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# A new approach to Direct Laser Interference Patterning with scanner optics for high productivity

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**Abstract**
Surface texturing with laser beams is a versatile method able to process micrometric features on different materials. Commonly, in the direct writing mode a laser beam is moved by scanner optics over the surface to be textured. In this approach, despite the high quality of the obtainable micrometric pattern, the use of a diffraction limited beam with a size of the order of micrometers generates two limitations: i) inability to machine submicrometric features, and ii) low productivity on large areas. Direct laser interference patterning (DLIP) has been found to be a valid route for overcoming the feature size limitation. By using two or more interfering beams, the feature size can be decreased to sub-micrometric levels. Moreover, modelling of the interference pattern provides a higher process control than the one offered by other techniques, that work at sub-micro and nano level, such as laser induced periodic surface structures (LIPSS). However, traditional DLIP has not overcome the limit given by the poor productivity on large area. The optical arrangements used in DLIP technique is based on interferometric setups, which commonly require two or more beam paths converging on the processed zone. Accordingly, relative movement is given to the workpiece by means of linear stages, which reduces productivity compared to scanner optics. In this work, a new approach to DLIP is demonstrated, where interference patterns are processed using a scanner head. A nanosecond industrial laser source at 532 nm was used. The original beam was split in two. The interference was realized with a Michelson-Morley interferometric set-up. The interfering beams were then launched successfully into a conventional galvanometric scanner head, reflected by two mirrors and finally focused by an f-theta lens. Linear patterns were transferred to metallic surfaces with different periods in order to demonstrate the feasibility of the new system. At this initial phase, a texturing speed up to 500 mm/s was achieved, validating the capability and high productivity on large area fabrication.
**Keywords:** surface texturing, interferometry, laser ablation, sub-micrometric texturing, green laser, scanner head

## 1. Introduction

In the last 20 years, a large number of works focused their attention on surface pattern fabrication for device functionalization. Direct laser methods present the advantage of absence of post processing in surface patterning [1]. The mostly used laser method is the Direct Laser Writing (DLW) [1],[2]. On the other hand, DLW presents some limitation in pattern dimension, which is strictly confined to diffraction limit of the focused beam in tens of micrometers scale, when a nanosecond pulsed laser source source is used [1],[2]. A relatively new approach is Direct Laser Interference Patterning (DLIP). DLIP uses interference and ablation phenomena to realize micrometric and sub-micromicrometric structures, overcoming limits of DLW approach with ns pulsed laser sources [3],[4]. DLIP also permits a good control on pattern shape and pattern dimension, which are function of laser wavelength and interference angle, overcoming also the limitation of laser induced periodic surface structure (LIPSS) [5]. In scientific field, DLIP technique was investigated considering different aspects like laser parameters [6],[7], pattern dimensional limits [7],[8] and pattern quality [6]-[8]. DLIP is generally realized with complex, rigid and fixed optical set-ups. Laser texturing of large areas with DLIP is generally performed by moving the sample with motorized stages [4]. However, in view of manufacturing large areas with high productivity, new approaches should be investigated. In this work, two-beam DLIP process is investigated with a new optical set-up, which involves the combination of interference phenomena with a scanner head. The new approach is demonstrated in terms of new process fesability through the qualitative assessment of the quality of the textured pattern with a scan speed suitable for industrial productivity (500 mm/s) is reached.

## 2. Materials & Methods

### *2.1. Employed material*

AZ31 Mg alloy cold rolled sheets with a thickness of 0.2 mm were used throughout the study. The alloy compounds were nominally composed as 2.5-3.5 wt% Al, 0.6-1.4 wt% Zn and bal. Mg. AZ31 Mg was investigated since it is a valid bioassorbable metallic alloy in biomedical applications where micrometric and sub-micrometric patterns can be benefitial for biological performance and application of consecutive surface coatings [9]. Moreover, laser texturing of AZ31 is shows further difficulty given the low melting point of this alloy (905 K).

