Fabrication of anti-reflection coatings on GaSe crystal surfaces by laser-induced periodic surface structuring (LIPSS)

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GaSe monocrystals hold promise for various applications including nonlinear optics, metrology, spectroscopy and quantum electrodynamics. However, performance of this material is limited by high Fresnel reflection, while common multi-layer antireflection coating technologies are hardly applicable owing to adhesion problems. Antireflection microstructures (ARMs) represent an alternative way for tuning surface reflectivity.

Here we demonstrate the fabrication of novel ARMs on a GaSe crystal surface using surface nanotexturing by ultra-short femtosecond (fs) laser pulses. Laser-based technology utilizing femtosecond pulses provides facile and economically justified way for the large-area formation of high-quality self-organized surface morphologies also referred to as laser-induced periodic surface structures (LIPSSs).

Here, high-quality LIPSSs were produced, for the first time, on the both facets of the GaSe crystal increasing its total transmittance by 20% being compared to pristine sample with no additional light localization effects in the material upon its exposure.
Our studies justify the LIPSS patterning as a promising strategy for improvement of functional characteristics of the nonlinear IR crystals.

Fabrication

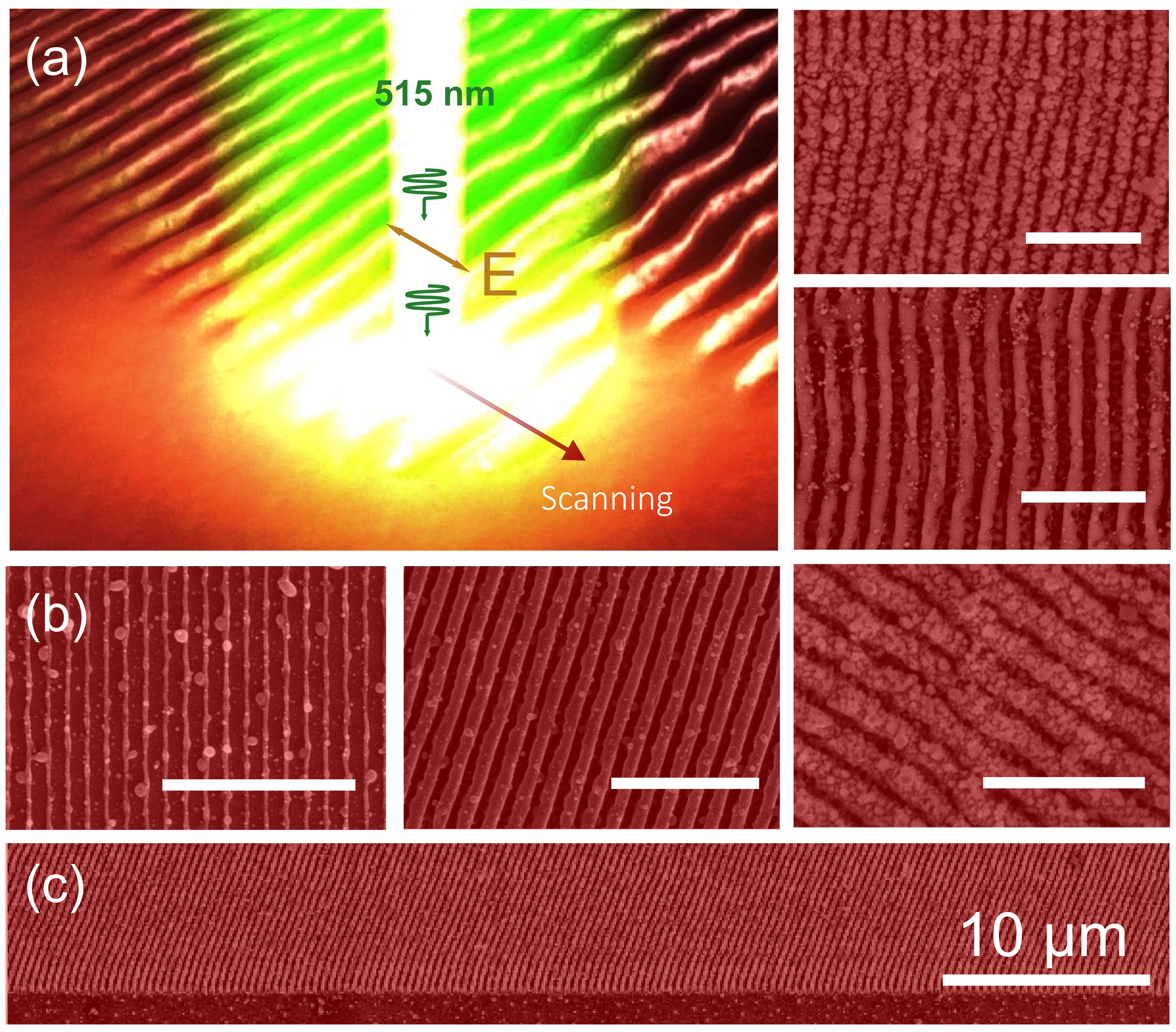

Рис. 1. (a) laser fabrication process of LIPSS on a GaSe crystal using laser radiation (200 fs pulse duration, 515 nm wavelength, 1 kHz pulse repetition rate) focused into a stripe-shape flat-top beam with a focal-plane size of 50×1 µm² (b) Series of SEM images illustrating the morphology of LIPSS fabricated by various laser processing regimes. The scale bar corresponds to 2 µm. (c) SEM image of large area LIPSS.

Ablation threshold

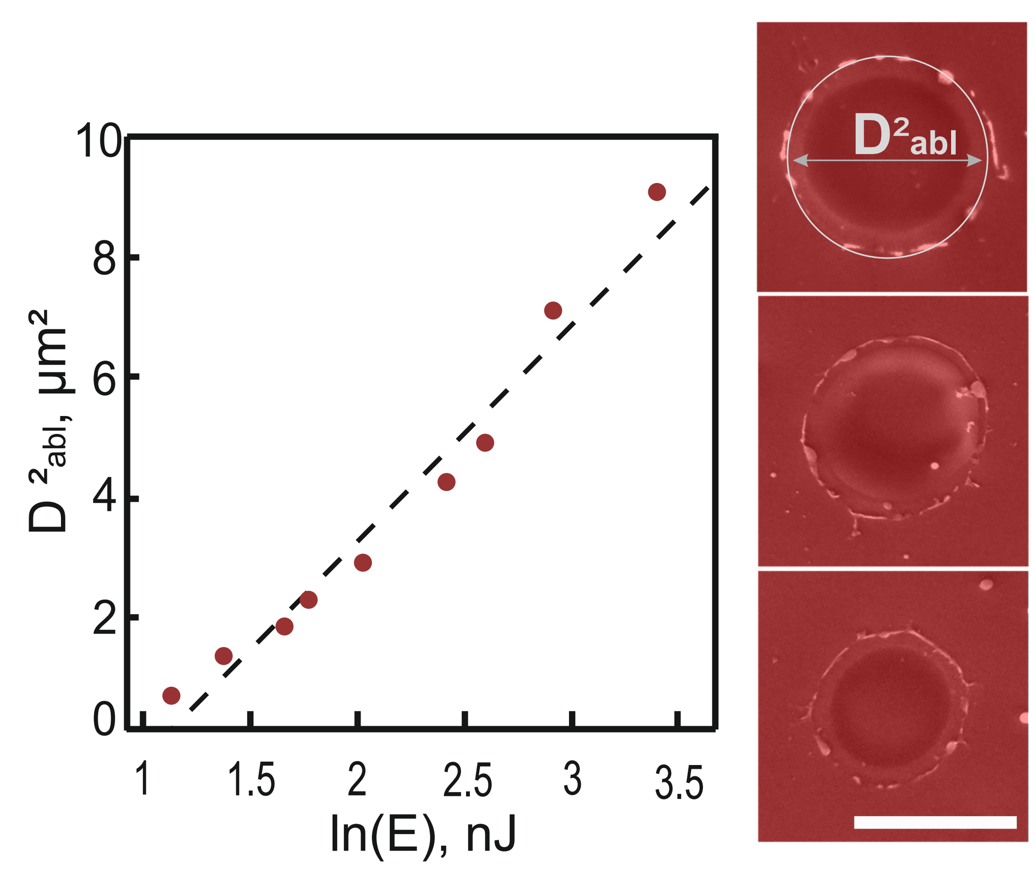

Fig. 2. Squared diameter D^2_{abl} of the surface modification of the GaSe wafer surface as a function of natural logarithm of applied pulse energy ln[E]. Insets provide reference SEM images of the laser-irradiated GaSe surface. The scale bar is 14 µm.

