A DP-QPSK Transmitter

A Phase Shifter

\[ A \text{e}^{i(\phi + \delta \phi)} \]

\[ n + \delta n \]

\[ I_m \]

\[ \delta \phi = \frac{2\pi}{\lambda} (\delta n) I_m \]
A Mach-Zehnder Optical Modulator

\[ A_t = \frac{1}{2} A_i \left( e^{i\phi_1} + e^{i\phi_2} \right) \]

\[ t_m = \frac{A_t}{A_i} = \cos\left[ \frac{1}{2} (\phi_1 - \phi_2) \right] \exp\left[ i\left( \phi_1 + \phi_2 \right) / 2 \right] \]

A Mach-Zehnder Optical Modulator

\[ t_m = \frac{A_t}{A_i} = \cos\left[\frac{1}{2}(\phi_1 - \phi_2)\right] \exp\left[i\left(\frac{\phi_1 + \phi_2}{2}\right)\right] \]

\[ V_2 = -V_1 \Rightarrow \phi_1 + \phi_2 = \text{const.} \Rightarrow \text{Pure Amplitude Modulation} \]

\[ V_2 = V_1 \Rightarrow \phi_1 = \phi_2 \Rightarrow \text{Pure Phase Modulation} \]
### Phase, Amplitude, and In-Phase and Quadrature Modulation

<table>
<thead>
<tr>
<th>Device structure</th>
<th>Phasor diagram</th>
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<td><img src="image1.png" alt="Device structure image" /></td>
<td><img src="image2.png" alt="Phasor PM" /></td>
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<td><img src="image3.png" alt="Device structure image" /></td>
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<td><img src="image5.png" alt="Device structure image" /></td>
<td><img src="image6.png" alt="Phasor IQ" /></td>
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“Coherent Optical Communications: Historical Perspectives and Future Directions”, Kazuro Kikuchi, in *High Spectral Density Optical Communication Technologies* (Springer Verlag, 2010)
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