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Goos–Hänchen-like shift related to spin and valley polarization in ferromagnetic silicene*

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We study the Goos–Hänchen-like shift of single silicene barrier under the external perpendicular electric field, off-resonant circularly polarized light and the exchange field modulation using the stationary-phase method. The results show that the Goos–Hänchen-like shift of silicene resulting from the external perpendicular electric field does not have the characteristics of spin or valley polarization, while that from off-resonant circularly polarized light or the exchange field is spin-polarized. More importantly, the combined effect of the external perpendicular electric field and the exchange field or off-resonant circularly polarized light can cause the Goos–Hänchen-like shift of the system to be spin and valley polarized. It is particularly worth noting that when the three modulations are considered at the same time, as the exchange field changes, the system will have a positive or negative Goos–Hänchen-like shift.

Keywords: Goos–Hänchen-like shift, silicene, polarization

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1. Introduction

The Goos–Hänchen (GH) shift was first discovered by Goos and Hänchen in 1947.[1,2] This is an optical phenomenon, which means that when a very narrow beam is totally reflected, the reflection point and the incident point are not at the same position, and the reflected light has a very small lateral shift at the interface relative to geometric optics. The GH shift is widely used in integrated optics, near-field optics and optical devices. For example, optical switch based on GH shift,[3] solution concentration sensor[4] and temperature sensor.[5] In addition, quantum GH effect has been considered in electronics. For example, it has shown that the effect at a p–n interface in graphene is strongly dependent on the sublattice degree of freedom.[6] And it has been studied in graphene double barriers,[7] which provides feasibility for making valley splitter. Furthermore, the GH effect can be affected by the presence of a magnetic field in graphene triangular barrier.[8] This GH shift can be applied to spintronics to obtain spintronic devices.[9] Compared with traditional electronic devices, spintronic devices have the advantages of large information storage capacity, fast data processing speed, and low power consumption.[10]

Combining semiconductor materials with the optical phenomenon[11,12] of GH shift, Chen *et al.*[13–15] extended it to partial reflection to obtain Goos–Hänchen-like (GHL) shift, which is similar to but different from GH shift and has nothing to do with evanescent waves. Researchers studied GHL shift on various graphene-based nanostructures in single barrier,[16] and have proved that the GHL shift can be adjusted by changing the electrostatic potential and the induced gap. The GH shift in Weyl semi-metallic electrons is analogous to that in graphene.[17] It is also found that the GHL shift, as the function of the barrier's width and incidence angle, can be negative and positive in the cases of Klein tunneling and classical motion. Studies in strained graphene[18–20] have shown that the GHL shift is the function of the strain tensor and direction. In a gated monolayer WS_2,[21] the GHL shift of spin-polarized electrons extremely rely on the width of the gated region and can be positive or negative in both Klein tunneling and classical motion regimes.

In addition, silicene is similar in structure and physical properties to graphene. However, there is a significant difference between silicene and graphene, the strong spin–orbit coupling (SOC), which results in a band gap in the energy spectrum of silicene.[22,23] It has demonstrated that for a normal/ferromagnetic/normal silicene junction, the GHL shift is negative and positive.[24,25] However, there are few further studies on simultaneous valley- and spin-polarized GHL shift in silicene. Recently, it is reported that the off-resonant circularly polarized light can open a band gap of the Dirac cone in silicene,[26–28] which can lead to the valley separation.[29] In this paper, we investigate the GHL shift of a single silicene barrier with the external perpendicular electric field, the

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exchange field and the off-resonant circularly polarized light. The GHL shift of spin-polarized can be achieved in silicene with off-resonant circularly polarized light or the exchange field. The addition of the external perpendicular electric field can make the GHL shift of the system have the characteristics of spin polarization and valley polarization at the same time. What's more, the continuous exchange field can realize the transition between positive and negative GHL shifts.

2. Model and formalism

We place a ferromagnetic insulator on the bottom of the silicene to form a ferromagnetic silicene. The external perpendicular electric field λ_z and off-resonant circularly polarized light λ_Ω are applied to the ferromagnetic silicene area, as shown in Fig. 1. The low-energy effective Hamiltonian of the ferromagnetic silicene region with the external perpendicular electric field and off-resonant circularly polarized light can be written as[28–31]

$$H = \hbar v_{\rm F}(k_x\tau_x - \eta k_y\tau_y) - \eta\lambda_{\rm so}s\tau_z + \lambda_z\tau_z + sM + \eta\lambda_\Omega\tau_z. \quad (1)$$

Here, $v_{\rm F} \approx 5.5\times10^5$ m/s is the Fermi velocity, $\lambda_{\rm so} \approx 3.9$ meV is the spin–orbit coupling in silicene, $\tau_{x,y,z}$ are the Pauli matrixs in sublattice pseudo-spin space, M is the effective exchange field obtained by the magnetic neighboring effect of ferromagnetic insulators, λ_z is the external perpendicular electric field and λ_Ω is the effective energy induced by the off-resonant circularly polarized light.

