Supplementary Online Materials

Images of edge current in InAs/GaSb quantum wells

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Section 1: Non-linearity

Our measurements of the Si-doped device were not made in the linear regime, i.e. the amount of current applied to take images (150 nA_{rms} in the case of all images in the main text) is outside the range where the voltage drop across the sample scales linearly with the applied current. V-I characteristics of the device near the resistance maximum taken in the same gate sweep as (FIG.1 c,e,g) are shown in Fig. S1. At $150\sqrt{2}$ nA applied current amplitude (red-highlighted data), the V-I characteristic already noticeably deviates from the low-current behavior (black dashed line).

To show the origin of this effect, we applied higher currents (500 nA_{rms}) to a Si-doped device. This device is a 2nd Si-doped device was prepared identically to the one presented in the main text. The device was tuned to the resistance peak, using the front gate (V_g) which was defined with respect to ground, and a current was applied to flow from the left most contact to the rightmost contact which was grounded (Fig S2a). Spatially closest to the grounded contact ground, the sample showed behavior close to what was expected on the low current resistance maximum, with the majority of the current along the edges. Farther away from ground, the current appears to flow more along the bulk (Fig S2b,c). We attribute this non-linearity to the AC potential which deviates farthest from zero on parts of the sample 'farthest' away from ground. This interpretation is confirmed by switching which contact is grounded, and observing that the trend in the images also flips (Fig S2 d-f). The lock-in measured images are the amplitude of the first harmonic of the applied current, which will be determined primarily by the high-current behavior. We did not observe a systematic gradient in the images taken at 150 nA, and therefore conclude that the main features of the images are not affected by the non-linearity. The effect of a strongly gate-voltage dependent scatterer may be masked by this effect.

Section 2: Effective Resistance Model

The effective resistance in the text is defined as the four-terminal resistance ($R_{14,23}$) over the ratio of the current flowing in each edge. Using the nomenclature defined in Fig. S3 and Kirchoff's laws the relation of the effective resistances, defined as $R_{eff,(top,bulk,bot)}$ to the physical resistances in the model are given by $R_{eff-(top,bulk,bot)} = R_{top2}/R_{top}*R_{(top,bulk,bot)}$.

Therefore, the effective resistance is proportional to the actual resistances of the edges with a proportionality constant that we did not directly measure. As long as the ratio remains constant, any trend in the temperature dependence is valid.

Section 3: The top edge

The contacts on the top edge of the sample provide striking evidence of the high conductivity of the edge in comparison to the bulk. In the gap, the current flows along ~60 μm of extra edge rather than shorting across the relatively small ~10 μm gap of bulk material (Fig 1 c,e,g). At a certain finite bulk conductivity, this was no longer the case and more current flowed across the bulk rather than taking the detour along the edges of the contacts. An example of this behavior is shown in Fig S3, where at V_g=-2.7 V there was significant current flow in the bulk. The edges are more conducting than the bulk, but current no longer flows all the way up and down the contacts. The bulk “shorting” of this portion of the contacts reduces the effective length of the edge by roughly a factor of two.

This behavior is especially important for interpreting the effective resistance of the edge (Fig. 3d). The bottom edge’s resistance remains constant as a function of temperature, while the resistance of the top edge drops by a factor of 2 with higher temperatures. The drop with increasing temperature of the top edge’s effective resistance is consistent with increased bulk conductivity which “shorts” the contacts, rather than the actual resistance per unit length of the top edge changing as a function of temperature.

The proportionality ratio mentioned in Section 2 will also depend on the shorted edges. Assuming that the resistance per unit length along the top edge is consistent within the three segments this ratio only depends on the length of the edges. The percent difference between the shorted and non-shorted cases is only ~5%, determined by the optically measured dimensions of the sample, and therefore does not affect our conclusions of no strong temperature dependence.

