

Fermi surface mapping of the kagome superconductor RbV_3Sb_5 using de Haas-van Alphen oscillations

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We present the results from torque magnetometry studies of the kagome superconductor RbV_3Sb_5 under applied fields up to 45 T and temperatures down to liquid ^3He temperature (0.32 K). The torque signal shows clear de Haas–van Alphen (dHvA) oscillations with eight distinct frequencies ranging from ≈ 150 to 3000 T. Among these, five are above 500 T. Angle-dependent measurement of dHvA oscillations shows that all frequencies follow $1/\cos\theta$ dependence, where θ is the tilt angle with respect to the applied field direction, and the oscillations disappear above $\theta = 60^\circ$, which confirms that the Fermi surfaces corresponding to these frequencies are two dimensional. The Berry phase (ϕ), calculated by constructing a Landau level fan diagram, is found to be $\approx \pi$, which strongly supports the nontrivial topology of RbV_3Sb_5 . Using the Lifshitz-Kosevich formula, we estimate the effective mass (m^*) of charge carriers in RbV_3Sb_5 , and it is found to be heavier ($\approx 0.7m_0$, where m_0 is the free electron mass) than that for other topological insulators. The findings of high frequencies up to 3000 T in RbV_3Sb_5 have not been reported previously, and the results regarding the Fermi surface of RbV_3Sb_5 are crucial for understanding the charge density wave order, superconductivity, and nontrivial topology in AV_3Sb_5 ($A = \text{K}, \text{Rb}, \text{and Cs}$), as well as the interplay among them.

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I. INTRODUCTION

Due to their unusual lattice geometry, novel materials with a kagome lattice exhibit fascinating quantum physical phenomena, such as geometrically frustrated magnetism, nontrivial band topology, and flat bands [1–3]. Recently, the discovery of a new family of kagome materials, AV_3Sb_5 ($A = \text{K}, \text{Rb}, \text{and Cs}$) [4–6], with multiple electronic orders, such as charge density wave (CDW) order, superconductivity ($T_c \approx 0.3\text{--}3$ K), and nontrivial band topology has attracted enormous interest in the field of condensed matter physics. AV_3Sb_5 crystallizes with a hexagonal lattice of V atoms that are coordinated by Sb atoms [4,7,8]. The proximity of multiple Dirac points to the Fermi level [4–6] with a nonzero Z_2 topological invariant suggests that Dirac particles might have a dominant effect on the electrical and thermal transport of these materials. Several exotic quantum phenomena, such as CDW order near $T_{\text{CDW}} \approx (80\text{--}110$ K) [7,9–11], anomalous Hall effect [12,13], and van Hove singularity [14], have also been observed in this new family.

With the application of increasing external pressure, the CDW order in AV_3Sb_5 gradually disappears and is completely absent under a moderate pressure of 1.8 GPa, whereas superconductivity shows an unusual M -shaped double dome

[9,10]. These observations strongly suggest that there is an unusual interplay between the CDW order and superconductivity of AV_3Sb_5 requiring investigation. Detailed knowledge of the Fermi surface would be invaluable for understanding the CDW phase and superconductivity in AV_3Sb_5 . Several Fermi surface studies [12–18] of these materials using both quantum oscillations and angle-resolved photoemission spectroscopy measurements have been reported. However, most have focused on CsV_3Sb_5 [17,19–23]. Quantum oscillation frequencies up to 10 kT and a heavy effective mass (m^*) of the charge carriers, $m^* \approx 2m_0$, where m_0 is the free electron mass, were observed in CsV_3Sb_5 . The presence of such high quantum oscillation frequencies in CsV_3Sb_5 is fascinating and their physical origin has yet to be explored. It has been proposed that high frequencies arise from the reconstructed Fermi surface pockets which are caused due to the CDW transition [17,20]. Thus far, there have been limited published studies [13,15] on other members of the AV_3Sb_5 family (KV_3Sb_5 and RbV_3Sb_5), in which only low frequencies below 500 T have been reported. Using Shubnikov–de Haas (SdH) oscillations, Yang *et al.* [13] observed two frequencies (34.6 and 148.9 T) in KV_3Sb_5 and Yin *et al.* [15] reported two frequencies (33.5 and 117.2 T) in RbV_3Sb_5 , however detailed Fermi surface properties have yet to be reported.

