

Measuring the full strain tensor with second-harmonic generation in TMDs

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Two-dimensional transition metal dichalcogenides (TMDs) [1] have many unique optical and electrical properties. Strain has a considerable impact on the physical properties of atomically thin TMDs. For example, it changes the band gap [2], which is a key property for many applications like transistors, solar cells and quantum emitters. Since TMDs are far more flexible than conventional semiconducting materials, the applicable maximal strain values can reach very high numbers [3].

We demonstrate a new method that allows to optically measure the local strain matrix in two-dimensional TMDs. This method is based on the nonlinear optical effect of second harmonic generation (SHG). We show that SHG in TMDs is modulated by strain and we present an accurate physical model that reproduces this effect. Based on this model, we are able to extract the full strain matrix from polarization resolved SHG measurements. For this purpose, we determined the photoelastic tensor [4] of MoS₂. This was done by building a polarization resolved SHG setup and a two-point bending technique that allows to uniaxially strain atomically thin TMD flakes. Once the photoelastic tensor was identified, we could show that local strain can be measured by means of SHG.

Furthermore, we are able to map the two-dimensional strain field in inhomogeneously strained TMD samples. We use the polarization resolved SHG along the three armchair directions of the TMD crystal and extract the full strain tensor from these measurements.

References

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- [2] Desai, S. B. *et al.* Nano Lett. 14, 4592–4597 (2014)
- [3] Bertolazzi, S. *et al.* ACS Nano 5, 9703–9709 (2011)
- [4] Lyubchanskii, I. L. *et al.* Appl. Phys. Lett. 76, 1848 (2000)

Figures

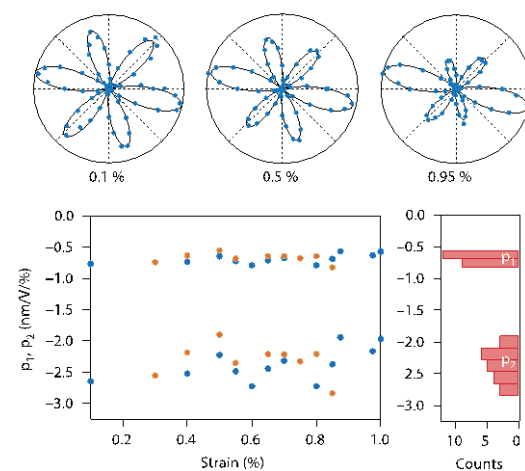


Figure 1: SHG patterns for applied uniaxial tensile strains of 0.1, 0.5 and 0.95%. Extracted photoelastic parameters p_1 and p_2 for monolayer MoS₂. Left panel: strain dependence; right panel: histogram of measurement data.

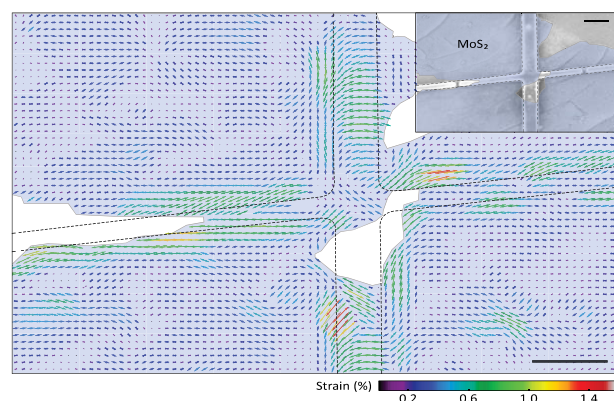


Figure 2: Uniaxial strain map of MoS₂ monolayer flake on a lithographically defined structure. Image: SEM picture; arrows: measured uniaxial strain field. Scale bar: 1 μm .