Laser ablation of 2D materials: Mechanistic characterization and applications in nanophotonics

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The field of two-dimensional (2D) materials has grown exponentially over the past decade or more, due to the numerous applications of these materials in nanophotonics [1], nanofluidics [2], and other areas of nanoscience [3]. Multiphoton laser ablation is one promising method of patterning such materials [4]. A robust method exists for measuring the laser ablation threshold of such materials, although this method involves analysis of the ablated sample via atomic-force or electron microscopy [5]. Here we use this method as a benchmark to demonstrate that different conditions that lead to the same amount of ablation can be identified using direct optical inspection on the ablation tool. This capability enables us to employ a new 2-beam action technique [6], 2-beam ablation threshold (2-BAT) spectroscopy, to determine the number of photons involved in ablation, providing important clues into the mechanism of this process.

Here we investigate the ablation mechanism of transition-metal phosphorus trichalcogenides, which are 2D materials that exhibit interesting electrical [7], magnetic [8], catalytic [9], and optical properties [10]. In particular, we use 2-BAT to study how ablation changes with chalcogen composition in multilayer, exfoliated $MnPS_xSe_{3-x}$.

$MnPS_3$ has a refractive index of 2.41 [11], and this value grows with the substitution of selenium for sulfur. Consequently, these materials are attractive for their ability to act as waveguides. We investigate the ability of pristine and laser-machined, exfoliated crystals of these materials to guide ultrafast pulses over distances of 10 μm or more, driving remote nonlinear optical processes in other optical nanomaterials that are in contact with the 2D materials.

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