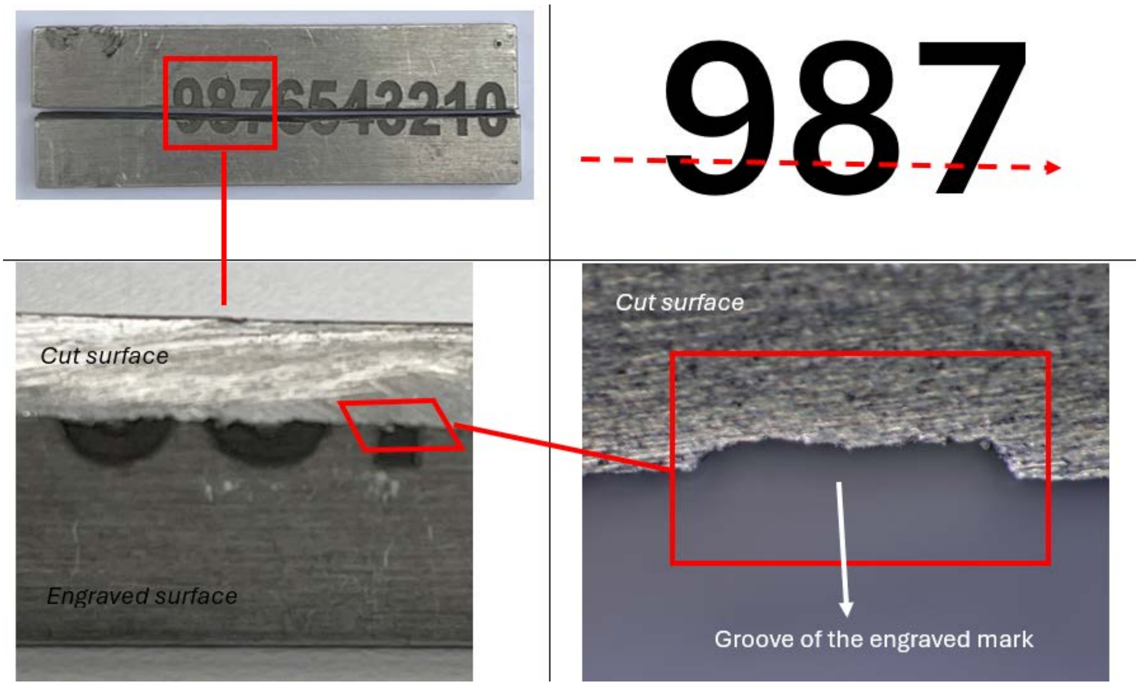
Laser engraving implies a less deep permanent deformation of the crystalline structure than stamping. In the case of laser engraving, the marks are created by removing material through heat, instead of compressing it, so there is not the same plastic deformation.

However, the heat of the laser beam also affects the immediate area subjacent of the marks by annealing it, so there is a modification of the crystalline structure in the heat-affected zone. The alteration of the properties of the material underneath the markings affected by the laser heat is different from the alterations caused by the compression of material through stamping. Theoretically, the depth of the heat affected zone will depend on the exposure to the laser heat (controlled by the power and the engraving speed).[17] Preliminary research (Azlan et al.) on the matter indicated that the affected area beneath the groove can be of few micra 2-25µm.[18] As such, the laser's effect on the areas subjacent to the marks is typically thinner and less pronounced, even if the marking depth is the same as with other methods. The risk of that thin layer being more easily removed can hence pose some challenges in restoring certain markings. Nonetheless, not sufficient scientific research has been conducted on the alteration of the material, without being able to extract clear conclusions about the recoverability of obliterated marks.

To better understand the above for the purpose of this paper, a microscopic examination at 243x magnification of a transversal cut of a marking of approximately 0,18mm was conducted. The observation revealed no visible changes in colour or shape in the substrate directly beneath the engraved area. If any alterations to crystalline structure beneath the engraved area did occur in the range of 2 to 25µm (0,002-0,25m) as suggested by Azlan et al.'s study, they would not be detectable at this magnification. Therefore, it is recommended to observe the alteration of the crystalline structure with a scanning electron microscope (SEM) in future research.

Figure 5 | Transversal cut of an aluminium plate with laser-engraved marks at 0.2mm deep. The image in the centre highlights the depth of the annealed layer (in darker colour) beneath the engraved markings.[19] In the right, microscopic view (obtained using a VisionX microscope, with a magnification of 243x) of a groove from the engraved mark, showing minimal disruption to the area beneath the groove.

[15] United Nations Office for Disarmament Affairs. *MOSAIC 05.30* (2022). Annex 1, A.1 "Stamping".
[16] Ibid.
[17] J.M. Collins. (1999). "Modern Marking and Serial Numbering", *AFTE Journal Vol. 31, number 3*. 309-317
[18] M. Azlan et al. (2007), "Restoration of Engraved Marks on Steel Surfaces by Etching Technique", *Forensic Science International 171(1)*. 27-32, as cited in L. da Silva and P.A. Marques dos Santos, "Case Report: Recovering Obliterated Laser Engraved Serial Numbers in Firearms", *Forensic Science International 179* (2008), 63-66.
[19] Test conducted at UNLIREC headquarters (Lima, Peru).



As with stamping, the recoverability of laser-engraved markings depends on the engraving depth and the properties of the material being marked. The depth of the laser engraved markings also played a role in facilitating the restoration, either because fully obliterating them was more difficult or because they leave a more pronounced imprint on the substrate, which should be demonstrated through additional research. As a conclusion, when using laser engraving, if the marks were applied at sufficient depth and the obliteration was not below that affected layer, the markings could also be restored. As such, an adequate application of laser engraving will determine its effectiveness.

The following section presents the results of a preliminary study aimed at assessing the recoverability of obliterated laser-engraved serial numbers. The goal was to identify the optimal applications of laser engraving for marking firearms to prevent, to the extent possible, their obliteration, and ensure, as far as technically possible, their recoverability.

Research work: recoverability of obliterated laser-engraved serial numbers

The present research investigated whether, and under which conditions, laser engraved marks on materials commonly used for essential firearm components can be restored using the chemical etching and electromagnetic methods. This research provided valuable insights into the minimum depth required for laser-engraved markings to remain recoverable. UNLIREC conducted the research in collaboration with the Scientific Police of Dominican National Police and Dominican Republic's National Defence University, Royal Grenada Police Force, Jamaica's Institute of Forensic Science and Legal Medicine, and Saint Lucia Forensic Science Laboratory, over the period between 11 April and 31 October 2024. The methodology applied in the research involved two stages, namely, laser engraving test, and a test on obliteration and restoration of the obliterated markings.

Stage 1: Laser Engraving (Using Fibre Laser Technology)

The first stage focused on assessing the efficiency of laser engraving on the metals most commonly used metals in firearms' essential components, as well as examining the influence of certain parameters in achieving the desired depth. The experiment aimed at a depth of at least 0.2mm, established as a reference based on the recommended standards for classical (stamped) markings, as outlined in MOSAIC 05.30. The tests did not aim, however, to identify specific values for the parameters, since each machine has different specifications like power, spot diameters, etc., requiring their own set-up. The experiment entailed engraving alphanumeric markings, using three different fibre laser machines, on steel and aluminium plates, each approximately 76 mm long, 25 mm wide, and 6.5 mm thick. Three samples of polymer previously removed from a Glock frame were also examined.

These included:

- 304 stainless steel (13 samples),
- mild steel (12 samples),
- aluminium 7075 (10 samples), and
- aluminium 6082 (6 samples).
- Glock polymer (3 samples).

The depths of the marks placed on each sample were then measured with an electronic depth gauge, and results were recorded in an Excel sheet (see Annex II). The recorded data allowed for the comparison of results and identification of the most adequate parameters to achieve the recommended depth of 0.2mm. This phase was conducted in three locations employing a different **fibre laser machine**:[20]

- UNLIREC office in Lima, Peru (11-12 April 2024), with Lotus Laser Systems – Model I-Meta, manufactured in 2018.

- National Defence University in Santo Domingo, Dominican Republic (10-13 September 2024), with an EVLaser – Model LUX PLUS 50W Fibre, manufactured in 2024.

- Accuttech Engineering lab in Norfolk, United Kingdom (between August and October 2024), with Lotus Laser Systems – Model I-Meta, manufactured in 2020.

[20] All three machines were ytterbium-doped fibre laser. Their technical specifications are detailed in Annex I.

