Realization of Valley-Dependent Multidirectional Electron Beam Super Collimations in 8-Pmmn Borophene

Yafang Xu*

Department of Physics, College of Physics Science and Technology, Yangzhou University, Yangzhou, China

Commentary

Received: 01-Dec-2023, Manuscript No. JPAP-23-121735; **Editor assigned**: 04-Dec-2023, Pre QC No. JPAP-23-121735 (PQ); **Reviewed**: 18-Dec-2023, QC No. JPAP-23-121735; **Revised**: 26-Dec-2023, Manuscript No. JPAP-23-121735 (R) **Published**: 02-Jan-2024, DOI:10.4172/2320-2459.11.4.008.

***For Correspondence:** Yafang Xu, Department of Physics, College of Physics Science and Technology, Yangzhou University, Yangzhou, China

E-mail: yfxu@yzu.edu.cn

Citation: Xu Y, Realization of Valley-Dependent Multidirectional Electron Beam Super Collimations in 8-Pmmn Borophene. Res Rev J Pure Appl Phys. 2023;11:008.

ABOUT THE STUDY

Since the successful fabrication of graphene in 2004, many novel physical properties attract people's attention in multiple areas such as topological phases, spintronics, valleytronics, thermo electronics and so on. Nowadays, the electron-optics which imports similar concepts in optics to electronics is actively pursued, in which superlenses, guiding, focusing, and negative refraction all have been realized in two-dimensional Dirac materials. Among most of the electron-optics phenomena, the electron beam super collimation, i.e., the quasi-one-dimensional motion of the electron wave packet is still a long-standing goal. How to realize it becomes very important. The research group of professor S.G.Louie has found that the electron beam supercollimation can be obtained no matter in periodic or disordered graphene superlattice, where the main reason is that the band structure is renormalized due to the multiple potentials, and the velocity of the electron is along only one direction [1,2]. However, in the graphene superlattice, the direction of the supercollimation is difficult to be tuned because of the integrated potentials in experiment technique, and the electron beam is valley degenerate which limit the application in valleytronics.

Inspired by these research findings, the 8-Pmmn borophene is also found to host massless Dirac fermions like graphene. But the Dirac cones on different valleys are anisotropic and tilted, which provide an ideal platform no matter in electron-optics or valleytronics. It is known that applying external fields is an effective and flexible approach to manipulate the band structure and electronic properties. As one of the common methods, the light field can induce various unique physical properties. It is found that by irradiating an off-resonant linearly polarized light, the dispersion of the 8-Pmmn borophene can also be renormalized effectively [3]. The dispersion of the pristine 8-Pmmn borophene is given as.

$$E = \eta\hbar v_t k_y \pm \hbar\sqrt{(v_x k_x)^2 + (v_y k_y)^2} \quad ....(1)$$

which becomes to the form under the modulation of light as follows,

$$E = \eta\hbar v_t k_y \pm \hbar\sqrt{(v_1 k_x + v_2 k_y)^2 + (v_3 k_y + v_4 k_x)^2} \quad \text{......... (2)}$$

The coefficients v1 , v2, v3, v4 are the renormalized velocities, which are

$$v_1 = v_x(1-\gamma v_y^2 \sin^2\xi / v_F^2)$$

$$v_2 = v_x v_y^2 \gamma \sin\xi \cos\xi / v_F^2$$

$$v_3 = v_y(1-\gamma v_x^2 \cos^2\xi / v_F^2)$$

$$v_4 = v_y v_x^2 \gamma \sin\xi \cos\xi / v_F^2 \quad \text{........ (3)}$$

The parameter $\gamma = (eE_0 v_F/\hbar\omega^2)^2$ is related to the off-resonant light, and ξ is the polarization direction, E_0 is the amplitude, ω is the frequency of the light. The valley-dependent band structures are modified, and the group velocity of the chiral electronic state is controlled by the off-resonant light with no need for additional structural design comparing with that in graphene superlattice. In addition, the pseudospin of the electrons undergoes a great change, which from the helical form collapse into two specific directions, i.e., the left and right or the up and down at certain parameters. The Dirac cones in pristine 8-Pmmn borophene become into peculiar wedge-shaped structures at special illumination parameters, the electron wave packet can be guided to propagate virtually undistorted along +20.4° for the electrons on K_D valley and −20.4° for K'_D valley. As the interesting tunneling phenomena, all-electrons Klein tunneling and omnidirectional reflection can be achieved in the off-resonant light modified n-p and n-p-n junctions. In conclusion, by applying the off-resonant linearly polarized light, it provides a convenient way to construct novel quasi-one-dimensional electronic states so as to realize the valley-dependent electron beam supercollimation. These findings are expected to offer more opportunities in device applications especially in valleytronics and electron optics [4-6].

REFERENCES

1. Park CH, et al. Electron beam supercollimation in graphene superlattices. Nano Lett. 2008;8:2920-2924.
2. Choi SK, et al. Measurement of the branching fraction B(Λ+c→pK−π+). Phys Rev Lett. 2014;113:026802.
3. Xu Y, et al. Pseudospin collapse, multidirectional supercollimations, and all-electrons transmission and reflection in irradiated 8-Pmmn borophene. New J Phys. 2023;25:113002.
4. Armstrong CM. The Na/K pump, Cl ion, and osmotic stabilization of cells. Proc Natl Acad Sci USA. 2003;100:6257-6262.
5. Lew VL, et al. Volume, pH, and ion-content regulation in human red cells: Analysis of transient behavior with an integrated model. J Membr Biol. 1986;92:57-74.
6. Vereninov IA, et al. Computation of pump-leak flux balance in animal cells. Cell Physiol Biochem. 2014;34:1812-1823.