Algorithm-improved high speed and non-invasive confocal Raman imaging of two-dimensional materials

Sachin Nair†, Jun Gao†, Qirong Yao§, Michael H.G. Duits†, Cees Otto‡, Frieder Mugele†

†Physics of Complex Fluids, University of Twente, ‡Medical Cell BioPhysics, University of Twente, §Physics of Interfaces and Nanomaterials, University of Twente.

Motivation
- Confocal Raman Microscopy (CRM) is an important tool for characterizing 2D materials, but its low throughput significantly hinders its applications.
- For metastable materials like graphene oxide (GO), this problem is aggravated by the requirement of very low laser power dose per unit time to avoid laser induced reduction.
- Reduction of the laser power and exposure time often results in insufficient signal to noise ratio (SNR).

Fast mapping of GO
- ai-CRM facilitates fast mapping of GO (10 ms/pixel), at a low laser power of 0.75 mW and integration time of 1 ms!
- GO can be imaged at a laser dose of 4.9 x 10^-2 J/m^2, at a low laser power of 0.75 mW and exposure time of only 20 ms.
- Reliable mapping of GO
  - ai-CRM can facilitate GO mapping at a laser power of 4 μW and integration time of only 20 ms.
  - The analysis shows that the laser induced damage can be minimized to a much greater extent.

Fast volumetric mapping
- Fast volumetric mapping of a reduced GO-PAA composite.
- Laser power of 0.75 mW and integration time of 1 ms
- a 3D reconstruction of resolution 100 x 100 x 20 pixels took 12 mins.
- The principle of ai-CRM is based on SNR improvement by using an EMCCD camera and principal component analysis (PCA) guided data denoising.

Fast mapping of other 2D materials
- ai-CRM can also be applied to other 2D materials like MoS2, WS2 and BN.
- The technique can be used for GO and graphene, on arbitrary substrates (not shown).

Conclusions
- We introduce algorithm-improved Confocal Raman Microscopy (ai-CRM), which increases the Raman scanning rate by one to two orders of magnitude with respect to state-of-the-art works for a variety of 2D materials.
- GO can be imaged at a laser dose that is 2 to 3 orders of magnitude lower than previously reported, such that laser-induced variations of the material properties can be avoided.
- Since ai-CRM is based on general mathematical principles, it is cost-effective, facile-to-implement and universally applicable to other hyperspectral imaging methods.

For details, contact: s.s.nair@utwente.nl