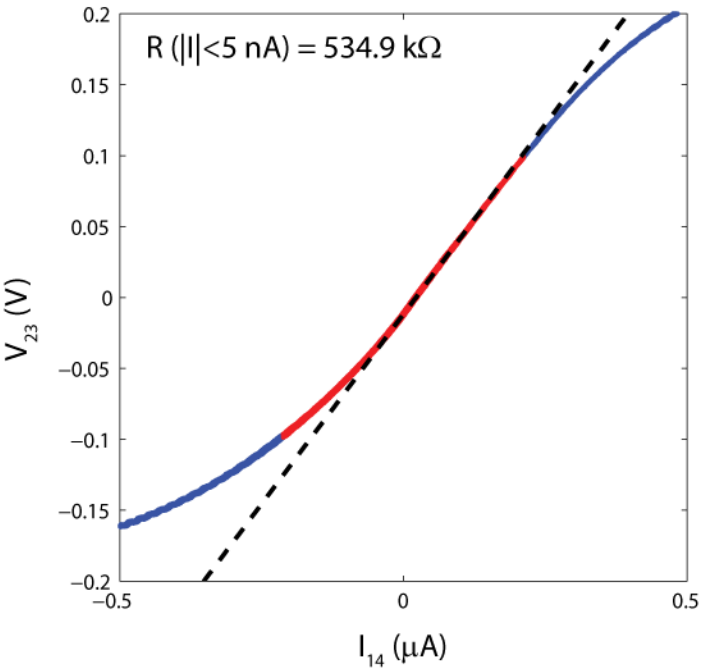

Fig. S1. V-I Characteristics of the Si-doped device when it is tuned into the gap using a front gate (V_g= -2.35 V). The range of the applied current for the images shown (150 nA_{rms}) is indicated by the red portion of the curve. A linear fit to the low current resistance between –5 nA and +5 nA is indicated by the dashed black line.

