Determination of Rashba and Dresselhaus spin-orbit fields

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Determination of Rashba and Dresselhaus spin-orbit interaction strengths in a particular sample remains a challenge even today. In this article we investigate the possibilities of measuring the absolute values of these interaction strengths by calculating persistent charge and spin currents in a mesoscopic ring. Our numerical results can be verified experimentally.

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\section{I. INTRODUCTION}

Determination of spin-orbit (SO) coupling strengths in meso-scale and nano-scale semiconductor structures has drawn a lot of attention since it is extremely crucial for designing spintronic devices. SO interactions couple the orbital motions of electrons to their spin and lift the degeneracy between spin up and down states. It gives the possibility of manipulating and controlling the spin of an electron rather than its charge \cite{1–5}. In solid-state materials one comes across two types of SO fields, namely, Rashba and Dresselhaus fields. SO interaction is a relativistic effect. In the reference frame of a moving electron, an electric field is converted to a magnetic field which induces a spin splitting through the coupling of the electron spin with its momentum. Depending on the origin of the electric field we refer SO field as a Rashba or Dresselhaus field. If the electric field is originated from a structural inversion asymmetry we get Rashba SO interaction. On the other hand, Dresselhaus term is obtained when the electric field is developed from a bulk inversion asymmetry. The precise measurement of both these two fields are extremely important to design spin based electronic devices.

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{ring.png}
\caption{(Color online). Schematic view of a mesoscopic ring threaded by an AB flux $\phi$. The filled red circles correspond to the positions of the atomic sites.}
\end{figure}

Rashba and Dresselhaus fields. SO interaction is a relativistic effect. In the reference frame of a moving electron, an electric field is converted to a magnetic field which induces a spin splitting through the coupling of the electron spin with its momentum. Depending on the origin of the electric field we refer SO field as a Rashba or Dresselhaus field. If the electric field is originated from a structural inversion asymmetry we get Rashba field. On the other hand, Dresselhaus field is obtained when the electric field is developed from a bulk inversion asymmetry. The precise measurement of both these two fields are extremely important to design spin based electronic devices.

Usually the strength of Rashba SO coupling is much higher than the Dresselhaus SO coupling, and therefore, people have initially tried to measure the Rashba term. In an experiment Koga \textit{et al.} \cite{6} have measured the values of Rashba coupling in quantum wells using the weak antilocalization (WAL) analysis in terms of structural inversion asymmetry of the quantum wells. This WAL approach provides a useful tool for determining Rashba SO coupling. Using photocurrent measurements \cite{7} on quantum wells, on the other hand, the relative strengths of Rashba and Dresselhaus terms can be very nicely deduced where angular distribution of the spin-galvanic effect at certain directions of spin orientation in the plane of a quantum well is used. A gate-controlled crossover from weak localization to antilocalization in coherent transport using a two-dimensional electron gas has allowed to estimate separately the Rashba and Dresselhaus SO coupling terms \cite{8}. In a particular sample, Rashba strength can also be monitored by applying electric fields from gates \cite{9,10} or by controlling the density of electrons \cite{11,12} which generates a tremendous interest in the field of spintronics. Very recently, in a nice experiment Meier \textit{et al.} \cite{13} have shown that both Rashba and Dresselhaus SO fields can be measured by optically tuning the angular dependence of the electrons’ spin precession on their direction of movement with respect to the crystal lattice.

Though some experiments are available for measuring Rashba and Dresselhaus SO fields, yet the determination of these fields in a single sample, particularly within a tight-binding (TB) formalism, is still lacking, to the best of our knowledge. The present work tries to answer this issue. Here we propose the possibilities of measuring the absolute values of Rashba and Dresselhaus SO interaction strengths by calculating persistent charge and spin currents in a mesoscopic ring. A mesoscopic ring formed at the interface of two semiconducting materials is an ideal candidate for observing the interplay between two types of SO interactions. Due to the band offset at the interface of two semiconducting materials an electric field is established which can be described by a potential gradient normal to the interface \cite{14}. This potential becomes asymmetric, leading to the presence of Rashba SO interaction. On the other hand, at such interfaces bulk inversion symmetry is naturally broken which gives rise to Dresselhaus term.

