Ultra-low noise HEMT LNAs used in first demonstration of quantum supremacy

Quantum computing has become a large scientific undertaking worldwide where leading institutions and companies are engineering processors based on principles of quantum physics. The most promising technical solution is to scale-up superconducting processors where the quantum bits are represented by photons operating at microwave frequencies. In late October 2019, a paper was published by Google showing for the first time a quantum computer faster than any existing classical one, in other words demonstration of *quantum supremacy* [1]. The quantum system, based upon a 53 qubit processor, used microwave amplifiers from Low Noise Factory AB (LNF) in Gothenburg. These components take advantage of the ultra-low noise transistor technology developed in GHz Centre.

Quantum bits represent immensely weak signal power levels less than 10^{-16} W (-120 dBm). The operation of such fragile qubits, processed at millikelvin temperature, requires classical electronics at higher temperature stages, capable of amplifying these weak signals. In Fig. 1, the Google quantum computer wiring with ingoing devices is schematically shown. The cryogenic low-noise amplifier LNA (cryo-LNA) used at the 3 K stage is a 4-8 GHz three-stage hybrid design manufactured by LNF using indium phosphide HEMT technology optimized for cryogenic applications (Fig. 2). All transistor chips in the HEMT LNA have been fabricated in the MC2 cleanroom. Many years of research how to engineer these devices for lowest noise has resulted in leading C-band microwave products from LNF for readout components in quantum computing development. Research in GHz Centre is now carried out to reduce the power dissipation in these LNAs [2].

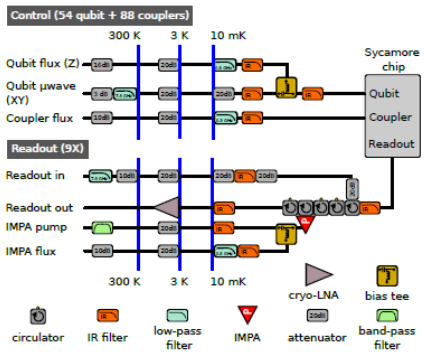

FIG. S3. **Cryogenic wiring.** Control and readout signals are carried to and from the Sycamore chip with a set of cables, filters, attenuators, and amplifiers.

Fig. 1. From [1]: Supplementary information.

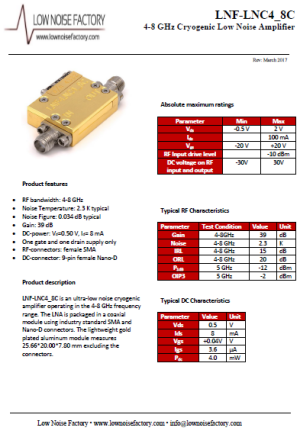

Fig. 2. C-band cryo-LNA used in Fig. 1. Data sheet LNFs home page: www.lownoisefactory.com.

References

[1] F. Arute, K. Arya, R. Babbush *et al.*, **Quantum supremacy using a programmable superconducting processor,** Nature, 574, 505–510, Oct. 2019.

[2] E. Cha, N. Wadefalk, G. Moschetti, A. Pourkabirian, J. Stenarson, J. Grahn, **A 300-μW Cryogenic HEMT LNA for Quantum Computing**, post-deadline paper accepted for International Microwave Symposium 2020.