### *2.2. DLIP set-up*

DLIP was realized by a nanosecond pulsed laser source (NanioAir, InnoLas Photonics Gmbh). The laser parameters employed throughout the work, are reported in Table 1. The new DLIP optical set-up was composed by a Michelson-Morley interferometer and a scanner head, as represented in Figure 1. The interfered and collimated beams, obtained as the output of Michelson-Morley interfereometer, were handled using a scanner head system (Cambridge ProSeries I). Then the two beams were focused at the target point, using a telecentric lens with a focal length of 100 mm. Two different interference angles were evaluated at this preliminary stage by processing the material at a fixed position on the surface. Then, the large area fabrication was realized by moving the galvanometric mirrors of the scanner. The treatment was performed by a continuous scanning movement along linear vertical paths. The horizontal pitch was set at 75 μm. The marking speed (v [mm/s]) was changed between 100 and 500 mm/s.

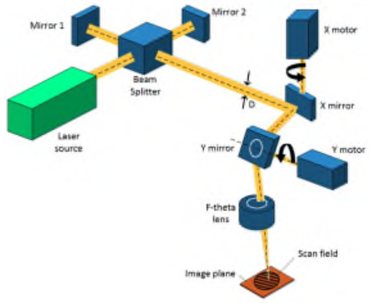


**Figure 1.** Schematic representation of employed DLIP set-up

**Table 1** Employed laser parameters

| | |
|---|---|
| Wavelength, λ [nm] | 532 |
| Quality factor, $M^2$ | 1.2 |
| Polarization | Linear |
| Pulse duration, τ [ns] | <20 |
| Stable Pulse Energy, E [μJ] | 138 |
| Pulse Repetition Rate, PRR [kHz] | 20 |
| Collimated diameter, D [mm] | 10 |
| Waist diameter, $d_0$ [μm] | 8.1 |
| Drillin time, t [μs] | 10 |
| Focal position, Δz [mm] | 2 |
| Interference Angle, θ [°] | 0.026 - 0.036 |

### *2.3. Pattern quality evaluation*

In this preliminary work, the textured spots and the textured surfaces were evaluated by SEM technique (EVO-50, from Carl Zeiss, Oberkochen, Germany). SEM was used in order to determine the pattern visual quality. An image analysis software was used in order to measure the pattern period (Λ [μm], see Figure 2-a), for the two conditions of interference angle. The measurement was performed considering four fringes and three different position along the spot.

## 3. Results

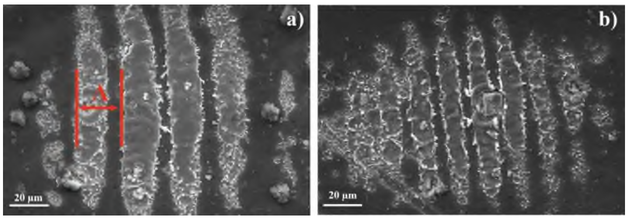


**Figure 2.** SEM images of treated spot by DLIP approach considering two different interference angles: a) θ=0.026° b) θ=0.036°. Polarization is parallel to the machine lines.

In figure 2 the evidences of DLIP treatment with new scanner approach are reported. The fringes pattern is clearly visible in terms of destructive and constructive areas. The two angles led to a different fringe density, as the comparison of Figure 2-a and Figure 2-b shows. The increase of interference angle, from 0.026° to 0.036°, resulted in a greater fringes number and a consequent decrese of pattern period, as stated by the interference law [3]. The measured pattern period, at θ=0.026°, was Λ=22.6 ± 0.14 μm, whereas at θ=0.036° was Λ=16.2 ± 0.15 μm. It is interesting to observe that pattern period values were related to employed optical set-up. In fact, the interference phenomenon, considered at collimated spot level, was traduced by the scanner F-theta lens in an image projection. The lens operated with a scale factor on the pattern dimension, which was reduced at micrometric dimension on the sample surface. The quasi-Gaussian distribution of the employed laser source clearly affected the pattern quality. The definition of fringes patterns got worse moving on the annular zone of interference spot, with a disappareance of treated material. This trend in clearly visible in Figure 2-a and Figure 2-b where fringes definition is gradually lost moving toward the edge of treated spots.

