Identification of non-uniform strain in WS$_2$ monolayers using P-SHG

G. Kourmoulakis$^{1,2,*}$, S. Psilodimitrakopoulos$^{1,*}$, G. M. Maragkakis$^{1,3}$, L. Mouchliadis$^1$, A. Michail$^{4,5}$, J. A. Christodoulides$^6$, J. Parthenios$^5$, K. Papagelis$^{5,7}$, E. Stratakis$^{1,3,*}$, and G. Kioussis$^{1,2}$

$^1$ FORTH/IESL, Heraklion, 71110, Crete, Greece
$^2$ Dept. of Materials Science and Technology, Univ. of Crete, Heraklion, 71003 Crete, Greece
$^3$ Department of Physics, University of Crete, Heraklion Crete 71003, Greece
$^4$ Department of Physics, University of Patras, Patras, 26504, Greece
$^5$ FORTH/ICE-HT, Stadiou str Platani, Patras 26504 Greece
$^6$ Naval Research Laboratory, 4555 Overlook Ave SW, Washington, DC 20375-5320, U.S.A
$^7$ School of Physics, Dept. of Solid-State Physics, Aristotle University of Thessaloniki

Strain in Transition Metal Dichalcogenide (TMD) monolayers (ML) changes the interatomic distances and the band structure, providing a new degree of freedom that allows manipulating their electronic properties, introducing the field of straintronics. Having an all-optical, minimally-invasive tool that rapidly probes strain in large areas of TMD MLs, would be of great importance in the research and development of novel 2D devices [1-3]. Here, we use polarization-resolved second harmonic generation (P-SHG) optical imaging to identify strain, induced in a single, spatially differentiated WS$_2$ ML placed on a pre-patterned Si/SiO$_2$ substrate with cylindrical wells. By fitting the P-SHG data pixel-by-pixel, we produce spatially resolved images of the crystal armchair direction. In the regions where the WS$_2$ monolayer is under non-uniform stain, we reveal a characteristic cross-shaped pattern in the armchair image. The presence of strain in these regions is independently confirmed using combination of atomic force microscopy and Raman mapping.

Figure 1: a) SHG intensity color map of strained (ROI3) and suspended (ROI1) ML WS$_2$, b) P-SHG color map of the corresponding crystal armchair orientation for the two ROIs, and c) Raman mapping for same ROIs: strained (ROI3) and suspended (ROI1)

Acknowledgements
G. Ko., L.M. and G. Kio., acknowledge funding by the Hellenic Foundation for Research and Innovation (H.F.R.I.) under the ‘First Call for H.F.R.I. Research Projects to support Faculty members and Researchers and the procurement of high-cost research equipment grant’ project No: HFRI-FM17-3034. AM, JP, and KP acknowledge financial support by the synergy grant SPIVAST funded by Foundation for Research and Technology Hellas

References

* geokourm@iesl.forth.gr