High-capacity Directly-Modulated Optical Transmitter for 2-μm Spectral Region

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***Abstract*—The 2-μm wave band is emerging as a potential new window for optical telecommunications with several distinct advantages over the traditional 1.55μm region. First of all, the Hollow-Core Photonic Band Gap Fiber (HC-PBGF) is an emerging transmission fiber candidate with ultra-low nonlinearity and lowest latency (0.3% slower than light propagating in vacuum) that has its minimum loss within the 2-μm wavelength band. Secondly, the Thulium-doped fiber amplifier that operates in this spectral region provides significantly more bandwidth than the Erbium-doped fiber amplifier. In this paper we demonstrate a single-channel 2-μm transmitter capable of delivering >52 Gbit/s data signals, which is twice the capacity previously-demonstrated. To achieve this we employ discrete multi-tone (DMT) modulation via direct current modulation of a Fabry-Perot semiconductor laser. The 4.4-GHz modulation bandwidth of the laser is enhanced by optical injection locking, providing up to 11 GHz modulation bandwidth. Transmission over 500-m and 3.8-km samples of HC-PBGF is demonstrated.**

***Index Terms*— Optical fiber communication, Optical transmitter, Optical modulation, Digital signal processing, Photonic band gap fiber.**

I. Introduction

The capacity of optical communication networks has grown exponentially over the past few decades, leading to today's global communication systems and the ubiquitous internet. This growth has been enabled by many technological breakthroughs including low-loss, single mode transmission fiber (SMF), the erbium-doped fiber amplifier (EDFA), wavelength division multiplexing (WDM), and more recently digital signal processing (DSP) combined with coherent detection. Throughout this technological evolution, silica-based single mode optical fiber has been used as the transmission medium. For long distance and large-capacity transmission, most work has been done within the 4-5 THz bandwidth of the C-band telecommunication window where the fiber transmission loss is at a minimum and low-noise amplification is available. The advanced modulation format signaling allows significant increase of capacity within this limited bandwidth. However, the capacity-transmission distance product is ultimately limited by fiber nonlinearity [1]. The record reported transmission capacity for SMF is now within about a factor of 2 of its theoretical maximum defined by the nonlinear Shannon limit [2]-[3]. However, as a result of the exponentially increasing volume of internet traffic, today's telecom networks are rapidly being driven towards their capacity limits, sparkling concerns over a potential future "capacity crunch" [4]. To keep pace with the increasing traffic demand at a reasonable cost-per-bit, new physical layer technology for communication networks will soon be necessary. In the search for solutions, the research community is investigating various new approaches [5]. For instance, mode division multiplexing assisted by MIMO (Multiple-Input-Multiple-Output) signal processing has recently attracted much interest and shown impressive data transmission performance [6].

Further opportunities are provided by a radically new form of transmission fiber, the Hollow-Core Photonic Band Gap Fiber (HC-PBGF), which guides light in a hollow core by virtue of photonic bandgap effects determined by a carefully designed glass microstructure [7]. The HC-PBGF has a number of intriguing optical properties relevant to optical communications, including ultralow optical nonlinearity, excellent power handling capabilities, low latency, and even offers the prospect of ultralow losses within around 2.0 μm spectral region, where its loss is predicted to be similar to - if not lower than - that of conventional SMF at 1.55 μm [8]. Such a combination of advantages relative to conventional solid core silica optical fibers points to an exciting vision of future optical communications. In addition to HC-PBGF, it is also worth noting that other glass systems exist with potential for losses as low as 0.1 dB/km at wavelengths around 2 μm [9], providing

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