Figure 6 | EVLaser LUX PLUS 50W Fibre

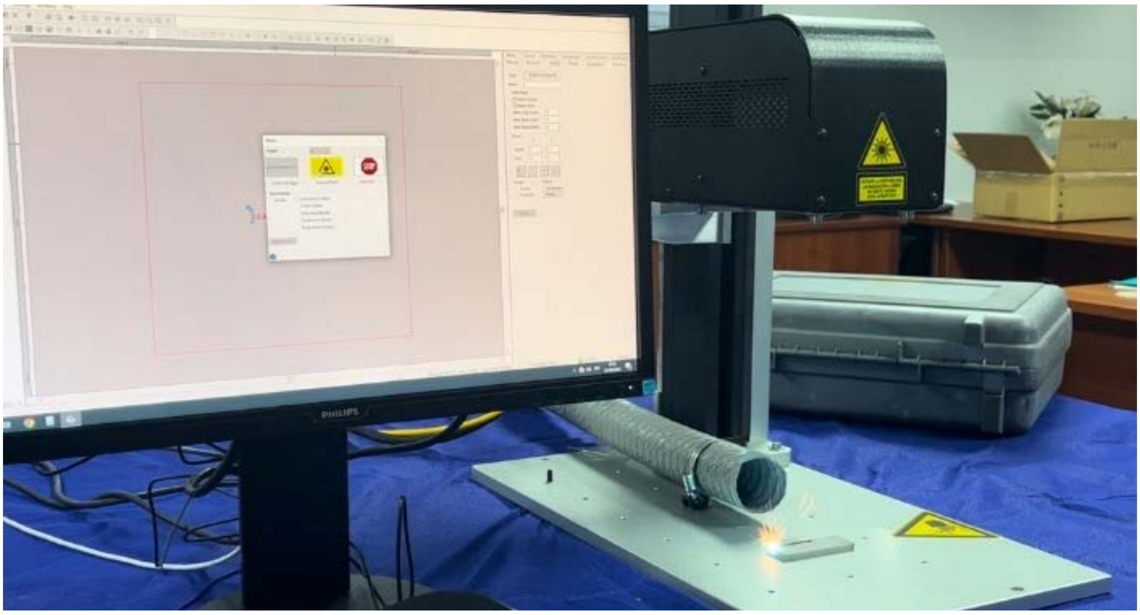


Image of the EVLaser LUX PLUS 50W Fibre functioning. The image exhibits the EZCAD2 software where the parameters and the design of the markings can be set up on the left, and the laser head engraving a serial number on an aluminium plate. An air extractor was also placed to prevent the chemicals in the air causing any damage to the operators. Image taken during the research conducted at Dominican Republic's National Defence University on 12 September 2024.

To achieve the desired depth in each of the metals, the laser machine parameters were configured for each material. Configuration involved adjusting the power, speed, frequency and number of loops to each material, based on the material's hardness, thermal conductivity, and reflectivity.[21] For example, because stainless steel has a higher hardness and slightly better resistance to thermal distortion, high power, medium speed, and relatively lower frequencies with several loops were applied to penetrate its hardness. Similar parameters applied for mild steel. Meanwhile, aluminium 6082 and 7075, which have a lower melting point, speed was increased to avoid overheating the material and causing damage. In contrast to metals, polymers have different thermal and optical properties, such as low thermal conductivity and high absorbance of laser energy. As a result, the laser engraving parameters for polymer materials are distinct, with low power, high speed and only one loop, to prevent melting.

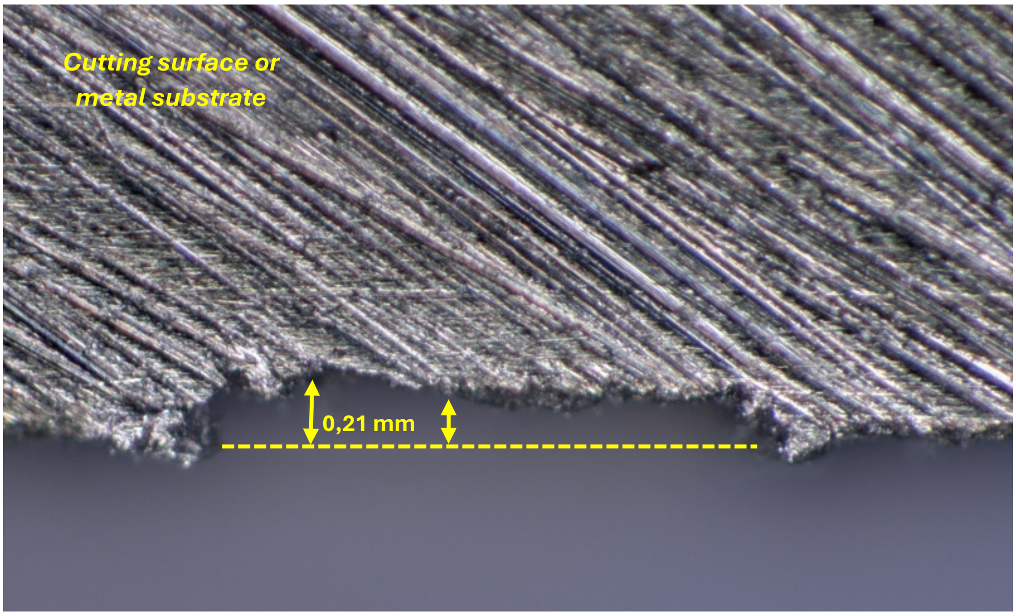
[21] The tests conducted with the two fibre laser machines (Lotus Laser Systems I-Meta and EVLaser LUX PLUS 50W Fibre) used the following parameters to achieve approximately 0.2mm depth. For stainless steel, the following was used: high power (100), medium speed (350-400mm/s), medium frequency (50-70 kHz), and a varying number of loops (3-15) to account for hardness. For mild steel, medium to high power (100), medium speed (300-400 mm/s), medium frequency (50-60 kHz), and 3-15 loops as well. Aluminium 7075 requires medium to high power (70-100), slightly higher speed (400-500 mm/s), medium to high frequency (50-70 kHz), and 3-10 loops. For polymers, low power (5-30), high speed (300–1000 mm/s), high frequency (100–200 kHz), and only 1 loop to avoid damage.

Figure 7 | 304 stainless steel plate with laser engraved markings

304 stainless steel plate with four markings engraved using different parameters with the Lotus Laser Systems Model I-Meta and reaching different depths between 0.08 and 0.22mm. The exercised sought to test the right combination to achieve the desired depth during the research in UNLIREC headquarters, Peru, on 11 April 2024.

Note: During the research, a depth gauge was calibrated and used to measure the depth of the engraved characters, which were subsequently recorded in the Excel. The laser engraved marks on the metal may exhibit minimal variations in depth due to slight density differences within the alloy across its surface. The differences are minimal, but they may result in a marginal difference of microns in the groove's depth. As such, to account for these small variations, at least three measures of each marking were collected to compare results.

Figure 8 | Microscopic view of a steel plate showing laser-engraved markings, with the groove of one number transversally cut for better observation. The image highlights the surface irregularities within the groove of the engraved mark. Image obtained using a VisionX microscope, with a magnification of 243x.



It is also worth noting that during laser engraving, the edges of the engraved marks oftentimes exhibit slight raised areas, which can interfere in the accuracy of depth measurements using the depth gauge. To ensure measurement precision, the engraved surfaces were lightly polished during the experiment. This slight polishing step removed irregularities caused by the raised edges without altering the actual engraving depth, thereby ensuring that the measurements were consistent and accurate.

Figure 9 | Example of the data recorded during the experiment conducted at UNADE, Dominican Republic (10-13 September 2024).

Marking workshop													
Santo Domingo, 10-13 September 2024													
Present: UNLIREC personnel (Ruben Arancibia, Silvia de Pedro)													
	Machine:	EVELASER											
		Marcador laser Industrial Laser marking				Frequency: 50-60Hz							
		Model: LUX PLUS 50W FIBRA				Full load current: 12A							
		No Serie: EVMOF2405011				Manufactured: August 2024							
		Rated voltage: 110-230 Vac				Weight: 90kg							
		Number of phases: 1F+N				Electric schematic number: 0120/2024							
Material	**Steel 304**												
Parameters	Distance	Duration	Loops	Speed	Power	Frequency	Colour	Font	Measure 1	Measure 2	Measure 3	Measure 4	Average
	Automatic	332.4 secs	3	350	100	50	N/A	Arial	0.276	0.307	0.275	N/A	0.286
	Automatic		3	350	100	50	N/A	Arial	0.21	0.214	0.199	N/A	0.207666667
	Automatic		3	350	100	50	N/A	Arial	0.203	0.256	0.21	N/A	0.223
	Automatic		3	350	100	50	N/A	Arial	0.196	0.215	0.204	N/A	0.205
	Automatic		3	350	100	50	N/A	Arial	0.216	0.205	0.222	N/A	0.214333333
Material	**Aluminium 7075**												
Parameters	Distance	Duration	Loops	Speed	Power	Frequency	Colour	Font	Measure 1	Measure 2	Measure 3	Measure 4	Average
	Automatic	60 secs	3	500	100	50	N/A	Arial	0.315	0.27	0.234	0.307	0.2815
	Automatic	60 secs	3	500	100	50	N/A	Arial	0.272	0.314	0.325	0.234	0.28625
	Automatic	60 secs	3	500	100	50	N/A	Arial	0.264	0.442	0.207	0.241	0.2885
	Automatic	60 secs	3	500	100	50	N/A	Arial	0.228	0.3	0.238	0.339	0.27625
	Automatic	60 secs	3	500	100	50	N/A	Arial	0.356	0.301	0.36	0	0.339
	Automatic	60 secs	3	500	100	50	N/A	Arial	0.331	0.336	0.438	0.273	0.3445
	Automatic	60 secs	3	500	100	50	N/A	Arial	0.339	0.241	0.424	0.373	0.34425

Conclusions of marking tests

As a conclusion of the tests, generally, for stainless steel, it is more effective to use high power, slower speeds, and lower frequencies with various loops to penetrate its hardness. For mild steel, moderate power, medium speed, and balanced frequencies with a few loops provide efficient marking. Aluminium 7075 requires moderate power, medium speed, and higher frequencies for precise marks. For polymers, low power, high speed, and high frequencies to prevent damage, typically requiring only one loop. Each machine varies; therefore, calibration and tests should be carried out before starting a firearms marking exercise.

Stage 2: Obliteration of Markings and Restoration of Obliterated Markings

This part of the research involved laser engraving alphanumeric markings on a total of 84 plates made of the most commonly used materials in essential components of firearms to different depths between 0.12 and 0.23 mm (see Annex 3), then intentionally obliterating the markings, and eventually applying different restoration methods to recover them.

