ULTRAFAST LASERS ENABLE UNIQUE MARKING EFFECTS

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Picosecond ultrafast lasers have already proven their ability to mark a variety of materials in unique ways. For example, they are used to produce indelible and difficult to counterfeit "black marks" on premium smart phones and tablets, or for applications in which it is critical to make a mark without inducing any peripheral damage due to excessive thermal effects. Ongoing research at the University of Dundee shows that there are other types of marks that can only be produced effectively and affordably with picosecond lasers. Here we describe three very different examples – colored marks on metal, dichroic marks in glass, and metal in glass marking.

Coloured oxide marking of steel and titanium

In coloured marking on metals, such as steel and titanium, the output of a Coherent picosecond laser is focused down to a small spot size on the workpiece. The highly localised energy delivered by the laser oxidises the metal atoms at the surface of the material and forms a metal oxide thin film. When viewed in white light, optical interference effects cause only certain wavelengths of the incident light to be returned constructively (just as in a thin film coating). The end result can be a highly coloured mark, as shown in Figure 1.

This coloured marking process is aesthetically versatile, with the ability to produce different shaped and sized marks, as well as a wide palette of different colors. The colour of each mark depends on the thickness and optical properties of the oxide layer. These are repeatable parameters that are determined empirically and then stored in the computer that controls the laser pulse energy and the scanning parameters of the beam.

With these parameters programmed in, any arbitrary pattern can then be reproduced on the metal surface by simply loading a mark design file in the appropriate file format. Moreover, just like black marking, there is no change in surface relief, and the marks are quite robust under normal "wear and tear" conditions. This

Figure 1: Vivid color marks with incredible detail can be created on metal samples such as this 25 mm × 25 mm sample using a Coherent picosecond laser).

makes them suitable for consumer products and jewellery, for example. The most vibrant marks are produced on steel, and particularly titanium, because the low thermal conductivity of titanium results in intense and localised thermal effects with each laser pulse.

Why picosecond lasers? In truth, some coloured marks can also be produced using nanosecond lasers. However, the precise control of energy dosing and penetration depth afforded by picosecond lasers enables them to deliver marks with more vivid colors and with tighter control of these colours.

Marks with Optical Dichroism

A completely different type of glass mark based on optical dichroism and nanotechnology has also been developed. Optical dichroism refers to a material that behaves differently when illuminated by linearly polarised light at different polarisation orientations. Figure 2 shows an example of this type of marking. These are two images of the exact same mark viewed using two orthogonal (x and y) polarisations.

In this application, we used a glass containing embedded spherical particles of noble metals (e.g., silver) with a typical diameter of around 30 nm, i.e. on the nano-scale. Because these particles are initially spherical, they scatter and reflect light with equal efficiency in every direction and under any polarisation. We then irradiated these particles with linearly polarised light from a Coherent picosecond laser focused within the glass. The high electric field at the beam waist leads to electronic mobility in the particles which are then reshaped into a cigar-like form, where the direction of the long axis is parallel to the electric field vector of the picosecond pulses [1]. These marks are thus internal and permanent to the glass.

Dichroic marks cannot be produced using nanosecond pulses since only an ultrafast laser delivers the necessary intensity for electronic mobility at the point of focus. Incidentally, this mechanism can also be used as a data-storage technique or making diffractive optical elements.

Metal in Glass Marking

A third marking process relies on the natural presence of alkali metal ions in conventional window glass. For this application, we created glass containing noble metal ions by

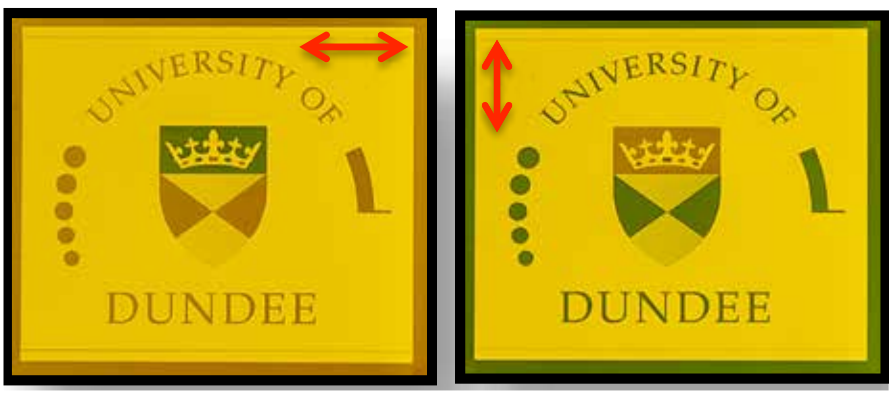

Figure 2: Two images of the same mark viewed using orthogonally polarised light. The mark (16 mm × 20 mm) is created by subtle reshaping of metal nanoparticles in glass matrix using a Coherent picosecond laser).

replacing the native alkali metal ions inside the glass matrix with noble metals but in ionic state [2].

Figure 3: Another process enabled by picosecond lasers was used to create this metallic pattern (18 mm × 25 mm) in clear glass

When picosecond pulses are tightly focused into the glass, free electrons are created which combine with the metal ions to produce metallic atoms, which in turn form spherical metallic nanoparticles. The laser parameters and focusing details are used to pre-determine the size and spacing of these metallic nanoparticles [3]. The process can thus be used to create elaborate, detailed, permanent metal marks in or on the glass surface (see Figure 3). Incidentally, this technique can also be used for applications in sensing and circuitry.

Summary

The unique properties of ultrafast laser pulses enable several novel marking techniques based on nanometer-scale photonic mechanisms. These can deliver permanent marks with micron scale spatial resolution.

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