Synthesis of Quadrature Amplitude Modulated (QAM) signals by direct modulation of simple semiconductor lasers under injection locking

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Coherent optical communications allows for better resilience to transmission-related linear and nonlinear impairments (e.g., using binary phase shift keying, BPSK) and/or for increased capacity via the transmission of several bits per symbol (QPSK, 16 QAM, …). For these modulation formats, which exploit modulation of phase, direct modulation of the signaling laser is generally not possible due to the high chirp associated with such a modulation approach. Instead, an external IQ modulator is typically used. Although this approach clearly works well it brings several drawbacks: (i) a relatively high cost; (ii) significant insertion loss and limited optical power handling; (iii) the need for high drive voltage RF booster amplifiers; and (iv), a typical IQ modulator requires the processing (division into I and Q) and associated multiplexing of multiple high-speed binary electronic data signals, resulting in increased power loss and power consumption, noise and non-linearity (which is particularly detrimental when the I and Q data streams have more than two levels, e.g., for 16-QAM, each has 4 levels).

Here, we show our solution that simultaneously avoids all four issues associated with the use of external IQ modulators. It is based on ultralow chirp direct modulation of injection-locked (IL) semiconductor lasers followed by coherent superposition and coherent carrier suppression of their output. We show experimental results for BPSK and QPSK modulation, although it is straightforward to extend the basic concept to 16 QAM and higher modulation formats. We note that several techniques have previously been reported for constant-envelope modulation (e.g. BPSK, QPSK) based on direct laser or SOA based phase modulation, with some of these incorporating injection-locking. Unlike these previously-proposed schemes, our scheme can be straightforwardly extended to higher modulation formats (e.g. 16 QAM), offer near-to-zero chirp and is applicable to both, return-to-zero (RZ) as well as non-return-to-zero (NRZ) formats.