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Unveiling the bosonic nature in an ultrashort single-electron pulse

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Quantum dynamics is very sensitive to dimensionality. While two-dimensional electronic systems form Fermi liquids, one-dimensional systems - Tomonaga-Luttinger liquids - are described by purely bosonic excitations, even though they are initially made of fermions. With the advent of coherent single-electron sources [1- 3], the quantum dynamics of such a liquid is now accessible at the single-electron level. Very little is known, however, on the propagation of such single electron charge excitations. Here, we investigate in a time-resolved manner the propagation of an ultrashort single-electron charge pulse injected into a quasi-one-dimensional quantum conductor. This allows us to extract the collective charge excitation velocity. We show that the velocity of such a single electron pulse is found to be much faster than the Fermi velocity due to the presence of strong electron-electron interactions and can be tuned over more than an order of magnitude by electrostatic confinement. In addition, our set-up allows us to tune our system continuously from a clean one-channel Tomonaga-Luttinger liquid to a multi-channel Fermi liquid. Our results [4] are in quantitative agreement with a parameter-free theory and demonstrate a powerful new probe for directly investigating real-time dynamics of fractionalisation phenomena in low-dimensional conductors. [1] G. Fève, A. Mahé, J.-M. Berroir, T. Kontos, B. Plaçais, D.C. Glattli, A. Cavanna, B. Etienne, Y. Jin. "An On-Demand Coherent Single-Electron Source". Science 316, 1169-1172 (2007). [2] J. Dubois, T. Jullien, F. Portier, P. Roche, A. Cavanna, Y. Jin, W. Wegscheider, P. Roulleau and D.C. Glattli. "Minimal-excitation states for electron quantum optics using levitons.", Nature 502, 659-663 (2013) [3] C. Bäuerle, C. Glattli, T. Meunier, F. Portier, P. Roche, P. Roulleau, S. Takada, and X. Waintal, "Coherent control of single electrons: a review of current progress", Rep. Prog. Phys (2018) DOI: 10.1088/1361-6633/aaa98a [4] G. Roussely, E. Arrighi, G. Georgiou, S. Takada, M. Schalk, M. Urdampilleta, A. Ludwig, A. D. Wieck, P. Armagnat, T. Kloss, X. Waintal, T. Meunier, and C. Bauerle. Unveiling the bosons in an ultra-short single electron pulse, Nature Communications 9, 2811 (2018)

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