The aim was to reproduce the action carried out by criminals to conceal the origin of the weapons and hamper tracing efforts by firearms examiners and criminal investigators and assess their recoverability in the case of laser engraved markings.

It included plates of 304 stainless steel (16 samples), mild steel (13 samples), aluminium 7075 (13 samples), and aluminium 6082 (22 samples). The dimension of the plates was approximately 76 mm long, 25 mm wide, and 6.5 mm thick. Additionally, tests were conducted on 20 samples of Glock polymer. To effectively obliterate the laser engraved marking, a rotary power tool (Dremel-like) was applied to grind the surface until the markings were no longer visible.

After being effectively obliterated, a restoration process was conducted on the 84 samples to evaluate the recoverability of the obliterated markings. The restoration methods used in the experiment were (a) chemical etching (with Frys Reagent on ferrous materials and with 20% Sodium Hydroxide on the aluminium alloys), and (b) electromagnetic method[22] on the magnetic materials (stainless steel and mild steel).[23] The results were recorded as "success" if fully recovered, "partial success" if partially recovered, or "fail" if the marks were not recovered (see Annex 3).

On the stainless steel and steel, both chemical etching and electromagnetic methods were applied in combination. Since the electromagnetic method is non-destructive, it was applied first, and then chemical etching was applied to the same samples. The results of both methods were recorded separately. This allowed to compare the effectiveness of each restoration method on the same samples, whilst ensuring that the results remained consistent and unaffected.

The restoration experiment was conducted by UNLIREC in collaboration with national authorities from the following countries:

- Jamaica's Institute of Forensic Science and Legal Medicine, Jamaica, from 16 to 18 April 2024, using chemical etching method.
- Facilities of the TA Marryshow Community College with Royal Grenada Police Force, Grenada, from 27 to 31 May 2024, using both chemical etching and Magnaflux® methods.
- Saint Lucia Forensic Science Laboratory, Saint Lucia, from 3 to 7 June 2024, using both chemical etching and Magnaflux® methods.
- National Defence University with the Scientific Police of Dominican National Police, Dominican Republic, from 10 to 13 September 2024, using chemical etching method.
- Norfolk, United Kingdom, by UNLIREC technical expert, between August and October 2024, using both chemical etching and Magnaflux® methods.

[22] The product used for the electromagnetic method was MagnaFlux®.
[23] See section 3.1. of this paper for a detailed explanation of each of these restoration methods.

Results of the Restoration Tests:

All the results of the restoration tests can be found in Annex 3 of the present document. The time taken for the recovery ranged from a few minutes to up to 2 hours. What follows is an analysis of the collected data.

a) 304 stainless steel samples

A total of sixteen 304 stainless steel samples were examined, including:

- 14 samples with obliterated laser-engraved markings with a depth of >0.2mm.
- 2 samples with obliterated laser-engraved markings with a depth of 0.15mm.

The restoration methods applied for these samples include electromagnetic method (as 304 stainless steel is a magnetic material), followed by chemical etching with Frys Reagent:

- Electromagnetic method was applied on 12 of the samples with obliterated laser-engraved markings with a depth of >0.2mm, which resulted in “success”.
- Electromagnetic method was applied on the 2 samples with obliterated laser-engraved markings with a depth of 0.15mm, which resulted in “success”.
- Chemical etching applied on the 14 samples with obliterated laser-engraved markings with a depth of >0.2mm, which resulted in “success”.
- Chemical etching applied on the 2 samples with obliterated laser-engraved markings with a depth of 0.15mm, which resulted in “success”.

Laser engraved markings of at least 0.15mm depth on 304 stainless steel were recovered either entirely or partially. Additional research is recommended, especially with shallower depths and other restoration methods.

b) Mild steel samples

A total of 16 mild steel samples were examined, including:

- 11 samples with obliterated laser-engraved markings with a depth of 0.2mm.
- 2 samples with obliterated laser-engraved markings with a depth of 0.14mm.

The restoration methods applied for these samples include chemical etching with Frys Reagent and electromagnetic method (as mild steel is a magnetic material):

- Electromagnetic method was applied on the 11 the samples with obliterated laser-engraved markings with a depth of 0.2mm, which resulted in “success”.
- Chemical etching applied on 10 samples with obliterated laser-engraved markings with a depth of 0.2mm, which resulted in “success”.
- Electromagnetic method was applied on the 2 the samples with obliterated laser-engraved markings with a depth of 0.14mm, which resulted in “fail”.
- Chemical etching applied on the 2 samples with obliterated laser-engraved markings with a depth of 0.14mm, which resulted in “success”.

As a conclusion, laser engraved markings of at least 0.2mm depth on mild steel were recovered with both chemical etching and electromagnetic methods in some instances, whereas markings with a depth of 0.14mm in that material presented challenges, especially with the electromagnetic method. Additional research is recommended, especially with shallower depths and other restoration methods.

Figure 10 | Chemical etching restoration process

Images of the restoration process conducted at the National Defence University, in collaboration with the Scientific Police of Dominican National Police (12 September 2024, Dominican Republic). In the left, the image shows the polishing process on a 304 stainless steel plate where a laser-engraved serial number had been obliterated, prior to applying the acids. In the right, the obliterated markings [ADYP964] temporarily visible after applying the acids.

c) Aluminium 7075 samples

A total of 13 samples of aluminium 7075 were examined, including:

- 11 samples with obliterated laser-engraved markings of >0.22mm deep.
- 1 sample with obliterated laser-engraved markings of 0.15mm deep.
- 1 sample with obliterated laser-engraved markings of 0.12mm deep.

The restoration method applied was chemical etching with 20% Sodium Hydroxide in all the cases, as the materials are not magnetic and therefore unsuitable for the electromagnetic method:

- Chemical etching applied on 11 samples with obliterated laser-engraved markings with a depth of >0.22mm, which resulted in “success”.

- Chemical etching applied on 1 sample with obliterated laser-engraved markings with a depth of 0.15mm, which resulted in “success”.

- Chemical etching applied on 1 sample with obliterated laser-engraved markings with a depth of 0.12mm, which resulted in “fail”.

As a conclusion, laser engraved markings of at least 0.15mm depth on 7075 aluminium were recovered under some circumstances with chemical etching, with successful results of the restoration attempts for the samples of 0.15 and 0.22mm deep of the same material. The attempt to restore the obliterated marking of 0.12mm deep failed. As a conclusion, shallow markings on 7075 aluminium present challenges for recoverability. Additional research is recommended, especially with shallower depths and other restoration methods.

d) Aluminium 6082 samples

A total of 22 samples of aluminium 6082 were examined, including:

- 17 samples with obliterated laser-engraved markings of 0.22mm deep.
- 2 samples with obliterated laser-engraved markings of 0.15mm deep.
- 3 samples with obliterated laser-engraved markings of 0.12mm deep.

The applied restoration method was chemical etching with 20% Sodium Hydroxide, as the materials are not suitable for the electromagnetic method for not being magnetic, and the results were the following:

- Chemical etching applied on 16 samples of >0.22mm deep resulted in "success".
- Chemical etching applied on 1 sample of >0.22mm resulted in "fail".
- Chemical etching applied on 2 samples of 0.15mm deep resulted in "success".
- Chemical etching applied on 1 sample of 0.12mm deep resulted in "success".
- Chemical etching applied on 2 samples of 0.12mm deep resulted in "fail".

As a conclusion, laser engraved markings of at least 0.22mm depth on 6082 aluminium were recovered with chemical etching in some instances, although with more challenges than in other materials. Markings with a depth of 0.12mm in that material also presented more challenges. Additional research is recommended, especially with shallower depths and other restoration methods.

Figure 10 | Example of the data recorded during the experiment conducted in Norfolk, United Kingdom (September-October 2024)

Results from UK (Sept - Oct 2024)

Material	Depth (mm)	Obliterate technique	Restoration method	Result (success, partial success, fail)	Evidence	Comments
304 Stainless Steel	0.15	Grinding (Dremel)	Magnaflux	Success	Noted	Non-destructive method
304 Stainless Steel	0.15	Grinding (Dremel)	Chemical etching	Success	Noted	Same sample as above, applying chemical etching after Magnaflux
304 Stainless Steel	0.15	Grinding (Dremel)	Magnaflux	Success	Noted	Non-destructive method
304 Stainless Steel	0.15	Grinding (Dremel)	Chemical etching	Success	Noted	Same sample as above, applying chemical etching after Magnaflux
Aluminium 6082	0.12	Grinding (Dremel)	Chemical Etching	Success	Noted	
Aluminium 6082	0.12	Grinding (Dremel)	Chemical Etching	Fail	Noted	
Aluminium 6082	0.12	Grinding (Dremel)	Chemical Etching	Fail	Noted	
Aluminium 6082	0.15	Grinding (Dremel)	Chemical Etching	Success	Noted	
Aluminium 6083	0.15	Grinding (Dremel)	Chemical Etching	Success	Noted	
Aluminium 7075	0.12	Grinding (Dremel)	Chemical Etching	Fail	Noted	
Aluminium 7075	0.12	Grinding (Dremel)	Chemical Etching	Success	Noted	
Aluminium 7075	0.15	Grinding (Dremel)	Chemical Etching	Success	Noted	
Aluminium 7075	0.15	Grinding (Dremel)	Chemical Etching	Success	Noted	
Mild steel	0.14	Grinding (Dremel)	Magnaflux	Fail	Noted	Non-destructive method
Mild steel	0.14	Grinding (Dremel)	Chemical Etching	Success	Noted	Same sample as above, applying chemical etching after Magnaflux
Mild steel	0.14	Grinding (Dremel)	Magnaflux	Fail	Noted	Non-destructive method
Mild steel	0.14	Grinding (Dremel)	Chemical Etching	Success	Noted	Same sample as above, applying chemical etching after Magnaflux

Additionally, tests were carried out by UNLIREC in the United Kingdom on 20 samples of Glock polymer using solvents and heat treatment to recover serial numbers. The polymer samples were polished to achieve a near-mirror finish, after which a solvent (acetone) was applied, but this yielded no results. Heat treatment was then performed using a hot air gun at 250°C. **Restoration of obliterated markings of 0.22mm deep using solvents were not successful despite several**

attempts, and the method resulted destructive. Restoration of obliterated markings of 0.22mm or deeper by heat treatment was partially successful in approximately 50% of cases. However, the restored markings were only visible briefly, as the polymer began to melt under the applied heat, with the method being destructive.

