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High frequency axion search cavity using dielectric ring at IBS/CAPP

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The Center for Axion and Precision Physics Research (CAPP) of IBS in Korea is launching a microwave axion search experiment using a high Q-factor, tunable resonant cavity submerged in a strong magnetic field, which is originally proposed by P. Sikivie[1]. We are currently searching for axions in the 1.5 to 2.5 GHz (TM_{010} mode) frequency range, but would like to extend the search range in the future without suffering volume loss. In order to access high frequencies without much degrading the axion to photon conversion power and the scanning rate of the experiment, a new type of cavity with dielectric material (sapphire) inside is proposed. With proper geometry of the dielectric material, it is possible to create higher modes with larger form factors.

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In the microwave cavity axion search experiments, the cavity volume, quality factor of the microwave resonant mode, and average electric field of the mode in the direction of an external magnetic field, so called form factor, greatly affect the detection speed. Here, we introduce a delectric ring designed to utilize the TM_{030} mode aiming for higher frequencies. The new structure can reduce volume contribution of electric field with opposite direction. This can enhance the form factor, which used to be the problem of using TM_{030} mode for an empty cavity.

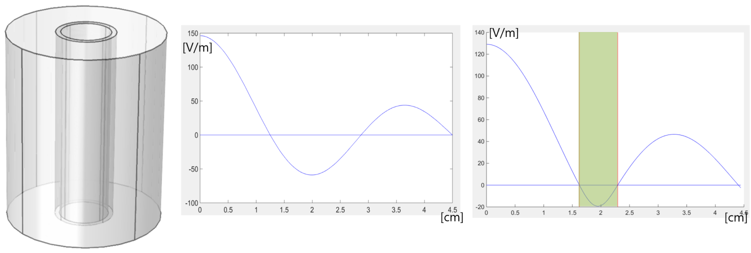

Figure 1: Cavity design with a dielectric ring(left) and effect of the dielectric material on the electric field of the TM_{030} mode(right)

Assuming a dielectric constant of 10, we calculated physical quantities, Q and C, using MATLAB, and obtained the field solutions analytically. It is found that Q is maximized at quarter-wavelength thickness case, while C (form factor) is maximized at half-wavelength thickness case.

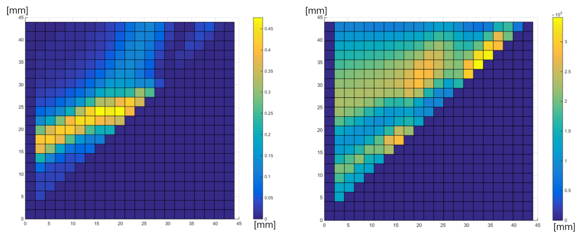

Figure 2: Q(left) and C(right) as a function of the inner(x-axis) and outer(y-axis) radii of the ring

Also it was possible to tune the frequency by introducing a gap, shown in Fig. 3. For a cylindrical cavity with 45 mm inner diameter and a quarter-wavelength thick dielectric ring, the tuning range was from 7.44 GHz to 8.16 GHz. This cavity size originally corresponds to 2.6 GHz, if one uses TM_{010} mode of the empty cavity.

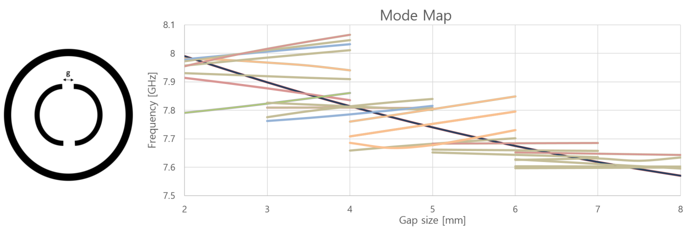

Figure 3: Tuning mechanism(left) and mode map with the TM_{030} mode(black line) (right)

References

[1] Sikivie, P. "Experimental tests of the" invisible" axion." *Physical Review Letters* 51.16 (1983): 1415.