Here we present the fermiology of RbV_3Sb_5 using torque magnetometry with applied fields up to 45 T. The torque

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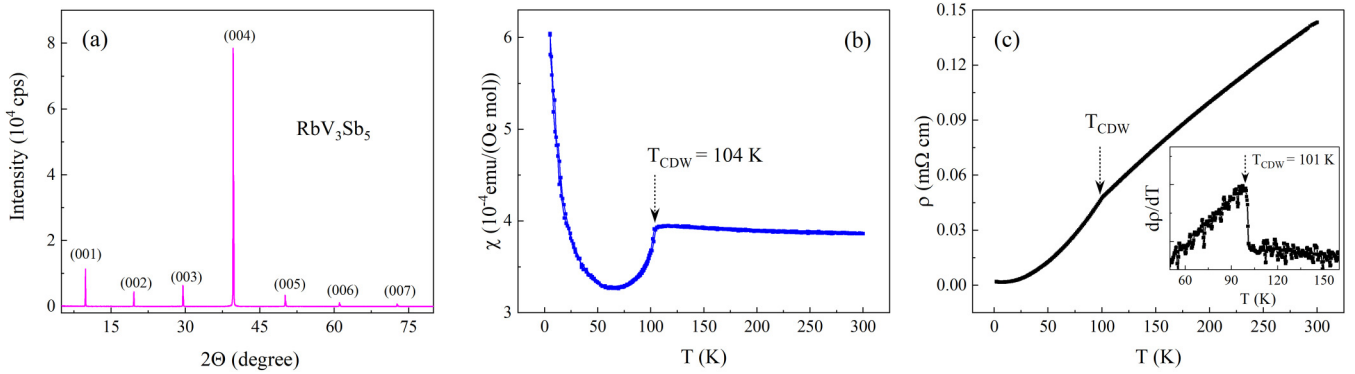


FIG. 1. XRD, magnetic susceptibility, and electrical resistivity. (a) Room-temperature XRD pattern of a RbV_3Sb_5 single crystal. All peaks can be indexed to the $P6/mmm$ structure. (b) Temperature-dependent magnetic susceptibility, $\chi(T)$, of a RbV_3Sb_5 single crystal measured by applying $H = 7$ T along the c axis. There is a clear jump at $T_{\text{CDW}} \approx 104$ K, marked by the arrow, due to the CDW order. (c) Temperature-dependent electrical resistivity, $\rho(T)$, of a RbV_3Sb_5 single crystal. The $\rho(T)$ curve shows a slope change due to the CDW transition, $T_{\text{CDW}} \approx 101$ K, marked by the arrow. The transition is evident in the first derivative data, as shown in the inset.

signal clearly shows de Haas–van Alphen (dHvA) oscillations with eight distinct frequencies up to 3000 T. Analysis of the field-angle dependence of the dHvA oscillations, Berry phase calculation results, and Lifshitz-Kosevich (LK) analyses are also presented to completely elucidate the Fermi surface properties of this material.

II. EXPERIMENTAL DETAILS

High-quality single crystals of RbV_3Sb_5 were synthesized using a self-flux method. Alkali metal Rb (99.5%), V powder (99.5%) and Sb (99.999%) were mixed at a Rb:V:Sb mole ratio of 2:1:5.2. The mixture was loaded into an alumina crucible and sealed inside a titanium container that was further sealed inside a quartz tube that was subsequently heated to 1273 K over 300 min, maintained at this temperature for 600 min, rapidly cooled down to 1173 K over 100 min, and finally slowly cooled down to 923 K over one week. The RbV_3Sb_5 crystals were separated from the flux using centrifugal treatment. From element analysis based on energy-dispersive x-ray (EDX) spectroscopy (Fig. S1 and Table S1 in the Supplemental Material [26]), the Rb:V:Sb atomic ratio of the obtained single-crystal RbV_3Sb_5 is $(0.98 \pm 0.04):(3.00 \pm 0.03):5$, very close to the stoichiometric ratio of 1:3:5.

The crystal structure of RbV_3Sb_5 samples was characterized using an x-ray diffractometer (Rigaku SmartLab) equipped with Cu $K\alpha$ radiation and a fixed graphite monochromator. A field-emission scanning electron microscope (Sirion 200) was used to analyze the crystal composition through EDX and results are presented in Fig. S1 and Table S1 in the Supplemental Material [26]. Magnetic susceptibility and electrical transport measurements were carried out using a superconducting quantum interference device magnetometer (Quantum Design, MPMS 5 T) and a physical property measurement system (Quantum Design, PPMS 9 T), respectively.

