FURTHER READING

Page 1090
'Monolithic integration of high linearity attenuated counter-propagating optical phase-locked loop coherent receiver',
A. Bhardwaj, Y. Li, R. Wang, S. Jin, P. R. Herczfeld, J. Bowers and L. A. Coldren

Optical PLLs can improve the dynamic range of coherent receivers

non-spurious reception*

Researchers in the US have demonstrated a monolithically integrated attenuated counter-propagating optical phase-locked loop photonic integrated circuit (ACP-OPLL PIC) as a highly linear coherent receiver. Their results show that such devices can realise a high dynamic range in future phase-modulated RF/photonic links.

Head narrow and noisy

OPLLs are similar to conventional PLLs – familiar in electronics – but instead use optical phase modulators (or tuneable lasers) as local oscillators, with optical couplers and balanced photodetectors for phase detection. Using negative feedback, the OPLL forces the phase of the local optical phase modulator to track the phase of an incoming optical signal. Thus, the OPLL performs linear optical phase demodulation and can be used as a coherent receiver.

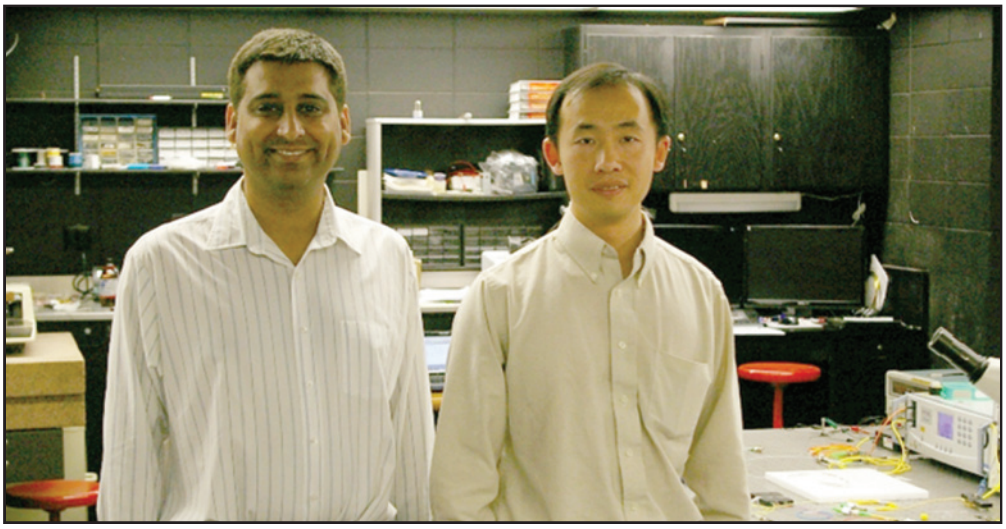
Although an OPLL-based coherent receiver can considerably increase the dynamic range of a phase-modulated RF/photonic link, current state-of-the-art coherent receivers using OPLLs require significant improvements – in particular, their frequency bandwidth and noise properties – before their widespread use becomes a reality.

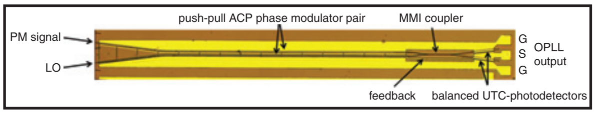
Photonic complexity

One measure of the quality of these receivers is their spurious-free dynamic range (SFDR). This is defined as the ratio of the strength of the fundamental signal to the strongest spurious signal in the output. To increase this quantity, the team have developed a high-linearity optical phase modulator on an InP material platform using a detuned shallow multi-quantum well structure. These modulators were realised using a newly developed waveguide fabrication process allowing for very long deep ridge modulators with low optical propagation losses. "These low-loss high-linearity ACP-modulators were critical in achieving the record SFDR values reported in our Letter", said Dr Ashish Bhardwaj.

The team's main problems in developing their single-chip receivers was the sheer number of processes involved in making them, as Bhardwaj explained: "The biggest challenge in realising the ACP-OPLL PIC was the development of a processing methodology that comprised a set of very complex fabrication steps to enable monolithic integration of the deep ridge modulators with other components of the OPLL." In fact, the fabrication required "over sixteen photolithography steps along with multiple dielectric material depositions, several different types of etching steps, one regrowth step, two ion implantation steps and seven separate metal depositions."

As well as increasing the SFDR, the team's techniques allow different active components such as tuneable lasers, optical amplifiers, high-speed modulators and photodetectors to be monolithically integrated with passive waveguides on a single InP chip. Compact multimode interference (MMI) couplers as well as signal routing with a tight bend radius were also realised using the deep ridge waveguides. As a result, they were able to realise a loop propagation delay of approximately 10 picoseconds.





ABOVE: Dr. Ashish Bhardwaj (left) from the University of California Santa Barbara and Dr. Yifei Li (right) from the University of Massachusetts Dartmouth have collaborated to develop a high-linearity single-chip coherent receiver.
RIGHT: Photograph of a fully fabricated high-linearity ACP-OPLL PIC coherent receiver.

A front-end future

While the team have reported a record SFDR, they feel that the technology can be improved. By further optimisation of component design and the fabrication process, Bhardwaj believes it should be possible to improve the bandwidth and dynamic range of such OPLL-based coherent receivers compared to those observed in current devices. This would include improvements in the design of the UTC photodetectors, further reduction in the optical propagation loss of the deep ridge waveguides, and improvement in the coupling efficiency between the input optical fibre and the deep ridge waveguides by using integrated spot-size converters.

Bhardwaj also explained that the possibilities of photonic integration go beyond the current industrial concerns of cost saving, reduced complexity and footprints. "There is a substantial interest in using photonic integration to realise optical functionality that is impossible using discrete optical components," said Bhardwaj. Furthermore, looking into the future, he says that "we envision PICs that perform complex optical signal processing, where more of the front-end processing is moved into the optical domain at high data rates, especially as equivalent electronic solutions become cumbersome or simply impractical."