Solderable Multi-Gigabit Optical Wireless Transceiver for Rotary Communication Setups

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This work presents an optical wireless short-range transceiver for on-axis communication over rotary setups or docking applications. The transceiver is solderable and designed for device integration with a small footprint. Bit error ratio (BER) and signal power measurements show the performance for a rotation setup.

Introduction

The increasing system complexity and the simultaneously growing data generation in nearly all kinds of electronics push the demand for higher bandwidth data transfers. While there are powerful cable networks on copper and fiber technology, the situation for wireless communications, which is widely radio-frequency (RF) based, is even more tensed [1]. RF is a shared medium. Frequency bands are limited and differently regulated by every nation. This leads to the so-called "spectrum crunch". Optical wireless communication (OWC) provides a promising approach to address the bottleneck with local license-free links. At mid-range, Li-Fi covers such technologies with an expanded field-of-view (FOV) that focus on indoor local area networks and local beam spots from infrastructure to mobile devices [2]. Short-range OWC links are of interest to overcome any gap that are not possible for static cable connections. In industrial environments, for example, this could be docking of mobile devices, connector replacement to avoid mechanical wear or making a connection to rotary devices without using a mechanical slip-ring. In machine-to-machine (M2M) communications, the factors real-time (RT) and latency are added to the requirement list. Using a bidirectional full-duplex link is almost mandatory to achieve real-time cycle times down to few microseconds. Examples for industrial base protocols are Ethernet from 100 Mbit/s to 10 Gbit/s or camera links like 3G-SDI. With Ethernet Time Sensitive Networking (TSN) both kinds of traffic (RT and Best-Effort) can be mixed on the same line which requires a link technology with deterministic latency.

Transceiver

The transceiver in this work focuses on short-range communication with a small design footprint. It is designed for full-duplex communication. The electronics are based on 850 nm telecommunication technology shown in a previous work [3]. In this work, the transceiver shown in Fig. 1c uses a freeform lens that is injection-molded with temperature stable material to enable mechanical handling and reflow processes. The lens is designed for a rotationally symmetric FOV. However, the lens design is asymmetric and has required a freeform design to merge emitter and detector in a monolithic package [4]. The small size is suitable for device integration, for example, for connector replacement or enabling on-axis rotationally symmetric links, like data communication with generators or setting up a camera link in a periscope. The data rate ranges from 20 Mbit/s to 5 Gbit/s. The link FOV decreases at higher data rates. The data rate has no sharp limit at 5 Gbit/s. However, the link penalty for the FOV is much more substantial at rates above. Primarily, network speeds of 1.25 Gbit/s and 5.0 Gbit/s are anticipated with this design. The following measurements present the behavior similar to an environment with a rotary joint.

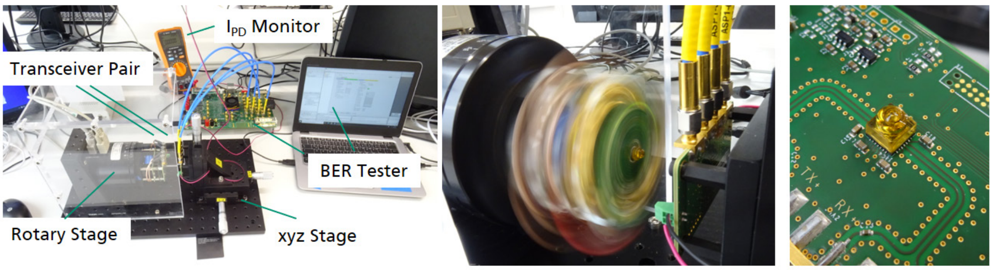

Fig. 1. OWC transceiver under test: a) Setup for BER rotation measurement b) Transceiver during rotation c) Transceiver soldered on PCB

Results

A pair of OWC transceivers is mounted on a PCB with SMA connectors (Fig. 1c) and further on a test stage for BER testing (Fig. 1a, 1b). One transceiver is battery-driven and mounted on a rotary stage with an axis center precision better than 200 µm and is called rotary transceiver. The other one is mounted on xyz-stage and is called reference transceiver. The BER tester uses PRBS7 to be close to an 8b10b line coding. For checking, a loopback is set on the rotary transceiver. Hence, the BER value covers both link directions and runs at full-duplex. The setup allows setting different rotation speeds while displacing the reference transceiver in three directions and measuring the BER at every position. As a result, the measurement shows the possible displacement range of the transceiver pair, which is named alignment in this context. Additionally to every BER value, the RX power is measured by the monitor current I_{PD} of the reference receiver.

The results in Fig. 2 show the link performance at 0 rpm and 100 rpm at a link distance of 25 mm that corresponds to a board-to-board distance of 35 mm. At 1.289 Gbit/s an alignment of ±1.5 mm is achieved for a BER limit of 1E-11 and at 5.128 Gbit/s an alignment of ±0.75 mm is achieved. For specific static angles like 0° a wider alignment of –2.75 mm to +2.25 mm is possible as it shown in Fig. 2b. In general, the BER during rotation shows the worst case alignment. The power distribution in Fig. 2c shows that the beam profile is aligned to the rotation axis.

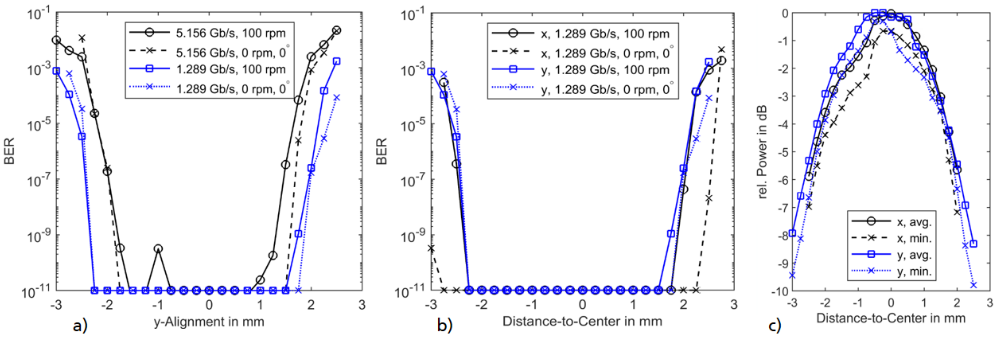

Fig. 2. Results of rotation measurements: a) BER for 1.289 Gbit/s and 5.156 Gbit/s over y-alignment; b) BER with 1.289 Gbit/s over x- and y-alignment; c) relative RX power at reference transceiver over x- and y-alignment

Conclusion

In this work, a further development of an optical wireless transceiver with a size of 5 mm x 5 mm x 5 mm was presented and characterized on a rotary stage. The transceiver package is supported by pick-and-place machines and is able to be soldered by a PCB reflow process in contrast to the previous design [3]. The shown OWC transceiver links achieve sufficient high alignment tolerances without the need of active alignment or any mechanical guiding. Self-aligning by the soldering phase on the PCB is sufficient. Furthermore, the on-axis rotation test showed sufficient alignment for most rotary joints designs. Measurements at 5.128 Gbit/s and 100 RPM showed an x/y-alignment of ±0.75 mm with a BER of 1E-11. At 1.25 Gbit/s, a rotary alignment of ±1.5 mm is achieved. The rotation speed was only limited by the mechanical setup and not by the transceiver itself. Therefore, the presented short-range transceiver opens mobile application fields that are locked for other RF and cable-based technologies. The main challenge in this transceiver design is the difficult trade-off between data rate, FOV, size and system complexity. The urge for higher data rates stresses all parameters and leaves multiple starting points for interdisciplinary research.

References

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