Femtosecond laser beam shaping for asymmetric nano-structuring

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Recent advances in laser beam shaping have enabled the generation of complex micrometric features such as asymmetric or even chiral surface structures. This new capability paves the way for groundbreaking applications across diverse fields, including chiral molecular sensing, enantiomer separation, surface-enhanced spectroscopy, disease diagnosis and chiral light manipulation.

While structuring with laser beams in the nanosecond regime have demonstrated the growth of 3D nanostructures [1], interactions at femtosecond timescales revealed enhanced self-organizing mechanisms compared to longer pulse durations [2]. This difference highlights the importance of using ultrashort pulses while controlling the spatial beam asymmetry to explore new laser-matter interaction perspectives.

In this context, we aim to investigate the effects of ultrafast structured laser light for the generation of asymmetric surface nanostructures by manipulating vector beams. The study will focus on optimizing polarization, spatial, and temporal shaping parameters to control light-matter interactions from exotic polarization states, such as radial, azimuthal, left and right spiral polarization (Figures 1 (a), (b), (c) and (d), respectively), to more complex vortex beams. The induced surface micro and nano structures will then be characterized thoroughly by quantifying their asymmetry for future functional purposes.

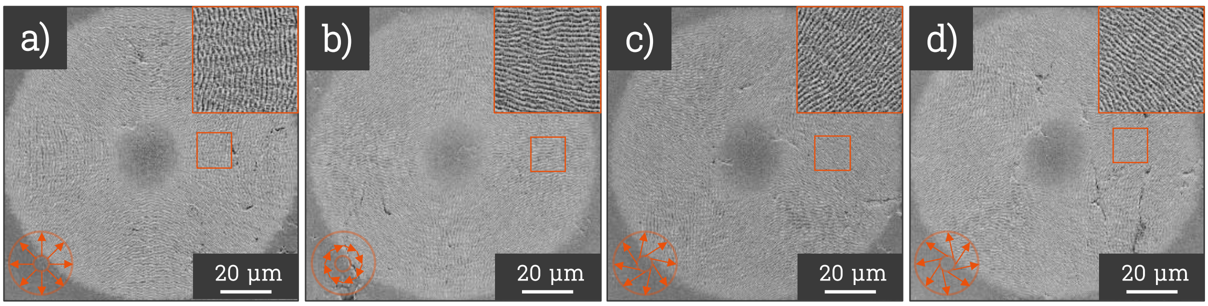

Figure 1: SEM images of asymmetric surfaces on stainless steel, structured by cylindrically polarized femtosecond beams: radial (a), azimuthal (b), counterclockwise spiral (c), and clockwise spiral (d).

References:

[1] S. Syubayev, A. Zhizhchenko, A. Kuchmizhak, A. Porfirev, E. Pustovalov and al. Zero-orbital-angular-momentum laser printing of chiral nanoneedles, Opt. Express, Vol. 25, No. 9, 1 May 2017.
[2] A. Nakhoul and J-P. Colombier. Beyond the Microscale: Advances in Surface Nanopatterning by Laser-Driven Self-Organization. Laser Photonics Rev.,18(5):2300991, May 2024.