

Thematic Session: Nanophotonics & nano-optics

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Saturable absorption of nonlinear graphene coated Si_3N_4 waveguides

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The unique properties of graphene make it an attractive candidate for optoelectronic and photonic devices [1]. Its planar geometry facilitates its integration onto chip-based photonic devices, which is key to enhance the otherwise poor light-matter interaction with this monolayer-thick material. Among its relevant properties, the graphene nonlinear optical response includes both photo-refractive processes and saturable absorption. Most graphene nonlinear studies combined with integrated optics used the mature silicon-on-insulator platform. However, both high values of the silicon nonlinearity and its undesirable two-photon absorption make it difficult to efficiently harness the graphene nonlinear response and to unambiguously extract it from measurements. Here, we study graphene integrated onto chip-based Si_3N_4 waveguides. This very robust material platform exhibits low propagation losses while the large Si_3N_4 electronic bandgap (5eV) forbids two-photon absorption and free carrier generation under optical excitation at telecom wavelengths.

We probed the nonlinear response of these hybrid waveguides via measuring the transmission of sub-picosecond pulses at $1.5\mu\text{m}$. We focused here on graphene saturable absorption, which is linked to Pauli blocking of photo-excited carriers in the upper band of the Dirac cone. We indirectly probed the excited carrier dynamics by varying the pulse duration and comparing the transmission measurements with simulation results. We indeed developed a model through adapting the nonlinear Schrödinger equation so that it accounts for a power dependent absorption loss, i.e. graphene saturable absorption. This allows us to extract the relaxation lifetime and saturation carrier density values that phenomenologically describe graphene saturable absorption in our hybrid waveguides [2].

[1] Geim, A. K., & Novoselov, K. S. "The rise of graphene". *Nature Materials*, 6(3), 183–191. (2007).

[2] Demongodin P., El Dirani H., Lhuillier J., ... Monat C. "Ultrafast saturable absorption dynamics in hybrid graphene/ Si_3N_4 waveguides". *APL Photonics*, 4(7), 076102. (2019).