CINAP IBS Seminar

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Whispering galleries and Berry Phase Switches in Circular Graphene Resonators

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Abstract

Ballistic propagation and the light-like dispersion of graphene charge carriers make graphene an attractive platform for optics-inspired graphene electronics where gate tunable potentials can control electron refraction and transmission. In analogy to optical wave propagation in lenses, mirrors and metamaterials, gate potentials can be used to create Fabry-Pérot interferometers and a negative index of refraction for Veselago lensing. In circular geometries, gate potentials can induce whispering gallery modes(WGM), similar to optical and acoustic whispering galleries [1,2] albeit on a much smaller length scale. Klein scattering of Dirac carriers plays a central role in determining the coherent propagation of electron waves in these resonators. In this talk, I examine circular electron resonators in graphene produced with pn junction rings in two ways: 1) a traveling resonator produced by the tip potential [1], and 2) a fixed resonator produced by impurity charges in the underlying boron nitride insulator [2]. The spectrum of WGM modes in these resonators are mapped as a function of energy, position, and magnetic field with the scanning tunneling microscope (STM). Here I show that the Berry's phase associated with the topological singular Dirac point in graphene gives rise to a *sudden* and *giant* increase in energy of the WGM states in the circular graphene pn junction resonators when very small magnetic fields are applied. This Berry phase can be switched on and off with field changes on the order of 10 G, which will prove useful in future optoelectronic graphene device applications. These results agree well with recent theory on Klein scattering in graphene electron resonators [3].

1. Y. Zhao, J. Wyrick, F. D. Natterer, J. F. Rodriquez-Nieva *et al.*, Science **348**, 672 (2015).
2. Juwon Lee *et al.*, *Nature Physics*advance online publication, DOI: 10.1038/NPHYS3805, (2016).
3. J. F. Rodriguez-Nieva and L. S. Levitov, *arXiv:1508.06609*

Biography

Joseph Stroscio is a Project Leader and NIST Fellow in the Electron Physics Group in the CNST. He received a B.S. and an M.S. in Physics from the University of Rhode Island. Joe received a second M.S. and a Ph.D. in Physics from Cornell University working in the group of Professor Wilson Ho. Prior to joining NIST in 1987, he worked as a postdoctoral researcher at the IBM T. J. Watson Research Center, where he pioneered the development of scanning tunneling microscopy and spectroscopy measurements. At NIST, Joe leads multiple projects in nanoscale physics and technology. His research has encompassed areas including: atomic manipulation; the physical properties of nanostructures; nanoscale magnetism; the epitaxial growth of metal and semiconductor systems; and low-dimensional electron systems in graphene and related 2D materials. Joe has designed and constructed numerous state-of-the-art scanning probe systems involving creative custom designs that operate in ultra-high vacuum, at ultra-low temperatures, and in ultra-high magnetic field environments. Joe has authored or coauthored over 100 publications with over 8000 citations (google scholar citations), and has given more than 280 presentations. He is a Fellow of the American Association for the Advancement of Science (AAAS), the American Physical Society (APS), the American Vacuum Society (AVS). He has received the Arthur S. Flemming Award, the Department of Commerce Silver Medal Award, the Sigma Xi Young Scientist Award, the Department of Commerce Gold Medal Award, the Nano50 Award, the AVS Nanotechnology Recognition Award, and the NIST Samuel Wesley Stratton Award, and was the recipient of the Presidential Rank Award. He has served on numerous committees of the AVS, APS, and on the Editorial Board of the *Review of Scientific Instruments*. Joe's hobbies include dog fancier, playing the bass viola da gamba, building historical musical instruments, and hiking in the Rocky Mountains.