Integrated Microwave Photonic Component Technologies

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Abstract: Key integrated microwave photonic component technologies are presented including low-loss waveguide true time delays for optical signal processing functions and high-performance hybrid integrated active devices. © 2018 The Author(s)
OCIS codes: (130.3120) Integrated optics devices

1. Introduction

Microwave photonics is the discipline that utilizes photonic components and techniques to assist RF processing or provide alternatives to achieve those same functions. In the same way that microwave photonics has leveraged mature commercial-off-the-shelf component technologies that were developed for the telecommunications industry, the emerging field of integrated microwave photonics (IMWP) is leveraging integrated photonic technologies that have been maturing at an unprecedented rate due to the pull of data communications and the significant investments made in silicon photonics [1]. This paper describes a few IMWP component technologies that have been developed recently including integrated true time delays (TTDs) based on low-loss waveguide optical ring resonators (ORRs), and high-performance hybrid integrated active components such as 3D integrated lasers and photodetectors.

2. Integrated component technologies

2.a. Low-loss waveguide true time delays

Integrated TTD is an enabling technology for optical signal processing functions in microwave photonics. TTD elements can be used, for example, in integrated optical beam forming networks (OBFNs) for photonics-enabled signal generation with squint-free beam steering capability. ORR TTDs are particularly attractive for continuous delay tuning. These can be realized with traditional silicon photonics waveguides based on silicon on insulator (SOI) or with low-loss waveguides such as those based on silicon nitride. Novel implementations of cascaded ORR delays in 1x4 OBFNs were demonstrated and calibrated for their delay characteristics [2, 3]. These were based on low-loss silicon nitride waveguides and ORRs that include independent control of the coupling coefficient and phase. Building on this technology, Fig. 1(a) depicts a schematic of a conceptual fully integrated 1x4 OBFN with ORR-based TTDs and hybrid integrated photodetectors that could be made possible with IMWP technologies.

2.b. Hybrid integrated active components

Silicon photonics remains in need of a reliable and tested laser integration technology especially for microwave photonics applications that demand high performance. For laser integration, the primary approaches are co-packaging with bulk optics, butt coupling, wafer bonding, and 3D hybrid integration [4, 5]. The 3D hybrid integration approach is based on the flip-chip integration of a laser or reflective semiconductor optical amplifier (RSOA) that includes a total internal reflection (TIR) turning mirror for surface emission, and subsequent coupling to a silicon photonic waveguide with a surface grating coupler (see Fig. 1(b)). This approach enables the p-side down bonding of the active laser device to the silicon substrate providing an effective means to dissipate heat from the active region. This is particularly attractive for microwave photonics because it leads to lower thermal impedance, and in turn higher laser efficiency and potentially lower relative intensity noise (RIN). 3D hybrid integration also has the advantage that fully fabricated lasers are attached to a silicon photonic chip or wafer in a backend step, thereby avoiding the co-fabrication of incompatible materials.

In addition to integrating standalone lasers, such as distributed feedback (DFB) or distributed Bragg reflector (DBR) lasers, novel laser geometries are possible with the integration of a RSOA that couples to filtering and feedback elements realized in the silicon photonic waveguides. For example, a laser cavity can be formed with a RSOA, ORR filters, and a DBR mirror to enable wavelength tuning and narrow linewidth [6].

Although silicon photonic modulators and photodetectors yield reasonable performance for telecom and datacom applications, this may not be sufficient for microwave photonics. The 3D hybrid integration approach could enable the integration of high performance modulators and photodetectors. As an example, surface illuminated modified uni-traveling-carrier (MUTC) photodiodes were bonded to a silicon photonics chips comprising grating couplers [7]. The photodiodes were illuminated through the grating couplers.
3. Conclusions

Several key IMWP component technologies have been described including low-loss waveguide ORR-based TTD elements for optical signal processing functions, and hybrid integrated lasers and photodetectors. These technologies have demonstrated integrated OBFNs, high-performance tunable lasers, and high-performance integrated photodetectors, showing promise for future fully integrated microwave photonic subsystems.

4. References