High-field measurements were carried out at the National High Magnetic Field Laboratory (NHMFL), Tallahassee, Florida, with the maximum applied fields of 41.5 T (dc resistive water-cooled magnet) and 45 T hybrid (33.5-T dc

resistive magnet nested in an 11.5-T superconducting magnet) top-loaded with a ^3He cryostat. The magnetic torque was measured using a miniature piezoresistive cantilever. A tiny RbV_3Sb_5 crystal was selected and then fixed to the cantilever arm with vacuum grease. The cantilever was subsequently mounted on the rotating platform of a special probe designed at NHMFL [27]. The probe was then slowly cooled down to the base temperature of 0.32 K. Two resistive elements on the cantilever were incorporated with two other room-temperature resistors to form a Wheatstone bridge, which was balanced at base temperature before taking field dependence data. The angle-dependent torque data were obtained by rotating the sample *in situ* with the applied field. Magnetic fields were swept at each fixed temperature at a rate of 2.2 T/min.

III. EXPERIMENTAL RESULTS AND DISCUSSION

The room-temperature x-ray diffraction (XRD) pattern of RbV_3Sb_5 is displayed in Fig. 1(a), which shows that all peaks can be indexed to the hexagonal structure with the space group $P6/mmm$. It should be noted that there are only peaks with Miller indices $(00l, l = 1, 2, 3, \dots)$, which implies that the c axis is perpendicular to the flat surface of the crystal. Figure 1(b) shows the temperature dependence of magnetic susceptibility, $\chi(T)$, for RbV_3Sb_5 measured under an applied field of 7 T along the c axis. There exists a clear anomaly in the $\chi(T)$ data near $T_{\text{CDW}} \approx 104$ K, marked by the arrow, which arises due to the CDW order [4,6] in RbV_3Sb_5 .

Electrical resistivity (ρ) vs T for RbV_3Sb_5 is shown in Fig. 1(c). ρ decreases with decreasing temperature, showing the compound's metallic behavior. The residual resistivity ratio (RRR) = $\rho(300 \text{ K})/\rho(2 \text{ K})$ is calculated to be 73, nearly twice the value (≈ 40) reported for RbV_3Sb_5 previously [11,15]. Such a high RRR value confirms the excellent crystallinity of the samples studied here. The $\rho(T)$ curve in Fig. 1(c) has a slope change near $T_{\text{CDW}} \approx 101$ K, marked by the arrow, which could be an indication of the CDW transition. For confirmation, we calculated the first derivative of $\rho(T)$, $d\rho/dT$, and results are shown in the inset to Fig. 1(c). The $d\rho/dT(T)$ curve has a sharp transition near $T_{\text{CDW}} \approx$