Conclusions of the Research on the Recoverability of Obliterated Laser-engraved Markings

The restoration process, though time-intensive and requiring patience and determination, hold promising potential. **The research reveals that laser-engraved alphanumeric markings on stainless steel, mild steel and aluminium with a depth greater than 0.2 mm, can to certain extent be restored.** However, shallower markings present more significant challenges. Despite some obliterated markings being irrecoverable due to a lower depth of crystalline deformation, this research suggests that **laser-engraving offers "visible, durable, and as far as technically possible, recoverable" markings, in line with the International Tracing Instrument (para 7, ITI).**

Tests on magnetic materials (304 stainless steel and mild steel) demonstrated a higher success rate with chemical etching compared to electromagnetic methods. **Notably, the electromagnetic method caused no surface damage, allowing subsequent chemical etching on the same sample – a combination of methods identified as good practice, where both methods are applicable.**

It is worth noting that this preliminary research introduces the topic, but its limited scope necessitates further controlled testing with larger sample sizes to validate the findings. The experiments conducted in this research provided empirical evidence indicating that laser-engraved markings can, to some extent, be restored. However, it is necessary to gather complementary data to strengthen the scientific basis for this conclusion. This research can contribute to, and be further expanded by, the ongoing efforts of the United Nations, in line with the mandate from RevCon4[24]. Future research should aim to collect data across Latin America and the Caribbean and beyond. The insights gained from these efforts will benefit forensic practitioners in restoring serial numbers on firearms and aid authorities and individuals in designing effective firearms marking protocols.

[24] United Nations. (2024). *Report of the Fourth United Nations Conference to Review Progress Made in the Implementation of the Programme of Action to Prevent, Combat and Eradicate the Illicit Trade in Small Arms and Light Weapons in All Its Aspects* (A/CONF.192/2024/RC/3).

4. CONCLUSIONS AND RECOMMENDATIONS ON THE USE OF LASER FOR EFFECTIVE FIREARMS MARKING

Based on a review of best practices and the findings of this research, several conclusions can be drawn regarding the use of laser technology for engraving markings on firearms, ensuring compliance with international standards.

Advantages and Disadvantages of Laser Engraving for Firearms Marking

There are various marking methods available, most of which are generally effective, though some may better meet specific needs than others. Therefore, when a State is determining which marking method to adopt, it is crucial to first identify its specific requirements. For instance, while stamping remains the most commonly used firearms marking method, laser engraving is increasingly becoming a preferred option in certain cases, especially among manufacturers. The research institute Small Arms Survey has proposed a set of factors to consider during the evaluation process, categorised into technical and cost factors.[25] In this section, we analyse the advantages and disadvantages of laser engravings based on that framework.

Technical factors

a) Ability to Mark Different Materials

The versatility of laser engraving is an advantage. While mandatory markings at the time of manufacture and importation should be applied to metal parts (such as the frame, receiver, barrel, slide, and cylinder), laser engraving also offers the flexibility to include additional markings to non-metallic components made of polymer, which are increasingly found in modern firearms. Unlike other marking methods, laser engraving is effective on any material used in firearms manufacturing, including metals, polymers, and composite materials like wood. On the contrary, mechanical methods like stamping, dot-peen, or scribing do not work on polymers or the use is not recommended. It is crucial, though, to adjust the laser settings to the specific material to be engraved and conduct a test before marking a batch of firearms, in order to avoid potential damage, such as microcracks caused by the rapid heating and cooling of the laser beam.

b) Suitability of Marking Assembled Firearms

Marking assembled firearms present challenges for certain methods, particularly stamping, which requires physical contact that can potentially damage delicate parts of the firearm or be difficult to apply in hard-to-reach areas. Laser engraving, however, offers an advantage as it marks surfaces without direct contact, making it ideal for marking assembled firearms and accessing small areas. This flexibility allows laser engraving to be used effectively at virtually any stage of a firearm's lifecycle, making it especially valuable for importation and secondary markings. This enhances compliance with international regulations and improves traceability, offering greater adaptability in meeting diverse marking requirements.

[25] Small Arms Survey. (2010). "The Method Behind the Mark: A Review of Firearms Marking Technologies". *Small Arms Survey*.

c) Recoverability of Obliterated Markings

Recoverability of obliterated markings is an essential factor in the choice of a marking method, in order to facilitate the tracing of the firearms. Lack of sufficient scientific research on the matter has led to a general believe that laser engraved markings cannot be recovered This paper sought to challenge that assumption by contributing to the discussion and highlighting the need for further research. The test findings indicated that, under certain conditions and with a depth of 0.2mm, it can be possible to recover obliterated serial numbers on steel, stainless steel, and aluminium. However, additional studies are necessary to further substantiate these findings and provide a more comprehensive understanding of the recoverability of laser-engraved markings. Such research would support evidence-based decisions on the effectiveness of laser engraving compared to traditional methods and inform standards for its application in firearm marking.

d) Marking Speed and Marking Rate

Marking speed reflects the time it takes the machine to imprint the marking, whereas the marking rate is the number of firearms marked per unit of time. The marking speed depends only on the machine, but the marking rate depends on other factors like the time it takes to prepare the firearm for marking the rate of creating a unique marking code, and the registration of the marking.[26]

Modern marking methods can mark firearms in a few seconds, allowing for high-throughput operations. Modern laser systems can produce clear, durable markings in a few seconds too.[27] Nonetheless, one of the primary advantages of laser engraving is its marking rate. Three characteristics mainly save time compared to other methods: (1) the software permits automatising serialised numbers and codes, which is particularly valuable in scale manufacturing or marking large numbers of firearms, (2) the possibility of automatically registering data, and (3) the non-contact nature of the laser also minimises the set-up time, reducing delays caused by wear-and-tear on marking tools, increasing productivity.

e) Precision and Access to Minuscule Areas

Laser engraving ensures high precision and enables the creation of intricate designs and fine markings. This capability is crucial for firearms, as it allows for the marking of small, confined, or hard-to-reach areas that may be inaccessible to traditional stamping or mechanical engraving tools, especially after assembly. The precision also ensures consistent marking quality, even on curved or irregular surfaces, making it ideal for high-detail requirements such as serial numbers or micro-text. The software that controls the machine enables control of the parameters with accuracy, reaching the desired depth and size with precision.

f) Advantage for Security Markings

In addition to traditional markings, firearms may incorporate security markings[28] as a safeguard against the removal or alteration of classical markings. These security markings are discreetly applied to components that are challenging to access post-manufacture or would damage the weapon, such as the ejector, breech, extractor, or internal barrel surfaces. Security markings should replicate the information provided by traditional markings.

Security markings provide a discreet method of identification, supporting law enforcement efforts by providing a means to trace firearms even when overt markings have been tampered with.

[26] Small Arms Survey. (2010). "The Method Behind the Mark: A Review of Firearms Marking Technologies". *Small Arms Survey*.
[27] The time to engrave a 10-digit number on steel with a fibre laser engraving machine depends on several factors, such as the laser's speed, power, and the type of engraving. However, for example, based on the research conducted as part of this paper, engraving a 10-digit number with a depth of 0.2mm could take typically between 50 seconds to 2 minutes.
[28] United Nations Office for Disarmament Affairs. *MOSAIC 05.30* (2022). 5.7.3. "Security markings".

Based on its capacity to mark without physical contact and to reach minuscule areas, laser technology is particularly advantageous for this purpose.

g) Engraving Additional Symbols and Other Markings

Laser allows for engraving very small marks, enabling options beyond traditional alphanumeric markings. International standards require manufacturing and import markings to be easily recognisable and readable using alphanumeric codes or combination of geometric symbols with alphanumeric symbols, but additional markings like logos, symbols or barcodes can also be engraved providing a wealth of information in a confined space. Barcodes, in particular, are gaining attention as they can store extensive data, such as manufacturing details, ownership history, and import records – provided they are supported by robust record-keeping systems. These alternative markings can improve traceability and add a layer of technological sophistication to firearm marking practices.

h) Estimated Lifespan

Lifespan of laser engraving machines, as with other types of marking methods, depends on the use given to the machine. Usually, fibre laser engraving machines have a lifespan of 50,000-100,000 working hours, which can be between 5 to 10 years depending on the model and the given use. Nd:YAG lasers have a shorter lifespan of approximately 15,000 hours. On the other hand, the lifespan of mechanical marking methods like stamping, dot-peen, and scribing can be between 8 and 15 years too, usually limited by the wear of consumables and components due to the physical use.

