Femtosecond laser surface structuring of silicon using optical vortex beams generated by a q-plate

K. K. Anoop,[1,2] A. Rubano,[1,2] R. Fittipaldi,[3] X. Wang,[2] D. Paparo,[2] A. Vecchione,[3] L. Marrucci,[1,2] R. Bruzzese,[1,2] and S. Amoruso[1,2]

[1]Dipartimento di Fisica, Università di Napoli Federico II, Complesso Universitario di Monte S. Angelo, Via Cintia, I-80126 Napoli, Italy
[2]CNR-SPIN, UOS Napoli, Complesso Universitario di Monte S. Angelo, Via Cintia, I-80126 Napoli, Italy
[3]CNR-SPIN, UOS Salerno, Via Giovanni Paolo II 132, I-84084 Fisciano (SA), Italy

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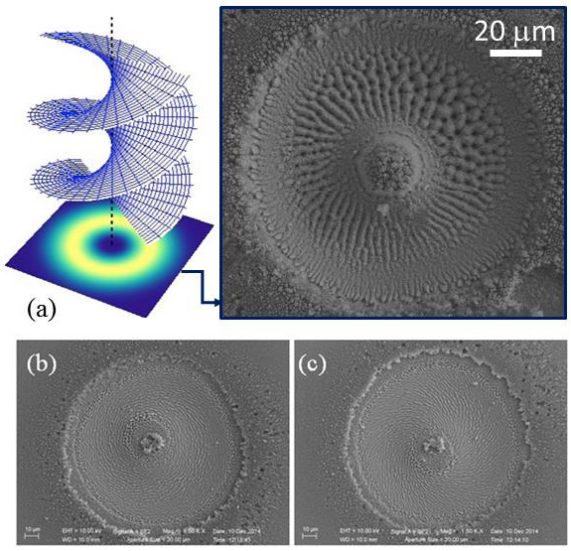
Creation of patterns/structures on a surface at the micro- and nano-scale has many potential applications (e.g. in material processing, tailoring of optical properties, THz optics, etc.). Many patterns can be obtained by direct laser structuring through femtosecond (fs) laser ablation, with Gaussian-like beam spatial intensity profile. Recently, non-Gaussian laser beams are emerging as interesting candidates for strategic tailoring in material processing. We demonstrated fs laser structuring using optical vortex (OV) annular beams created with a liquid crystal q-plate [1]. Our findings show emergence of diverse (radial, azimuthal, spiral, etc.) surface micro-structures, highlighting the multi-pulse feedback mechanism responsible for the surface structuring process. Moreover, the central zero intensity singularity of the OV ring intensity profile also leads to a central micro-needle decorated with nanoparticles. Direct laser structuring with fs pulses is very promising to create complex surface microstructures [2], also providing a powerful method to evaluate focal intensity and polarization distribution of complex, unconventional ultrashort laser beams.



(a) Schematic representation of an OV beam and annular spot on a Si (100) target surface showing the developed radial microstructure. Panels (b) and (c) show examples of circular and spiral microstructures, respectively. Interestingly, the microstructure formed in the annular beam region is sensitive to the local laser polarization. A micro-needle is present at the laser spot center, corresponding to the nearly zero intensity central singular region of the OV beam, with a nanoparticles-assembled structure on the top.

[1] L. Marrucci, C. Manzo, and D. Paparo, Phys. Rev. Lett. **96**, 163905 (2006).
[2] K. K. Anoop, R. Fittipaldi, A. Rubano, X. Wang, D. Paparo, A. Vecchione, L. Marrucci, R. Bruzzese, and S. Amoruso, J. Appl. Phys. **116**, 113102 (2014).