Tunable Terahertz Plasmons in Graphite Thin Films

Qiaoxia Xing[1,2], Chaoyu Song[1,2], Chong Wang[1,2], Yuangang Xie[1,2], Shenyang Huang[1,2], Fanjie Wang[1,2], Yuchen Lei[1,2], Xiang Yuan[1,6], Cheng Zhang[1,3], Lei Mu[1,2], Yuan Huang[5], Faxian Xiu[1,3,4] and Hugen Yan[1,2]*

[1]State Key Laboratory of Surface Physics and Department of Physics, Fudan University, Shanghai 200433, China.
[2]Key Laboratory of Micro and Nano-Photonic Structures (Ministry of Education), Fudan University, Shanghai 200433, China.
[3]Institute for Nanoelectronic Devices and Quantum Computing, Fudan University, Shanghai 200433, China.
[4]Shanghai Research Center for Quantum Sciences, Shanghai 201315, China
[5]Institute of Physics, Chinese Academy of Sciences, Beijing 100190, China.
[6]State Key Laboratory of Precision Spectroscopy, East China Normal University, Shanghai 200062, China.

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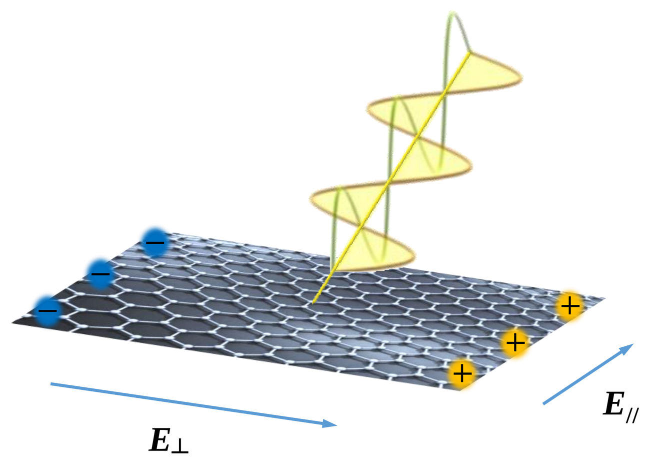
Introduction

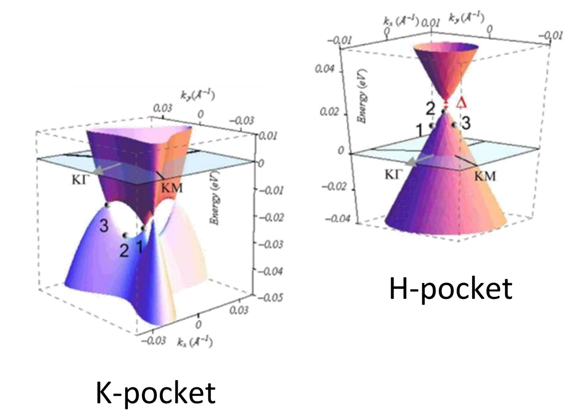
Graphene plasmons

- good gate tunability
- With relatively weak response to light, graphene has to be combined with metallic structures to realized feasible modulation.

