Distributed Cavity Phase Variation of $m = 1$ Azimuthal Mode Caused by TM_{111} Mode Choker of Ramsey Cavity

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The Ramsey resonator used in atomic fountain clocks is made with a cylinder-shaped or rotationally symmetric structure. The TE_{011} mode of the cavity is used for interrogating atomic resonance because the dominant oscillating magnetic field is at the cavity center aligning its direction to the cavity axis. If the resonator is of a perfect cylinder, the TM_{111} mode, which has the same frequency as the TE_{011} mode, can be excited resulting in unwanted transitions and perturbations. To suppress the TM_{111} mode, it has become customary to introduce a mode choker, an additional volume at the edge of the cylinder, that effectively shifts the TM_{111} mode frequency with little change in the TE_{011} mode.

We investigated the effects of the choker on the distributed cavity phase (DCP) using a finite element method. Thanks to the ability of performing 2D axisymmetric domain simulations instead of full 3D calculations[1], without spending a lot of time, we were able to parametrically scan the depth of the choker and observe changes in mode frequencies and field distributions. Since the structure of a choker is analogous to a coaxial cable with an inner conductor and an outer shield, a TEM mode field can exist inside the tiny gap of the choker. In particular, when the depth of the choker is around an odd multiple of the RF quarter wavelength, a resonant field inside the choker predominantly survives and mixes with the natural modes of the cavity producing mode pulling effect.

Figure 1 shows an example of dramatic field change against a small choker depth variation. Because the choker depth is around the RF quarter wavelength, one of originally off-resonant $m = 1$ modes is pulled near to the clock frequency and produces a significant $m = 1$ phase variation. This effect is thought to be responsible for the comparatively large tilt sensitivity of $m = 1$ DCP shifts in KRISS-F1[2]. In this forum, we plan to present detailed field calculation results, expected DCP shifts from Monte Carlo simulation, and their comparison to the experimental data.

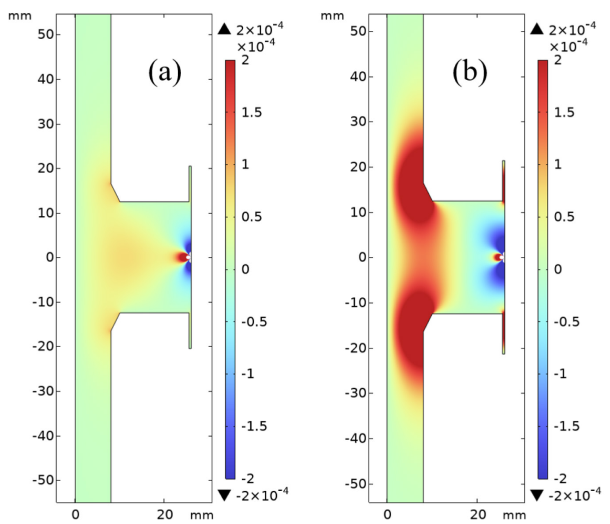

Fig. 1: Imaginary part of $m = 1$ field distributions for choker depth of (a) 8.0 mm and (b) 8.9 mm.

[1] Ruoxin Li and Kurt Gibble, "Evaluating and minimizing distributed cavity phase errors in atomic clocks," Metrologia, vol. 47, p. 534, 2010.

[2] S Lee, M-S Heo, TY Kwon, H-G Hong, S-B Lee, AP Hilton, AN Luiten, JG Hartnett, SE Park, "Operating Atomic Fountain Clock Using Robust DBR Laser: Short-Term Stability Analysis," IEEE Trans. Instrum. Meas., vol. 66, p. 1349, 2017.