# Modelling of Notch Filter using Whispering Gallery Mode Resonator

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**ABSTRACT**

*Whispering Gallery Mode Resonators represent a class of cavity devices with exceptional properties such as extremely small mode volume, very high power density, and very narrow spectral line width. In this paper we present the modelling of notch filter using Whispering Gallery Mode Resonator (WGMR) in terahertz frequency domain. We also discuss about the basic concept of WGMR, simulated result for frequency response of notch filter.*

*Keywords: WGMR, THz.*

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## I. INTRODUCTION

Whispering gallery modes or waves are specific resonances modes of a wave field inside a given resonator (a cavity) with smooth edges. Notch filters can be used in a number of different applications where a particular frequency or band of frequencies needs to be removed. Often notch filers are fixed frequency, although it is possible to design some that have variable frequencies. Fixed frequency notch filters find applications such as removing fixed frequency interference.

In signal processing, a band-stop filter or band-rejection filter is a filter that passes most frequencies unaltered, but attenuates those in a specific range to very low levels. It is the opposite of a band-pass filter. A notch filter is a band-stop filter with a narrow stopband (high Q factor).WGMR correspond to waves circling around the cavity, supported by continuous total internal reflection of the cavity surface, that meet the resonance condition. After one roundtrip they return to the same point with the same phase (modulo) and hence interfere constructively with themselves, forming standing waves. These resonances depend greatly on the geometry of the resonator cavity. It is found that the increase of either effective microsphere size or the refractive index of the medium surrounding the microsphere down-shifts the WGM resonance frequency. The larger the change, the stronger is the shift. A linear relationship between the variation of microsphere effective size and the resonance frequency shift is found. Demonstrated the feasibility to simulate quartz and polyethylene whispering gallery mode resonators for the THz frequency range with coinciding mode spectra over more than ten times the free spectral range. Point out the advantage of large size and the possibility of post processing of WGM resonators in the Terahertz frequency range.

## II. BASIC CONCEPT

Resonant phenomena in cavities of acoustic and optical domains frequently depend on the geometric properties such as size and shape, and also on the composition of the cavities. Such resonances are often known as Morphology Dependent Resonances (MDRs). An important example of MDR is that of whispering gallery mode resonator in the acoustic domain. The WGM in the acoustic domain comprises a moving pressure wave guided around a closed concave surface, like the whispering gallery in St. Paul’s Cathedral shown in a schematic Figure 1(a). From geometric considerations, neglecting absorption, scattering, and material dispersion, these modes are guided by repeated total internal reflections and continue endlessly.

However, in reality, the wave losses continue through the surface via absorption, scattering, and material dispersion, and mode undergoes a decay in its amplitude, in the absence of an external excitation, thereby causing a finite lifetime. It is important to note that WGM is a subclass of MDR and is characterized by its surface mode nature and high quality (Q) factor as a result of low losses.

Figure 1(b) shows the schematic of WGM in the optical domain illustrating WGMs can also occur in optical cavities having a closed concave interface. Among the important and simplest WGM geometries in the optical domain are discs/cylinders, spheres, and ring cavities which have been studied extensively during the last two decades. Since the resonators in the optical domain are in the region of few 10's of micrometers, they are generally difficult to fabricate and also tune to the optical waveguide, though they give rise to extremely high Q factor. On the other hand, THz waves have an advantage, since the WGMRs in the THz domain are in the sub-millimeter and millimeter range which are easy to fabricate and also to tune to the THz waveguide. Hence, substantial work is going on currently on WGMRs in the THz domain.

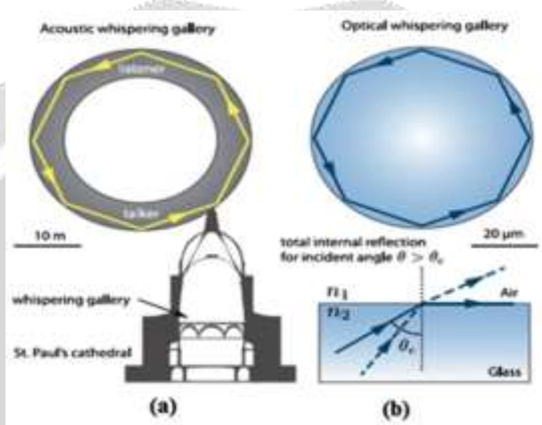


**Figure 1: WGMs supported by total internal reflection in (a) an acoustic mode, and (b) an optical wave.**

In its simplest form, an terahertz ring resonator consists of a straight waveguide and a ring waveguide. The waveguides are placed close to each other, making the waves affect each between the two structures. If the propagation length around the ring is an integral number of wavelengths, the field becomes resonant and a strong field builds up in the ring. After propagation around the ring waveguide, some light couples back to the straight waveguide and interferes with the incident waves.