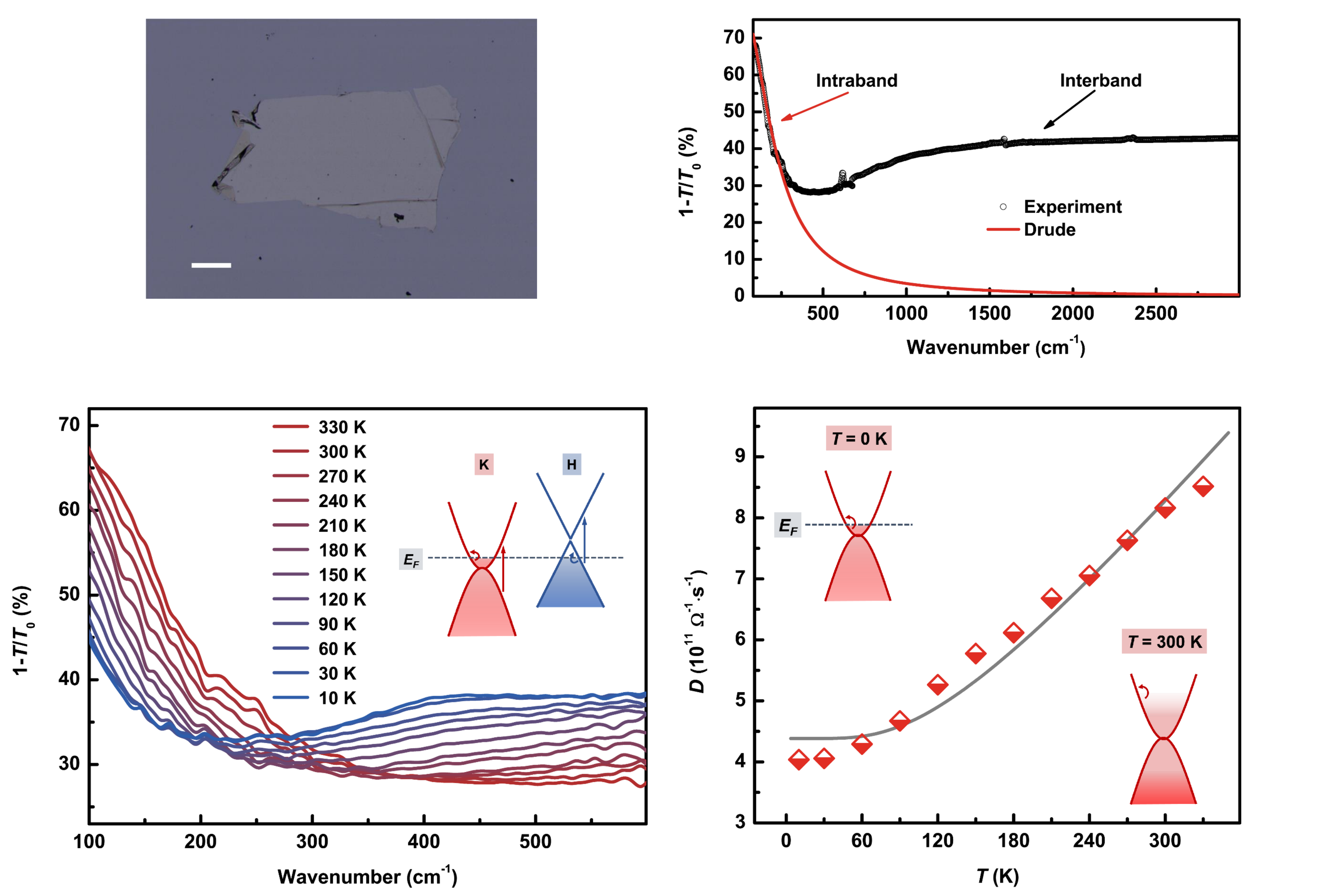


Graphite plasmons

- The thermal carrier density in graphite depends strongly on temperature, which promises sensitive tuning of plasmons by temperature.
- Graphite is a semimetal where massive electrons and massless Dirac holes coexist, residing around K-point and H-point of the Brillouin zone, respectively, and forming a two-component plasma.

