# Quantum Oscillations from a 2D Electron Gas at a Mott/band Insulator Interface

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## Introduction

The discovery of mobile charge carriers at interfaces between insulating perovskite oxides has opened up new scientific opportunities, such as the investigation of 2DEGs in $SrTiO_3$. Shubnikov-de Haas (SdH) oscillations in a quantizing magnetic field (B) establish the 2D character of these electron gases and elucidate the 2DEG properties. Several studies have reported on SdH oscillations from $LaAlO_3/SrTiO_3$ interfaces, which have mobile carrier density for $LaAlO_3/SrTiO_3$ interfaces on the order of ~$10^{13}$ $cm^{-2}$. Further understanding can be obtained by examining alternative interfaces, such as $GdTiO_3/SrTiO_3$, which show mobile carrier densities (residing on the $SrTiO_3$ side) on the order of ~$3\times10^{14}$ $cm^{-2}$, closely corresponding to the density needed to compensate the polar discontinuity. The high carrier density is expected to produce tighter spatial confinement.

## Experimental

$GdTiO_3$ and $SrTiO_3$ were grown on (001) $(LaAlO_3)_{0.3}(Sr_2AlTaO_6)_{0.7}$ single crystals by molecular beam epitaxy. The sample consisted of 80 nm $SrTiO_3$ layer followed by 8 nm $GdTiO_3$ layer. Magneto-transport measurements were performed with the contacts arranged in a van der Pauw geometry on a 10×10 $mm^2$ sample in a 31 T magnet at the National High Magnetic Field Laboratory (NHMFL) at temperatures between 360 mK and 10 K. The sample was mounted on a rotator probe. The angle 0° indicates that **B** is perpendicular to the interface [1].

## Results and Discussion

The Hall mobility at 2 K was 322 $cm^2/Vs$. For B greater than 16 T, SdH oscillations were detected in measurements. The non-oscillating background was subtracted using multiple polynomial fits. **Figure 1a** shows the oscillations measured at 360 mK as a function of $(B\cos\theta)^{-1}$, for different tilt angles ($\theta$) of the B-field. Simpler characteristics compared to oscillations reported for $LaAlO_3/SrTiO_3$ interfaces are observed. Periodic oscillations in 1/B and appearance of maxima (and minima) at the same $(B\cos\theta)^{-1}$ for all angles confirms the 2D behavior of the electron system. **Figure 1b** shows the oscillations measured at 0° at different temperatures from 360 mK to 10 K. The effective electron mass, $m^*$, was extracted from the temperature dependence of the oscillations and was found to be about 1.08 $m_e$ ($m_e$ is the free electron mass). This low effective mass points to the oscillations being due to the more strongly confined $d_{xy}$-derived subbands in $SrTiO_3$, which also explains their strongly 2D character [1].

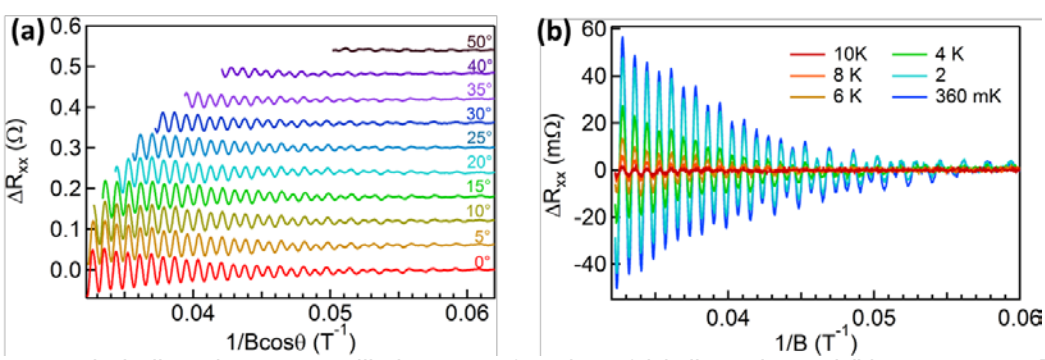


**Figure 1.** Shubnikov de-Haas oscillations as a function of (a) tilt angle, and (b) temperature [1].

## Conclusions

SdH oscillations observed in $GdTiO_3/SrTiO_3$ sample confirmed 2D behavior of the electron gas. The SdH oscillations were attributed to the electrons in the strongly confined $d_{xy}$-derived subbands in $SrTiO_3$.

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## References

[1] Moetakef, P., *et al*., Applied Physics Letters **101**, 151604 (2012).