GRAPHENE FOR US
International Conference
ONLINE
★ April 06-07, 2022 ★

Miniaturizing transmon qubits using van der Waals materials

Raytheon BBN Technologies

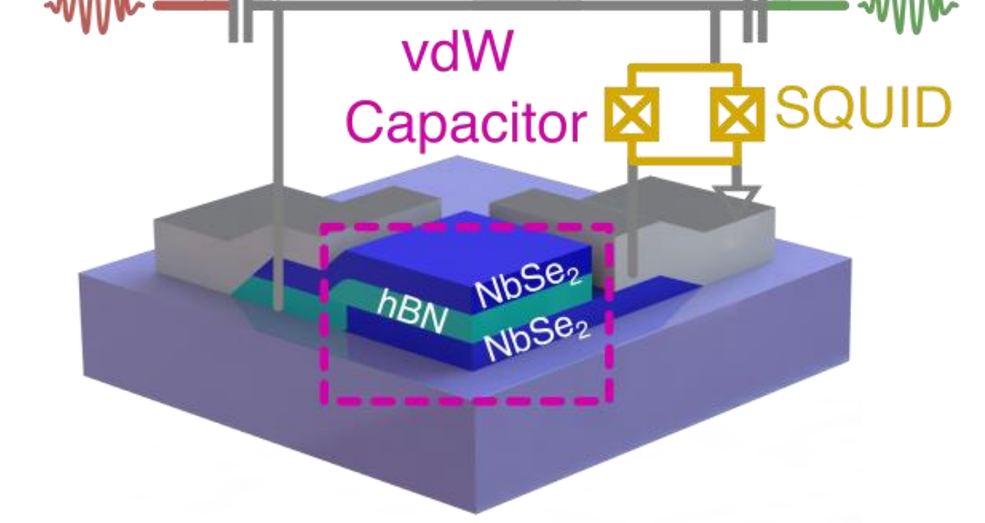
Abhinandan Antony[1], Martin V. Gustafsson[2], Guilhem J. Ribeill[2], Matthew Ware[2], Anjaly Rajendran[3], Xuanjing Chu[1], Luke C. G. Govia[2], Thomas A. Ohki[2], Takashi Taniguchi[4], Kenji Watanabe[5], James Hone[1], and Kin Chung Fong[2]

1. Department of Mechanical Engineering, Columbia University, New York, NY, 10027
2. BBN Technologies, Raytheon, Cambridge, Massachusetts, 02138
3. Department of Electrical Engineering, Columbia University, New York, NY 10027, USA
4. International Center for Materials Nanoarchitectonics, National Institute for Materials Science, 1-1 Namiki, Tsukuba 305-0044, Japan
5. Research Center for Functional Materials, National Institute for Materials Science, 1-1 Namiki, Tsukuba 305-0044, Japan

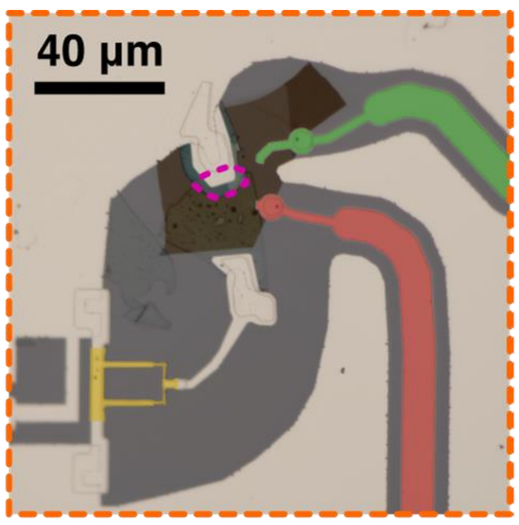
Introduction

Ultra low loss capacitance elements make up a fundamental part of many different quantum devices. Today, the bulk and interfacial losses that plague conventional parallel plate capacitors have mandated the use of extremely large coplanar capacitors. While they have been successful in increasing device performance by reducing coupling to lossy two level systems, their size proves a major obstacle when considering the scaling up of quantum systems. Van der Waals materials can be grown as single crystals with extremely low defect densities and then stacked to create heterostructures with ultra-clean laminated interfaces. Here we report results of a qubit with an all van der Waals (vdW) parallel plate capacitor as it's primary external capacitance. Using exfoliated vdW materials, such as niobium diselenide (NbSe2), and hexagonal boron nitride (h-BN), our process allows us to create capacitors with atomically flat, ultra clean interfaces, and dramatically reduced footprints when compared to conventional coplanar capacitors. Using a recipe we developed to make low loss superconducting contacts to NbSe2, We couple an all VdW capacitor to a SQUID loop to form a flux tunable "SuperVan Qubit." We report relaxation times of ~ 1 us , which is the first demonstration of coherence for a device with an all VdW capacitance.

