Seminario

Grupo de Procesado por Láser

Instituto de Óptica, CSIC

New Dimensions Open to Ultrafast Laser Material Modifications

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Abstract:

High-peak power compact femtosecond lasers allow strong-field interactions that are the basis for high-precision laser processing. However, a relatively narrow region of the spectrum remains today exploited in this field. We study femtosecond laser interactions in various bandgap materials at non-conventional driving wavelengths from the ultraviolet up to the mid-infrared part of the spectrum. The range of nonlinear responses accessible by radiation tuning allows revisiting questions as important as the achievable precision and performance in surface processing technologies. Concentrating on the mid-infrared region of the spectrum we also discuss the unique opportunity for internal structuring of silicon and new solutions for semiconductor technologies. Semiconductor materials remain today extremely challenging to process in the three dimensions (3D writing) due the important distortions of intense infrared light inside narrow gap materials. Our first proposed solution used a solid-immersion focusing technique to achieve internal carrier injection up to local breakdown with sub-100-fs pulses. For more practical alternatives, we rely today on optimizations in the time and space-domain. For instance, we generate and apply ultrafast trains of pulses up to Terahertz repetition-rates to rely on efficient local energy accumulation. These explorations lead us today to the introduction of a plasma-optics concept to access new process performance levels. To achieve highly localized and reliable processing inside silicon, we create plasma seeds with tightly focused pre-ionizing femtosecond pulses. We show how critical plasma density conditions can be found under damage threshold inside silicon. This is used for extremely confined energy deposition with a synchronized longer writing irradiation creating isotropic modifications with sub-diffraction-limit size for the first time. With the approach, drastic improvement is also found on the material change controllability. This is supported by unique demonstrations including rewritable optical memories (>100 writing/erasure cycles) and the writing of graded-index functionalities. By solving its controllability issues and enhancing precision with critical plasma seeds, ultrafast laser writing is poised to offer its full potential for flexible fabrication of reconfigurable monolithic silicon-based devices.

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