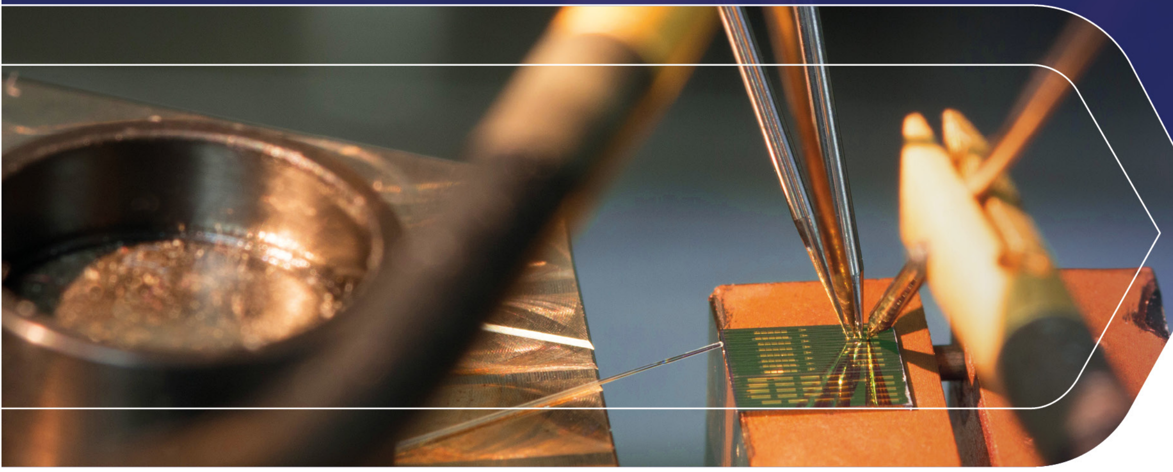
Application Note
5G Communication Networks

JePPIX
Platform for Photonic Integration



InP integration future 5/6G communication networks

In an interconnected world, wireless communication faces an ever-increasing demand for higher transmission speeds, lower latency and reliable high-throughput to more and more end-users. The 5G standard is not only a new standard for mobile communications, but is also essential for the manufacturing industry to achieve the connectivity needed for Industry 4.0 and networked mobility, like autonomous driving. The 5G and 6G frequency ranges are significantly wider than the previous frequency range used for, e.g., 4G, see table 1 for specification comparison, covering multiple ranges:

- FR 1: sub-6 GHz frequencies
- FR 2: 24.25 GHz to 52.6 GHz

Signal generation and transmission in the 10s to 100s of GHz can be challenging for electronics. Photonic technologies are seen as a key enabler for communication at frequencies between 30 GHz and 300 GHz[1], leveraging their benefits of high bandwidth, scalability, low latency, high resilience

Table 1 Comparison of 4G and 5G specifications

4G (LTE)	5G	6G
700 MHz – 2.7 GHz	sub-6 GHz & 24.25-52.6 GHz	< 3 THz
<1 Gb/s	20 Gb/s	1000 Gb/s

and network re-configurability. Photonic integration offers additional size, cost and power-efficiency advantages[2]. Photonic integrated circuit (PIC) technologies are nowadays offered, through multi-project wafer (MPW) services, by foundries and the JePPIX pilot line will enable pilot manufacturing for fabless InP PIC product development.

Radio-over-Fiber

High losses of electrical RF waveguides strongly limit the RF signal transmission distance. Radio-over-Fiber (RoF) uses the principle of loading the RF signal onto an optical carrier, enabling RF signal transfer over broadband, low-loss optical fibers. The concept is straight

InP Photonic Integrated Circuits (PICs)

Optical chips or PICs can contain tens to hundreds of optical components. While electronic integrated circuits (EICs) consist of transistors, capacitors, and resistors, a PIC consists of, for example, lasers, modulators, photodetectors, and filters, all integrated on a single substrate. Several application fields, such as data- and telecom, sensing, and lidar are already using or are considering the use of PICs for their products. This PIC technology is accessible to users without a cleanroom, through so-called multi-project wafer runs and open access foundries. InP based technology is commercially available through SMART Photonics and Fraunhofer Heinrich-Hertz-Institut. Access is individually coordinated by JePPIX.