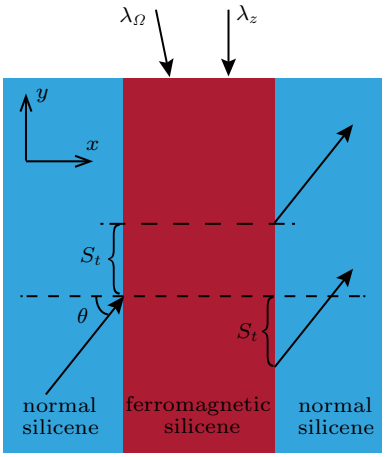


Fig. 1. Schematic diagram of the normal-ferromagnetic-normal silicene under the external perpendicular electric field λ_z and off-resonant circularly polarized light λ_Ω. The transport direction is along the x-axis.

Upon diagonalization of the Hamiltonian, the energy dispersion can be calculated as following:

$$E_{\eta,s} = sM \pm \sqrt{(\hbar v_{\rm F}k)^2 + (\eta s\lambda_{\rm so} - \eta\lambda_\Omega - \lambda_z)^2}, \quad (2)$$

where $k = \sqrt{\frac{E^2-(\eta s\lambda_{\rm so})^2}{\hbar^2 v_{\rm F}{}^2}}$, $s = \pm1$ denotes the spin-up (spin-down) degree of freedom and $\eta = \pm1$ is the sign of the valley K (K'). Because of the translation invariance in the y direction, the transverse wave vector k_y is conserved. Inevitably, $k_x = k\cos\theta$, $k_y = k\sin\theta$ in this structure and θ is the corresponding incident angle. With taking into account the modulation along the x direction, the wave function of the plane wave components in the incident region is given by

$$\varphi_1 = \begin{bmatrix} 1 \\ \frac{\beta_1}{\alpha_1}e^{i\eta\theta} \end{bmatrix} e^{i(k_x x + k_y y)} + r \begin{bmatrix} 1 \\ -\frac{\beta_1}{\alpha_1}e^{-i\eta\theta} \end{bmatrix} e^{-i(k_x x + k_y y)}, \quad (3)$$

the corresponding wave function in the transmitted region can be expressed by

$$\varphi_3 = t \begin{bmatrix} 1 \\ \frac{\beta_3}{\alpha_3}e^{i\eta\theta} \end{bmatrix} e^{i(k_x x + k_y y)}, \quad (4)$$

and the wave function in ferromagnetic silicene region can be written as

$$\varphi_2 = a \begin{bmatrix} \beta_2 e^{\frac{i\eta\theta_j}{2}} \\ \alpha_2 e^{\frac{-i\eta\theta_j}{2}} \end{bmatrix} e^{i(q_x x + k_y y)} + b \begin{bmatrix} \beta_2 e^{\frac{-i\eta\theta_j}{2}} \\ -\alpha_2 e^{\frac{i\eta\theta_j}{2}} \end{bmatrix} e^{-i(q_x x + k_y y)}, \quad (5)$$

where r and t are the reflection coefficient and transmission coefficient, respectively. $\alpha_1 = \alpha_3 = \sqrt{1 - \frac{\eta\lambda_{\rm so}s\tau_z}{E}}$, $\alpha_2 = \sqrt{1 + \frac{\Delta}{E - sM}}$, $\beta_1 = \beta_3 = \sqrt{1 + \frac{\eta\lambda_{\rm so}s\tau_z}{E}}$, and $\beta_2 = \sqrt{1 - \frac{\Delta}{E-sM}}$, among them, $\Delta = \eta(s\lambda_{\rm so} - \lambda_\Omega) - \lambda_z$. $\theta_j = \arctan(k_y/q_x)$ is refraction angle, $q^2 = {q_x}^2 + {k_y}^2$ and the longitudinal wave-vector q_x in ferromagnetic silicene region can be further derived from Eq. (2) as

$$q_x = \sqrt{\frac{(E - sM)^2 - (\eta s\lambda_{\rm so} - \eta\lambda_\Omega - \lambda_z)^2}{\hbar^2 {v_{\rm F}}^2} - {k_y}^2}. \quad (6)$$

