Unique Marking of Metals and Glass using Picosecond Lasers

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19 January 2016

Picosecond ultrafast lasers are recognized for their ability to produce marks with superior spatial resolution in materials that cannot be marked using nanosecond lasers. For this reason, they have been used in commercial applications such as “black marking” to produce indelible, high contrast logos on the metal casings of smart phones and tablets. Now, research at the University of Dundee (Scotland) using a Coherent industrial ultrafast laser has demonstrated that picosecond lasers can produce an even wider range of novel marking effects that would be impossible or very difficult to create using other laser types. This article explores some of the most interesting of these marking processes.

Fine detailed metal patterns *within* clear glass

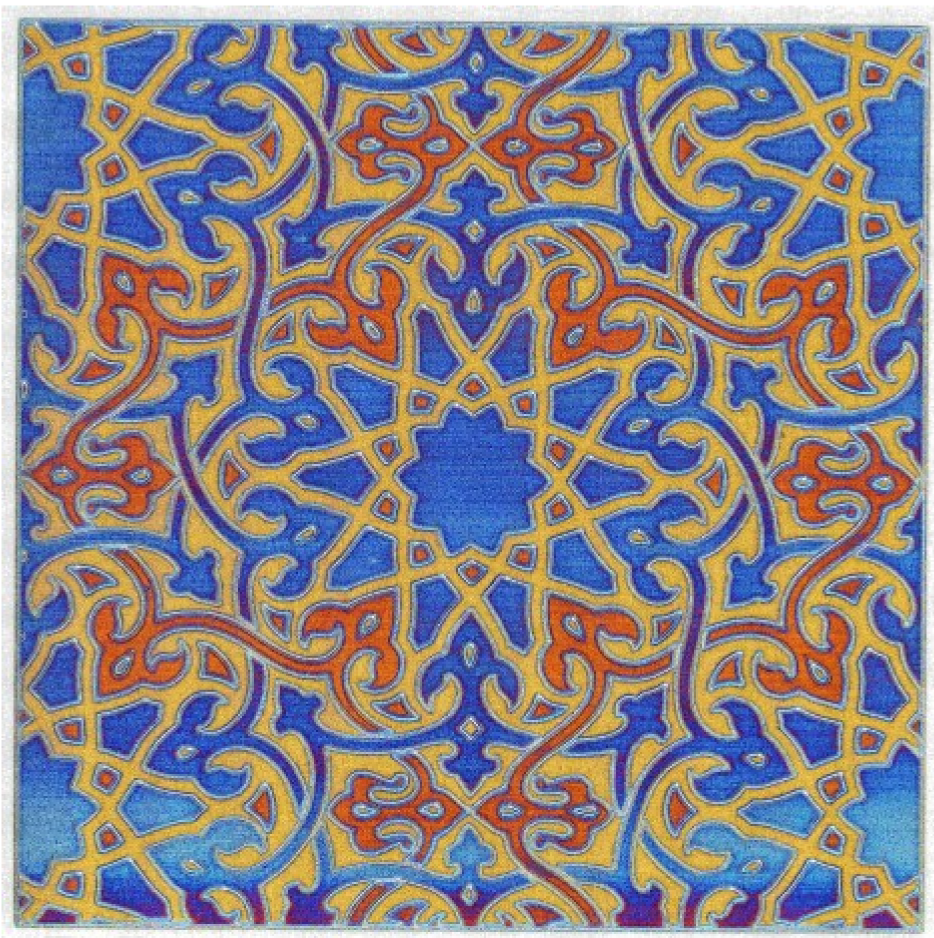
One of the advantages of processing optically transparent materials with an ultrafast laser is that it enables marking inside the material, without affecting the surfaces. This is possible because glasses have very low linear absorption at the wavelength (1064 nm) of most industrial ultrafast lasers. Thus, the material is unaffected along most of the beam path, except at the focused beam waist, where the high intensity drives efficient non-linear absorption. Numerous applications exploit this property of the laser-material interaction. The novel technique presented here combines laser processing with pretreated glass to create metal patterns. (See Figure 1.)

This new process relies on the natural presence of alkali metal ions in conventional soda glass. In the Abdolvand lab, silver paste is applied to one side of a thin glass plate. The plate is then heated to 300°C while a DC field is applied. The electric field pulls the alkali ions from one side of the plate while replacing them with silver ions from the other side. After cooling, removal of the paste yields a still transparent plate.

Tightly focused picosecond pulses create free electrons that combine with silver ions to produce silver atoms, which in turn form silver nanoparticles. This can occur at very high processing speeds. The laser pulse parameters and focusing details determine the size, concentration and spacing of these metallic nanoparticles. The process can create elaborate, detailed, permanent marks inside the glass. While this can deliver spectacular graphics for commercial or artistic marking applications, it also has potential in microelectronics and sensing. Glass is a non-conducting dielectric increasingly used for substrates and interposers in advanced packaging formats. The ability to produce three-dimensional conducting metal lines in glass obviously presents exciting new possibilities.