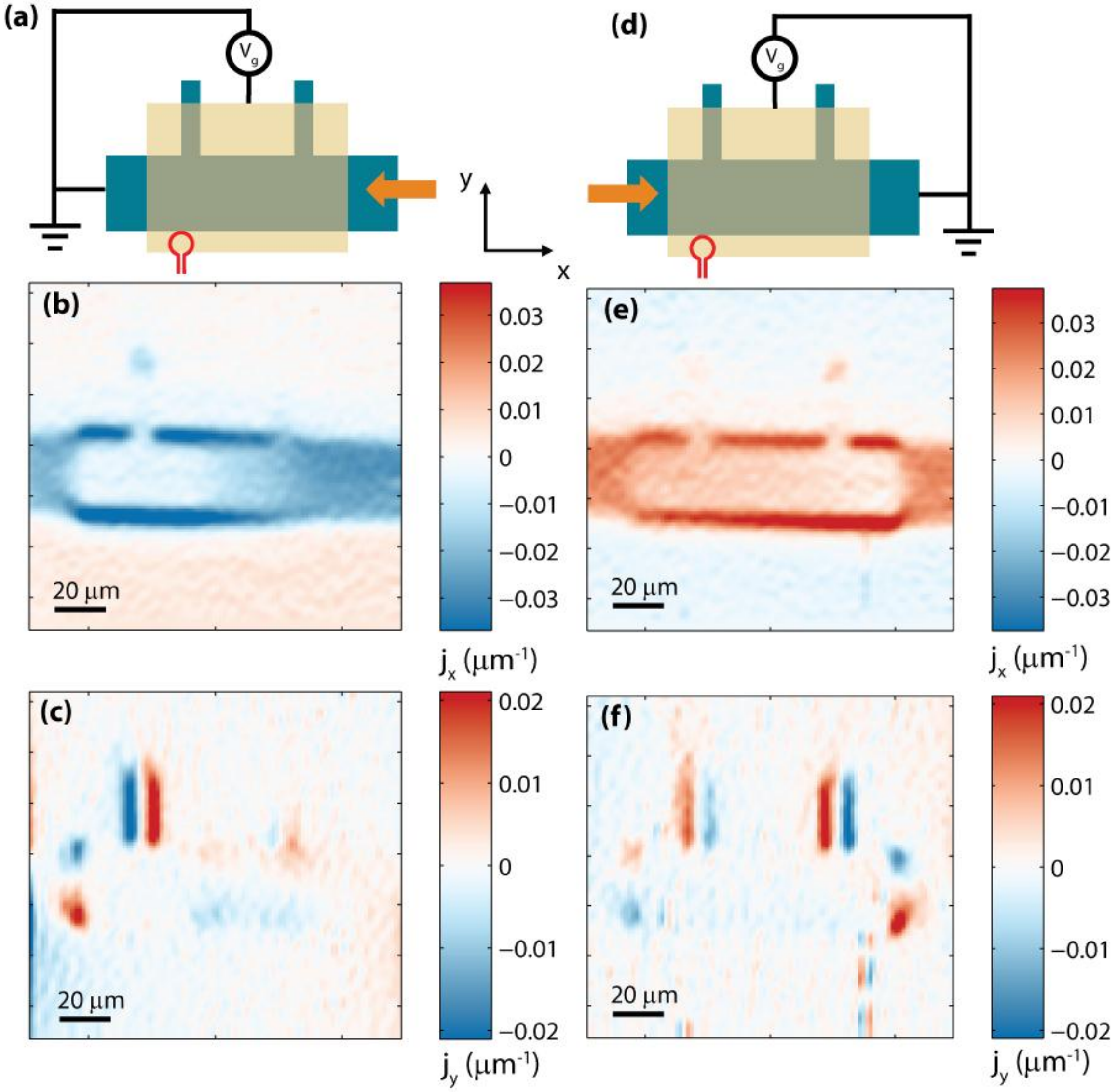

Fig S2. Images of the Si-doped device at high applied currents (500 nA$_{rms}$) in the middle of the gap. The front gate voltage is applied with respect to a ground that is shared with side of the sample, while an AC excitation is applied to the other side. (a-c) When the left contact is grounded, as shown schematically in (a), the behavior closest to ground is that of a device tuned into the gap, showing strong edge conduction with very little current flowing in the bulk. However, the right side of the image is much more bulk like indicating that the potential of the interface with respect to the gate become important (b,c). When the right side is grounded and the excitation applied to the left, the non-linear behavior flips as well (d-f).

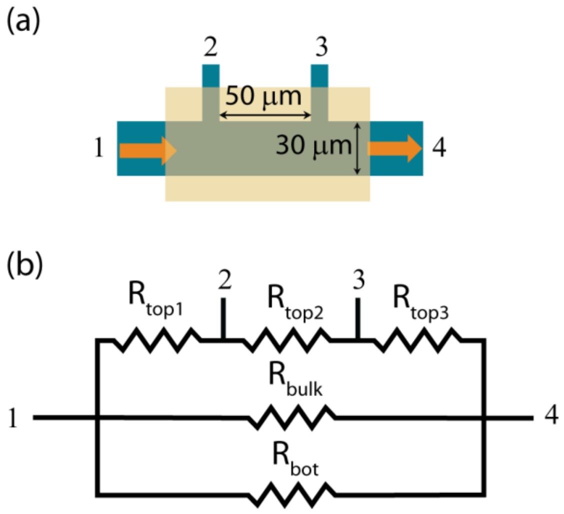

Fig. S3. Resistor network model of the device. (a) Schematic of the device geometry and (b) a resistor model including the three segments of the top edge to account for the four-terminal geometry.

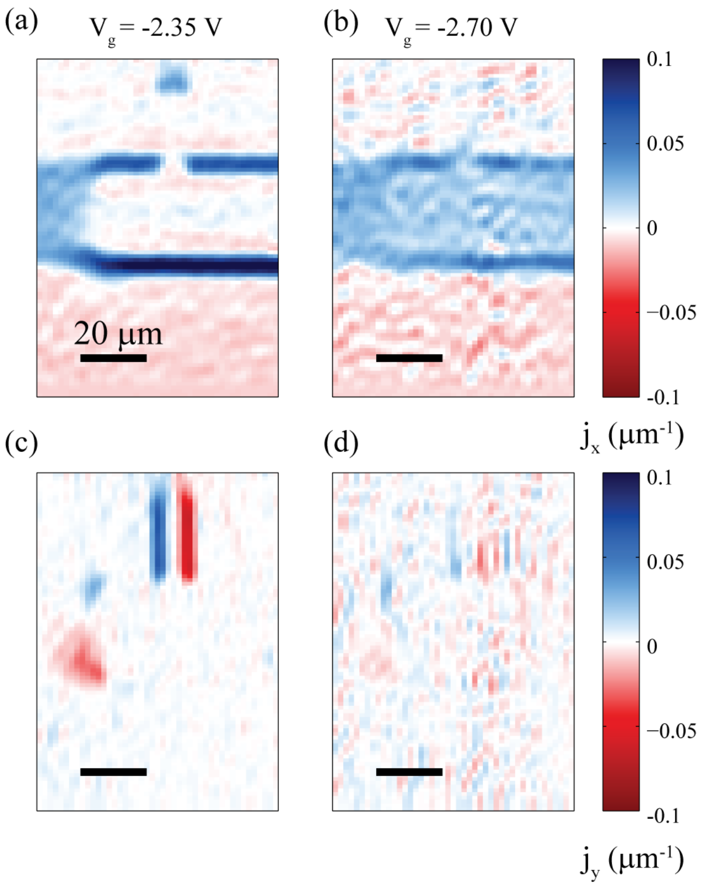

Fig S4. Comparison of edge current flow with and without bulk conduction (a,b) The x component of the current density shows enhanced current flow along the in the main body of the device both with (a) and without (b) significant bulk conduction. (c,d) The y component of the current density shows that current flows up the entirety of the gated contact when there is little bulk conduction (c), but when there is bulk conduction current does not flow up the narrow contacts (d), showing that the edges along the narrow contact are effectively "shorted" by the conducting bulk.