Linear fit of the obtained experimental data (markers) gives the threshold fluence of F_{th}=0,105±0,03 J/cm².

Raman spectroscopy

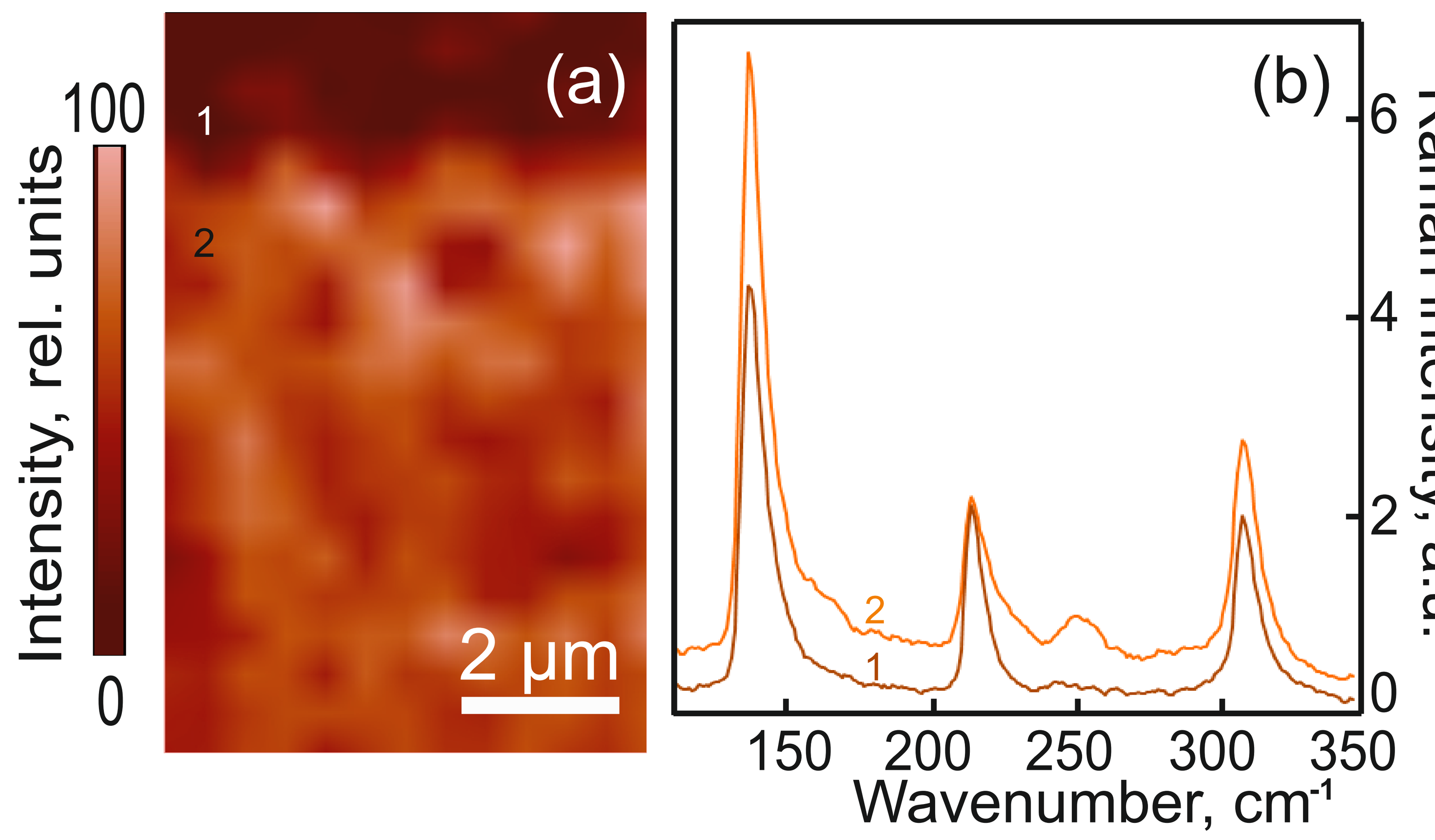

Fig. 3. (a) Raman map of surface distribution intensity of the band at ~251 cm⁻¹ taken at the boundary between the pristine and LIPSSs-textured GaSe areas. (b) Averaged Raman spectra of (1) pristine and (2) LIPSSs-textured areas of GaSe crystal. Raman spectrum of the pristine GaSe exhibits 3 main bands at 133 cm⁻¹, 307 cm⁻¹, 212 cm⁻¹, while laser-patterned sample has two additional low-intensity bands which can be associated with amorphous selenium (~251 cm⁻¹) and Ga_2Se_3 (~155 cm⁻¹).