It is well known that a mesoscopic ring threaded by a magnetic flux, the so-called Aharonov-Bohm (AB) flux, carries persistent charge current. Büttiker \textit{et al.} \cite{15}
first studied the phenomenon of persistent charge current in a mesoscopic ring and then several works have been made to understand its behavior in single-channel rings and multi-channel cylinders [16–22]. Later many experiments [23–26] have also been performed to justify the existence of non-decaying charge current in such systems. Similar to persistent charge current in a mesoscopic ring induced by an AB flux, the spin of an electron acquires a spin Berry phase while traversing through a ring in presence of SO interaction results a persistent spin current [27]. A mesoscopic ring with SO coupling can provide persistent spin current even in the absence of any external magnetic flux or magnetic field. This is the so-called pure persistent spin current since it is not accompanying any charge current.

To determine the absolute values of Rashba and Dresselhaus SO fields here we propose two different possibilities. First, by measuring persistent charge current in a mesoscopic ring and then several works have calculated persistent charge and spin currents in a mesoscopic ring induced by an AB flux, the spin of an electron acquires a spin Berry phase while traversing through the ring with spin $\sigma (\uparrow, \downarrow)$. $t$ is the nearest-neighbor hopping integral and $\theta = 2\pi \phi / N$ is the phase factor due to AB flux $\varphi$ threaded by the ring. $\alpha$ and $\beta$ are the isotropic nearest-neighbor transfer integrals which measure the strengths of Rashba and Dresselhaus SO couplings, respectively, and $\varphi_{n,n+1} = (\varphi_n + \varphi_{n+1}) / 2$, where $\varphi_n = 2\pi (n-1) / N$. $\sigma_x$, $\sigma_y$ and $\sigma_z$ are the Pauli spin matrices. $\gamma_{\alpha\sigma} (\epsilon_{\alpha\sigma})$ is the creation (annihilation) operator of an electron at the site $n$ with spin $\sigma (\uparrow, \downarrow)$.

### B. Calculation of persistent charge current

To get persistent charge current, we begin with the basic equation of charge current operator $J_c$ in terms of the velocity operator $\dot{x}$ as,

$$J_c = \frac{1}{N} e \dot{x}$$  \hspace{1cm} (2)

where, the displacement operator $x$ is expressed in the form $x = \sum_n c_n^\dagger c_n$. From Eq. (2) we can write,

$$J_c = \frac{e}{Nh^c} \begin{bmatrix} x, H \end{bmatrix} = \frac{2\pi i e}{Nh} \begin{bmatrix} H, x \end{bmatrix}. \hspace{1cm} (3)$$

Substituting $x$ and $H$ in Eq. (3) and, simplifying it we get final expression of the charge current operator in the form,

$$J_c = \frac{2\pi i e}{Nh} \sum_n \left( c_n^\dagger t_\varphi c_{n+1} e^{-i\varphi} - c_{n+1}^\dagger t_\varphi c_n e^{i\varphi} \right)$$  \hspace{1cm} (4)

where, the matrix elements of $t_\varphi^{n,n+1}$ are as follows.

$$t_\varphi^{n,n+1}_{1,1} = t \hspace{2cm} t_\varphi^{n,n+1}_{1,2} = -i \alpha e^{-i\varphi_{n,n+1}} + \beta e^{i\varphi_{n,n+1}}$$

$$t_\varphi^{n,n+1}_{2,1} = -i \alpha e^{i\varphi_{n,n+1}} - \beta e^{-i\varphi_{n,n+1}} \hspace{2cm} t_\varphi^{n,n+1}_{2,2} = t$$

Therefore, for a particular eigenstate $|\psi_k\rangle$ the persistent charge current becomes,

$$J_c^k = \langle \psi_k | J_c | \psi_k \rangle$$  \hspace{1cm} (5)

where $|\psi_k\rangle = \sum_p a_p |p \uparrow\rangle + a_{p,\downarrow} |p \downarrow\rangle$. Here $|p \uparrow\rangle$'s and $|p \downarrow\rangle$'s are the Wannier states and $a_{p,\uparrow}$'s and $a_{p,\downarrow}$'s are the...
corresponding coefficients. After simplification of Eq. 4 the final expression of charge current looks like,