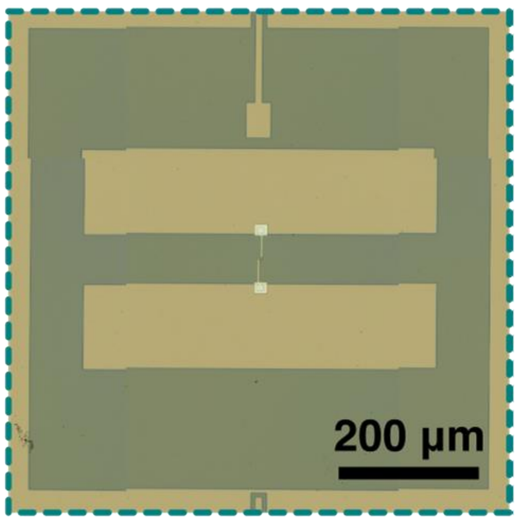
Device



Schematic circuit diagram



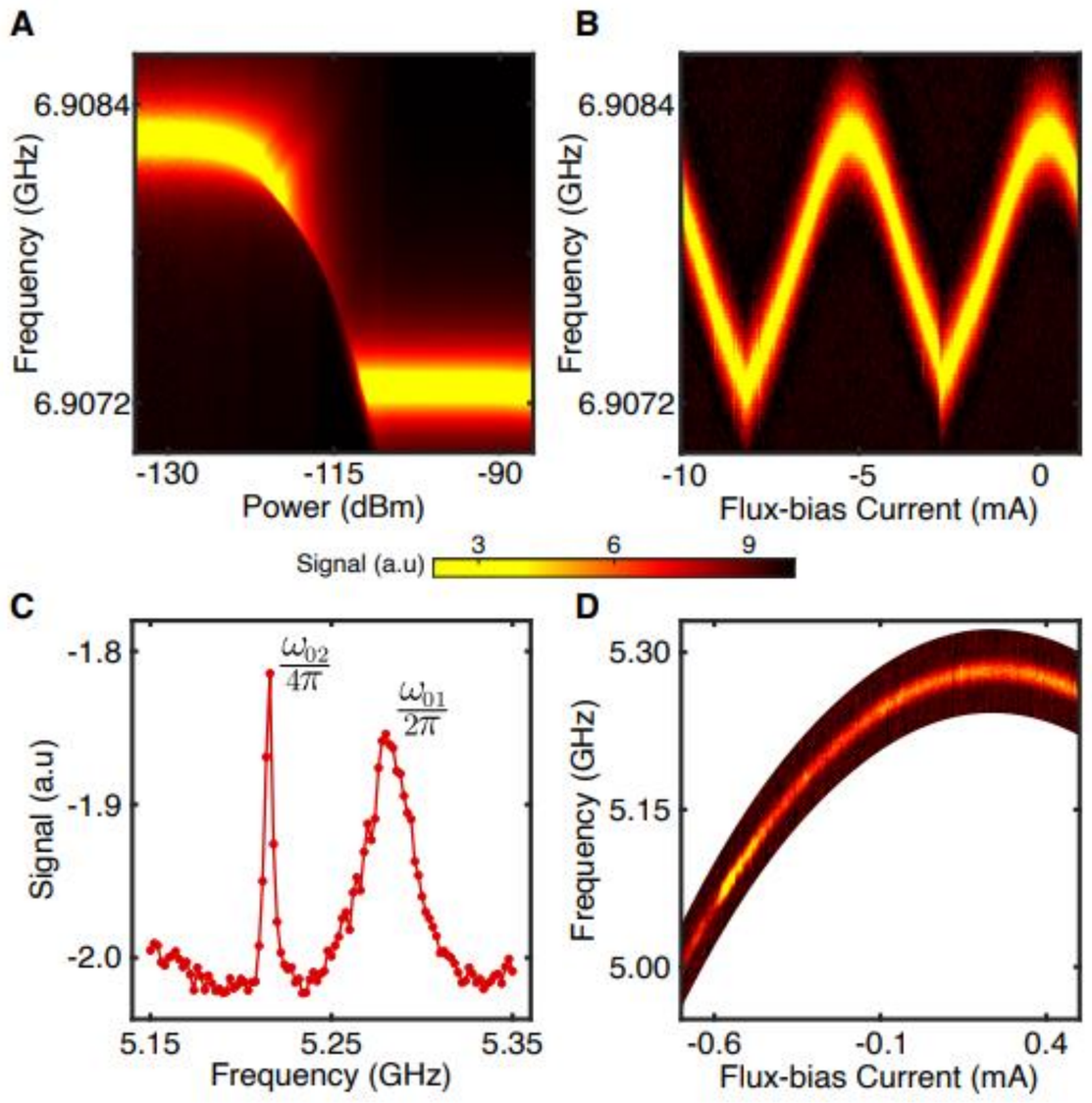
vdW Capacitor (pink)