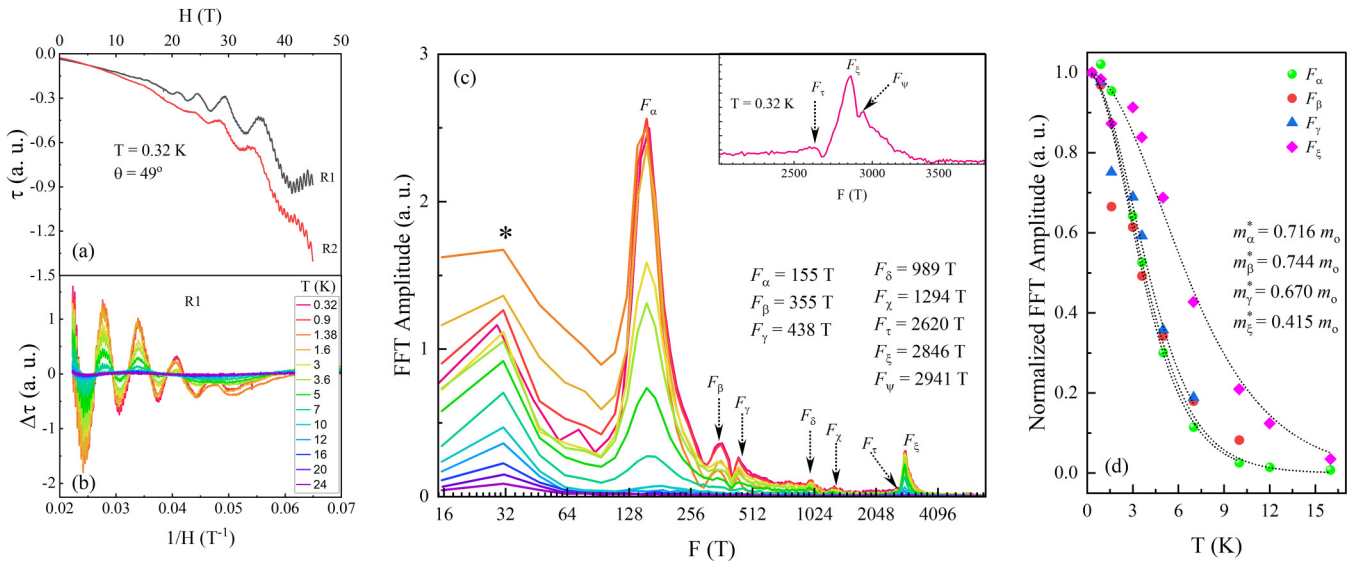


FIG. 2. dHvA oscillations and LK analyses. (a) Magnetic torque vs H for two RbV₃Sb₅ single crystals (R1 and R2) at $\theta = 49^\circ$ and $T = 0.32$ K. The torque signal shows clear dHvA oscillations above 20 T. (b) Background-subtracted dHvA oscillations for R1 at different temperatures. (c) Fast Fourier transform (FFT) spectra of background-subtracted data from (b) at different temperatures, which shows that the FFT amplitude decreases at high temperatures and that there are eight distinct peaks, five of which are above 500 T. The peak near 32 T, marked by an asterisk, is likely an artifact. The x axis is on a logarithmic scale for better visibility of high frequencies. Inset: Magnified view of the FFT data at $T = 0.32$ K to show the highest frequencies (F_τ , F_ξ , and F_ψ) more clearly. (d) Normalized FFT amplitude vs T for F_α , F_β , F_γ , and F_ξ . Dotted curves: Best fits using the LK formula [24,25].

101 K, marked by the arrow. The T_{CDW} values determined from magnetic susceptibility and resistivity measurements are thus comparable to one another and are also in close agreement with those previously reported [4,6,11,15] for RbV₃Sb₅.

To explore the Fermi surface properties of RbV₃Sb₅, we measured the magnetic torque (τ) under applied fields up to 45 T and temperatures down to 0.32 K. τ (H) for two single crystals (denoted as R1 and R2) of RbV₃Sb₅ measured at $\theta = 49^\circ$, where θ is the angle between the magnetic field and the c axis of the sample, is displayed in Fig. 2(a). The amplitude of the τ signal increases with increasing H and shows clear dHvA oscillations at high fields. The oscillations are observed for both R1 and R2, and frequency analyses confirm that their frequency spectra are comparable to one another (Fig. S2 in the Supplemental Material [26]). Therefore, to explore the Fermi surface properties of RbV₃Sb₅ here, we present the temperature- and angle-dependence data for R1 only. Figure 2(b) shows the background-subtracted torque ($\Delta\tau$) data for R1 at different temperatures. The amplitude of the oscillations decreases at high temperatures, and they completely disappear at 24 K. The oscillations appear to have multiple periods (and hence several frequencies). The frequencies of the oscillations can be determined by applying the fast Fourier transform (FFT).

Figure 2(c) shows the FFT spectra of the background-subtracted data from Fig. 2(b) at different temperatures. As expected, there are multiple (eight) distinct peaks with values ranging from ≈ 150 to 3000 T. Three frequencies ($F_\alpha = 155 \pm 25$ T, $F_\beta = 355 \pm 30$ T, and $F_\gamma = 438 \pm 22$ T) are below 500 T (denoted as low frequencies) and the remaining five ($F_\delta = 989 \pm 26$ T, $F_\chi = 1294 \pm 65$ T, $F_\tau = 2620 \pm 51$ T, $F_\xi = 2846 \pm 23$ T, and $F_\psi = 2941 \pm 15$ T) are above 500 T (denoted as high frequencies). We noticed that F_τ and F_ψ are visible at

low temperature, as shown in the inset to Fig. 2(c), but they disappear quickly at higher temperatures (above 5 K). To the best of our knowledge, there has been only one previously reported quantum oscillation study of RbV₃Sb₅, by Yin *et al.* [15], who observed two low frequencies, 33.5 and 117.2 T, in SdH oscillations. We likewise noticed a peak near 32 T, marked by the asterisk in Fig. 2(c). Under such a high field of 45 T, it is difficult to justify the peak at 32 T as a real frequency. In addition, F_α changes with θ and its value is ≈ 110 T at $\theta = 6^\circ$ (see discussion below). Therefore, F_α is consistent with the frequency of 117.2 T reported by Yin *et al.* [15]. However, the remaining seven frequencies (F_α , F_γ , F_δ , F_χ , F_τ , F_ξ , and F_ψ) shown in Fig. 2(c) have never been reported previously. Our recent torque measurements of other AV₃Sb₅ family members (CsV₃Sb₅ and KV₃Sb₅) under high fields up to 45 T, together with results reported by other groups [17,19–21,28], have shown multiple quantum oscillation frequencies with values as high as 10 kT. Therefore, the observation of high frequencies in RbV₃Sb₅ is consistent with the findings for KV₃Sb₅ and CsV₃Sb₅, and these high frequencies might also have the same origin, i.e., Fermi surface reconstruction due to the CDW order [17,20].