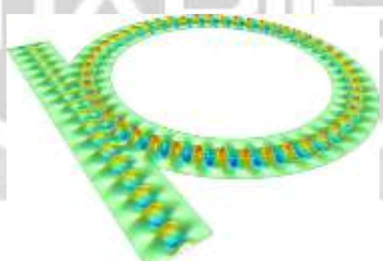

**Fig.2 Notch filter design**

## III. SIMULATED RESULT

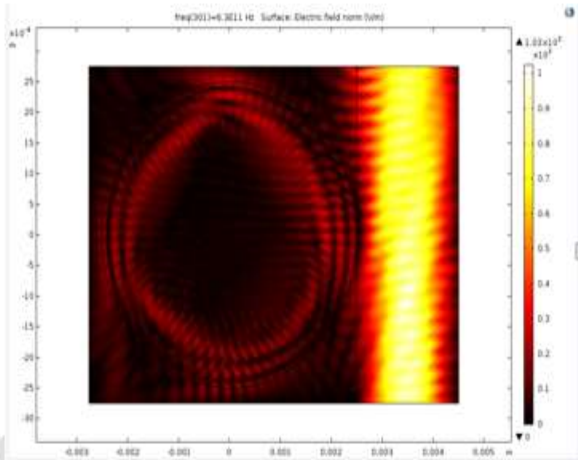

**Fig.3 WGMR response in the rectangular waveguide coupling mode**

Fig.3 is the simulation result obtained with 5 millimeter quartz sphere tuned to a rectangular THz waveguide in the CW-mode. Simulation was carried out using COMSOL Multiphysics version. 5.3. Fig:3 shows WGMR response in the rectangular waveguide coupling mode. Cavity resonator material used is Quartz with refractive index, n=1.5 and 5 mm diameter.

Further, a minute change in the size of the microsphere or a change in the properties of the surrounding medium would shift resonant frequencies.

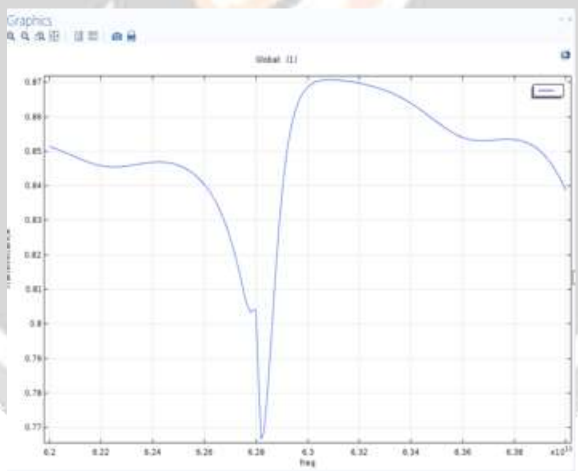

**Fig.4 Response Curve of Notch Filter in WGMR**

The transmittance curve at the output port is drawn for the Notch Filter using quartz material as shown in Fig.4 It can be seen from the transmittance curve that the Notch filter has zero transmittance at resonating wavelength and has more than 90 % transmittance at non-resonating wavelengths.

**CONCLUSION**

WGMs can be described as propagating modes around the centre of Dielectric Resonator(DR) with repeated total reflection from the rim of the resonator and phase shift of integer multiples of $2\pi$ in each rotation. Because of the large size, terahertz WGM resonators are easy to handle and also their fundamental modes are accessible. The ideal response for any notch filter would be a completely flat response over the usable range with the exception of the notch frequency. Here it would fall very fast providing a high level of attenuation that is able to remove the unwanted signal.

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