Diamond bulk acoustic resonators for coupling superconducting circuits to color center spins

Stefan Pfleging,
Arianne Brooks, Chris Adambukulam, Laura Schneider, and Yiwen Chu

Department of Physics, ETH Zürich, Rämistrasse 101, 8092 Zurich, Switzerland

spfleging@phys.ethz.ch

Abstract

Superconducting (SC) qubits are a promising platform for quantum computing, but are limited by their coherence times. They can be coupled to the negatively charged silicon-vacancy (SiV) color center by using a diamond high-overtone bulk acoustic wave resonator (HBAR) as an intermediate system. The SiV's energy levels, shown in Fig. 2a, are strain-susceptible and its spin qubit can exhibit coherence times on the order of 10 ms at mK-temperatures [1,2], orders of magnitude larger than state-of-the-art SC qubits, making it suitable for quantum memory. We demonstrate electromechanical strong coupling of a transmon to a diamond HBAR using the sample architecture shown in Fig. 1 and building on previous work that established a coherent interface to HBARs [3]. Furthermore, we present an approach for achieving spin-phonon strong coupling of acoustic modes of the HBAR to an SiV's spin and simulate its requirements (Fig. 2b). Combining the techniques enables a hybrid platform for fast and flexible quantum processing at high coherence times.

References

[1] S. Meesala *et al.*, Phys. Rev. B 97 (2018), 205444
[2] D.D. Sukachev *et al.*, Phys. Rev. Lett. 119 (2017), 223602
[3] Y. Chu *et al.*, Nature 563 (2018), pp. 666-670

Figures

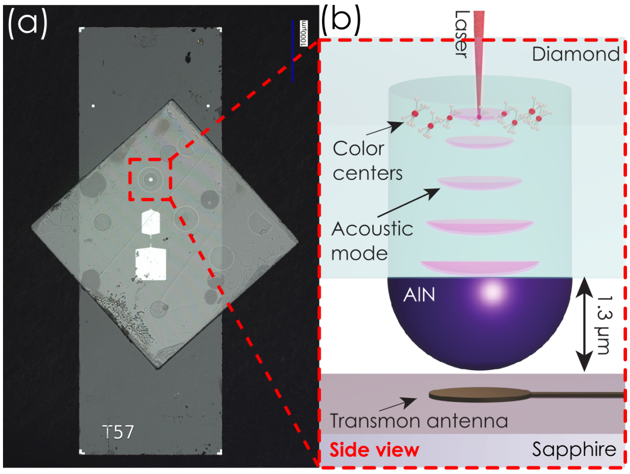

Figure 1: (a) Microscope image of a transmon flip-chip bonded to a diamond HBAR. The HBAR is positioned above the transmon's antenna. (b) Schematic side view of a diamond HBAR hosting color centers in the vicinity of a transmon's antenna. The color centers' spin states are initialized and read out optically.

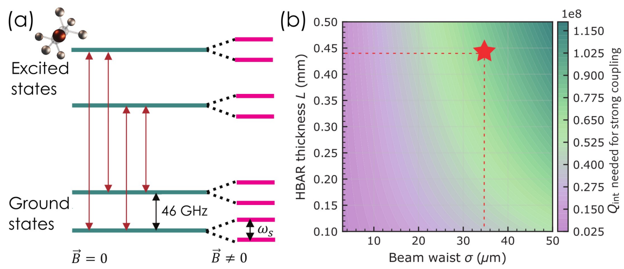

Figure 2: (a) Level scheme of the negatively charged SiV color center. The red arrows mark its optical transitions and ω_S the spin qubit transition. (b) Required internal quality factor of a diamond HBAR for achieving spin-phonon strong coupling in dependence of HBAR parameters and for a targeted spin-strain susceptibility d_S = *100* THz/strain and qubit transition frequency ω_S = *3.5* GHz. The red star marks our current device parameters.