Ultrafast laser inscribed near field lenses in Lithium Niobate crystals

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The possibility of creating controlled periodic nanostructures at the surface of ferroelectric nonlinear lithium niobate (LN) crystals is nowadays attracting much attention because of its numerous applications including the fabrication of two-dimensional (2D) photonic crystals [1], micro-diffraction elements [2], 2D phononic crystals [3], and novel focusing structures when combined with metallic coatings [4]. Among the different techniques capable of controlled surface structuring in LN crystals at the sub-micrometric scale (such as focused ion beam milling, ion beam enhanced etching, or mask assisted plasma etching), femtosecond laser ablation (FLA) is of special relevance because its simplicity, reduced processing times and absence of sample preparation requirements. [5] Nevertheless, for most of the above mentioned applications (especially those involving visible light control) reduced hole sizes are required. The possibility of using high-NA (NA > 1) optics has been already demonstrated in several materials (including glasses and self-assembled monolayers) [6,7], but its potential application in LN crystals for beating the 200 nm limit is still unexplored. In addition to the above mentioned practical applications, the creation of sub-200 nm surface structures in a high refractive-index nonlinear medium such as LN (n ~ 2.2 - 2.4) is also interesting from a fundamental point of view since they could open the avenue novel fundamental effects, such as extraordinarily high transmission or polarization-sensitivity effects [8].

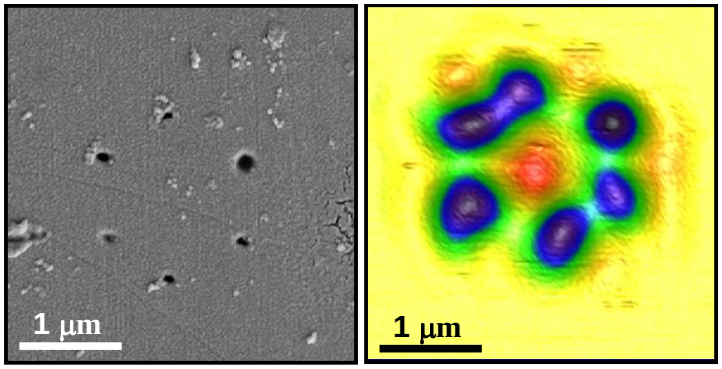

Figure 1.- Scanning electron microscopy (SEM) of a six nano-hole array fabricated by fs pulses in LN crystal (left). The Near Field transmited intensity as measured with a SNOM (right).

In this work we report on the femtosecond laser fabrication of orderes arrays of sub-λ/4 holes in a LN crystal by multi-pulse ablation, with a full control over the hole diameter in the 80-200 nm range. We demonstrate that the presence of the fabricated nano-holes strongly modulates the near-field optical transmission of the LN surface. We show that the near-field transmitted intensity almost vanishes at hole´s central position, whereas a significant near-field enhancement is produced at its surroundings. The increment observed in the near field intensity in the surroundings of the nano-holes has been found to be weak for single nano-holes but of relevance in the case of ordered arrays of nanoholes. By comparing the measured and 3D FDTD simulated NSOM images we found nanometric surface relief in combination with cooperative multiple-scattering as the key factors for the optical contrast mechanisms.
As an exciting example we provide above the results obtained from a six-nanohole ordered array fabricated by fs laser inscription in a LN surface as well as the near field transmission

intensity distribution experimentally observed with our SNOM. In this Figure it is more than evident the strong light concentration caused at the geometrical center of the array (in excess of 60%).

In this talk we will explain the fundamentals of such phenomena as well as the new windows that it opens in modern nano-photonics.

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