As expected, the FFT amplitude decreases at higher temperatures, and this behavior can be described by the LK formula [24,25]. The normalized FFT amplitude vs T for F_α , F_β , F_γ , and F_ξ is displayed in Fig. 2(d), which shows that the temperature-dependent FFT data can be explained by the LK formula (dotted curves). From the best-fit parameter, we have estimated the effective mass (m^*) of the charge carriers for F_α , F_β , F_γ , and F_ξ to be $m_\alpha^* = (0.72 \pm 0.10)m_o$, $m_\beta^* = (0.74 \pm 0.10)m_o$, $m_\gamma^* = (0.67 \pm 0.10)m_o$, and $m_\xi^* = (0.41 \pm 0.10)m_o$, respectively. These m^* values are much heavier than $m^* = 0.125m_o$ reported by Yang *et al.* [13] for KV₃Sb₅, $m^* =$

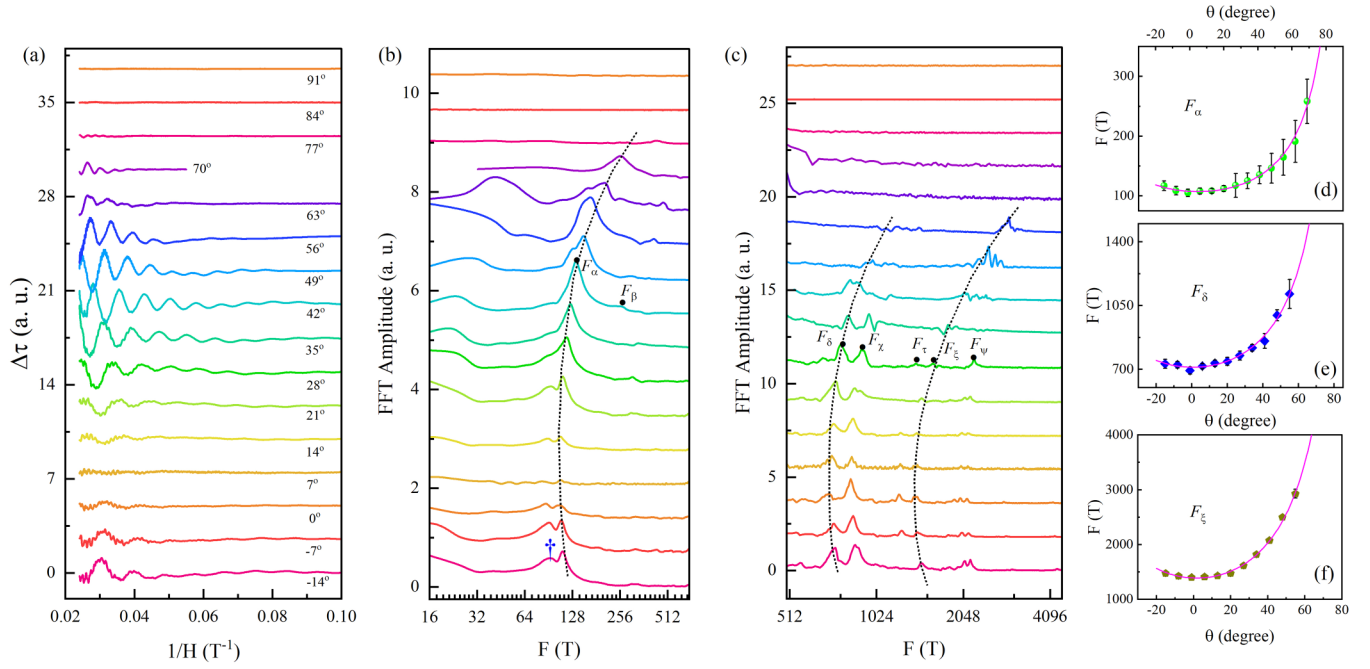


FIG. 3. Angular dependence of quantum oscillation frequencies. (a) Background-subtracted torque data for RbV_3Sb_5 at different θ values. The period (and hence the frequency) changes with θ , and the oscillations are completely absent at 91° . (b, c) FFT spectra in the ranges of (b) 0–550 T and (c) 500–5000 T. All peaks shift to the right at high angles and completely disappear above $\theta = 60^\circ$. The x axes in (b) and (c) are in the logarithmic scale for better visibility of frequencies and the dotted lines are guides for the eye. The curves in (a), (b), and (c) are shifted vertically for clarity. (d–f) Angle dependence data for (d) F_α , (e) F_δ , and (f) F_ξ . All frequencies can be clearly resolved up to 60° and they exhibit the $1/\cos\theta$ dependence (solid curves), implying that their Fermi surfaces are two dimensional. The error bar for each data point is defined as the half width at half maximum of the corresponding peak in the respective frequency spectrum.

$0.028m_0$ and $0.031m_0$ reported by Yu *et al.* [12], and $m^* = 0.06m_0, 0.08m_0, 0.09m_0,$ and $0.11m_0$ reported by Ortiz *et al.* [17] for CsV_3Sb_5 . However, they are comparable with $m^* \approx 0.6m_0$ reported in recent studies [19,21–23] for CsV_3Sb_5 .

According to Onsager's relation [24,29,30], the Fermi wave vector (and hence the size of the Fermi surface) is directly proportional to the quantum oscillation frequency (F), that is, $F = \hbar/(2e)k_F^2$, where \hbar is Planck's constant and k_F is the Fermi wave vector. Therefore, the presence of multiple frequencies in RbV_3Sb_5 with values reaching up to 3000 T implies that there exist many Fermi surface pockets with large cross-section areas in this compound. To understand the shape, size, and dimensionality of these Fermi surface pockets, we carried out angle-dependent torque measurements by rotating the sample with respect to the applied