The total transfer matrix X relating wave function between two leads is given by

$$X = {P_{\rm L}}^{-1} Q_j P_{\rm R}, \quad (7)$$

where

$$P_{\rm L} = \begin{bmatrix} \beta_1 e^{i\eta\theta_{\rm L}/2} & \beta_1 e^{-i\eta\theta_{\rm L}/2} \\ \alpha_1 e^{-i\eta\theta_{\rm L}/2} & -\alpha_1 e^{i\eta\theta_{\rm L}/2} \end{bmatrix},$$
$$P_{\rm R} = \begin{bmatrix} \beta_3 e^{i\eta\theta_{\rm R}/2} & \beta_3 e^{-i\eta\theta_{\rm R}/2} \\ \alpha_3 e^{-i\eta\theta_{\rm R}/2} & -\alpha_3 e^{i\eta\theta_{\rm R}/2} \end{bmatrix}, \quad (8)$$

and the transfer matrix in ferromagnetic silicene is $Q_j = P_j G_j {P_j}^{-1}$ with

$$G_j = \begin{bmatrix} e^{-iq_x d} & 0 \\ 0 & e^{iq_x d} \end{bmatrix}, \quad P_j = \begin{bmatrix} \beta_2 e^{i\eta\theta_j/2} & \beta_2 e^{-i\eta\theta_j/2} \\ \alpha_2 e^{-i\eta\theta_j/2} & -\alpha_2 e^{i\eta\theta_j/2} \end{bmatrix}. \quad (9)$$

By applying the transfer matrix method,[32] the transmission coefficient t can be calculated and expressed as the following form:[33,34]

$$t_{\eta,s} = [\cos(q_x d) + i\gamma_{\eta,s}\sin(q_x d)]^{-1}, \quad (10)$$

with

$$\gamma_{\eta,s} = (2E_1E_2k_y^2 - E_2k^2 - E_1q^2)/2E_1E_2k_xq_x. \tag{11}$$

Here, $E_1 = E + \eta s\lambda_{so}$ and $E_2 = E - sM + \Delta$. The phase of the transmission coefficient can be derived as

$$\varphi_{\eta,s} = \arctan[-\gamma_{\eta,s}\tan(q_xd)]. \tag{12}$$

The Goos–Hänchen-like shift can thus be obtained through the stationary phase method [7,16] as follows:

$$S_t{}^{\eta,s} = -\frac{\partial\varphi_{\eta,s}}{\partial k_y}. \tag{13}$$

3. Results and discussion

Firstly, we calculate the GHL shift as a function of q_xd at the different external perpendicular electric field, off-resonant circularly polarized light or the exchange field. Herein, S_t has been rescaled by λ_F, where λ_F is the Fermi wavelength of electrons, while d is rescaled by ${q_x}^{-1}$.

We discuss the GHL shift for silicene with different external perpendicular electric field strength (as seen in Figs. 2(a) and 2(b)). The shifts of spin-up electrons at K valley ($K\uparrow$) are the same as that for spin-down electrons at K' valley ($K'\downarrow$), and the shifts of spin-down electrons at K valley ($K\downarrow$) are also the same as that for spin-up electrons at K' valley ($K'\uparrow$). As $\lambda_z = 25$ meV (as shown in Fig. 2(b)), the shifts of spin-up (spin-down) electrons at K (K') valley are high, while the shifts of spin-down (spin-up) electrons at K (K') valley vanish. The maximum value of the GHL shift corresponds to the resonance conditions $q_xd = k\pi$ ($k = 0, 1, 2, 3, \ldots$), which is given as

$$S_t = -\frac{(2E_1E_2k_y^2 - E_2k^2 - E_1q^2)k_yd}{2E_1E_2k_x{q_x}^2}. \tag{14}$$

For sake of clearness, the inset of Fig. 2(b) further displays the magnitude of S_t-peak versus external perpendicular electric field at $q_xd = 3\pi$, where the GHL shift demonstrates obvious jump. For example, the shift values of spin-up (spin-down) electrons at K (K') valley suddenly change from a large positive shift to zero when $\lambda_z \approx 21$ meV, while the shift values of spin-down (spin-up) electrons at K (K') valley emerge the same adjustment at $\lambda_z \approx 29$ meV.