\[ J^k_c = \frac{2\pi i e}{N} \sum_n \left\{ t a^\dagger_{n+1} a_{n+1,\uparrow} e^{-i\theta} - t a^\dagger_{n+1,\uparrow} a_{n,\uparrow} e^{i\theta} \right\} + 2\pi i e \sum_n \left\{ t a^\dagger_{n,\uparrow} a_{n+1,\downarrow} e^{-i\theta} - t a^\dagger_{n+1,\downarrow} a_{n,\uparrow} e^{i\theta} \right\} + \frac{2\pi i e}{N} \sum_n \left\{ (i\alpha e^{-i\varphi_{n+1} z} - \beta e^{i\varphi_{n+1} z}) a^\dagger_{n} a_{n+1,\uparrow} e^{-i\theta} + (i\alpha e^{i\varphi_{n+1} z} + \beta e^{-i\varphi_{n+1} z}) a^\dagger_{n+1, \uparrow} a_{n,\uparrow} e^{i\theta} \right\} + \frac{2\pi i e}{N} \sum_n \left\{ (i\alpha e^{-i\varphi_{n+1} z} + \beta e^{i\varphi_{n+1} z}) a^\dagger_{n+1, \uparrow} a_{n,\uparrow} e^{i\theta} + (i\alpha e^{i\varphi_{n+1} z} - \beta e^{-i\varphi_{n+1} z}) a^\dagger_{n+1, \uparrow} a_{n,\uparrow} e^{i\theta} \right\}. \]

The persistent charge current can also be determined in some other ways as available in literature. Probably the simplest way of determining charge current is the case where first order derivative of ground state energy with respect to AB flux \( \phi \) is taken into account. Mathematically we can write \( J_c = -\partial E_0(\phi)/\partial \phi \), where \( E_0(\phi) \) is the total energy for a particular electron filling. But, in our present scheme (Eq. 5), the so-called second quantized approach, there are some advantages compared to other available procedures. Firstly, we can easily measure charge current in any branch of a complicated network. Secondly, the determination of individual responses in separate branches helps us to elucidate the actual mechanism of electron transport in a more transparent way.

C. Calculation of persistent spin current

In order to calculate persistent spin current we start with the following relation,

\[ J^s = \frac{1}{2N} \left( \sigma \dot{\hat{x}} + \hat{x} \sigma \right) \]

where, \( \sigma = \{ \sigma_x, \sigma_y, \sigma_z \} \). Therefore, the polarized spin current operator along the quantized direction (+Z) becomes,

\[ J^z_s = \frac{1}{2N} \left( \sigma_z \dot{\hat{x}} + \hat{x} \sigma_z \right). \]

Substituting \( \hat{x} \) in Eq. 5 and expanding it the spin current operator gets the form,

\[ J^z_{s} = \frac{i\pi}{N} \sum_n \left( c^\dagger_{n} \sigma_z t \varphi c_{n+1} e^{-i\theta} - c^\dagger_{n+1} \sigma_z t \varphi c_{n} e^{i\theta} \right) + \frac{i\pi}{N} \sum_n \left( c^\dagger_{n} \sigma_z c_{n+1} e^{-i\theta} - c^\dagger_{n+1} \sigma_z c_{n} e^{i\theta} \right). \]

Using the same prescription, as illustrated in Eq. 5, we reach the final expression of persistent spin current for \( k \)-th eigenstate as,

\[ J^z_{s,k} = \frac{2\pi i t}{N} \sum_n \left\{ a^\dagger_{n+1,\uparrow} a_{n+1,\uparrow} e^{-i\theta} - a^\dagger_{n+1,\downarrow} a_{n,\uparrow} e^{i\theta} \right\} - \frac{2\pi i t}{N} \sum_n \left\{ a^\dagger_{n,\uparrow} a_{n+1,\downarrow} e^{-i\theta} - a^\dagger_{n+1,\downarrow} a_{n,\uparrow} e^{i\theta} \right\}. \]

In our presentation we refer the polarized spin current \( J^z_{s,k} \) as \( J^z_s \) for the sake of simplicity.

In the present work we examine all the essential features of persistent charge current, spin current and related issues at absolute zero temperature and choose the units where \( c = h = e = 1 \). Throughout our numerical work we fix \( t = 1 \) and measure the energy scale in unit of \( t \).