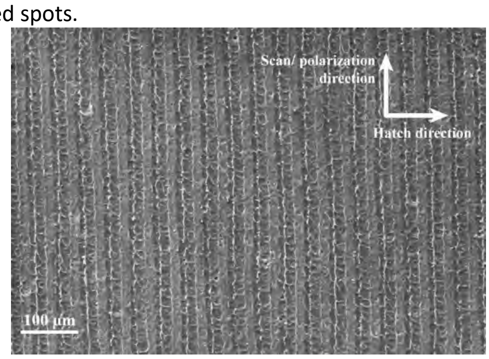


**Figure 3.** SEM image of a large area treated by DLIP approach, considering θ=0.026° and a v=150 mm/s.

In Figure 3 large area fabrication was demonstrated. The treatment was performed with θ=0.026° and v=150 mm/s, considering a interfered spot dimension of 150 μm. The galvo movement was able to handled interference spot over the target plane, maintaining the same interference angle and realizing the treatment at high speeds. Considering this conditions a fabrication speed of $10^{-3}$ $m^2$/min was achievable. Moreover, marking speed could be increase up to 500 mm/s, improving the productivity to >$10^{-3}$ $m^2$/min.

## 4. Conclusion

In this work the feasibility of a new optical set-up for DLIP treatment is proved. The DLIP was realized with the combination of an interferometer and a scanner head in order to realize interference beam handling by galvanometric mirrors. At this initial stage two different interference angles were tested, and parallel manufacturing of micrometric periodic structures was realized on a biodegradable Mg alloy. Obtained structures were characterized, at this preliminary stage, in terms of periodic period and pattern quality. Furthermore the ability of this new-optical setup for DLIP treatment of large area fabrication is also demonstrated. Marking speeds up to 500 mm/s were tested, achieving fabrication speed >$10^{-3}$ $m^2$/min.

## References


[1] Liu Q, Duan X and Peng C 2014 Novel Optical Technologies for Nanofabrication *Springer*

[2] Li L, Hong M, Schmidt M, Zhong M, Malshe A, Huis B and Kovalenko V 2011 Laser nano-manufacturing – State of the art and challenges *CIRP Ann. Manuf. Technol.* **60**(2) 735–755

[3] Lasagni F A and Lasagni A F 2011 Fabrication and Characterization in Micro-Nano Range Springer

[4] Lasagni A, Benke D, Kunze T, Bieda M, Eckhardt S, Roch T, Langheinrich D, Berger J 2015 Bringing the Direct Laser Interference Patterning Method to Industry: a One Tool-Complete Solution for Surface Functionalization *J. Laser MicroNanoen.* **10**(3) 340–344

[5] Ahmmed K M T, Grambow C and Kietzig A 2014 Fabrication of Micro/nano Structures on Metals bt Femtosecond Laser Micromachining *Micromach.* **5** 1219–1253

[6] Tan B and Sivakumar N R 2005 Direct grating writing using femtosecond laser interference fringes formed at the focal point. *J. Opt A-Pure App. Opt.* **7** 169–174

[7] Furlan V, Biondi M, Gokhan A G, Pariani G, Previtali B, Bianco A 2017 Sub-micrometric surface texturing of AZ31 Mg-alloy through two-beam direct laser interference patterning with a ns-pulsed green fiber laser, *Appl. Surf. Sci.* **423** 619-629

[8] Alessandria M D, Lasagni A and Mu F 2008 Direct micro-patterning of aluminum substrates via laser interference metallurgy *Appl. Surf. Sci.* **255** 3210–3216

[9] Yang J, Cui F, and Lee I S 2011 Surface Modifications of Magnesium Alloys for Biomedical Applications, *Ann. Biomed. Eng.* **39**(7) 1857–1871