When only the external perpendicular electric field is considered, the electronic band structures do not have the characteristics of spin or valley polarization (as seen in Fig. 2(c)). Equation (2) can be reduced to $E_{\eta,s} = \pm\sqrt{(\hbar v_F k)^2 + (\eta s\lambda_{so} - \lambda_z)^2}$. That is, $E_{+,+} = E_{-,-}$ and $E_{+,-} = E_{-,+}$. Thus, silicene with only external perpendicular electric field can distinguish neither valleys nor spins.

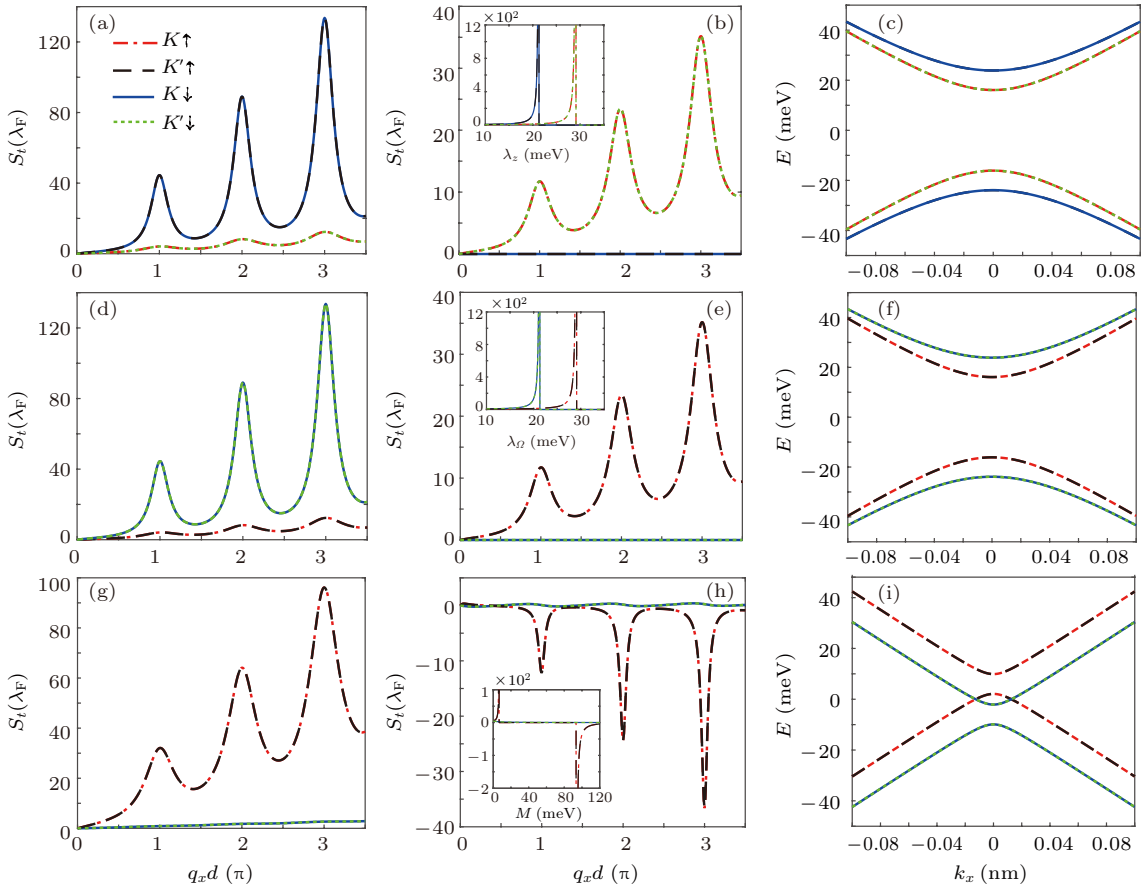


Fig. 2. GHL shift for the transmitted beam as a function of barrier width d with parameters $E = 50$ meV, $\lambda_{so} = 3.9$ meV, and $\theta = \pi/3$. (a) $\lambda_z = 20$ meV, (b) $\lambda_z = 25$ meV. (d) $\lambda_\Omega = 20$ meV, (e) $\lambda_\Omega = 25$ meV. (g) $M = 6$ meV, (h) $M = 100$ meV. Panels (c), (f) and (i) are electronic band structures for spins and valleys corresponding to (a), (d) and (g), respectively.