field. Figure 3(a) shows background-subtracted torque data, $\Delta\tau$ vs $1/H$ for RbV_3Sb_5 at different θ values, and indicates that both the amplitude and frequencies of the oscillations appear to vary with θ , the high frequencies seem to dominate only up to 63° , and the oscillations are completely absent above 63° . These findings are clearly reflected in the FFT plots, as shown in Figs. 3(b) and 3(c).

Figure 3(b) shows that, with increasing θ , F_α first decreases from -14° to 0° , increases at higher θ values up to 70° , as indicated by the dotted-line guide, and disappears completely above 70° . Similarly, as shown in Fig. 3(c), frequencies F_δ and F_ξ shift to the right at high θ before vanishing above 56° , as indicated by the dotted-line guides. The angular dependences of selected frequencies $F_\alpha, F_\delta,$ and F_ξ are shown in Figs. 3(d)–

3(f), respectively. As expected, these frequencies increase at high θ values and follow $1/\cos\theta$ behavior [solid curves in Figs. 3(d)–3(f)]. It was found that other frequencies ($F_\chi, F_\sigma,$ and F_ψ) also display $1/\cos\theta$ dependence, as shown in Fig. S3 in the Supplemental Material [26], strongly suggesting that all these frequencies originate from the two-dimensional (2D) Fermi surfaces [29,31,32]. The vanishing of these frequencies above $\theta = 63^\circ$ further supports the 2D Fermi surface origin [29,33–35] of these frequencies. There have been a few recent reports of the existence of 2D Fermi surfaces in CsV_3Sb_5 [17,19,20,22], and the existence of 2D Fermi surfaces in KV_3Sb_5 is consistent with these reports. It should be noted that there exists a peak ≈ 90 T, as marked by the dagger in Fig. 3(b). However, it appears only at low θ values, so we did not carry out angular dependence analyses for this frequency.

Based on the above discussion, RbV_3Sb_5 consists of several 2D Fermi surface pockets. To identify the topological nature of RbV_3Sb_5 , we calculated the Berry phase (ϕ) by constructing a Landau level (LL) fan diagram [29,34]. The ϕ values for topologically trivial and nontrivial systems are zero and π , respectively [29,32,36]. However, due to the presence of multiple frequencies in the quantum oscillation data (Figs. 2 and 3), it is difficult to disentangle the oscillation corresponding to a single frequency. Therefore, we have used the bandpass filter technique [37–40] to isolate the individual frequency. The black and red curves in Fig. 4(a) represent the original torque signal and filtered data, respectively, for RbV_3Sb_5 . There exists a single peak at 158 T in the frequency spectrum of the filtered data [see the inset to Fig. 4(a)],