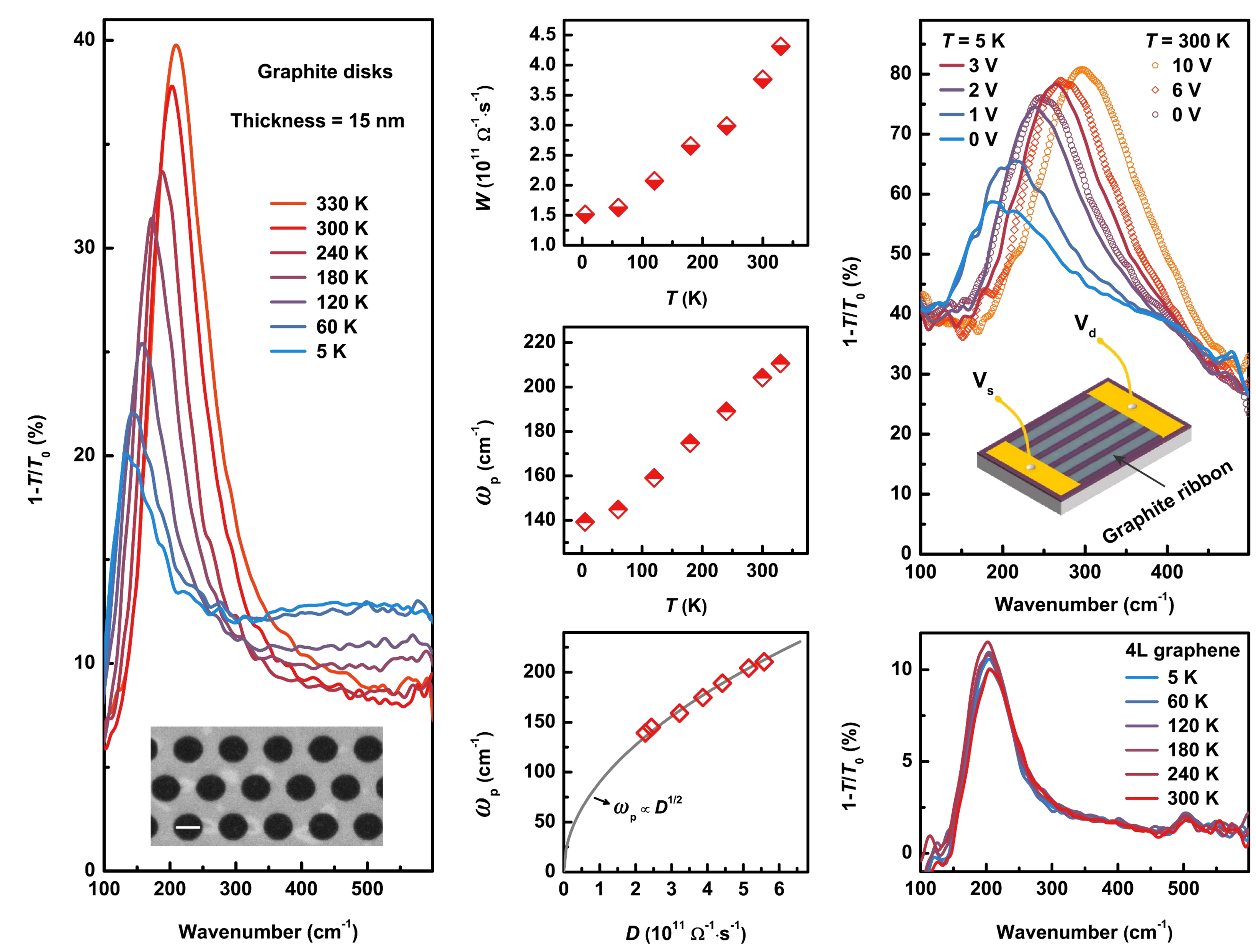


Temperature-dependent infrared absorption of graphite thin films



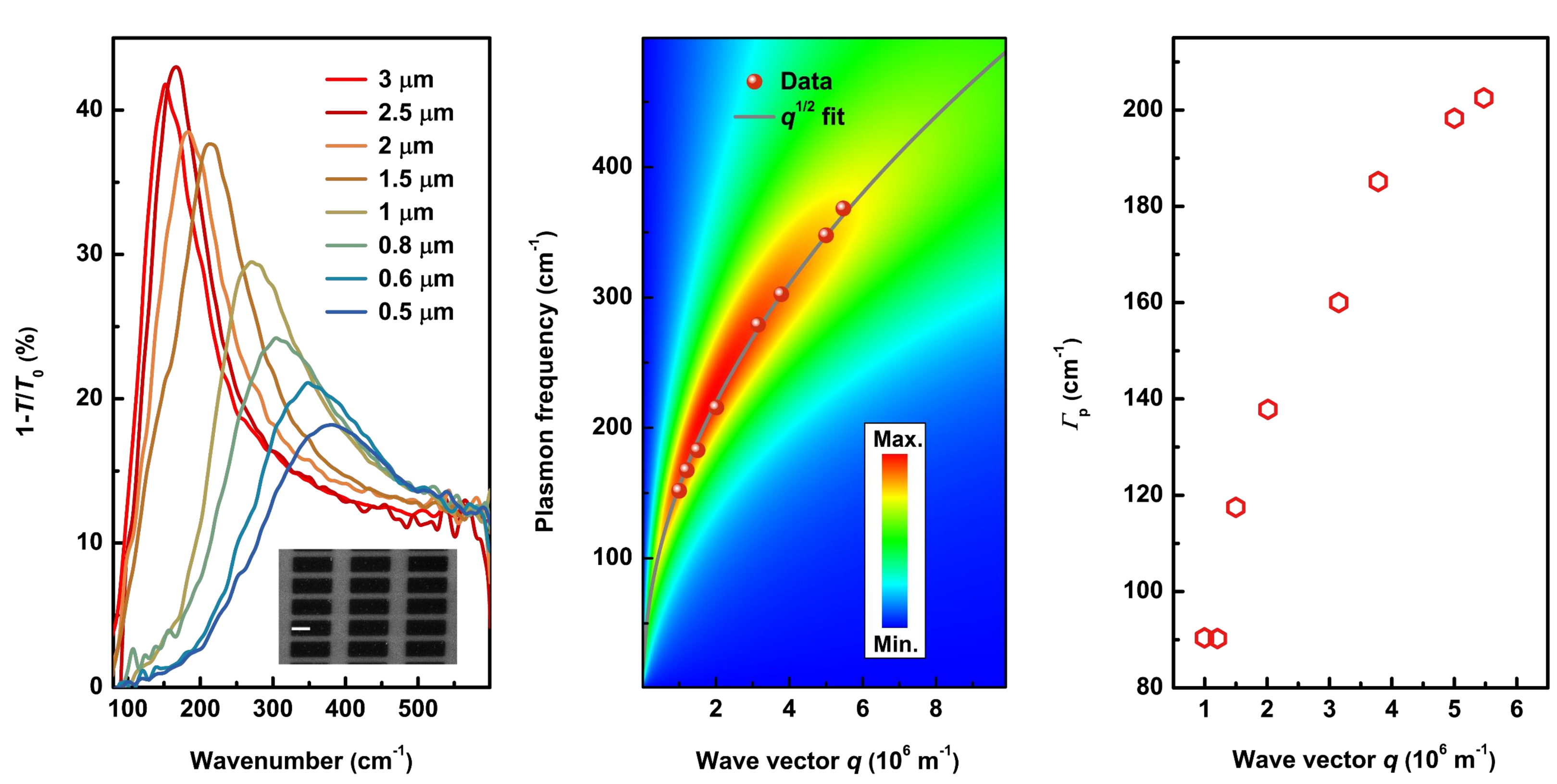
- The Drude response and