Under the modulation of the off-resonant circularly polarized light (as seen in Figs. 2(d) and 2(e)), the values of CHL shift have no difference, which is similar to that of Figs. 2(a) and 2(b). However, the shifts of the spin-up electrons are identical, and the spin-down of that are also identical. As $\lambda_\Omega = 25$ meV (as shown in Fig. 2(e)), the shifts of spin-up electrons become higher, while the shifts of spin-down electrons vanish. In the inset of Fig. 2(e), the values of all shifts increase first, then rapidly decrease to zero. However, the position where the shift of the spin-up electrons and the spin-down electrons vary to zero is different. We can find that the shift of spin-up electrons exhibits a mutation at $\lambda_\Omega \approx 21$ meV, and comparably, the shift of spin-down electrons is at $\lambda_\Omega \approx 29$ meV.

This result can be well explained by the band structures (as shown in Fig. 2(f)), the band gap for $K\uparrow$ ($K\downarrow$) is the same as $K'\uparrow$ ($K'\downarrow$). Only taking the off-resonant circularly polarized light into account, Eq. (2) shows that the band structure can be written as $E_{\eta,s} = \pm\sqrt{(\hbar v_{\rm F}k)^2 + \eta^2 s^2 {\lambda_{\rm so}}^2 - 2\eta^2 s\lambda_{\rm so}\lambda_\Omega - \eta^2{\lambda_\Omega}^2}$. One can derive that the shift is spin-polarized according to this formula. Therefore, the shift is spin-dependent with the circularly polarized light modulation, which indicates that the silicene with off-resonant circularly polarized light can be designed as the spin beam filter.

The electrons shifts are also spin-dependent with only adjusting the exchange field (as shown in Figs. 2(g) and 2(h)). But the difference is that the fluctuation in shifts of spin-down electrons is very weak. When $M = 6$ meV, the shifts of spin-up electrons are positive. While, for the case of $M = 100$ meV, the shifts of spin-up electrons are negative. To show this reversal more clearly, we plot S_t-peak at $q_x d = 3\pi$ in the inset of Fig. 2(h). With the value of the exchange field M increasing from 0 meV to 6.65 meV, the shift value of spin-up electrons gradually increases to positive peak value, then it abruptly reduced to zero. When M surpasses to the critical value 93.34 meV, the shift value suddenly changes from 0 to negative peak value. Then it increases to zero gradually with the further increasing exchange field M. Such a changed shift is closely related to the longitudinal wave-vector which is determined by the exchange field M.

With the presence of exchange field, there are two valley-dependent gaps in the band structure (as shown in Fig. 2(i)). The spin-up (spin-down) bands are pushed upward (downward). The band structure in Eq. (2) can be reduced to the expression $E_{\eta,s} = sM \pm \sqrt{(hv_{\rm F}k)^2 + {\lambda_{\rm so}}^2}$. We can find that η has nothing to do with $E_{\eta,s}$. In other words, the shift with the exchange field modulation is spin-dependent. It should be pointed out that the negative shift is associated with the Klein tunneling effect.[35–38]

In order to explore the effect of combined modulation, the calculated results for GHL shift are shown in Fig. 3. The relationship between the GHL shift and incident energy is discussed when both off-resonant circularly polarized light and the exchange field are considered (as seen in Fig. 3(a)). The electrons shifts separate two spin-dependent beams for a specific valley. A strong contrast in amplitude can be observed for spins orientation. Specifically, at the same valley, the shift value of the spin-up electrons is about six times that of the spin-down electrons. These maximum values correspond to the transmission resonances and demonstrate the spin splitting of charge carriers in silicene, which means that the shift can be generated and controlled by the exchange field and off-resonant circularly polarized light. The equation of propagation mode is given as

$$(E_{\eta,s} - sM)^2 - \Delta^2 \geqslant (E_{\eta,s} - \eta s_z \lambda_{\rm so})^2 \sin^2\theta. \tag{15}$$

So the formula of the critical point can be derived from Eq. (15) as

$$E_{\eta,s}^2(1-\sin^2\theta) - 2sME_{\eta,s} + s^2M^2 - \Delta^2 + {\lambda_{\rm so}}^2\sin^2\theta \geqslant 0. \tag{16}$$

Only considering off-resonant circularly polarized light and the exchange field in this structure, we can obtain that the values of shift are 0 when $E_{1,1} = E_{-1,1} < 101.4145$ meV and $E_{1,-1} = E_{-1,-1} < 247.0904$ meV. Then, with increasing exchange field M, it reaches the maximum, and finally decay. The band gap for $K\uparrow$ ($K\downarrow$) is also the same as that of $K'\uparrow$ ($K'\downarrow$) (as seen in Fig. 3(a)). So, the GHL shift with both off-resonant circularly polarized light and the exchange field is only spin-dependent.