Cost factors

a) Costs of the Equipment

Compared to other marking methods, the initial disbursement for a laser engraving machine is usually more expensive. Prices would vary depending on the type of laser, manufacturers, makes and models, but on average entry-level models of fibre laser engraving machines cost around USD 40,000-48,000. Meanwhile, price of stamping machines can range between USD 5,500-7,000, dot-peen machines between USD 6,800-9,000, and scribing machines for USD 16,000-19,000.[29] However, it is worth noting that usually these entry-level models of laser engraving machines already offer capabilities that are often unavailable in other marking systems or offered as upgrades at additional costs. Such is the case of a software to design or automatically produce consecutive serial numbers and codes or creating a database. Moreover, considering its long lifespan and marking rate, the higher initial investment is offset by the long-term cost benefits, especially in large-scale production. For instance, when marking tens of thousands of firearms annually, the cost per unit can drop to as low as USD 1 or less, making laser marking a cost-effective choice in high-volume settings.

b) Operating Costs (Energy Consumption and Labour Costs)

Operating costs include energy and labour costs. In the case of energy costs, laser marking systems typically have higher energy consumption compared to mechanical systems. Based on the review conducted by Small Arms Survey, all modern methods normally operate with a maximum energy consumption of under 1kW. On average, fibre laser machines use on average

[29] This price comparison was based on information obtained by Small Arms Survey from questionnaires sent to and filled out by different marking machines suppliers (including Gravograph, Marking Methods, Inc. Pryor, Simet and Schmidt Marking Systems), as reflected in its publication "The Method Behind the Mark" (2010), as well as UNLIREC's market research on laser engraving machines in 2023-2024 (including Lotus Laser Systems and EVLaser).

500 watts, with a maximum of up to 800 watts, while for instance, a dot-peen machine has a maximum power consumption of 575 watts, with an average usage of under 200 watts.[30]

However, laser engraving machines require less manual labour due to their higher level of automation, as described in previous paragraph on marking rate. Related to that, laser machines also require minimal training, usually no more than a day, and providing companies often include basic training in the purchase price. This trade-off between energy and labour costs must be evaluated based on the foreseen use, namely the scale of the firearms to be marked annually and in the long run.

c) Maintenance Costs

Mechanical marking methods such as stamping, dot-peen and scribing machines generally require lower maintenance (mostly related to periodic replacement of components that wear due to their physical use) than laser engraving machines. Laser engraving machines represent a more complex and higher-maintenance technology. Over the first five years, the maintenance costs of a laser engraving machine are comparable of those of other mechanical systems, around USD 1,400, most significantly in relation to their cooling systems and air filters, which require periodic maintenance to prevent overheating and safety issues.[31] Over the years, the costs of maintenance the laser tube, computer system or the internal optics may increase. However, laser engraving machines suffer less deterioration since there is no physical contact when marking, ensuring its higher precision and quality over time.

In conclusion, the choice of firearms marking method – whether laser engraving, or mechanical methods like stamping, dot-peen or scribing – should depend on a comprehensive analysis of various technical and cost factors. Each method offers specific advantages and disadvantages based on the requirements of the marking process. In particular, laser engraving provides the greatest flexibility in marking different materials, as well as precision and the ability to access small or hard-to-reach areas without physical contact, making it suitable for assembled firearms and security markings. However, it comes with higher initial costs, energy consumption, and potentially higher maintenance expenses over time. Ultimately, the decision on which marking method to adopt should therefore be based on factors such as the number of firearms to be marked, the stage of marking (before or after assembly), available budget, labour capabilities, time efficiency, and the long-term maintenance and operational costs.

Recommendations for Implementing Laser Engraving

Based on the analysis above, if laser engraving is selected as the preferred method for a firearms marking exercise, the following recommendations should be taken into consideration. It is crucial to prioritise both operational safety and preservation of the firearm's functionality.

The objective is to achieve clear, durable and tamper-resistant markings, while mitigating risks to personnel, equipment and the firearm itself. It is therefore important to consider the technical specifications of the laser system, the material properties of the area to be marked, and the environment where the marking exercise will be carried out. What follows are some general recommendations extracted from a revision of relevant literature and the experiments conducted during the research of this paper.

[30] Information also collected by Small Arms Survey from the questionnaires referred above.
[31] Information based on Small Arms Survey's questionnaire and conversations with EVLaser engineer.

Selecting the Appropriate Laser Type

- The first step is to select the appropriate laser type. As previously mentioned, fibre laser and diode-pumped Nd:YAG laser machines may be most suitable, as they allow for highly controlled marking on metal surfaces without generating excessive heat or depth. Fiber laser machines tend to entail a greater upfront cost than Nd:YAG lasers, but they offer numerous long-term benefits that make them a more interesting option. Importantly, fibre laser machines have a significantly larger lifespan, lower operating costs, and reduced maintenance requirements. They also have a more compact design and reliability of the laser source.
- When deciding which machine to purchase, it is recommended that research and consultations be carried out with a technical expert on the required technical specifications. During procurement, consult with the supplier to review the technical specifications of their different products to identify the best option for the intended purpose. The decision should also consider maintenance costs and the location where it will be placed.

Equipment Location

- Equipment should be located in a dedicated area, which is either well-ventilated or equipped with fume extractors. The equipment should also be placed on a stable surface, with access to electricity and ample room for ergonomic operation. The environment must be maintained within the machine's recommended temperature and humidity ranges. The access to the marking area should be restricted to authorized personnel only, using physical barriers or access control systems.

Trained Personnel

- When planning, it is important to allocate sufficient funds for training of personnel. Only trained operators should be allowed to use the laser machine, including training on safety procedures, the use of the machine, maintenance of the equipment, and handling of firearms (see 4.4).

Ensuring Compliance with Regulations

- It must be ensured that the marking exercise complies with national and international regulations on firearms marking. For that purpose, standardised guidelines for the depth, size, legibility and design of the marks should be developed in advance and thoroughly followed during the engraving process. It could be a good practice to develop inspection procedures to verify marking quality and maintain consistency.
- Markings should be applied in full compliance with international standards and in line with national regulations and marking protocols. All the markings should be properly recorded in the relevant registries (digital/paperwork systems) to allow for adequate arms control practices and facilitate the tracing. The records should identify the serial number, make, model and type of firearm and record any additional original markings.
- In line with international standards (para. 7, ITI), the research conducted as part of this paper indicated that laser-engraving allows for markings "visible and durable", and whilst when the markings are not obliterated below the thin layer of altered material underneath the engraved areas, they seem to be "as far as technically possible, recoverable". While

the internationally accepted recommendation of a depth of *at least* 0.2mm[32]was initially established for classic markings applied with stamping method, this preliminary research suggests that ensuring at least the same depth or more with laser-engraved markings remains important. Doing so increases the difficulty of completely obliterating both the markings and the affected layer below.

- Additional scientific research is recommended on the recoverability of markings on firearms, so that the United Nations can make additional evidence-based arguments regarding the parameters and use of laser engraving for firearms marking. This recommendation aligns with the ongoing effort by the Secretariat, following the mandate received in RevCon4 (paragraph 164 of the Outcome Document), to conduct a study on obliterated markings and methods of marking recovery in the context of the International Tracing Instrument, and to report the findings to the next Biennial Meeting of States in 2026.

Optimising Machine Parameters and Material Composition

- Once the equipment is installed, attention must be turned to the laser's settings and parameters.
    - **Recommendations for firearms manufacturers applying primary markings (at the time of manufacture)**

      The laser machine might be installed on the production line. Operators must carefully calibrate the laser machine before applying the markings on a batch. This process starts with identifying the specific materials used in the firearm component to be marked (which will typically be known as part of the production). The laser parameters – such as power, speed, frequency, and number of passes – must be precisely adjusted to each material type to avoid overheating or damaging the firearm's functionality. Following the laser manufacturer's operational guidelines and incorporating quality control checks into the production workflow is essential to ensure consistent, compliant results.
    - **Recommendations for national authorities applying secondary markings (e.g. import or additional markings)**

      Operators must first verify the material composition of the firearm component to be engraved. Since this may vary between manufacturers and models, visual inspection, magnet testing, and the expertise of trained personnel are important in determining the appropriate laser settings. Parameters – power, speed, frequency, and number of loops – must be precisely adjusted to the material to avoid excessive heat or structural damage. It is crucial to ensure the depth and the quality of the markings. Authorities should adhere to the laser manufacturer's guidelines and, where possible, conduct preliminary tests on sample pieces to calibrate the machine appropriately for each marking operation.
- Conduct tests to identify which parameters produce the desired outcome before starting a marking process. Using the lowest power level necessary to achieve the desired marking and pairing it with higher speed settings can reduce heat exposure and ensure a clean result. However, the international standard of 0.2mm depth should generally be safe for essential metal components like the frame and the receiver.

[32] As recommended in MOSAIC 05.30 for markings applied with stamping method for manufacture marking.

- During the marking process, it is also recommended to securely fix the firearm using plasticine or a similar product to ensure it remains steady during the engraving process. This would reduce the risk of accidental slips.
- When marking a number of firearms, it is recommended to engrave the firearms or components in batches of the same make and model, because having the laser parameters and the placement pre-set will save a significant amount of time, and therefore resources.
- A clear and documented chain of custody for firearms must be maintained throughout all the process, to prevent loss, theft, or unauthorized handling during the process.

Enhancing Research and Methodology

- Complement the preliminary research in this paper with continuous and rigorous scientific investigation on this topic, enhancing the applied methodology to derive more robust conclusions. To achieve that, collaboration with universities, forensic laboratories and research centres is recommended.

Operational Considerations

In order to optimize the performance and efficiency of laser engraving, several operational factors must be carefully considered. These include the marking speed and rate, which influence the time and resources of the engraving process, as well as the energy requirements that directly affect both the quality of the engraving and operational costs. Additionally, ensuring safety is paramount, as proper safety measures are essential to protect operators and equipment. This subsection explores these considerations.