Colored marks in metal surfaces without coatings

In a simpler process, the Coherent picosecond laser produces vivid multi-colored marks and patterns directly in metal surfaces. Traditionally, colored laser marking has been confined mainly to plastic substrates, often involving additives. Multicolor metal marking typically involves some type of external coating. This new process is a one-step method with no additives, chemicals or coatings.



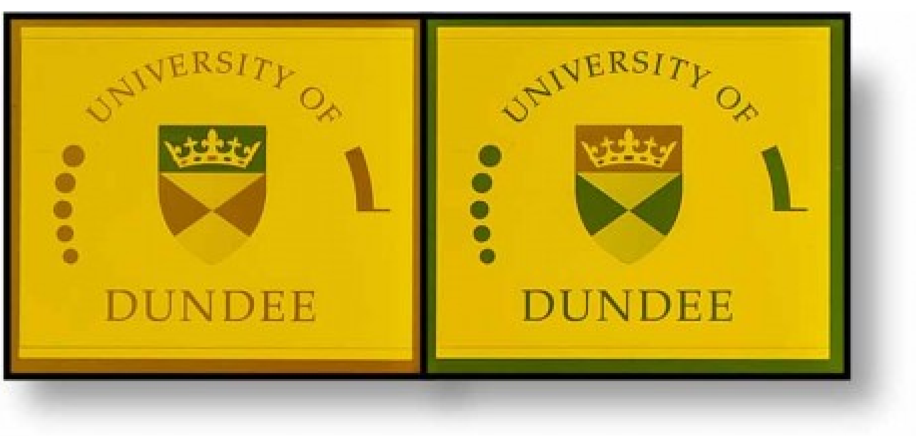
Vivid color marks with incredible detail can be created on metal samples such as this 25 mm ´ 25 mm pattern. Image credit Amin Abdolvand.

Again, tight focusing is employed so that the high peak intensity strips electrons from the metal surface at the focused spot. Some of the energized metal ions react with ambient oxygen, creating a thin outer layer of oxide in the metal. Optical interference between the two reflective surfaces means that only certain wavelengths of light are reflected, resulting in an extremely vivid colored mark, as shown in figure 2. And just like black marking, there is minimum change in surface relief, plus the marks are quite robust under normal “wear and tear” conditions, making them suitable for consumer products and jewelry, for example.

In practice, performing iterative optimization of the laser spot size and pulse energy is a prerequisite for each metal surface to determine the precise conditions for various colors. These parameters are then stored in the system’s computer, enabling the production of full color patterns from simple graphics files. The process details depend very highly on the metal involved. Because the process relies on intense localized energy deposition, steel and titanium deliver excellent results, by virtue of lower thermal conductivity.

Optically dichroic marks in glass

Figure 3 shows a third new type of mark created with the picosecond laser – optically dichroic marking inside glass. Optical dichroism refers to the difference in appearance of a surface when illuminated by linearly polarized light at different polarization orientations. Here the substrate is a specially prepared glass containing nanometer-scale silver particles. These are naturally spherical in shape and thus symmetrically scatter light, i.e., independent of the polarization of light used for viewing. The sizing and spacing of these spheres imparts a wavelength (color) bias to the scattering.



Two images of the same mark viewed using orthogonally polarized light. A Coherent picosecond laser creates the mark (16 mm ´ 20 mm) by subtle reshaping of metal nanoparticles in the glass matrix. Image credit Amin Abdolvand.

As with the metal-in-glass marking, the process relies on focusing picosecond laser pulses within the bulk material, where the energy is preferentially absorbed by the trapped silver nanospheres. Because light from the laser is linearly polarized, the transient electrical field has high intensity along a single axis. As a result, laser exposure permanently deforms the spheres, leaving them in an elliptical state. This ellipticity results in a scattering efficiency that is highly dependent on the polarization of incident light. The capability for three-dimensional discrimination also has potential as a novel approach for high-density data storage.

Providing new ways to mark metal and glass

Many consider laser marking a rather mature application, as it has decades of commercial history. Yet the advent of simple to use and cost-effective ultrafast lasers, specifically in the picosecond regime, is providing completely new ways to mark metals and glasses. Potential applications include high value logos on consumer products, microelectronics, data storage and even aesthetic applications like jewelry and digital art.

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Top Image: A unique process enabled by picosecond lasers was used to create this metallic pattern (18 mm ´ 25 mm) within clear glass. Image credit Amin Abdolvand.

Labels: picosecond laser,University of Dundee,Coherent,marking