Optical properties

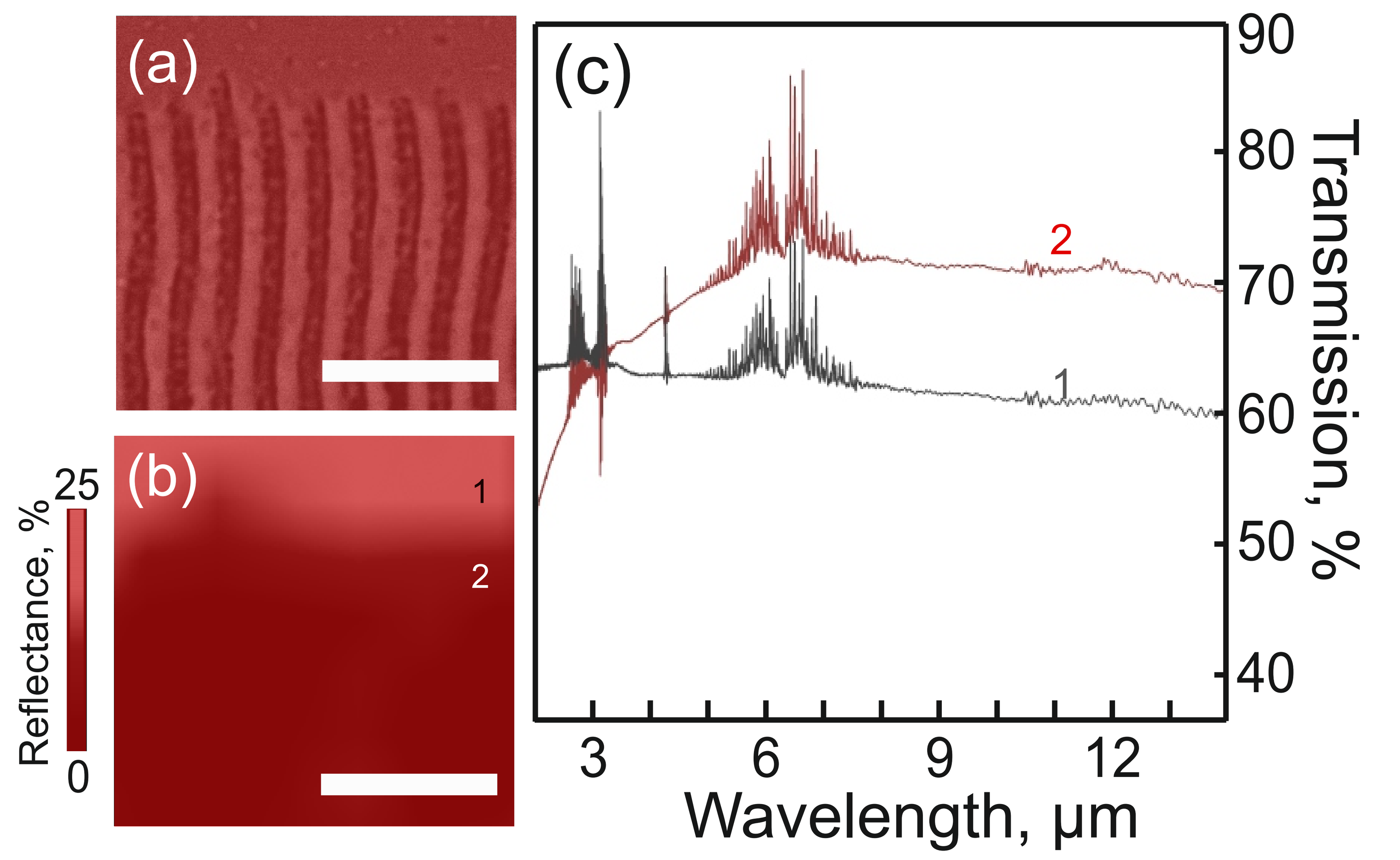

Fig. 4. Correlated (a) SEM image, (b) reflection map (at 473-nm laser pump) and (c) transmission spectra of LIPSSs on the both facets of GaSe crystal; (1) pristine and (2) LIPSSs-textured areas of GaSe crystal. The scale bar is 2 µm.