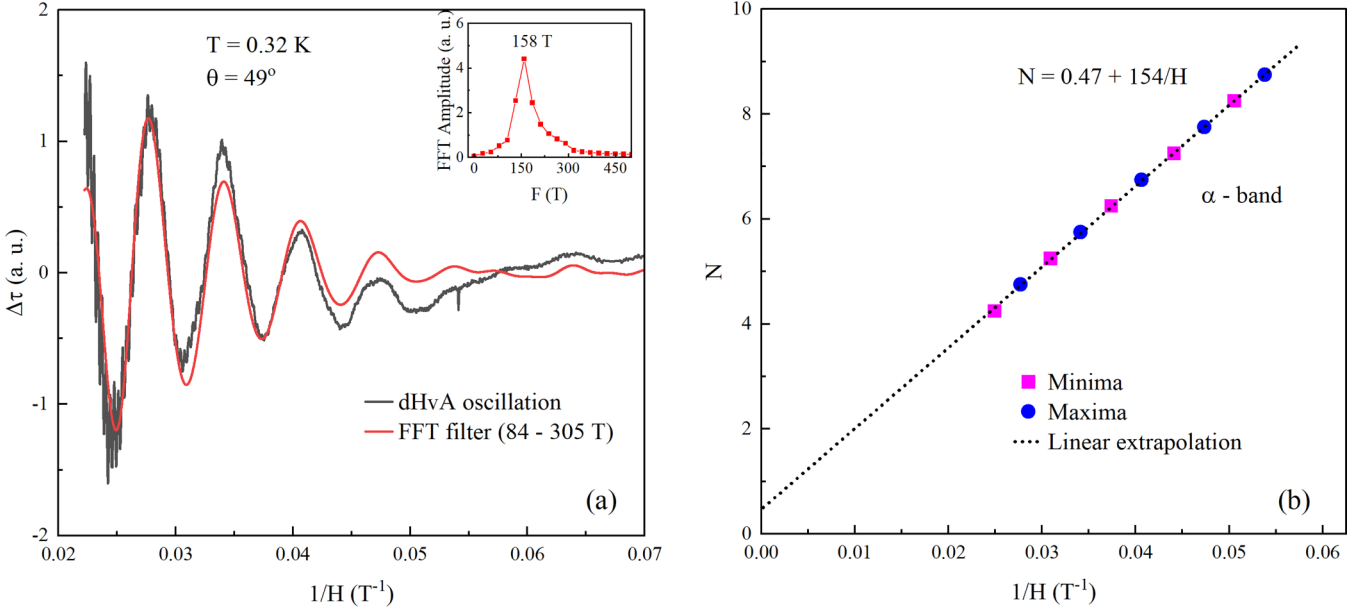


FIG. 4. Landau level (LL) fan diagram and Berry phase. (a) Separation of quantum oscillations for F_α using the bandpass filter of 84–305 T. Black and red curves represent the dHvA oscillation at $\theta = 49^\circ$ and the filtered signal, respectively. The FFT plot shows a single frequency at 158 T, as shown in the inset, confirming that the filtered signal has oscillations only for F_α . (b) LL fan diagram for F_α . Minima and maxima of the oscillations are assigned to $(N + 1/4)$ and $(N - 1/4)$, respectively, for constructing the LL plot. The dashed line is the linear extrapolation of data in the limit $1/H \rightarrow 0$.

confirming that the filtered data has dHvA oscillations only for F_α . It is important to note that the assignment of the LL index (N) for the torque data depends on the slope of the frequency vs θ plot, that is, $dF/d\theta$. For a positive slope, the minima and maxima of the oscillations are assigned to $(N + \frac{1}{4})$ and $(N - \frac{1}{4})$, respectively [19,24,40]. As seen in Fig. 3, all the frequencies analyzed here have $dF/d\theta > 0$. Therefore, we assigned $(N + \frac{1}{4})$ and $(N - \frac{1}{4})$ for the minima and maxima, respectively, to construct the LL fan plot [Fig. 4(b)].

The value of N_0 , obtained by a linear extrapolation of $1/H \rightarrow 0$, defines the value of the ϕ in units of 2π . $N_0 = 0.5$ ($\phi = \pi$) is expected for Dirac particles [29,34,36,41]. Here, from the linear extrapolation of the N vs $1/H$ plot in Fig. 4(b), we have obtained the intercept $N_0 = (0.47 \pm 0.04)$. This value corresponds to $\phi \sim \pi$, confirming a nontrivial Fermi surface topology of F_α . Moreover, the linear extrapolation yields a slope equal to (154 ± 0.9) T, which is consistent with the F_α value of 155 T obtained from the FFT [Fig. 2(c)]. This provides evidence that (i) there is no significant error in finding the intercept (and hence the ϕ value) using the linear extrapolation of the N vs $1/H$ plot and (ii) the bandpass filter still preserves the original dHvA oscillation signal.

