26 GHz Carrier Frequency 10 Gbit/s Radio-over-Fiber Link based on a Directly Modulated III-V/Si DFB Laser

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Worldwide mobile data traffic is expected to increase an eightfold by 2020 compared to 2015, reaching 30.6 exabytes per month [1]. To keep up with this increasing demand providers will need to use new technologies and network architectures, generally referred to as the 5th generation mobile network or 5G. Current mobile networks have pushed the link spectrum efficiency close to the Shannon limit by using complex modulation formats such as 64-QAM OFDM, leaving little room for improvement. To further improve connectivity and increase bandwidth more spectrum will be needed. This can be achieved through the use of currently unused bands and shrinking cell size to maximize spectrum re-use. To enable this, Radio-over-Fiber (RoF) links will be an important technology. When using higher carrier frequencies, it is beneficial to move the signal processing and signal up-conversion from the cell site to a central office. This greatly reduces deployment and operations cost, while enabling centralized control [2]. This is definitely the case for small cell architectures, where central control and low cost are essential. In many RoF links a Mach-Zehnder Modulator (MZM) is used to imprint the RF signal on an optical carrier, as the MZM provides good linearity and high bandwidth. However, in recent years directly modulated semiconductor lasers (DMLs) have shown rivalling performance in digital transmission [3]. Also as transmitter in RoF links DMLs have been demonstrated as good transmitters [4]. The great advantage of using directly modulated lasers is the lower complexity, cost and insertion loss (defining the link gain) compared to using external modulation. Since deployment and operation costs are essential in 5G scenarios, DMLs are ideally suited as transmitters.

In this work we demonstrate a RoF link where the transmitter is a directly modulated III-V-on-Silicon DFB laser. The hybrid silicon technology offers many advantages, such as the possibility to integrate it with high bandwidth Si-Ge PDs and passive optical functions such as wavelength multiplexing. The III-V-on-Silicon DFB laser was fabricated by adhesive wafer bonding of an InP epitaxial grown material with a multiple quantum well gain section on a SOI photonic integrated circuit as illustrated in Fig. 1(a). The photonic integrated circuit was fabricated by imec on a 400 nm thick top Si wafer with deep UV lithography. The DFB grating was defined in the Si rib waveguide with a 180 nm dry-etch and has a period of 245 nm with a 50% duty cycle. The laser is a quarter-wave shifted DFB with a length of 340 µm. A detailed description of the fabrication process can be found in [5]. The laser has an output of 5 mW in the Si waveguide for a driving current of 100 mA at a wavelength of 1571 nm. The bandwidth of the laser was determined using a 67 GHz Keysight PNA-X 67, and the result for different bias currents can be found in Fig. 1(b). More details about the laser characterization and digital transmission demonstration can be found in [3]. The high bandwidth characteristics of the device enable its use for high carrier frequency Radio-over-Fiber transmission. An overview of the measurement set-up is shown in Fig 1(c). For the experiment the III-V-on-silicon laser (DUT) was placed on a temperature-controlled stage and kept at 20°C. The laser was biased at 100 mA corresponding to the maximum small signal bandwidth. The DUT was driven with a Keysight M8195A AWG, the output of the AWG was amplified with a 50 GHz SHF RF amplifier. The laser was coupled to standard single mode fiber (SMF) using an on-chip grating coupler. The output was amplified to 1 dBm with an EDFA to compensate for the chip-to-SMF coupling losses.

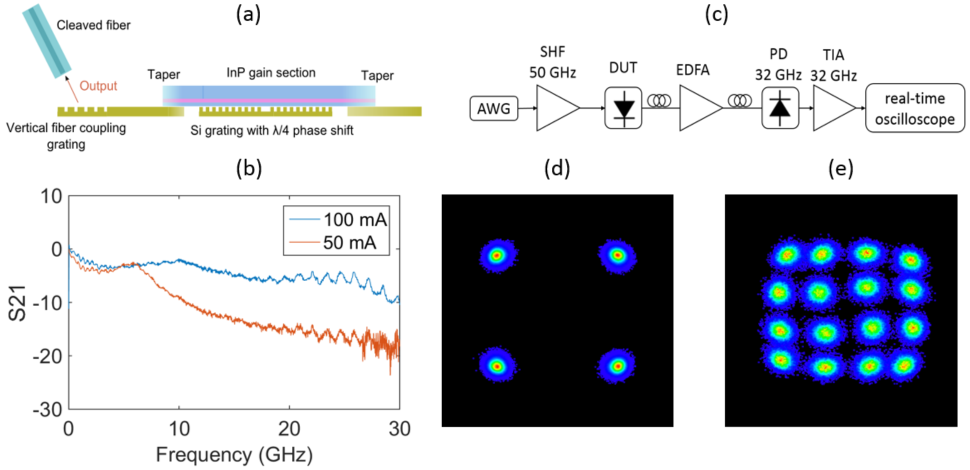

Figure 1: (a) Side view of the III-V-on-silicon DFB laser (b) S21 of the III-V-on-silicon DFB laser for different currents. (c) Overview of the measurement set-up. (d) Constellation of 1 Gbaud QPSK transmission on a 26 GHz carrier. (e) 2.5 Gbaud 16-QAM on a 26 GHz carrier

The optical output is then transmitted over 2 km of standard SMF. The receiver is a 32 GHz Discovery Semiconductor PD with TIA, and the output signal is analysed with a Keysight DSOZ634A real-time oscilloscope with 63 GHz bandwidth. We transmitted QPSK and 16-QAM signals at 1 and 2.5 Gbaud. This was done on a 26 GHz carrier frequency as will be used in 5G wireless networks. Transmission at 1 GBaud symbol rate gave an rms error vector magnitude (EVM) of 7-8% rms, independent of the modulation format. Such an EVM translates in error-free operation for QPSK modulation. Constellation diagrams of 2 Gbit/s QPSK and 10 Gbit/s 16-QAM on a 26 GHz carrier over 2 km of standard SMF is shown in Fig. 1(d)-(e). These experiments demonstrate that the III-V-on-Silicon DML is suited for high bit rate radio-over-fiber transmitters using high carrier frequencies to be used in 5G wireless access networks.

References

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