Optical Leaky Wave Antennas Integrated with Resonator Topologies

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In this work, we study the theory and design of an optical leaky wave antenna (OLWA) integrated with resonator topologies such as Fabry-Pérot resonator and ring resonator tuned to the telecommunication wavelength of 1550 nm (193.4 THz). The presented OLWA design is compatible with CMOS fabrication technologies. It comprises silicon (Si), silica glass (SiO_2) domains forming a dielectric waveguide that hosts numerous periodic perturbations. The radiation from an isolated OLWA takes place due to the leaky wave which decays slowly as it propagates along the perturbed waveguide. The design is tuned by purposely using perturbations of very small filling fraction in a unit cell, thus resulting in a leaky wave harmonic with very small attenuation and phase constants. This in turn leads to a very directive radiated beam almost in the direction normal to the axis of leaky wave propagation. In [Campione et al., Opt. Exp., 20, pp. 21305-21317, (2012)], for a similar isolated OLWA design, the tunability of radiation levels by modifying the optical properties of the Si domain through electron-hole excess carrier generation (thus the leaky wave's propagation constant) is proven to be limited, and an analytic model of OLWA in FPR is provided for the first time with a significant radiation level control. Therefore, in this research we turn our attention to utilizing the OLWA design integrated with resonator schemes such as ring resonators in order to achieve significant radiation control through the control of carrier densities in Si domains. We demonstrate effective control of radiation level alongside engineering a desired beam direction and directivity. Depending on the scheme of OLWA placement inside the resonator topology, the design procedure involves the construction of far-field as an interference beam radiated by different OLWA regions. Such a design allows for forming a stable radiated beam with frequency as well as achieving a high quality factor of resonance and hence an effective control of radiation level. Moreover the minimization of Si regions' sizes can lead to fast electronic operation through control of Si carrier density. The OLWA integrated with resonators are promising for improving the performances of optical switches.

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