Marking Speed and Marking Rate

The time dedicated to marking firearms is an important factor for States to consider when planning marking programmes and choosing a marking method. Efficient marking helps reduce administrative burdens, better allocate resources, and enhance firearm traceability.

Marking speed and the marking rate are central to operational efficiency. Compared to other marking methods, laser engraving offers slightly faster marking speeds and significantly faster marking rates. It requires minimal set-up time, allowing for the configuration and automatically engraving of consecutive serial numbers.

When planning a laser-marking exercise, it is essential to assess the number of firearms to be marked and the time needed per unit. This calculation must factor in the set-up time, actual marking time (marking speed and marking rate), quality checks, and record-keeping time. Additionally, it is recommended to account for potential machine maintenance, unexpected delays, and technical issues.

Energy Requirements

Laser systems vary significantly in their energy consumption, with more advanced systems, such as fibre lasers, offering higher efficiency compared to traditional Nd:YAG or CO_2 lasers. Energy requirements should be carefully assessed to minimise operational costs, especially for large-scale programs where energy usage can become a significant expense. Fibre lasers are particularly advantageous, as they provide high marking quality while consuming less electricity, reducing long-term utility costs.

In addition to cost considerations, energy efficiency aligns with environmental sustainability goals. In that sense, authorities may prioritise laser systems that are energy-efficient, reducing the carbon footprint of the marking process. Fiber lasers are an excellent choice in this regard, as they deliver superior performance with minimal energy wastage.

Authorities must evaluate the infrastructure required to support energy demands, particularly in decentralised or mobile marking setups. Portable laser marking systems that operate efficiently on standard power supplies can enhance flexibility in resource-constrained environments.

Safety Measures for Laser Engraving Firearms

When employing laser engraving technology for firearm marking, strict safety protocols must be observed:

a) Firearm Handling Safety

- Always treat a firearm as if it is loaded and point it in a safe direction.
- Never point a firearm at anyone/anything that you do not wish to harm or injure.
- Never place a finger on a trigger when transporting a firearm from one place to another even if you believe it to be unloaded.
- Anyone who has consumed alcohol, drugs, or other substances that are likely to impair normal mental or physical bodily functions, or is tired, cold or impaired in any way must never handle firearms.

b) Operator Safety

- Ocular protection: the use of laser safety goggles, certified for the specific wavelength and power output of the laser, is imperative to safeguard the operator's vision.
- Dermal protection: long-sleeved garments, gloves, and a lab coat to protect the skin from potential laser radiation exposure.
- Environmental considerations: the workspace should be well-ventilated to dissipate fumes and particulates generated during the engraving process. An air extractor is recommended. Additionally, flammable materials should be kept away from the laser's operational area.

c) Equipment Safety

- Routine maintenance checks are crucial to ensure the laser machine's optimal performance and safety.
- Accurate alignment of the laser beam is essential to prevent unintended laser exposure and ensure precise marking.
- Emergency procedures, such an emergency stop button to halt the laser operation, should be implemented in case of unforeseen circumstances.
- Change the filters of the air extractor regularly, following the instructions of the manufacturer.

By adhering to these safety measures, the risks associated with laser engraving firearms can be significantly mitigated, ensuring the safety of both the operator and the firearm itself.

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ANNEX 1 – Technical Specifications of Fibre Laser Machines Used for the Experiment

Laser engraving machine 1 *(UNLIREC – Lima, Peru)*	**Laser engraving machine 2** *(UNADE – Santo Domingo, Dominican Republic)*	**Laser engraving machine 3** *(Norfolk, United Kingdom)*
LOTUS Laser Systems	EVLaser	LOTUS Laser Systems
Model: I-Meta	Model: LUX PLUS 50W Fibre	Model: I-Meta
Laser type: Ytterbium-doped fibre	Laser type: Ytterbium-doped fibre	Laser type: Ytterbium-doped fibre
Wavelength: 1064nm	Wavelength: 1064nm	Wavelength: 1064nm
Input voltage: 100-240 Vac	Input voltage: 110-230 Vac	Input voltage: 100-240 Vac
Frequency: 50-60Hz	Frequency: 50-60Hz	Frequency: 50-60Hz
	Spot diameter: 30 µm @ F160	
Operating temperature: 15-30C	Operating temperature: 10-35C	Operating temperature: 15-30C
Safety class: 4 (according to EN 60825-1: 2014)	Safety class: 4 (according to EN 60825-1: 2014)	Safety class: 4 (according to EN 60825-1: 2014)
Manufacture year: January 2018	Manufacture year: August 2024	Manufacture year: January 2020
Weight: 66kg (no ventilation system)	Weight: 90kg (including ventilation system)	Weight: 66kg (no ventilation system)

ANNEX 2 – Results of Laser Engraving Tests

Marking workshop													
Lima, 11-12 April 2024													
Present: UNLIREC personnel (Jason Francis, Philip Boyce, Ruben Arancibia, Jimmy Arroyo, Silvia de Pedro)													
	Machine:	Lotus Laser Systems				Model: I-Meta							
		Ytterbium pulsed fiber				Weight: 66kg							
		Wavelength: 1064nm				Power supply: 100-240VAC 50/60Hz 1a							
		Output: 50w 1mJ 2-200kHz				Ambient temp:n15c min to 30c max							
		Safety: Class 4				Humidity: 40-70%							
		Pointer: <0.99mW cw @ 655nm				Manufactured: January 2018							
Material	**Stainless steel**												
Parameter	Distance	Duration	Loop	Speed	Power	Frequency	Colour	Font	Measure 1	Measure 2	Measure 3	Measure 4	Average
	Z20	N/A	5	400	100	70	black	Arial	0.036	0.057	0.035	N/A	0.04266667
	Z10	N/A	5	400	100	70	black	Arial	0.167	0.111	0.137	N/A	0.13833333
	Z10	N/A	10	400	100	70	black	Arial	0.196	0.106	0.135	0.17	0.15175
	Z10	N/A	10	400	100	70	blue	Arial	0.235	0.228	0.21	0.18	0.21325
	Z10	N/A	5	400	100	70	yellow	Arial	0.17	0.178	0.171	0.03	0.13725
	Z10	N/A	1	500	50	30	yellow	Arial	N/A	N/A	N/A	N/A	N/A
	Z10	N/A	10	500	100	70	red	Arial	N/A	N/A	N/A	N/A	N/A
	Z10	N/A	10	400	100	70	black	Arial	0.199	0.154	0.179	N/A	0.17733333
	Z10	N/A	**15**	**400**	**100**	**70**	**white**	**Arial**	**0.28**	**0.271**	**0.267**	N/A	**0.27266667**
	Z120	N/A	**16**	**400**	**100**	**70**	**black**	**Arial**	**0.25**	**0.22**	**0.206**	N/A	**0.22533333**
Material	**Aluminium 6082**												
Parameter	Distance	Duration	Loop	Speed	Power	Frequency	Colour	Font	Measure 1	Measure 2	Measure 3	Measure 4	Average
	Z10	N/A	5	400	100	70	white	Arial	N/A	N/A	N/A	N/A	N/A
	Z5	N/A	5	400	100	70	white	Arial	0.276	0.282	0.285	N/A	0.281
	Z5	N/A	**10**	**400**	**100**	**70**	**white**	**Arial**	**0.491**	**0.492**	**0.485**	N/A	**0.48933333**
Material	**Polymer**												
Parameter	Distance	Duration	Loop	Speed	Power	Frequency	Colour		Measure 1	Measure 2	Measure 3	Measure 4	Average
	Z5	**N/A**	**1**	**300**	**20**	**50**	**white**		**0.642**	**0.694**	**0.593**	**N/A**	**0.643**
Material	**Mild steel**												
Parameter	Distance	Duration	Loop	Speed	Power	Frequency	Colour	Font	Measure 1	Measure 2	Measure 3	Measure 4	Average
	Z120	N/A	15	400	100	70	white	Arial	0.141	0.131	0.137	N/A	0.13633333
	Z120	N/A	15	400	100	70	white	Arial	0.132	0.129	0.115	N/A	0.12533333
	Z130	N/A	15	400	100	70	white	Arial	N/A	N/A	N/A	N/A	N/A
	Z110	N/A	15	400	100	70	white	Arial	N/A	N/A	N/A	N/A	N/A
	Z125	N/A	15	400	100	70	white	Arial	N/A	N/A	N/A	N/A	N/A
	Z120	N/A	30	1000	100	70	black	Arial	0.098	0.094	0.079	N/A	0.09033333
	Z120	N/A	15	400	100	70	black	Arial	0.12	0.12	0.116	N/A	0.11866667
	Z120	N/A	30	500	100	70	white	Arial	0.12	0.112	0.123	N/A	0.11833333
	Z120	N/A	15	400	100	70	black	Arial	0.175	0.175	0.112	N/A	0.154
	Z120	N/A	**20**	**400**	**100**	**70**	**black**	**Arial**	**0.347**	**0.343**	**0.412**	N/A	**0.36733333**
Material	**Aluminium 7075**												
Parameter	Distance	Duration	Loop	Speed	Power	Frequency	Colour	Font	Measure 1	Measure 2	Measure 3	Measure 4	Average
	Z120	**N/A**	**10**	**400**	**100**	**70**	**black**	**Arial**	**0.33**	**0.466**	**0.402**	N/A	**0.39933333**

