Contribution ID: **11** Type: **not specified**

NbN Superconducting Coil Platform for Cryogenic Sensing and Actuation

Next-generation gravitational wave observatories operating at cryogenic temperatures demand advanced sensing and actuation platforms with minimal thermal noise and power dissipation. While superconducting systems have historically relied on wirewound coils operated at liquid helium temperatures, higher operating temperatures necessitate superconductors with elevated critical temperatures. We present a thin-film engineering approach to superconducting coils based on niobium nitride (NbN), a material system that enables device geometries unattainable through conventional wire-winding techniques. Our 200 nm thick NbN coils, fabricated on single-crystal MgO substrates, demonstrate sharp superconducting transitions with a critical temperature of 14.4 K and critical currents exceeding 180 mA, sufficient to sustain ampere- level persistent currents. The coils exhibit excellent mechanical stability under repeated thermal cycling, with optimized geometries featuring enlarged contact pads ensuring robust performance. Numerical and analytical simulations confirm that these coils generate sub-micronewton forces at 0.1 mm separation distances, substantially exceeding the nanonewton-scale actuation requirements for mirror suspension in gravitational wave detectors. These results establish thin-film NbN superconductors as a viable platform for precision cryogenic sensing and actuation in the next-generation observatories.

References:
1) Sharma, M., Singh, M., Rakshit, R. K., Singh, S. P., Fretto, M., De Leo, N., & Pinto, N. (2022). Complex phase-fluctuation effects correlated with granularity in superconducting NbN nanofilms. Nanomaterials, 12(23), 4109.
2) Van Heijningen, J. V., et al. "The payload of the Lunar Gravitational-wave Antenna." Journal of Applied Physics 133.24 (2023).
3) Ellenbroek, V. J., Sharma, M., Singh, S. P., Zeoli, M., Gatti, A., Collette, C., & Van Heijningen, J. V. (2026, February). Design and manufacturing of superconducting coils for cryogenic (inertial) sensing and actuation. In Journal of Physics: Conference Series (Vol. 3177, No. 1, p. 012102). IOP Publishing.
4) Cooper, S. J., Collins, C. J., Green, A. C., Hoyland, D., Speake, C. C., Freise, A., & Mow-Lowry, C. M. (2018). A compact, large-range interferometer for precision measurement and inertial sensing. Classical and Quantum Gravity, 35(9), 095007.
5) Ferreira, E. C., Bocchese, F., Badaracco, F., van Heijningen, J. V., Lucas, S., & Perali, A. (2021, December). Superconducting thin film spiral coils as low-noise cryogenic actuators. In J. Phys. Conf. Ser (Vol. 2156, p. 012080).
6) Blair, C., Gras, S., Abbott, R., Aston, S., Betzwieser, J., Blair, D., & Romie, J. H. (2017). First demonstration of electrostatic damping of parametric instability at advanced ligo. Physical review letters, 118(15), 151102.

Primary author: SHARMA, Meenakshi (CPFS)

Presenter: SHARMA, Meenakshi (CPFS)

Session Classification: Payload