FDTD simulations

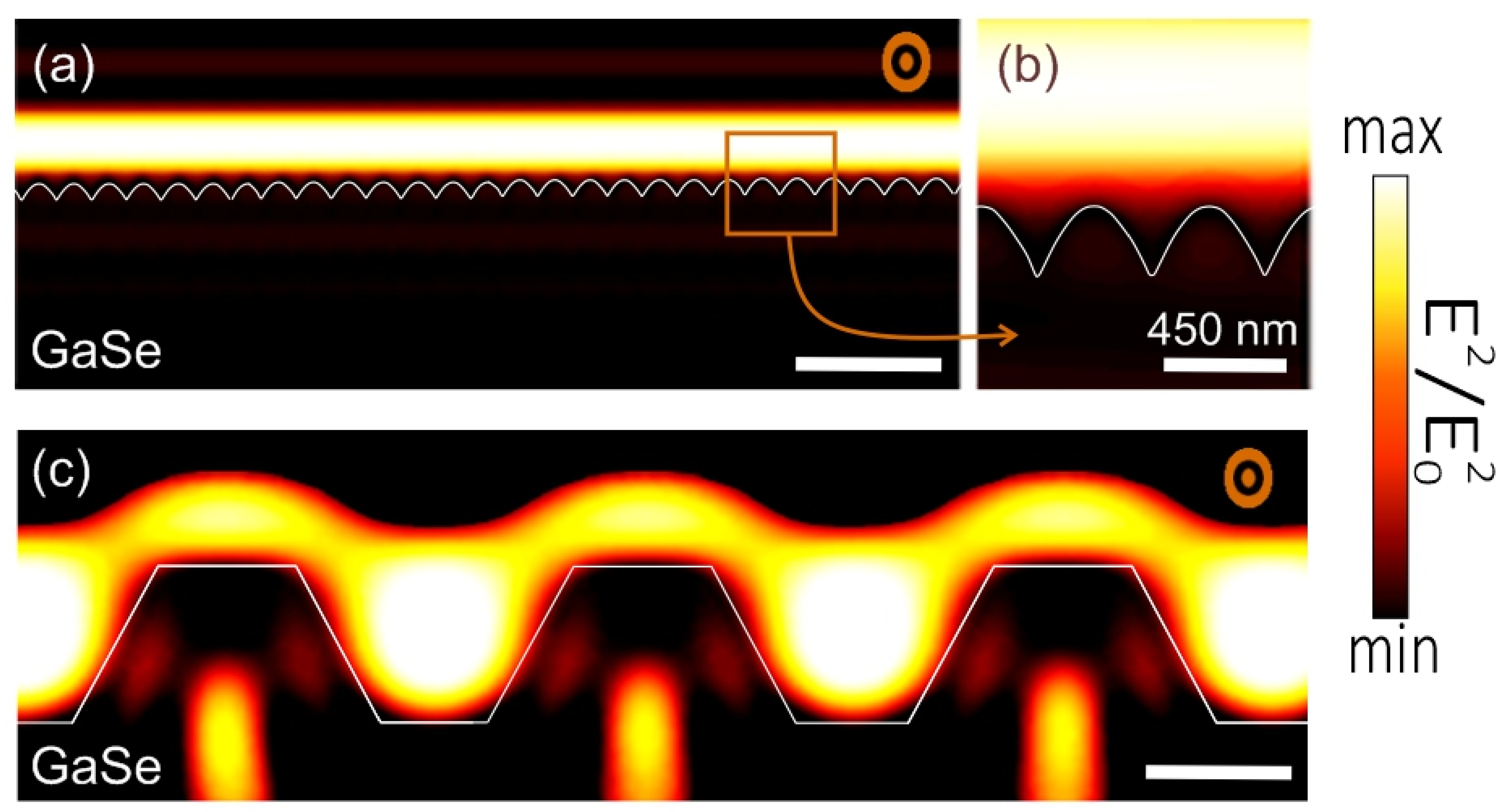

Fig. 5 FDTD simulations of normalized squared electric-field amplitude E^2/E_0^2 calculated for (a) subwavelength (Λ=450 nm) LIPSSs, (b) enlarged fragment of the LIPSSs and (c) micro-pitches formed on the GaSe surface irradiated at λ=4 µm.
The formed deep-subwavelength surface morphology cause no additional light localization effects in the material upon its exposure thus leaving intact the optical damage threshold of the material.