Wave-Coupled W-Band $LiNbO_3$ Mach-Zehnder Modulator

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Electro-optic modulators commonly use lithium niobate ($LiNbO_3$) as the substrate because of its high electro-optic coefficient. However, $LiNbO_3$ is dispersive, so the optical and electrical signals have different propagation times along the modulator electrodes. To prevent averaging of the signal in the modulator at high signal frequencies, the electrodes must be short, which gives low sensitivity.

We previously reported a method of cascading many short modulator electrodes, with the modulating signal coupled to the electrodes by antennas which were illuminated so that each electrode was driven in the proper phase. This makes it possible to construct sensitive modulators at high signal frequencies. In addition, since the modulator is radiatively coupled it is suited to waveguide-based systems and field sensing applications. We demonstrated X-band (10 GHz) and V-band (60 GHz) prototype phase-modulators at 633 nm optical wavelength. Our demonstration was restricted to phase-modulation because we used dipole antenna elements, and there was no convenient way to apply DC bias to the elements. A Mach-Zehnder amplitude modulator needs DC bias in order to operate in its linear region.

More recently we designed Mach-Zehnder amplitude modulators for W-band operation (94 GHz), at 1.3 μm optical wavelength. These modulators use bow-tie antennas, which are relatively insensitive to DC bias connections made to the ends of the antenna elements. The bow-ties should also give a greater bandwidth than the dipole antennas. The design and performance of these new modulators will be presented.