Plasmonic Crystals in Graphene and GaN for Terahertz Active Devices

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More than 40 years ago, a new direction in physics opened up with the arrival of plasma-wave electronics. The possibility that the plasma waves could propagate faster than electrons fascinated all. Therefore, it was initially expected that plasmonic devices, including detectors and generators of electromagnetic radiation, would be able to work effectively in the very high frequencies - terahertz (THz) range, inaccessible to standard electronic devices. However, numerous experimental attempts to realize the amplifiers or emitters failed: the intensity of radiation turned out to be too small, plasma resonances too broad, or devices operated only at cryogenic temperatures.

Recently we have demonstrated– for the first time- experimentally strong interaction of resonant plasmons in Graphene with drifting electrons leading to THz radiation amplification with a gain going up to 9%. The results were interpreted using a dissipative plasmonics crystal model, which captures some trends and basic physics of the amplification phenomena but is far from being completed [1] . [2]

During this lecture we will present challenges of both experimental and theoretical research on the strong plasmons-drifting electrons- THz light interaction in Graphene and GaN - that were recently (2022) recognized as an important research direction by EU commission - awarding ERC -Advanced grant – "TERAPLASM" starting August 2023.

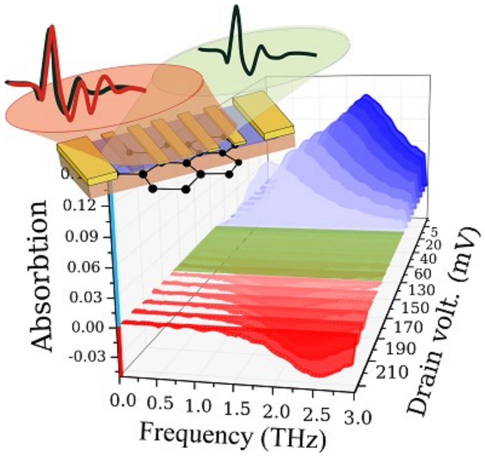

Fig. Schematic representing experimental configuration with a grating-gate graphene transistor structure along with incoming and outgoing THz beams. The 3D plot depicts experimentally recorded plasma resonances, highlighting that with increasing drain voltage/current, the resonant absorption (blue) turns to total transparency (green) followed by amplification (" negative absorption" – red) - after Ref. [1].

[1] Boubanga-Tombet S, Knap W, Yadav D, Satou A, But DB, Popov VV, Gorbenko IV, Kachorovskii V, Otsuji T: ***Room-Temperature Amplification of THz Radiation by Grating-Gate Graphene Structures*.** **Phys Rev X 2020**; [DOI: 10.1103/PhysRevX.10.031004]

[2] P. Sai, V. Korotyeyev, M. Dub, M. Słowikowski, M. Filipiak, D. But, Y. Ivonyak, M. Sakowicz, Y.M. Lyaschuk, S. Kukhtaruk, W.Knap
Electrical Tuning of Terahertz Plasmonic Crystal Phases,
Phys Rev X 2023 - In referring process - arXiv:2305.00211, (2023).

Short Biography:

W.Knap obtained his master and PhD degrees from Faculty of Physics – Warsaw University Poland.

His PhD concerned the Terahertz (Far infrared) properties of narrow gap semiconductors HgTe and InSb. After his PhD degree (1985) he left to France and worked at University of Montpellier, Grenoble High Magnetic Field Laboratory, Toulouse Pulsed High Magnetic Field Laboratory. In 1992 he obtained a permanent position at French National Center for Scientific Research - CNRS – Montpellier. Between 1999 and 2001 he worked as associated professor at USA – Rensellear Polytechnic Institute – at group of Prof.M.Shur . He obtained also a long term grant from Japan Society of Promotion of Science and spent a year in Prof.T.Otsuji group - Tohoku University 2007-2008. His main scientific interests and activities are concentrated around Fair Infrared-FIR (Terahertz - THz) properties of semiconductors and in particular in basic physics and applications of Terahertz Plasma excitations in nanotransistors. He is currently coordinating an International RESEARCH AGENDA Laboratory – CENTERA –UNIPRESS-PAN Warsaw POLAND