III. NUMERICAL RESULTS AND DISCUSSION

A. Energy spectra

To make this present communication a self-contained study let us first start with the energy spectrum of a mesoscopic ring considering SO interaction for some typical values of AB flux \( \phi \) threaded by the ring. In Fig. 2 we present the variation of energy levels of an ordered 8-site ring as a function of Rashba SO coupling strength \( \alpha \), where (a), (b) and (c) correspond to \( \phi = 0, \phi_0/2 \) and \( \phi_0/4 \), respectively. For all these spectra, Dresselhaus SO coupling is set at zero. Now we analyze the behavior of energy levels for the three different cases of \( \phi \). Case-I: \( \phi = 0 \). When \( \alpha = 0 \), the eigenvalues are four-fold degenerate, except the lowest and highest eigenvalues those are two-fold degenerate. As the SO interaction is switched on (\( \alpha \neq 0 \)) the four-fold degenerate energy levels split and provide two-fold Kramers degeneracy. With the increase of SO coupling strength, splitting of these energy levels becomes larger which is clearly seen from the energy spectrum. The appearance of two-fold degenerate energy level/levels at one edge or both edges of an energy spectrum solely depends on the ring size \( N \). If \( N \) is odd, a single two-fold degenerate energy level appears at the top of the spectrum. On the other hand, if \( N \) is even, in each side of the energy spectrum a single two-fold degenerate energy level is obtained (Fig. 2(a)). Case-II: \( \phi = \phi_0/2 \). At \( \alpha = 0 \), the energy levels are four-fold degenerate. They get splitted in the presence of SO coupling providing two-fold Kramers degeneracy. Depending on ring size \( N \), here also two-fold degenerate energy levels are obtained when SO coupling strength is set at zero.

When \( N \) is odd, a two-fold degenerate energy level appears at the bottom of the energy spectrum (opposite to the case of \( \phi = 0 \)). While, no two-fold degenerate energy levels at \( \alpha = 0 \) appears when \( N \) becomes an even
number (Fig. 2(b)). Case-III: $\phi = \phi_0/4$. For any other values of $\phi$, the energy levels are two-fold degenerate only when SO coupling is zero, while they are non-degenerate when SO coupling is turned on (Fig. 2(c)). Exactly similar spectra are obtained when the energy levels for an ordered ring are plotted as a function of Dresselhaus SO coupling considering $\alpha = 0$.

when SO coupling is turned on (Fig. 2(c)). Exactly similar spectra are obtained when the energy levels for an ordered ring are plotted as a function of Dresselhaus SO coupling considering $\alpha = 0$.

**B. Determination of $\alpha$ and $\beta$ by measuring persistent charge current**

The existence of dissipationless charge current in a mesoscopic ring in presence of magnetic flux is a well-known phenomenon. But at zero magnetic flux the issue of developing persistent charge current solely by SO interaction provides a key idea of measuring SO fields. To the best of our knowledge this approach of measuring SO coupling has remain unaddressed so far.

To establish persistent charge current in a mesoscopic ring in the absence of traditional AB flux, we consider a ring subject to magnetic impurities. To get a magnetically disordered ring, we choose $\epsilon_{n\uparrow}$ randomly from a “Box” distribution function of width $W$, and, set $\epsilon_{n\downarrow} = -\epsilon_{n\uparrow}$ for all $n$. It reveals that the localized magnetic moments, placed at different atomic sites of the ring, are aligned along the quantized ($+Z$) direction. In such a ring, SO interaction can produce persistent charge current even in the absence of AB flux $\phi$.

At absolute zero temperature ($T = 0k$), net persistent charge current for a ring described with $N_e$ electrons can be determined by taking the sum of individual contributions from the lowest $N_e$ energy eigenstates. Hence, for $N_e$ electron system total charge current becomes,

$$J_c = \sum_k J^k_c.$$  

(11)

In Fig. 3 we establish the variation of persistent charge current $J_c$ of a magnetically disordered ($W = 1$) 60-site ring in the quarter-filled case ($N_e = 30$) for different values of $\alpha$ and $\beta$ when conventional electromagnetic flux through the ring is set at zero. From the spectra we see that depending on the values of $\alpha$ and $\beta$, charge current

![FIG. 2: (Color online). $E-\alpha$ characteristics for a 8-site ordered ring, where (a), (b) and (c) correspond to $\phi = 0$, 0.5 and 0.25, respectively. For all these cases $\beta$ is fixed at 0.](image)