We analyzed the magnetic field attenuation of the dHvA oscillations and estimated the Dingle temperature (T_D) of the selected frequencies, as shown in Fig. S4 in the Supplemental Material [26]. Using the experimental results for m^* , T_D , and k_F , we have estimated different physical parameters characterizing the Fermi surfaces of RbV_3Sb_5 , as listed in Table I. There exist no previously reported data on RbV_3Sb_5 for comparison, but these Fermi surface parameters are comparable with those for CsV_3Sb_5 and KV_3Sb_5 [19,28].

IV. SUMMARY

We have presented detailed information on the synthesis of RbV_3Sb_5 , a member of the kagome superconductor family AV_3Sb_5 ($A = \text{K, Rb, and Cs}$), and its Fermi surface characterization using torque magnetometry. The torque signal measured under a dc magnetic field of 45 T and the liquid ^3He temperature (0.32 K) exhibit clear dHvA oscillations with multiple frequencies. There exist eight major peaks in the frequency spectrum, five of which are above 500 T. Using the temperature-dependent of quantum oscillations data, we estimated the effective mass (m^*) of the

TABLE I. Physical parameters, including frequency (F), Fermi wave vector (k_F), Fermi surface area (S_F), effective mass (m^*), Fermi velocity (v_F), Dingle temperature (T_D), quantum relaxation time (τ_s), mean free path (l_{2D}), and quantum mobility (μ), characterizing the dHvA oscillations of RbV_3Sb_5 .

Band	F (T)	k_F (\AA^{-1})	S_F (10^{-2}\AA^{-2})	m^*/m_0	v_F (10^4ms^{-1})	T_D (K)	τ_s (10^{-13}s)	l_{2D} (nm)	μ ($\text{cm}^2 \text{V}^{-1} \text{s}^{-1}$)
α	155	0.069	1.48	0.72	11.05	4.06	2.98	32.95	730.02
β	355	0.104	3.39	0.74	16.10	3.60	3.36	54.12	792.32
ξ	2846	0.294	27.14	0.42	81.73	15.86	0.76	62.35	322.42

charge carriers in RbV_3Sb_5 and found that it is heavier ($m^* \approx 0.7m_0$, where m_0 is the free electron mass) than that of other topological insulators and Dirac/Weyl semimetals. The angular dependence of quantum oscillations allows for probing the shape and dimensionality of a Fermi surface. Here, the application of extremely high fields up to 45 T enabled us to resolve the quantum oscillation frequencies even at high tilt angles (θ) up to 60° and hence helped in unambiguously determining the shape of the Fermi surface. From our analyses of the field-angle data, we found that most of the frequencies observed here follow $1/\cos\theta$ dependence, which suggests that these frequencies originate from 2D Fermi surfaces. The absence of frequencies above $\theta = 60^\circ$ further supports the 2D nature of the Fermi surface in RbV_3Sb_5 . The Berry phase was determined by constructing the Landau level fan diagram and found to be $\approx \pi$, strongly suggesting the nontrivial topology of RbV_3Sb_5 . Several Fermi surface properties of RbV_3Sb_5 were estimated assuming a 2D Fermi surface, and those parameters are reported in Table I.

In our previous high-field torque magnetometry studies of CsV_3Sb_5 and KV_3Sb_5 [19,28], we reported very high quantum oscillation frequencies up to 3000 T, the presence of 2D Fermi surfaces, and heavy effective masses of charge carriers (compared to other topological systems). Therefore, our detailed high field studies of RbV_3Sb_5 , together with our previous reports [19,28], confirm that high quantum oscillation frequencies, relatively heavy m^* , 2D Fermi surfaces, etc., are present in all members of the AV_3Sb_5 compound family. The observation of high frequencies above 500 T in AV_3Sb_5 is

quite intriguing, and these might originate from reconstructed Fermi surface pockets, as proposed previously [17,20]. Electronic band structure and Fermi surface calculations could be helpful in explaining these high frequencies and the relatively heavy m^* in AV_3Sb_5 . The detailed Fermi surface information for RbV_3Sb_5 presented here will be crucial in understanding the superconductivity, charge density wave order, and topological properties of AV_3Sb_5 .

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