[1] https://doi.org/10.1109/JLT.2015.2511040
[2] https://doi.org/10.1088/2040-8986/abc312

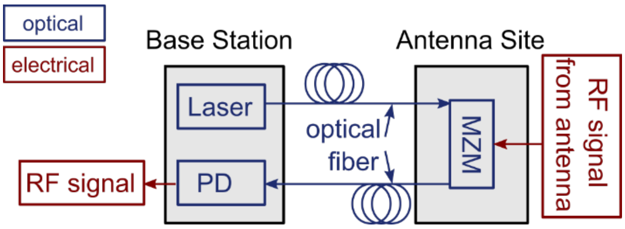


Figure 1: Scheme of a remote ROF receiver antenna for remote receiving.

forward: the RF signal is modulated onto an optical carrier at the transmitter side and detected at the optical receiver side by a wideband photodiode. For remote receiving, the RF signal can be loaded onto the optical carrier at the antenna site[3], as shown in Figure 1, allowing for a convenient separation of laser and receiving PD to a base station and optical modulator at the antenna location.

Photonic Building Blocks

Given a fiber-based transmission link, photonics-based RoF solutions require the following optical building blocks:

(1) The optical source: InP PIC technology offers integrated laser sources emitting in the telecom wavelength window around 1550 nm. Continuous-wave tunable lasers with extremely narrow linewidth have been demonstrated[4], as well as mode-locked lasers[5].

(2) The optical modulator: The modulators are required to transfer the electrical RF signal onto the optical carrier. Modulation can take place inside the laser cavity, using direct modulation, or outside the laser cavity, for external modulation. Generic InP modulators achieve up to 20GHz bandwidth[2], yet optimized modulators have been demonstrated exeeding 60-GHz 3-dB bandwidths[6].

(3) The optical filter: Filters are required for various signal processing functions and can be implemented in PICs in a multitude of variations, including Fabry-Pérot or ring resonators, asymmetric Mach-Zehnder interferometers (MZIs) or Whispering Gallery Mode based filters[2].

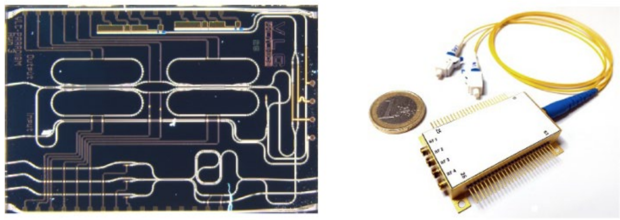


Figure 2: InP monolithic integrated photonic microwave filter. From [7].

(4) The optical detectors: Detectors are required to retrieve the RF signal and convert it back into the electrical domain.

Signal Generation

Different photonic signal generation techniques are available. Common approaches in photonic integration use optical heterodyning, based on integrating a dual wavelength source, or are achieved by means of on-chip integrated mode-locked lasers[1]. For the latter, excellent performance has been demonstrated in terms of frequency-stable, low phase-noise, and narrow linewidth sources.

Within the prominent PIC technologies, heterogenous or hybrid integration strategies of InP, either with silicon nitride (SiN) photonic circuits or with silicon photonics (SiPh) show high potential[2] for their applicability in 5G communication networks. Yet, among the prominent PIC technologies the InP material platform stands out, offering all required active components such as lasers, high-speed modulators, and detectors on chip, and monolithically integrated InP PIC solutions enabling the 5G era have been demonstrated[7,8].

Discuss your application with us

If you are interested in knowing more about the capabilities and use of InP PIC technology for 5G communication, contact JePPIX. The JePPIX Pilot Line (pilotline@jeppix.eu) provides low entrance-threshold to mature-manufacturing, enabling high-TRL development in a scalable design kit driven process, taking open access InP PICs from proof of concept to industrial prototyping levels.

[3] Bogoni et al. “Photonics fro 5G” https://www.5gitaly.eu/2018/en/white-ebook-2/
[4] https://doi.org/10.1109/JLT.2019.2952466
[5] https://doi.org/10.1364/OL.42.001532
[6] https://doi.org/10.1109/JLT.2016.2639542
[7] https://doi.org/10.1038/nphoton.2016.233
[8] https://doi.org/10.1109/JLT.2018.2836298