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Microwave photonic signal processing exploiting coherent interactions between Brillouin Stokes and anti-Stokes resonances

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Generation and processing of RF signals using photonic technologies enable electromagnetic interference (EMI) free low loss, light weight microwave photonic processor [1]. Generation of RF signals is typically achieved by beating multiple optical frequencies, which are created by exploiting nonlinear optical phenomenon in high-Q resonators [2]. RF photonic signal processing, on the other hand, is performed by modulating a laser with the incoming RF signal and processing one of the modulation side bands using active or passive optical resonance to achieve microwave photonic notch filter, RF switch, etc. [3]. Many of these photonics based RF signal processors use a phase modulator or a dual-parallel Mach-Zehnder modulator and a passive filter to create out-of-phase side bands with unequal amplitude. An active or passive resonance is then used to equalize the amplitude of the two out-of-phase sidebands [3, 4]. The resulting destructive interference between the beat signals, which are obtained by beating of the carrier with upper and lower sidebands, results in creation of a rejection band centered at the frequency of equal amplitude. Since the two sidebands are out-of-phase, the induced insertion loss is high because of cancellation in the pass band.

Here, we demonstrate a novel microwave photonic signal processor based on the coherent interaction between the Stokes and anti-Stokes Brillouin resonances of an optical fiber [5]. In many of the applications that exploit stimulating Brillouin scattering (SBS), only the Stokes or anti-Stokes resonance is harnessed to achieve the desired microwave photonic signal processing task. We exploit the phase and amplitude response associated with the Stokes and anti-Stokes Brillouin resonance of an optical fiber along with the phase shift induced by an off-the-shelf intensity modulator to demonstrate wideband excitation of Fano resonance and induced transparency like features in microwave domain [5]. While the SBS phase can be optically controlled, the phase shift induced by the modulator is electrically controllable resulting in electrical and optical control. Using a tunable pump, we demonstrate controlled excitation and switching of Fano resonance over a wide frequency range extending from 100 MHz to 43 GHz. Electrically controlled switching of the Fano resonance makes it a potential candidate for high speed, ultrafast resolution microwave photonic switch and filter. Controlling the amplitudes of the Stokes and anti-Stokes probe sidebands, we excite induced transparency like features over 2.5 GHz to 43 GHz. For a given microwave frequency, we demonstrate tuning of the 3 dB bandwidth of the induced transparency window from 14 MHz to 20 MHz while keeping the depth of the transparency window ~ 45 dB. By controlling the SBS pump power, we tuned the depth of the transparency window from 25 dB to 45 dB, with a small change in gain of 4 dB, without compromising the 3 dB linewidth (14 MHz).

References:

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