The GHL shift is spin-polarized when only the exchange field is modulated. By further involving a nonzero external perpendicular electric field λ_z, we can find that the shifts of different valleys can be distinguished weakly (as seen in Fig. 3(b)). Spin-up and spin-down states are mixed at the energy band intersection and spin degeneracy is broken. Similarly, from Eq. (15), the maximum shifts of $K\uparrow$, $K'\uparrow$, $K\downarrow$ and $K'\downarrow$ occur at 156.1 meV, 163.9 meV, 3.9 meV and -3.9 meV, respectively. Thus, the GHL shift under the external perpendicular electric field combined with exchange field is partial spin- and valley-polarized.

The GHL shifts with the external perpendicular electric field and the off-resonant circularly polarized light co-modulated are plotted in Fig. 3(c). From Eq. (15), we can obtain that the four spectras change from zero to the maximum at $E_{-1,1} = 111.9965$ meV, $E_{-1,-1} = 127.6214$ meV, $E_{1,1} = 192.0813$ meV and $E_{1,-1} = 207.6902$ meV, respectively, then oscillation decay. Moreover, the shift value of electrons from K' valley is a quarter of K valley, which can be perfectly reflected in Fig. 3(c). The band gap of spins and valleys

are both broader, and the gaps with different spins and valleys do not coincident. Since the both spin- and valley-dependent beams can be well separated under the external perpendicular electric field and off-resonant circularly polarized light modulations, the GHL shift is spin and valley polarization.

Considering all three external modulations, the polarization is more pronounced (as seen in Fig. 3(d)). The spin and valley are separate completely, which features that four S_t-peaks appear in $E_{-1,-1} = 65.2144$ meV, $E_{1,-1} = 138.9411$ meV, $E_{-1,1} = 211.6936$ meV and $E_{1,1} = 284.1940$ meV, respectively. These conclusions can also be proved from Eq. (15). More interestingly, the values of GHL shifts at $K'\downarrow$,$K\downarrow$, $K'\uparrow$, and $K\uparrow$ increase in turn. Based on Eq. (2), one can find that the valley and spin degenerate are lifted and different gaps are induced at different spins and valleys (as seen in Fig. 3(d)). Therefore, both spin and valley polarization are striking in this case.

Since the above researches were conducted under the fixed value of the field strength, we further explore the influence of the continuous off-resonant circularly polarized light, the external perpendicular electric field or the exchange field on the GHL shift, respectively. Figure 4(a) displays the shift as a function of the circularly polarized light modulation. As we can see, the shift of spin-down electrons occur, but the electrons shift of spin-up electrons is negligible. The formula of the critical point can be derived from Eq. (15) as

$$(E_{\eta,s} - sM)^2 - (E_{\eta,s}^2 - {\lambda_{\rm so}}^2)\sin^2\theta - (\eta(s\lambda_{\rm so} + \lambda_\Omega) + \lambda_z) \geqslant 0. \tag{17}$$

The shift of spin-down electrons increases oscillatingly, and then alters to zero abruptly. However, the shift values of spin-up electrons are negligible. The shift values of spin-down electrons at K and K' become maximum at the position of $\lambda_\Omega = 31.2036$ meV and $\lambda_\Omega = 71.2036$ meV, respectively, which can be derived from Eq. (17).