![FIG. 3: (Color online). Persistent charge current ($J_c$) of a 60-site magnetically disordered ring in the quarter-filled case for different values of $\alpha$ and $\beta$ when AB flux $\phi = 0$.](image)
show several complex behavior and we justify them in the following ways. Case-I: $\beta = 0$. At $\alpha = 0$, no charge current appears in the ring. But as long as Rashba SO coupling is turned on charge current is established in the ring (Fig. 3(a)). When an electron circulates in a magnetically disordered ring in presence of SO coupling, it acquires a geometric phase the so-called Berry phase \[20\]. This geometrical phase provides the dissipationless charge current in the ring. Accordingly, in the absence of SO coupling charge current does not appear. The existence of dissipationless charge current in presence of SO coupling can also be verified in other way by studying velocity distribution of different energy eigenstates. As illustrative example, in Fig. 4(a) we plot the velocity ($V$) of an electron in different energy eigenstates ($n$) of a 12-site magnetically disordered ring considering $\alpha = 0.5$ and $\beta = 0$. To reveal the $V$-$n$ spectrum more transparently we choose such a small sized ring ($N = 12$). The spectrum shows that the velocity of an electron changes significantly as we go on from one eigenstate to other, and also, for some energy levels electrons are moving in one direction and for other levels electrons are rotating in the opposite direction. Since the net charge current is obtained by taking the sum of individual contributions from the lowest $N_e$ energy levels, a finite non-zero charge current appears in presence of $\alpha$. Therefore, it can be manifested that Rashba SO interaction can induce a dissipationless charge current in a magnetic disordered ring even in the absence of traditional AB flux $\phi$. Case-II: $\alpha = 0$. Now we consider the effect of Dresselhaus SO interaction in a magnetic disordered ring when other SO field is set at zero. The nature of charge current is presented in Fig. 5(b). Similar to the above case here also the charge current disappears when $\beta = 0$. While, in the presence of Dresselhaus SO coupling non-vanishing charge current appears and it shows exactly opposite behavior of the $J_s-\alpha$ characteristic curve (Fig. 5(a)). The non-vanishing behavior of charge current in presence of $\beta$ can be easily justified from the $V$-$n$ spectrum plotted in Fig. 5(b). Comparing the $V$-$n$ spectra given in Figs. 4(a) and (b), opposite nature of charge current in the cases of $\alpha$ and $\beta$ is clearly understood. From these spectra it is observed that in presence of $\alpha$ the velocity of an electron in a particular energy eigenstate is exactly identical in magnitude and opposite in sign with the velocity of an electron in that particular eigenstate when $\alpha$ is replaced.
by $\beta$. It provides opposite currents in the two different cases of SO fields. Case-III: $\alpha = \beta$. The situation becomes very much interesting when both SO coupling strengths are identical in magnitude. In this particular case charge current completely disappears. The result is shown in Fig. 3(c) and the vanishing behavior of charge current is clearly understood from the V-n spectrum given in Fig. 4(c). For the typical case when $\alpha = \beta$, velocity of an electron drops exactly to zero for all the energy eigenstates which provides vanishing charge current. This phenomenon leads to an important idea for the determination of SO fields. It is well known that in a material Rashba strength can be tuned by applying electric fields from gate or by monitoring the density of electrons. Hence, for a particular sample subject to Rashba and Dresselhaus SO interactions, vanishing charge current can be obtained by properly tuning the Rashba SO coupling making its strength identical to the Dresselhaus SO coupling. This, on the other hand, determines the Dresselhaus SO coupling.

In presence of finite AB flux through the ring this approach cannot be used to determine SO fields, since then charge current will not vanish for the particular case when Rashba and Dresselhaus SO coupling strengths are identical to each other. Accordingly, some other methods have to be utilized for the determination of these fields. In a recent work [31] we have shown that by estimating conductance minimum, calculated in terms of Drude weight, a closely related parameter that characterizes conducting nature of a system as originally noted by Kohn [32], SO strengths can be determined.

C. Determination of $\alpha$ and $\beta$ by measuring persistent spin current

In this sub-section we establish another approach of estimating Rashba and Dresselhaus SO fields by measuring persistent spin current in a mesoscopic ring instead of charge current. In order to understand the meaning of a spin current, assume a current passes through a channel which contains only up-spin polarized electrons. Now include a similar current with it which flows in the opposite direction and contains only down-spin polarized electrons. As a result, the net transfer of electrons across any cross section of the channel becomes zero, but it leads to a current of spins which is the so-called spin current. It differs from a charge current in two aspects. First, it is associated with a flow of angular momentum. Second, it maintains the time-reversal symmetry [33].

Here we show that a non-magnetic mesoscopic ring with a SO interaction can provide a dissipationless pure spin current even in the absence of conventional electromagnetic flux through the ring and it provides an idea of measuring SO coupling strengths.

