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Enhanced electric and magnetic response of a THz sub-wavelength fiber excited by a localized source

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Recently we have shown that a nanofiber excited by a localized electric source can have enhanced electric and magnetic response depending of the relative orientation of the source and the fiber [1]. We have demonstrated that the dielectric nanofiber can suppress the electric response and enhance the magnetic response of the coupled system when excited with an electric dipole oriented along the circumference of the fiber. This result introduces a new platform for achieving enhanced magnetic response, which is the fundamental building block for metamaterial devices. Here we investigate experimentally the scattering of THz radiation from a sub-wavelength fiber excited by a localized source. We observe resonance peaks in the scattered light and attribute them to combined excitation of several lower order Whispering Gallery Modes (WGMs) of the fiber. To the best of our knowledge, this is the first demonstration of sub-wavelength fiber resonances at THz frequencies due to a localized source.

We used a 300 μm soft-glass fiber (F2 with $n=2.7$ and $\alpha < 10$ 1/cm [2]) and a 300 μm circular aperture (sub-wavelength for $f < 0.5$ THz) in a very thin copper plate to create a localized source. Using a THz photoconductive near-field probe we measured the electric field over a square area of $850 \times 850 \mu\text{m}^2$ parallel to the aperture, for the bare aperture and for aperture-fiber system (fiber in front of the aperture). The normalized integrated powers over the scanned area are shown in Fig. 1(a) for aperture only and aperture-fiber. The results closely match the numerical results obtained from CST Microwave Studio (dashed lines). As expected for a bare aperture the maximum transmission is observed when the diameter is equal to half of the operating wavelength ($\lambda=600\text{nm}$). When the fiber is placed in front of the aperture, enhanced transmission is observed around 0.3 THz due to electric and/or magnetic resonances of the fiber. The electric field intensity at 0.3 THz of the bare aperture (Fig.1(b)) and the aperture-fiber system (Fig. 1(c)) also verifies the enhanced transmission through the system.

Fig. 1 (a) Normalized integrated power over a 300 μm diameter aperture (black curves) and aperture-fiber (red curves with triangle markers). The solid and dotted lines represent the experimental and simulated results. Vertical arrows show the position of WGMs. (b) Electric field intensity at 0.3 THz for (b) aperture only and (c) aperture and fiber.

As a first order approximation, a sub-wavelength aperture in a perfect conducting plane can be expressed with effective electric and magnetic dipole moments [3]. Therefore, the enhanced response observed here is due to the presence of both electric and magnetic localized sources. Further studies will analyze the response of the coupled fiber and localized magnetic source [4,5]. Consequently, we will be able to investigate the contribution of the electric and magnetic response within each resonance of this coupled system.

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