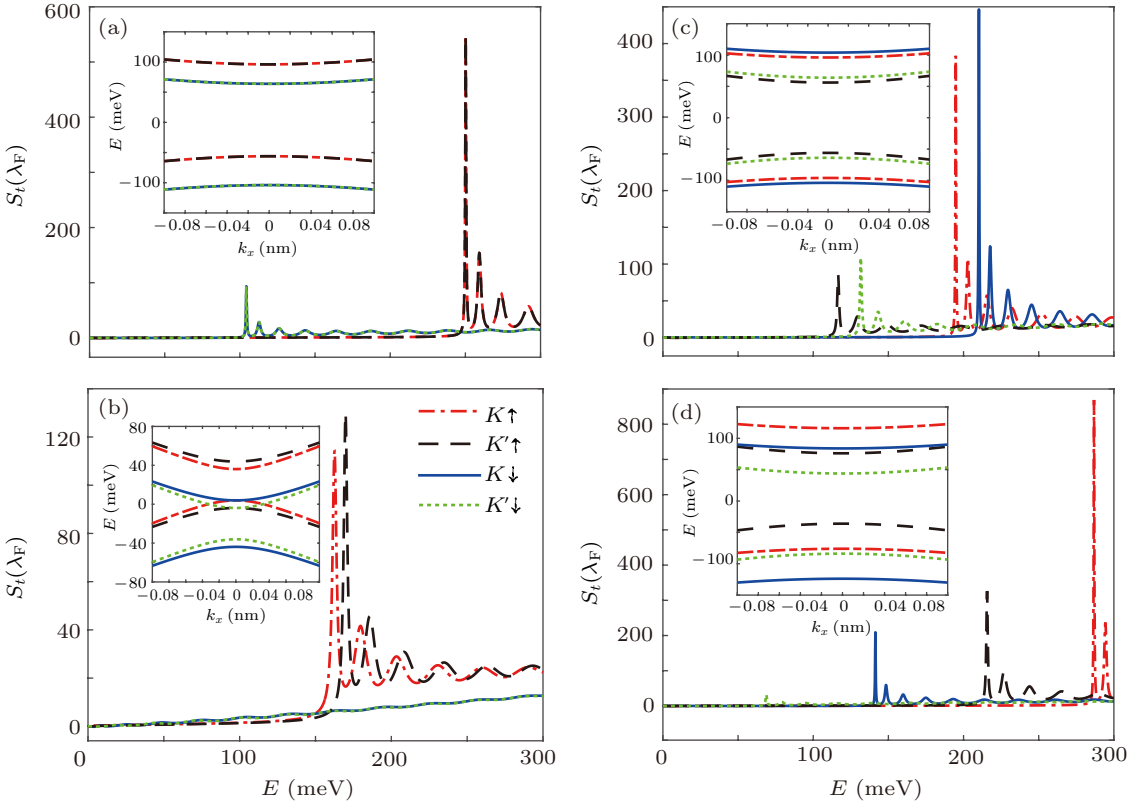


Fig. 3. GHL shift as a function of incident energy E with $\lambda_{\rm so} = 3.9$ meV, $\theta = \pi/3$, and $d = 40$ nm. (a) $\lambda_\Omega = 80$ meV, $M = 20$ meV and $\lambda_z = 0$ meV. (b) $\lambda_\Omega = 0$ meV, $M = 20$ meV and $\lambda_z = 20$ meV. (c) $\lambda_\Omega = 80$ meV, $M = 0$ meV and $\lambda_z = 20$ meV. (d) $\lambda_\Omega = 80$ meV, $M = 20$ meV and $\lambda_z = 20$ meV.

The effect of the external perpendicular electric field on the GHL shift in Fig. 4(b) is similar to that of off-resonant circularly polarized light modulation in Fig. 4(a). However, the values of the electrons shift for the same valley are different. In the case, with the external perpendicular electric field λ_z increasing to 55.0709 meV and 102.8709 meV, from Eq. (17), the shifts of $K'\downarrow$ and $K\downarrow$ increase gradually to maximum.

While under a continuous range of the exchange field modulation, in Fig. 4(c), all spin up-related peaks are displayed as a negative value, and spin down-related peaks are displayed as positive values. For valleys with the same spin direction, a strong amplitude contrast can be observed. The GHL shifts of $K'\downarrow$, $K\downarrow$, $K'\uparrow$, and $K\uparrow$ convert from zero to maximum in turn, and then the oscillation decrease. When $M = 11.5695$ meV, 44.3547 meV, 106.2744 meV and 137.4917 meV, the values of GHL shift reach maximum,

which can be derived from Eq. (17). Therefore, the filtering function can be modified by adjusting the values of the three fields.

From Eq. (16), we can find that the incident angle can also affect the GHL shifts of the electrons. The GHL shifts with different incident angles are demonstrated in Fig. 5. Indeed, it is shown that valley and spin are always polarization, and the GHL shift is closely related to the incident angle. In Fig. 5(a), for the incident angle $\theta = \pi/18$, the maximum shift of K' valley is always smaller than that of K valley. Increasing the incident angle to $4\pi/18$ (see Fig. 5(b)), the magnitude of the shift value is six times that of the original value in Fig. 5(a). By further comparing with the corresponding results for $\theta = 8\pi/18$ in Fig. 5(c), the spin up-related peaks become larger than the spin down-related peaks. We can regulate the GHL shift to higher values by increasing incident angle, which can be a good way to make valley correlation filters.