Conventional qubit

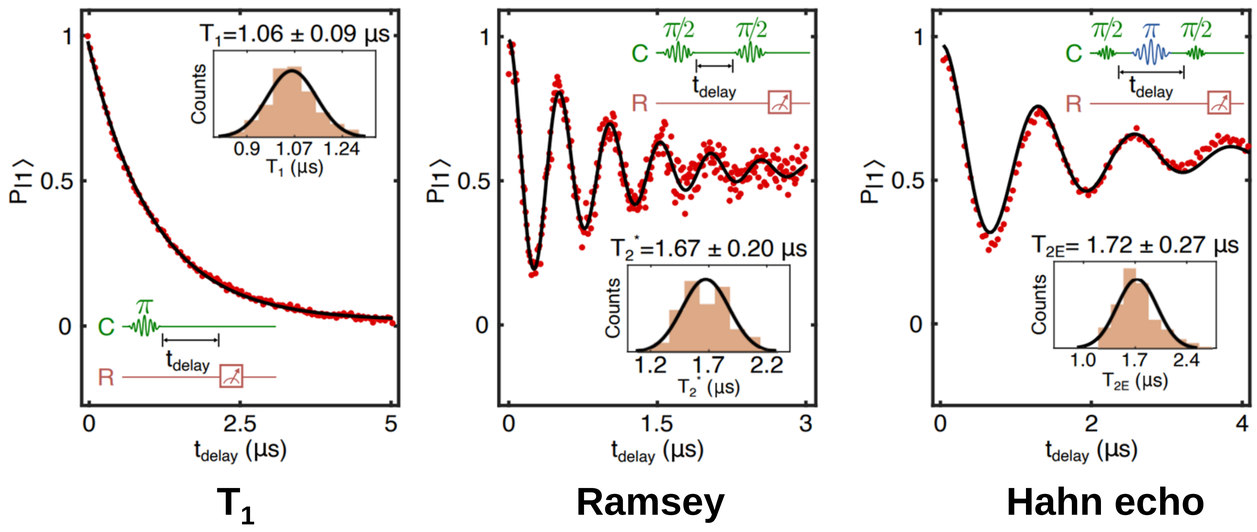
Reduce the qubit area by a factor of > 1000

Results: Spectroscopy



Spectroscopy of a vdW transmon

Results: Coherence



T_1 **Ramsey** **Hahn echo**

The first demonstration of coherence in a device with an all van der Waals parallel plate capacitor, showing T_1 times of ~1μs

Contact person

Xuanjing Chu
xc2562@columbia.edu
(646)-617-1889

References

1. Liu, X. & Hersam, M. C. 2D materials for quantum information science. Nat. Rev. Mater. 4, 669–684 (2019).
2. Antony, A. et al. Making high-quality quantum microwave devices with van der Waals superconductors. arXiv 2107.09147 (2021).
3. Blais, A., Grimsmo, A. L., Girvin, S. M. & Wallraff, A. Circuit quantum electrodynamics. Rev. Mod. Phys. 93, 025005 (2021).

Acknowledgements

We acknowledge funding support from ARO's quantum computing program (W911NF18C0044). AA thanks the sponsor of NSF's QISE-NET program (award number 1747426).