interband excitations are sensitive to temperature. $D = Ak_BT\ln\left(2\cosh\left(\frac{\mu}{2k_BT}\right)\right)$

Temperature- and bias-tunable plasmons in graphite thin films



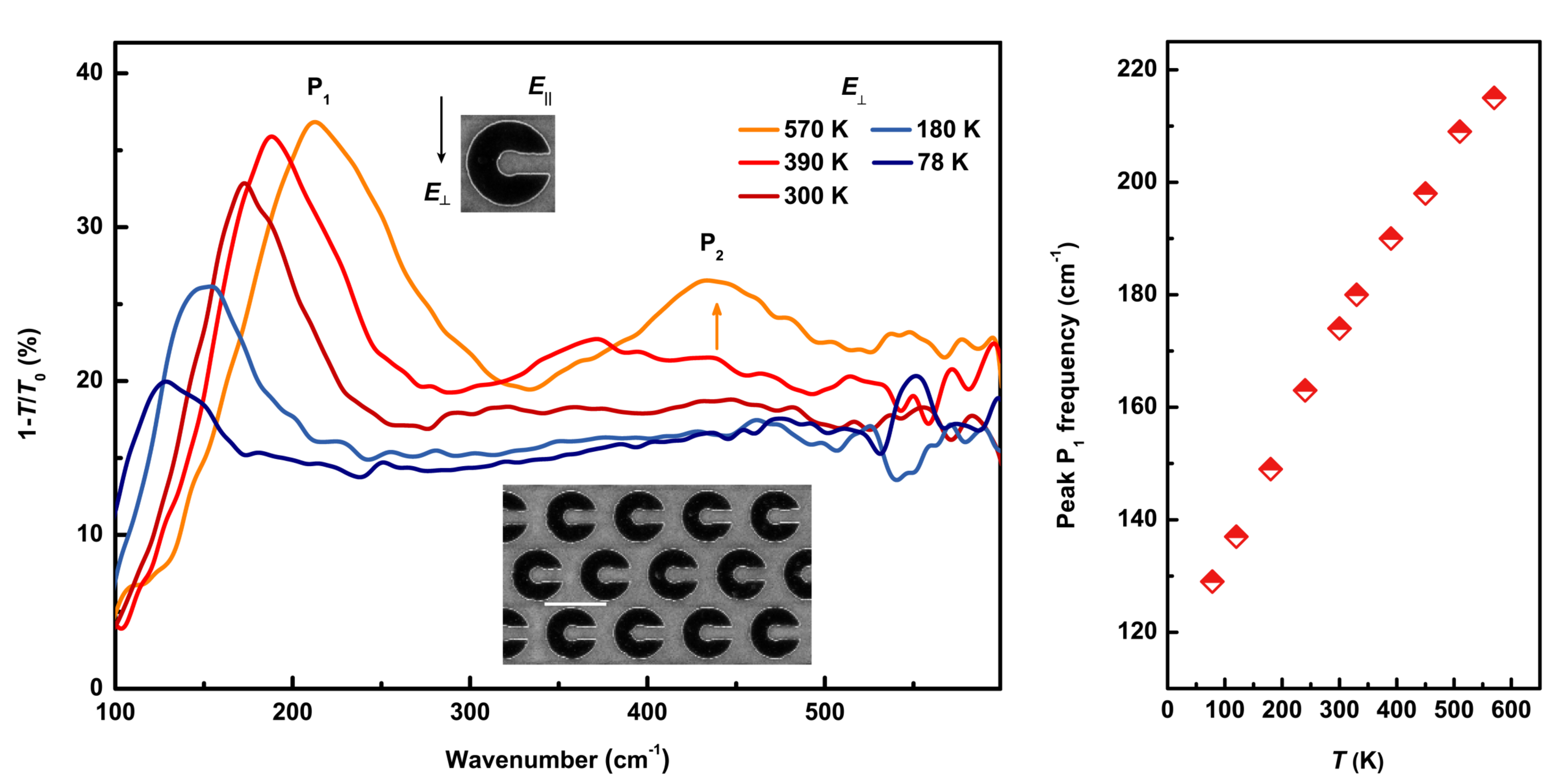
- Graphite plasmon manifests pronounced temperature and bias voltage dependence, which is in sharp contrast to the plasmon in graphene.