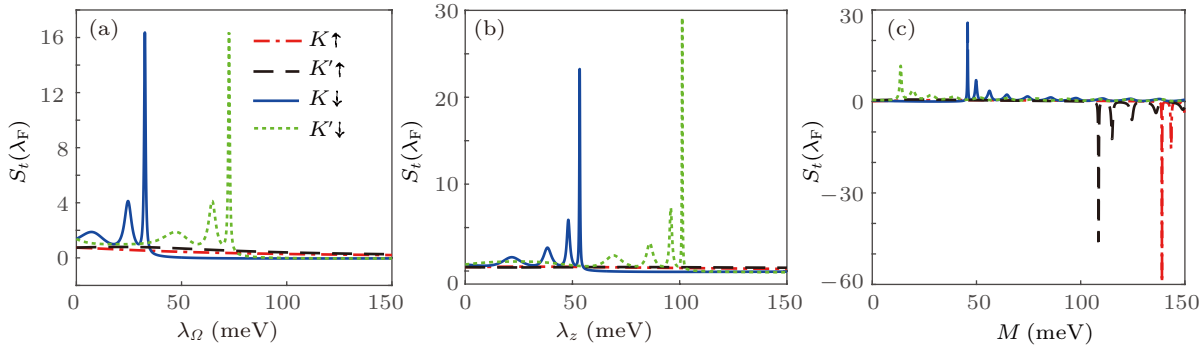


Fig. 4. (a) GHL shift as a function of off-resonant circularly polarized light λ_Ω with $M = 20$ meV, and $\lambda_z = 20$ meV. (b) GHL shift as a function of the external perpendicular electric field λ_z with $M = 40$ meV, and $\lambda_\Omega = 20$ meV. (c) GHL shift as a function of the exchange field M with $\lambda_\Omega = 60$ meV, and $\lambda_z = 20$ meV. Other parameters are $\lambda_{so} = 3.9$ meV, $\theta = \pi/3$, $E = 50$ meV, and $d = 40$ nm.

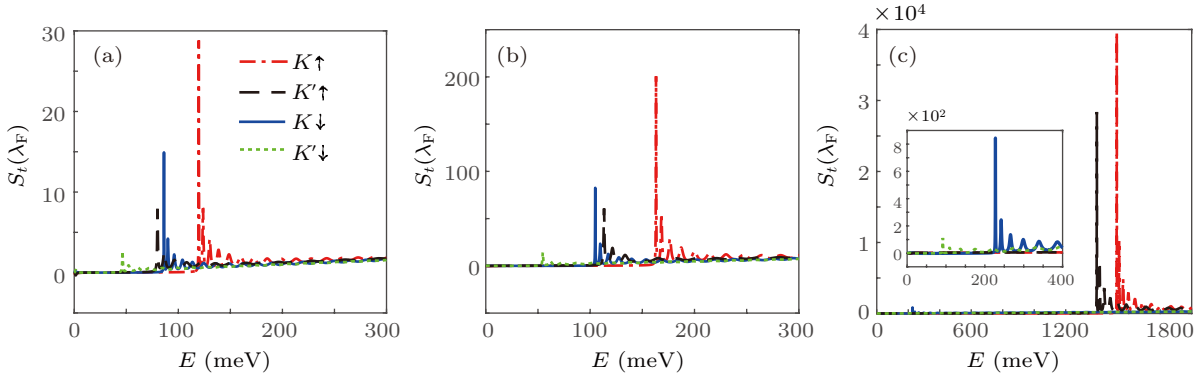


Fig. 5. GHL shift for the transmitted beam as a function of incident energy E with $\lambda_{so} = 3.9$ meV, $M = 20$ meV, $\lambda_\Omega = 80$ meV, $\lambda_z = 20$ meV, and $d = 40$ nm. (a) $\theta = \pi/18$. (b) $\theta = 4\pi/18$. (c) $\theta = 8\pi/18$. The regime for $0 < E < 400$ meV is enlarged as in the insets.

4. Conclusion

In summary, the Goos–Hänchen-like shift for single silicene with off-resonant circularly polarized light, exchange field and the external perpendicular electric field has been studied. It was found that the GHL shift of silicene with an external perpendicular electric field cannot distinguish valleys or spins. Only with the exchange field or the off-resonant circularly polarized modulation, the GHL shift was spin-dependent. Particularly, not only under the external perpendicular electric field and off-resonant circularly polarized light modulations but also under the exchange field and the external perpendicular electric field modulations, the GHL shift is both spin- and valley-polarized. Furthermore, by controlling the strength of these three fields appropriately, the spin- and valley-polarized of the shift is more noticeable. The magnitude of the shift can also be changed by adjusting the incident angle. We hope our findings can be helpful for the electrical control of spin and valley filtering and the application of quantum information.

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