Circuit quantum simulation of a Tomonaga-Luttinger liquid with a single impurity

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One-dimensional (1D) systems at low temperatures form exotic phases of strongly-correlated matter believed to be generically described by the so-called Tomonaga-Luttinger liquid (TLL) concept. A hallmark signature in 1D conductors is that, when the temperature is reduced, even a single impurity can drive them into an insulating state. However, the extreme sensitivity of this metal-insulator transition impedes experimental explorations of real-world TLLs. Furthermore, its theoretical treatment has only been achieved exactly for specific strengths of interaction. A quantum simulator can provide a powerful workaround, as we here show with a hybrid metal-semiconductor dissipative quantum circuit (Fig. 1a), implementing a TLL analogue with adjustable electronic interactions and a fully tunable scattering impurity. Measurements reveal the renormalization group 'beta-function' for the conductance (Fig. 1b), which completely determines the scaling flow to an insulating state upon cooling. Moreover, we establish the quantitative scaling temperature versus model parameters and explore the out-of-equilibrium regime. With the quantum simulator quality demonstrated by the precise quantitative agreement with existing and novel predictions, we then achieve quantum simulation in its strongest sense by elucidating theoretically unsolved regimes. Additional probes (dynamics, fluctuations, heat) and device evolutions could open the path to investigations of a broad variety of correlated phenomena, with direct nanoelectronic implications.

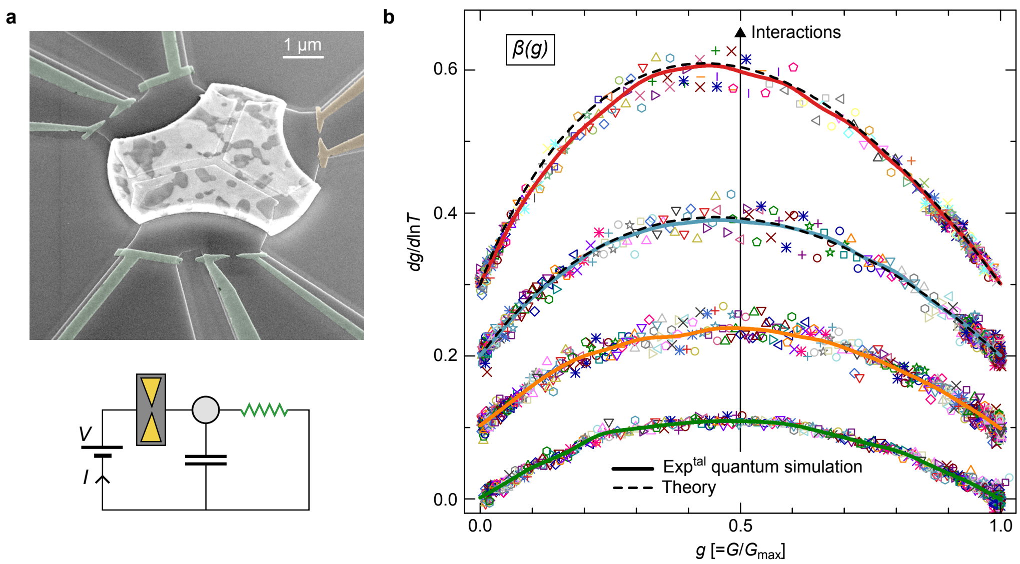

Figure 1. **a**, TLL analogue quantum simulator: device micrograph (top), circuit (bottom). **b**, Conductance renormalization group beta-function: theory and quantum simulation.