getting linear

Interferometric instrumentation combined with linear systems theory yields BER modeling from component measurement.

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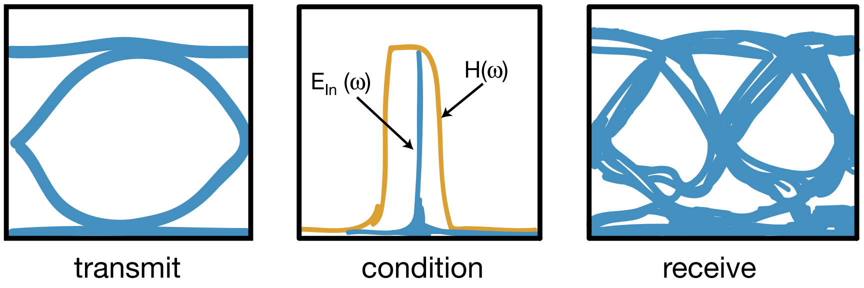
The ultimate test of an optical component's network worthiness is its ability to stand up to bit-error-rate (BER) testing. A component is dropped into a BER testbed and if its associated power penalty or BER is too large, it is rejected. The biggest challenge that the component manufacturer faces in this respect is the fact that there is not always a reliable way of predicting system performance based on the measurement of a single component.

As bandwidth increases on narrower channel spacings, components are qualified over a growing number of performance parameters such as loss, polarization-dependent loss, chromatic dispersion, group-delay ripple, differential group delay, and second-order polarization-mode dispersion. Coherent interferometry offers a fast and accurate means to measure all of these parameters. In addition, by the nature of its operating principle, interferometry also provides a simple way to predict final component performance.



Accurate BER prediction (right) is based on appropriate modeling of the input signal (left) and accurate characterization of the component's linear transfer function H(ω) (center). Interferometry provides direct access to H(ω), which, for singlemode components, is a 2 × 2 matrix with four complex elements.

To understand this, we must consider the fundamental question: how do we describe the effect of a singlemode component on a sequence of bits? The answer is, of course, linear systems theory. Neglecting polarization effects for the moment, we can describe a singlemode, two-port device by two frequency-dependent quantities: amplitude and phase. We can then model polarization effects by considering a two-port singlemode device as a four-port device with two polarization modes in and two modes out. Full characterization therefore requires four amplitudes and four phases that can be assembled into a 2 × 2 matrix known as the linear transfer function (LTF), or the Jones matrix. The matrix, or LTF characterization, is important because it describes the response of an optical component to all polarization states which can (and do) occur in the transmission system.

Test instrumentation based on coherent interferometry has the ability to directly measure the LTF. This is achieved by splitting a wavelength-tuned laser source into fixed reference and device-under-test (DUT) paths. Light from these two paths is then mixed at a receiver, and the amplitude and phase of the interference fringes are recorded. Recent advances have shown that the polarization state of the input light can itself be manipulated interferometrically, resulting in single-scan high-resolution LTF measurement of optical components with test times of only seconds.

Once assembled, the LTF leads transparently to an eye diagram simulation through a frequency-space multiplication. This is because for vector fields, given the LTF, the output signal $\vec{E}_{out}(\omega)$ is related to the input signal by $\vec{E}_{out}(\omega) = H(\omega)\vec{E}_{in}(\omega)$. This reduces the problem of calculating eye-opening power penalty and BER to one of choosing the appropriate input signal and accurately characterizing the LTF of the component under test.

Why focus only on components and not entire links? The coherent interferometric approach is based on the measurement of the amplitude and phase of fringes produced at an optical detector, generated by using a tunable laser and mixing a local oscillator signal with a signal from a DUT. The maximum measurable DUT length is thus limited by the coherence properties of the tunable laser source and the bandwidth of the acquisition electronics. Hence, at least in the near-term, interferometry is best suited for systems no more than tens of meters long.

The introduction of new instrumentation permitting the accurate characterization of transmitters and detectors is on the horizon. With the advent of this technology, optical communications design will be able to enter a new era in which highly accurate modeling permits faster design times, more reliable systems, and lower-cost components. **oe**

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