Charge-Transfer Plasmon Polaritons at Graphene/α-RuCl$_3$ Interfaces

**Presenter:**
Daniel Joseph Rizzo  
(Physics, Columbia University)

**Authors:**
Daniel Joseph Rizzo  
(Physics, Columbia University)

Bjarke S. Jessen  
(Columbia University)

Zhiyuan Sun  
(Columbia University)

Francesco Ruta  
(Columbia University)

Jin Zhang  
(Max Planck Institute for Structure and Dynamics of Matter and Center for Free-Electron Laser Science)

Jiaqiang Yan  
(University of Tennessee)

Lede Xian  
(Max Planck Institute for Structure and Dynamics of Matter and Center for Free-Electron Laser Science)

Alexander S McLeod  
(Columbia University)

Michael Berkowitz  
(Columbia University)

Kenji Watanabe  
(Research Center for Functional Materials, National Institute for Materials Science)

Takashi Taniguchi  
(International Center for Materials Nanoarchitectonics)

Stephen E Nagler  
(Oakridge National Laboratory)

David George Mandrus  
(Oakridge National Laboratory)

Angel Rubio  
(Max Planck Institute for Structure and Dynamics of Matter and Center for Free-Electron Laser Science)

Michael Fogler  
(Department of Physics, University of California San Diego)
The fundamental opto-electronic properties of two-dimensional (2D) materials can be tailored based on their nanoscale charge environment. While electrostatic doping offers a means of wholesale tuning of 2D charge densities, the minimum size of charge features is limited by fields fringing through relatively thick gate insulators. Conversely, charge transfer at the interface of two atomically-thin layers with different work functions should not be subject to such limitations. Specifically, the large work function of α-RuCl₃ (6.1 eV) makes it an ideal 2D electron acceptor.

In our study, we exploit this behavior to generate charge-transfer plasmon polaritons (CPPs) in graphene/α-RuCl₃ heterostructures. Using infrared near-field optical microscopy we measure the CPP dispersion, yielding a quantitative measure of the graphene Fermi energy (~0.6 eV) and thus the charge exchanged between α-RuCl₃ and graphene (~2.7x10¹³ cm⁻²). Concurrently, we observe dispersive edge modes and internal “circular” CPPs which reveal sharp (< 50 nm) changes in the graphene optical conductivity that correspond to nanoscale modulations in the graphene doping level. Further analysis of the CPP losses implies the presence of emergent optical conductivity in the doped interfacial layer of α-RuCl₃ and suggests that it no longer possesses a Mott insulating ground state. Our results demonstrate that using high work function materials such as α-RuCl₃ in Van der Waals heterostructures presents new opportunities for controlling the local charge carrier density of graphene and other 2D materials on nanometer length scales in excess of what can be achieved with an external gate.

*EFRC on Programmable Quantum Materials: US DOE, Office of Science, BES: DE-SC0019443
ERC-2015-AdG694097
IT1249-19
SFB925
Marie Skłodowska-Curie Grant 886291 (PeSD-NeSL)
EPiQS Initiative, grant GBMF9069 and program #9455
ESI at MEXT, JPMXP0112101001, JSPS KAKENHI JP20H00354 and CREST(JPMJCR15F3), JST
ONR N00014-18-1-2722, N00014-19-1-2630