Marking workshop													
Santo Domingo, 10-13 September 2024													
Present: UNLIREC personnel (Ruben Arancibia, Silvia de Pedro)													
	Machine:	EVELASER											
		Marcador laser Industrial Laser marking				Frequency: 50-60Hz							
		Model: LUX PLUS 50W FIBRA				Full load current: 12A							
		No Serie: EVMOF2405011				Manufactured: August 2024							
		Rated voltage: 110-230 Vac				Weight: 90kg							
		Number of phases: 1F+N				Electric schematic number: 0120/2024							
Material	**Steel 304**												
Parameters	Distance	Duration	Loops	Speed	Power	Frequency	Colour	Font	Measure 1	Measure 2	Measure 3	Measure 4	Average
	Automatic	332.4 secs	3	350	100	50	N/A	Arial	0.276	0.307	0.275	N/A	0.286
	Automatic		3	350	100	50	N/A	Arial	0.21	0.214	0.199	N/A	0.207666667
	Automatic		3	350	100	50	N/A	Arial	0.203	0.256	0.21	N/A	0.223
	Automatic		3	350	100	50	N/A	Arial	0.196	0.215	0.204	N/A	0.205
	Automatic		3	350	100	50	N/A	Arial	0.216	0.205	0.222	N/A	0.214333333
Material	**Aluminium 7075**												
Parameters	Distance	Duration	Loops	Speed	Power	Frequency	Colour	Font	Measure 1	Measure 2	Measure 3	Measure 4	Average
	Automatic	60 secs	3	500	100	50	N/A	Arial	0.315	0.27	0.234	0.307	0.2815
	Automatic	60 secs	3	500	100	50	N/A	Arial	0.272	0.314	0.325	0.234	0.28625
	Automatic	60 secs	3	500	100	50	N/A	Arial	0.264	0.442	0.207	0.241	0.2885
	Automatic	60 secs	3	500	100	50	N/A	Arial	0.228	0.3	0.238	0.339	0.27625
	Automatic	60 secs	3	500	100	50	N/A	Arial	0.356	0.301	0.36	0	0.339
	Automatic	60 secs	3	500	100	50	N/A	Arial	0.331	0.336	0.438	0.273	0.3445
	Automatic	60 secs	3	500	100	50	N/A	Arial	0.339	0.241	0.424	0.373	0.34425

Laser engraving tests													
Norfolk, UK, Aug-Oct 2024													
Present: UNLIREC personnel (Philip Boyce)													
Acuttech	Machine:	Lotus Laser Systems				Model: I-Meta							
Engineering		Ytterbium pulsed fiber				Weight: 66kg							
		Wavelength: 1064nm				Power supply: 100-240VAC 50/60Hz 1a				Gauge: Digital Tyre depth			
		Output: 50w 1mJ 2-200kHz				Ambient temp:n15c min to 30c max				accuracy to 0.01mm only			
		Safety: Class 4				Humidity: 40-70%							
		Pointer: <0.99mW cw @ 655nm				Manufactured: October 2020							
Material	**Stainless steel**												
Parameters	Distance	Duration	Loops	Speed	Power	Frequency	Colour	Font	Measure 1	Measure 2	Measure 3	Measure 4	Average
	Z10	N/A	15	400	100	70	white	Arial	0.25	0.26	0.26	NA	0.2566667
	Z20	N/A	16	400	100	70	white	Arial	0.24	0.23	0.23	NA	0.2333333
	Z10	N/A	20	400	100	50	white	Arial	0.22	0.22	0.22	NA	0.22
Material	**Aluminium 6082**												
Parameters	Distance	Duration	Loops	Speed	Power	Frequency	Colour	Font	Measure 1	Measure 2	Measure 3	Measure 4	Average
	Z5	N/A	5	400	100	70	white	Arial	0.26	0.28	0.26	NA	0.2666667
	Z5	N/A	10	400	100	70	white	Arial	0.38	0.39	0.38	NA	0.3833333
	Z20	N/A	10	400	100	50	white	Arial	0.29	0.28	0.28	NA	0.2833333
Material	**Glock Polymer**												
Parameters	Distance	Duration	Loops	Speed	Power	Frequency	Colour	Font	Measure 1	Measure 2	Measure 3	Measure 4	Average
	Z5	N/A	1	300	10	50	white	arial	0.26	0.27	0.26	NA	0.2633333
	Z5	N/A	1	300	5	50	white	arils	0.19	0.17	0.18	NA	0.18
Material	**Mild steel**												
Parameters	Distance	Duration	Loops	Speed	Power	Frequency	Colour	Font	Measure 1	Measure 2	Measure 3	Measure 4	Average
	Z20	N/A	15	400	100	70	white	Arial	0.19	0.2	0.19	NA	0.1933333
	Z20	N/A	20	400	100	70	white	Arial	0.25	0.26	0.27	NA	0.26
Material	**Aluminium 7075**												
Parameters	Distance		Loops	Speed	Power	Frequency	Colour	Font	Measure 1	Measure 2	Measure 3	Measure 4	Average
	Z20	N/A	10	400	70	50	white	Arial	0.19	0.2	0.2	NA	0.1966667
	Z20	N/A	10	400	100	50	white	Arial	0.25	0.26	0.26	NA	0.2566667

ANNEX 3 – Results of Obliterated Marking Restoration Tests

Marking restoration exercises

Results from Jamaica (16-18 April 2024)

Material	Depth (mm)	Obliterate technique	Restoration method	Result (success, partial success, fail)	Evidence	Comments
304 Stainless Steel	0.23	Grinding (Dremel)	Chemical etching	Success	Noted	

Results from Grenada (27-31 May 2024)

Material	Depth (mm)	Obliterate technique	Restoration method	Result (success, partial success, fail)	Evidence	Comments
304 Stainless Steel	0.23	Grinding (Dremel)	Magnaflux	Success	Noted	Non-destructive method
304 Stainless Steel	0.23	Grinding (Dremel)	Chemical etching	Success	Noted	Same sample as above, applying chemical etching after Magnaflux
Aluminium 6082	0.22	Dremel	Chemical Etching	Success	Noted	
Mild steel	0.2	N/A	Magnaflux	Success	Noted	

Results from Saint Lucia (3-7 June 2024)

Material	Depth (mm)	Obliterate technique	Restoration method	Result (success, partial success, fail)	Evidence	Comments
304 Stainless Steel	0.23	Grinding (Dremel)	Magnaflux	Success	Noted	Non-destructive method
304 Stainless Steel	0.23	Grinding (Dremel)	Chemical etching	Success	Noted	Same sample as above, applying chemical etching after Magnaflux
Aluminium 7075	0.22	Grinding (Dremel)	Chemical Etching	Success	Noted	

Results from Dominican Republic (10-13 September 2024)

Material	Depth (mm)	Obliterate technique	Restoration method	Result (success, partial success, fail)	Evidence	Comments
304 Stainless Steel	0.23	Grinding (Dremel)	Chemical etching	Success	Noted	
Aluminium 6082	0.23	Grinding (Dremel)	Chemical etching	Fail	Noted	

Results from UK (Aug - Sept 2024)

Material	Depth (mm)	Obliterate technique	Restoration method	Result (success, partial success, fail)	Evidence	Comments
304 Stainless Steel	0.23	Grinding (Dremel)	Magnaflux	Success	Noted	Non-destructive method
304 Stainless Steel	0.23	Grinding (Dremel)	Magnaflux	Success	Noted	Non-destructive method
304 Stainless Steel	0.23	Grinding (Dremel)	Magnaflux	Success	Noted	Non-destructive method
304 Stainless Steel	0.23	Grinding (Dremel)	Magnaflux	Success	Noted	Non-destructive method
304 Stainless Steel	0.23	Grinding (Dremel)	Magnaflux	Success	Noted	Non-destructive method
304 Stainless Steel	0.23	Grinding (Dremel)	Magnaflux	Success	Noted	Non-destructive method
304 Stainless Steel	0.23	Grinding (Dremel)	Magnaflux	Success	Noted	Non-destructive method
304 Stainless Steel	0.23	Grinding (Dremel)	Magnaflux	Success	Noted	Non-destructive method
304 Stainless Steel	0.23	Grinding (Dremel)	Magnaflux	Success	Noted	Non-destructive method
304 Stainless Steel	0.23	Grinding (Dremel)	Magnaflux	Success	Noted	Non-destructive method
304 Stainless Steel	0.23	Grinding (Dremel)	Chemical etching	Success	Noted	Same 10 samples as above, applying chemical etching after Magnaflux
304 Stainless Steel	0.23	Grinding (Dremel)	Chemical etching	Success	Noted	Same 10 samples as above, applying chemical etching after Magnaflux
304 Stainless Steel	0.23	Grinding (Dremel)	Chemical etching	Success	Noted	Same 10 samples as above, applying chemical etching after Magnaflux
304 Stainless Steel	0.23	Grinding (Dremel)	Chemical etching	Success	Noted	Same 10 samples as above, applying chemical etching after Magnaflux
304 Stainless Steel	0.23	Grinding (Dremel)	Chemical etching	Success	Noted	Same 10 samples as above, applying chemical etching after Magnaflux
304 Stainless Steel	0.23	Grinding (Dremel)	Chemical etching	Success	Noted	Same 10 samples as above, applying chemical etching after Magnaflux
304 Stainless Steel	0.23	Grinding (Dremel)	Chemical etching	Success	Noted	Same 10 samples as above, applying chemical etching after Magnaflux
304 Stainless Steel	0.23	Grinding (Dremel)	Chemical etching	Success	Noted	Same 10 samples as above, applying chemical etching after Magnaflux
304 Stainless Steel	0.23	Grinding (Dremel)	Chemical etching	Success	Noted	Same 10 samples as above, applying chemical etching after Magnaflux
304 Stainless Steel	0.23	Grinding (Dremel)	Chemical etching	Success	Noted	Same 10 samples as above, applying chemical etching after Magnaflux
Aluminium 6082	0.22	Grinding (Dremel)	Chemical Etching	Success	Noted	
Aluminium 6082	0.22	Grinding (Dremel)	Chemical Etching	Success	Noted	
Aluminium 6082	0.22	Grinding (Dremel)	Chemical Etching	Success	Noted	
Aluminium 6082	0.22	Grinding (Dremel)	Chemical Etching	Success	Noted	
Aluminium 6082	0.22	Grinding (Dremel)	Chemical Etching	Success	Noted	
Aluminium 6082	0.22	Grinding (Dremel)	Chemical Etching	Success	Noted	
Aluminium 6082	0.22	Grinding (Dremel)	Chemical Etching	Success	Noted	
Aluminium 6082	0.22	Grinding (Dremel)	Chemical Etching	Success	Noted	
Aluminium 6082	0.22	Grinding (Dremel)	Chemical Etching	Success	Noted	
Aluminium 6082	0.22	Grinding (Dremel)	Chemical Etching	Success	Noted	
Aluminium 6082	0.22	Grinding (Dremel)	Chemical Etching	Success	Noted	
Aluminium 6082	0.22	Grinding (Dremel)	Chemical Etching	Success	Noted	
Aluminium 6082	0.22	Grinding (Dremel)	Chemical Etching	Success	Noted	
Aluminium 6082	0.22	Grinding (Dremel)	Chemical Etching	Success	Noted	
Aluminium 6082	0.22	Grinding (Dremel)	Chemical Etching	Success	Noted	
Aluminium 7075	0.22	Grinding (Dremel)	Chemical Etching	Success	Noted	
Aluminium 7075	0.22	Grinding (Dremel)	Chemical Etching	Success	Noted	
Aluminium 7075	0.22	Grinding (Dremel)	Chemical Etching	Success	Noted	
Aluminium 7075	0.22	Grinding (Dremel)	Chemical Etching	Success	Noted	
Aluminium 7075	0.22	Grinding (Dremel)	Chemical Etching	Success	Noted	
Aluminium 7075	0.22	Grinding (Dremel)	Chemical Etching	Success	Noted	
Aluminium 7075	0.22	Grinding (Dremel)	Chemical Etching	Success	Noted	
Aluminium 7075	0.22	Grinding (Dremel)	Chemical Etching	Success	Noted	
Aluminium 7075	0.22	Grinding (Dremel)	Chemical Etching	Success	Noted	
Aluminium 7075	0.22	Grinding (Dremel)	Chemical Etching	Success	Noted	

