Graphene as optical limiters

G.K. Lim *et al*., Nonlinear optical effect in single-sheet graphene liquid dispersion and films, *Nature Photonics* 5: 554-560, 2011

The team of researchers from Organic Nano Device Lab (ONDL) at National University of Singapore (NUS), DSO National Laboratories and University of Cambridge, have observed optical limiting behaviour in graphene. For over a decade, the broadband optical limiting performance benchmark for carbon materials has been held by carbon black suspension and carbon nanotubes solutions. In this Nature Photonics paper published this year, they have jointly announced a new broadband benchmark in optical limiting behavior for carbon materials using alkyl-functionalized sub-oxidized graphene single sheets dispersed in heavy-atom solvents or polymer matrices. The report shows that it is now possible to achieve a nonlinear optical tolerance limiting threshold of *ca*. 10 mJ cm^{-2} with excellent clamping characteristics for 3.5-ns pulses at 532-nm and 1064-nm wavelengths in chlorobenzene liquid cell and in bisphenol-A polycarbonate films for 70% linear transmittance. This is about 5-10 times better than previous benchmark by carbon black suspensions. Patent applications have been jointly filed by NUS and DSO.

For carbon black suspensions and carbon nanotubes solution, their optical limiting mechanism is primarily due to damage mechanism which occurs at intense laser fluences, through nonlinear scattering of solvent microbubbles and breakdown-induced microplasmas. In contrast, the optical limiting mechanism found in this functionalized sub-oxidized graphene system is due to the nonlinear generation of highly-absorbing localized excited states in the 2D electronic structure of nano-graphene domains of these singly dispersed graphene sheets interaction with its local environment. This conclusion was corroborated by time-resolved measurements of the absorption taken which show for high enough fluence, the absorption rises very quickly, as it is typical of localized excited states.

This work in Singapore is supported by the Temasek Young Investigator's Award and Ministry of Education. The work in University of Cambridge was supported by University of Cambridge, Cavendish Laboratory in the group of Prof Sir Richard Friend, who is also the Tan Chin Tuan Foundation Centennial Professor of NUS.

The ONDL graphene researchers in NUS (http://www.physics.nus.edu.sg/~ondl/) focus on solution-processable graphene that are scalable for large-area manufacturing. They work on selective chemical modification of these graphenes and study their structure properties and device spectroscopies so as to make breakthroughs in high-mobility, high on/off ratio field-effect transistors and build novel device structure in high-efficiency solar cells and light-emitting diodes. They also work on transferred chemical vapor deposited graphene for optical and electronic applications.

Figure caption: Schematic structure of functionalized sub-oxidized graphene (sub-GOx) single sheet. A hybrid of sp^2 nano-graphene domains (π-electron network) and sp^3 domain of surface-grafted oxygen functional groups or solubilising alkyl chains are shown on the sheet. Schematic of the Z-scan technique. Typical Z-scan of sub-GOx in polycarbonate for 532 nm 3.5 ns pulses.