At absolute zero temperature ($T = 0k$), net persistent spin current in a mesoscopic ring for a particular filling can be obtained by taking the sum of individual contributions from the energy levels with energies less than or equal to Fermi energy $E_F$. Therefore, for $N_e$ electron system total spin current becomes,

$$J_s = \sum_{k} J_s^k. \tag{12}$$

In Fig. 5 we show the variation of persistent spin current $J_s$ of an ordered 40-site ring in the half-field case ($N_e = 40$) for different values of $\alpha$ and $\beta$ when AB flux $\phi$ is fixed at zero. Several interesting features are observed those are implemented as follows. Case-I: $\beta = 0$. At $\alpha = 0$, the ring does not support any spin current. While, a non-vanishing spin current appears as long as Rashba SO interaction is turned on (Fig. 5(a)). Like a driving force for the case of persistent charge current, one also looks for the analogous driving force in the case of pure persistent spin current. It is the SO interaction which plays the role of spin driving force and leads to a dissipationless pure spin current. This can be justified in the following way. Let us consider an electron with spin $\sigma \ (\uparrow, \downarrow)$ circulating in the ring subject to a SO interaction only. In presence of SO interaction, the spin of this electron rotates with an angular velocity $\Omega$ and a component of spin current $J_s \ (\uparrow, \downarrow)$ appears which circulates in the opposite direction and contains only down-spin polarized electrons. Now include a similar current with it which flows in the opposite direction and contains only up-spin polarized electrons. As a result, the net spin current becomes zero, but it leads to a current of spins which is the so-called spin current. It differs from a charge current in two aspects. First, it is associated with a flow of angular momentum. Second, it maintains the time-reversal symmetry [33].
The electron precesses and gets a geometric phase when the electron comes back to its initial position. This geometric phase is the so-called spin Berry phase \( [34, 35] \), and, for an electron with spin \( \sigma \) traversing along the ring it can be expressed as: \( \chi_\sigma = \sigma \chi, \) where \( \sigma = \pm \) for \( \sigma = \uparrow, \downarrow \). The spin Berry phase \( \chi_+ \) provides a clockwise polarized persistent spin current, while the phase \( \chi_- \) induces an anti-clockwise spin current with the polarization exactly opposite to the earlier one since the time-reversal symmetry is preserved for the ring \( \mathbb{P}_2 \). It reveals a pure persistent spin current. Case-II: \( \alpha = 0 \). When \( \beta = 0 \), no spin current appears in the ring since in this case there is no driving force for generating the current. On the other hand, a dissipationless spin current is appeared when \( \beta \) is finite (Fig. 5(b)). From the spectrum (Fig. 5(b)) we see that the nature of spin current is exactly opposite in nature compared to the \( J_\sigma-\alpha \) characteristic curve (Fig. 5(a)). This feature can be implemented exactly in the similar way as studied in the previous section. Thus, Rashba or Dresselhaus SO field can induce a pure spin current even in the absence of an external magnetic field or a magnetic flux. Case-III: \( \alpha = \beta \). Finally, when both the two spin orbit strengths are identical, spin current drops exactly to zero. It is given in Fig. 5(c). The vanishing nature of spin current in this particular case can be clearly understood since Rashba and Dresselhaus SO interactions induce spin currents exactly identical in magnitude but their directions are opposite to each other. Thus, for a particular material subject to Rashba and Dresselhaus SO fields, vanishing spin current is achieved by adjusting the Rashba coupling to the Dresselhaus strength. This behavior helps us to predict the strengths of these SO fields.

IV. CLOSING REMARKS

To summarize, we have explored two different possibilities of measuring the absolute values of Rashba and Dresselhaus spin-orbit fields in a single sample. In the first approach we have estimated the strength of the SO fields by calculating persistent charge current in a mesoscopic ring subject to magnetic impurities. In such a ring SO interaction induces persistent charge current even in the absence of conventional electromagnetic flux through the ring. The charge current completely disappears when the strengths of both these two SO fields are identical, and this phenomenon helps us to estimate the SO coupling strengths. In the other approach, we have determined the strengths of SO fields by calculating persistent spin current in a non-magnetic mesoscopic ring. We have shown that, even in the absence of conventional AB flux, SO interaction leads to a persistent spin current. Here also, spin current vanishes when Rashba and Dresselhaus SO fields are identical in magnitude. This on the other hand, gives the possibility of estimating SO strengths. We hope our numerical results can be observed experimentally.

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