Higher Order Modes in Sapphire Bragg Resonators

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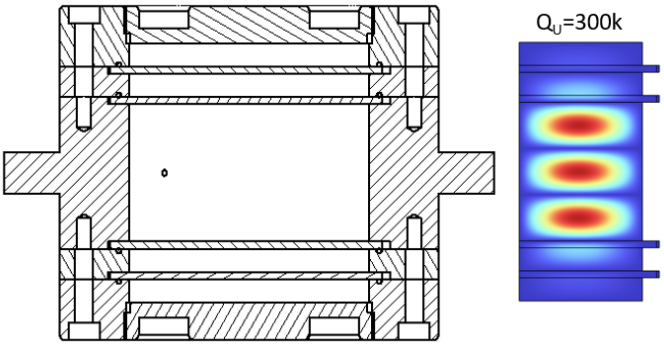
Low-phase noise microwave sources are crucial for advancements in radar, imaging, time and frequency metrology, and quantum processing. Traditional resonators suffer from energy losses due to microwaves' interactions with the metallic walls. To address this, some low-loss resonators utilizing a sapphire dielectric to shield the microwave energy from the metal walls have produced outstanding low-noise oscillators[1234]. Inspired by previous distributed Bragg reflector (DBR) designs[2,4], we investigate the use of higher-order modes in a cylindrical metal cavity with sapphire DBRs confining only in the axial direction. Our "sandwich" design allows for flexible configurations, enabling the creation of TE_{011}, TE_{013}, and TE_{015} center mode sections which can be paired with single or multiple reflectors of 1/4 or 3/4 wavelength thickness. We will present simulated results of multiple modes and reflector configurations versus cavity radius, as well as some vibration mitigation strategies. Simulated cavity modes exhibiting unloaded quality factors of $Q_U > 10^6$ and experimental results of a 10 GHz oscillator with $Q_U = 300\text{k}$ exhibiting single sideband phase noise of $\mathcal{L}(1\text{kHz}) < -155$ dBc/Hz will be shown.



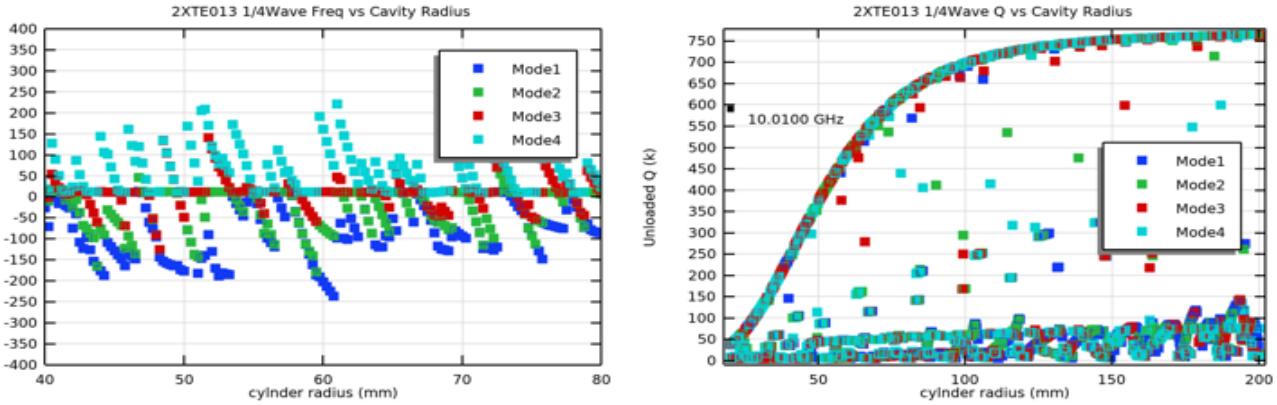


Fig. 1: (Top) Distributed Bragg Resonator with a TE_{013} center section, two 1/4λ sapphire wafer reflectors on each end, and threaded end caps for fine tuning. A simulated 2D-Axisymetric mode shape is also shown. (Bottom) TE_{013} mode frequencies and Q versus radius.

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