Mild steel	0.2	Grinding (Dremel)	Magnaflux	Success	Noted	Non-destructive method
Mild steel	0.2	Grinding (Dremel)	Magnaflux	Success	Noted	Non-destructive method
Mild steel	0.2	Grinding (Dremel)	Magnaflux	Success	Noted	Non-destructive method
Mild steel	0.2	Grinding (Dremel)	Magnaflux	Success	Noted	Non-destructive method
Mild steel	0.2	Grinding (Dremel)	Magnaflux	Success	Noted	Non-destructive method
Mild steel	0.2	Grinding (Dremel)	Magnaflux	Success	Noted	Non-destructive method
Mild steel	0.2	Grinding (Dremel)	Magnaflux	Success	Noted	Non-destructive method
Mild steel	0.2	Grinding (Dremel)	Magnaflux	Success	Noted	Non-destructive method
Mild steel	0.2	Grinding (Dremel)	Magnaflux	Success	Noted	Non-destructive method
Mild steel	0.2	Grinding (Dremel)	Magnaflux	Success	Noted	Non-destructive method
Mild steel	0.2	Grinding (Dremel)	Chemical Etching	Success	Noted	Same 10 samples as above, applying chemical etching after Magnaflux
Mild steel	0.2	Grinding (Dremel)	Chemical Etching	Success	Noted	Same 10 samples as above, applying chemical etching after Magnaflux
Mild steel	0.2	Grinding (Dremel)	Chemical Etching	Success	Noted	Same 10 samples as above, applying chemical etching after Magnaflux
Mild steel	0.2	Grinding (Dremel)	Chemical Etching	Success	Noted	Same 10 samples as above, applying chemical etching after Magnaflux
Mild steel	0.2	Grinding (Dremel)	Chemical Etching	Success	Noted	Same 10 samples as above, applying chemical etching after Magnaflux
Mild steel	0.2	Grinding (Dremel)	Chemical Etching	Success	Noted	Same 10 samples as above, applying chemical etching after Magnaflux
Mild steel	0.2	Grinding (Dremel)	Chemical Etching	Success	Noted	Same 10 samples as above, applying chemical etching after Magnaflux
Mild steel	0.2	Grinding (Dremel)	Chemical Etching	Success	Noted	Same 10 samples as above, applying chemical etching after Magnaflux
Mild steel	0.2	Grinding (Dremel)	Chemical Etching	Success	Noted	Same 10 samples as above, applying chemical etching after Magnaflux
Mild steel	0.2	Grinding (Dremel)	Chemical Etching	Success	Noted	Same 10 samples as above, applying chemical etching after Magnaflux
Glock Polymer	0.22	Grinding (Dremel)	Solvent	Fail	Noted	Several attempts made. Destructive method
Glock Polymer	0.22	Grinding (Dremel)	Heat tratment	Success	Noted	Destructive method
Glock Polymer	0.22	Grinding (Dremel)	Heat tratment	Success	Noted	Destructive method
Glock Polymer	0.22	Grinding (Dremel)	Heat tratment	Success	Noted	Destructive method
Glock Polymer	0.22	Grinding (Dremel)	Heat tratment	Success	Noted	Destructive method
Glock Polymer	0.22	Grinding (Dremel)	Heat tratment	Success	Noted	Destructive method
Glock Polymer	0.22	Grinding (Dremel)	Heat tratment	Success	Noted	Destructive method
Glock Polymer	0.22	Grinding (Dremel)	Heat tratment	Success	Noted	Destructive method
Glock Polymer	0.22	Grinding (Dremel)	Heat tratment	Success	Noted	Destructive method
Glock Polymer	0.22	Grinding (Dremel)	Heat tratment	Success	Noted	Destructive method
Glock Polymer	0.22	Grinding (Dremel)	Heat tratment	Success	Noted	Destructive method
Glock Polymer	0.22	Grinding (Dremel)	Heat tratment	Fail	Noted	Destructive method
Glock Polymer	0.22	Grinding (Dremel)	Heat tratment	Fail	Noted	Destructive method
Glock Polymer	0.22	Grinding (Dremel)	Heat tratment	Fail	Noted	Destructive method
Glock Polymer	0.22	Grinding (Dremel)	Heat tratment	Fail	Noted	Destructive method
Glock Polymer	0.22	Grinding (Dremel)	Heat tratment	Fail	Noted	Destructive method
Glock Polymer	0.22	Grinding (Dremel)	Heat tratment	Fail	Noted	Destructive method
Glock Polymer	0.22	Grinding (Dremel)	Heat tratment	Fail	Noted	Destructive method
Glock Polymer	0.22	Grinding (Dremel)	Heat tratment	Fail	Noted	Destructive method
Glock Polymer	0.22	Grinding (Dremel)	Heat tratment	Fail	Noted	Destructive method
Glock Polymer	0.22	Grinding (Dremel)	Heat tratment	Fail	Noted	Destructive method
Glock Polymer	0.22	Grinding (Dremel)	Heat tratment	Fail	Noted	Destructive method

Results from UK (Sept - Oct 2024)

Material	Depth (mm)	Obliterate technique	Restoration method	Result (success, partial success, fail)	Evidence	Comments
304 Stainless Steel	0.15	Grinding (Dremel)	Magnaflux	Success	Noted	Non-destructive method
304 Stainless Steel	0.15	Grinding (Dremel)	Chemical etching	Success	Noted	Same sample as above, applying chemical etching after Magnaflux
304 Stainless Steel	0.15	Grinding (Dremel)	Magnaflux	Success	Noted	Non-destructive method
304 Stainless Steel	0.15	Grinding (Dremel)	Chemical etching	Success	Noted	Same sample as above, applying chemical etching after Magnaflux
Aluminium 6082	0.12	Grinding (Dremel)	Chemical Etching	Success	Noted	
Aluminium 6082	0.12	Grinding (Dremel)	Chemical Etching	Fail	Noted	
Aluminium 6082	0.12	Grinding (Dremel)	Chemical Etching	Fail	Noted	
Aluminium 6082	0.15	Grinding (Dremel)	Chemical Etching	Success	Noted	
Aluminium 6083	0.15	Grinding (Dremel)	Chemical Etching	Success	Noted	
Aluminium 7075	0.12	Grinding (Dremel)	Chemical Etching	Fail	Noted	
Aluminium 7075	0.12	Grinding (Dremel)	Chemical Etching	Success	Noted	
Aluminium 7075	0.15	Grinding (Dremel)	Chemical Etching	Success	Noted	
Aluminium 7075	0.15	Grinding (Dremel)	Chemical Etching	Success	Noted	
Mild steel	0.14	Grinding (Dremel)	Magnaflux	Fail	Noted	Non-destructive method
Mild steel	0.14	Grinding (Dremel)	Chemical Etching	Success	Noted	Same sample as above, applying chemical etching after Magnaflux
Mild steel	0.14	Grinding (Dremel)	Magnaflux	Fail	Noted	Non-destructive method
Mild steel	0.14	Grinding (Dremel)	Chemical Etching	Success	Noted	Same sample as above, applying chemical etching after Magnaflux

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