Development of SC cavities for qubits and quantum memories

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Abstract:

3D architectures with superconducting qubits are highly attractive solutions for various quantum applications. We report our recent progress in the design, fabrication, and surface preparation of superconducting cavities, which has resulted in a significant increase in quality factor (Q).

3D architectures with superconducting qubits offer several advantages for applications that do not require a large number of qubits, such as single photon detection. Among the key advantages is the high Q factor of superconducting cavities, which enables prolonged photon storage times, and the inherently clean electromagnetic (EM) environment that minimises noise and enhances coherence. Furthermore, coherence times (T2) exceeding milliseconds have been reported in the literature [1].

Due to the London penetration depth, the active part of the cavity surface is limited to just a few tens of nanometres. Consequently, surface treatments are critical for achieving high Q factors.

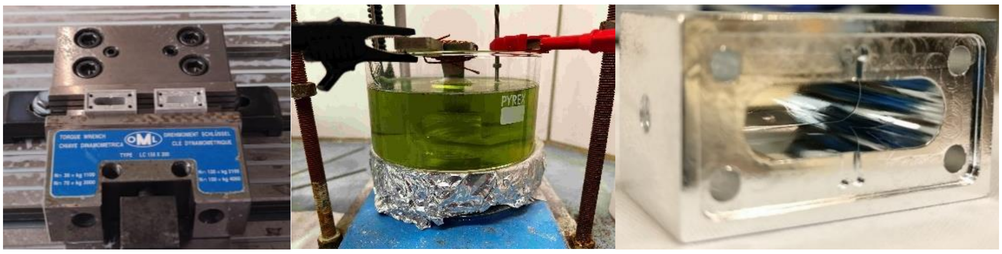

Fig. 1 SC cavity production, surface preparation and electropolished Al surface

This is a joint work between National Laboratories of INFN in Legnaro (LNL) and National Laboratories of INFN in Frascati (LNF). LNL has produced a series of superconducting cavities made of pure aluminium. We demonstrate the production process and post-treatment protocols developed for superconducting cavities designed for qubit and quantum memory applications.

The surface preparation and thermal treatment protocols have been optimised, and the final methodology is presented. These treatments have increased the quality factor *Q* by an order of magnitude, from 10^5 to 10^6, as measured at LNF. Additionally, progress towards the development and realisation of a bulk Niobium and 3D triple cavity for use as a two-qubit photon counter will also be presented.

References

[1] Aaron Somoroff, Quentin Ficheux, Raymond A. Mencia, Haonan Xiong, Roman Kuzmin and Vladimir E. Manucharyan, “Millisecond Coherence in a Superconducting Qubit,” Phys. Rev. Lett. **130**, 267001 (2023).