Dispersion of the graphite plasmon

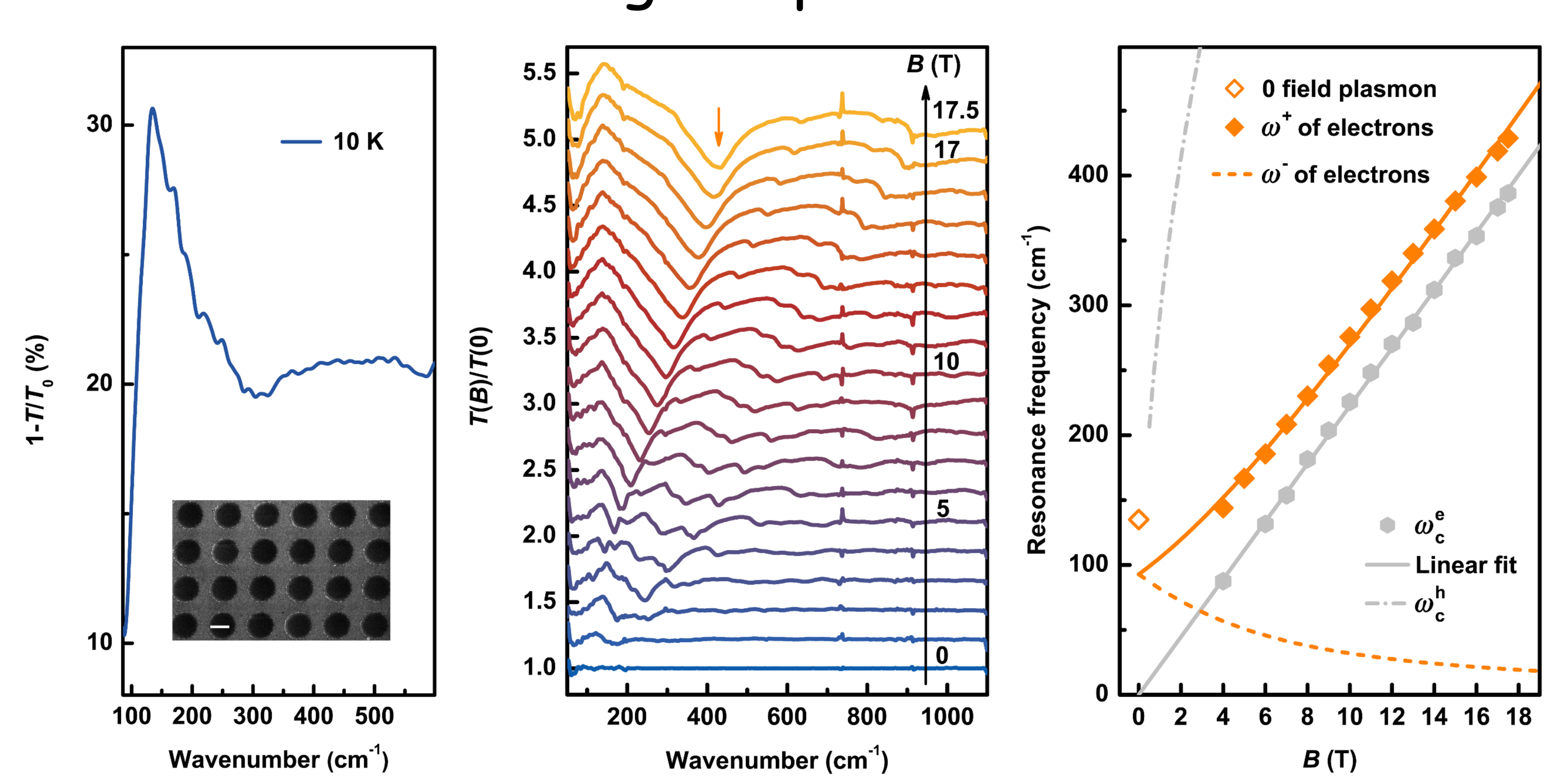


- The plasmon dispersion follows the standard $\omega_p \propto \sqrt{q}$ scaling law.
- The plasmon broadening and intensity reduction are compelling evidences of the increasing Landau damping.

Temperature tunable graphite split rings

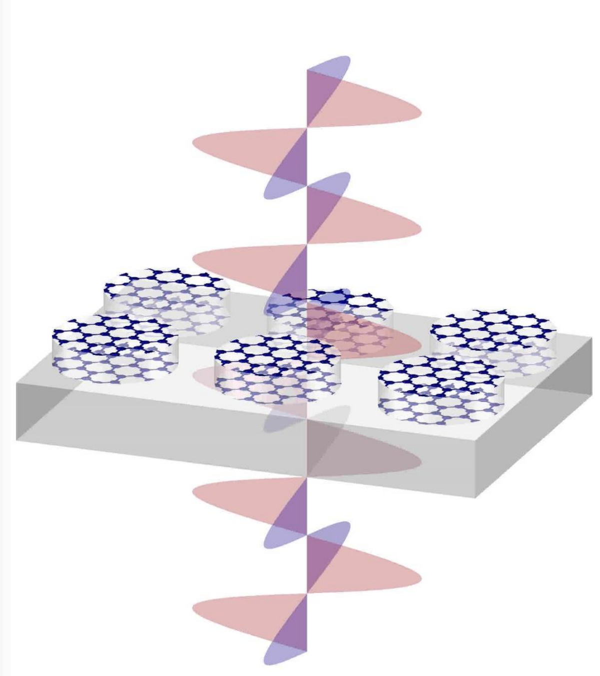


Magnetoplasmon



- The Drude weights of electrons and holes in graphite are comparable $\omega^{\pm} = \sqrt{\omega_0^2 + \left(\frac{\omega_c}{2}\right)^2} \pm \frac{\omega_c}{2}$

Conclusion



- For the first time, our work provides a comprehensive picture of the plasmon in graphite thin films through optical means.
- Plasmons in graphite combine merits of both graphene plasmons and noble metal plasmons: the tunability and strong response.
- We investigate the two-component plasma in graphite with both massive electrons and massless holes, and firstly reveal that only massive electrons play a role in the bulk plasmon mode in a moderate magnetic field.
- As a perspective of applications, the temperature and electrical bias tunable plasmons based on graphite thin film can be potentially used as a thermally, optically, and electrically tuned THz modulator.

Reference:
Qiaoxia Xing, Chaoyu Song, Chong Wang, Yuangang Xie, Shenyang Huang, Fanjie Wang,Yuchen Lei, Xiang Yuan, Cheng Zhang, Lei Mu, Yuan Huang, Faxian Xiu and Hugen Yan*, Phys. Rev. Lett. 126, 147401 (2021).
A. Grüneis, C. Attaccalite, L. Wirtz, H. Shiozawa, R. Saito, T. Pichler and A. Rubio, Phys. Rev. B 78, 205425 (2008).