Analysis of VCSEL Transmission for the Square Kilometre Array (SKA) in South Africa

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Abstract. For the first time, we propose the use of Vertical Cavity Surface Emitting Lasers (VCSELs) within the optical fibre network supporting data collection and transmission for Square Kilometre Array (SKA) South Africa. We give theoretical analysis for VCSEL transmission over typical SKA required distances. This work is valuable in providing SKA with a VCSEL technology, an option for extremely high network performance at reasonable cost.

Keywords: VCSEL, SKA, fibre optical network,

I. INTRODUCTION

SKA, South Africa is a large radio telescope, about 100 times more sensitive than the biggest existing radio telescope. Its design, construction and operation at Karoo region of the Northern Cape. A major component of the SKA telescope array will be an extensive array of approximately 3,000 antennas. Half of these will be concentrated in a 5 km diameter central region, and the rest will be distributed out to 3,000 km from this central concentration. The project will be completed in 2025 and expect to revolutionize our understanding of the Universe [1]. For the first time, we propose the use of Vertical Cavity Surface Emitting Lasers (VCSELs) within the optical fibre network supporting data collection and transmission.

Vertical Cavity Surface Emitting Lasers offer high bandwidth, single mode operation within C-L bands, wavelength tunabilities, the convenience of direct modulation and energy efficiency at low drive currents [2]. VCSELs are ideal for relatively short distance high speed optical communication networks. Square Kilometre Array (SKA) South Africa demands high transmission rates at reasonable cost because of enormous data rates. The proposed scheme constitutes 4.192 Pb/s (10^{15} bits per second) of data collected for transmission and eventual processing [3].This calls for the most efficient and high performance means of data transmission. VCSEL operation is however limited by wavelength chirp and chromatic dispersion [4]. In this study, we demonstrated VCSEL transmission over typical SKA required distances over ideal per-channel transmission rates of 2.5 Gb/s, 5 Gb/s and 10 Gb/s within the project. This work presented is simulation results for a typical VCSEL.

II. THEORY

Light chirping can be defined as the instantaneous change of the central wavelength or optical frequency υ in response to variations in optical power i.e. residual frequency modulation of an amplitude modulated optical wave. The instantaneous frequency chirp can be expressed as [5, 6]

$$\Delta\nu(t) = -\frac{\alpha}{4\pi}\left(\frac{d}{dt}\ln P(t) + kP(t)\right) .. (1)$$

where P(t) is the instantaneous optical power, α is the linewidth enhancement factor and the κ parameter is a constant. . The κ parameter is related to the non-linear gain and depends on the geometry of the device. The first term describes transient chirp relating to the time derivative of the changing instantaneous optical power with rising and falling pulse edges. The second term describes adiabatic chirp relating to the instantaneous optical power itself.

III. RESEARCH DESIGN

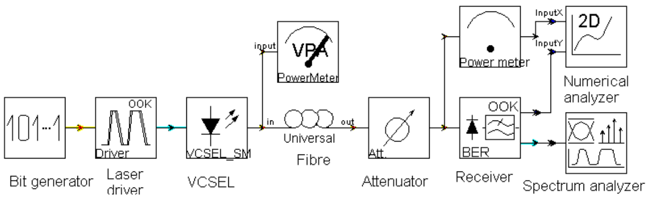

Figure 1: simulation set up

The schematic diagram for the simulation using VPI transmission Maker & VPI component Maker is as shown in fig. 1. The 1550 nm VCSEL is modulated at various bit rates (2.5, 5, 7.5 and 10 Gb/s) by a Non-Return-to- Zero (NRZ) Pseudo-Random Binary Sequence (PRBS) signal and propagated over an ITU-T G.652 Non-Dispersion Shifted single mode fibre. The length of the fibre is varied from 1.4 km, 5 km, 7.5 km and 10 km as the Bit Error Rate (BER) is measured and the power penalties due to chromatic dispersion established.

IV. RESULTS AND DISCUSSION

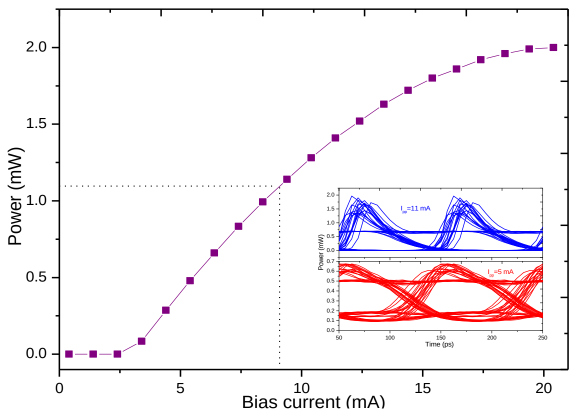

Figure 2: Unmodulated VCSEL output power as a function of bias current. Inset: Modulated eye diagrams for I_{pp} = 11 mA and 5 mA respectively.

Efficient VCSELs have high output power of 1 mW and above, high extinction ratio and low chirp. Fig. 2 represents the VCSEL characteristics at different bias currents. When modulation was added, the VCSEL bias current was set to 9 mA giving an output power of 1.08 mW (0.33 dBm). High modulation current (I_{pp}), give high chirp and high extinction ratio (Inset).

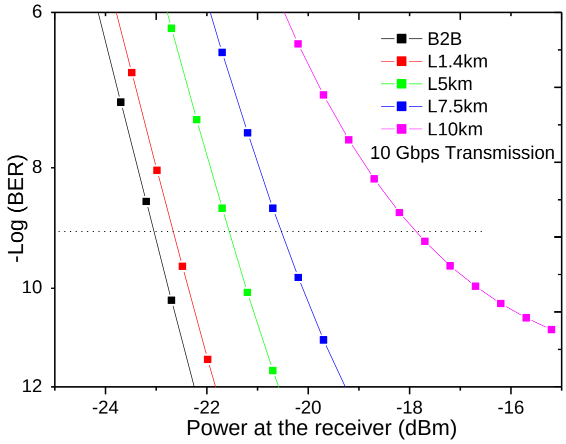

Figure 3: Transmission sensitivity at various fibre lengths (Reference BER=10^{-9})

In fig. 3, modulation current (I_{pp}) of 9 mA (off '0' - on '1';) was set and the Bit Error Rate measurements for 2.5 Gb/s, 5 Gb/s, 7.5 Gb/s and 10 Gb/s taken.

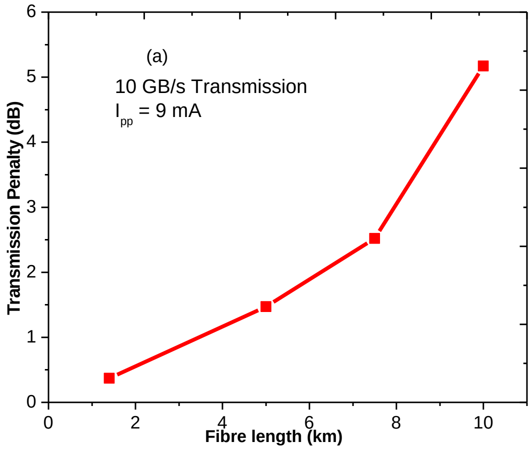

Figure 4: (a) Transmission penalty at various fibre lengths

At 10 Gb/s transmission, dispersion penalties of 0.37 dB, 1.47 dB, 2.52 dB and 5.17 dB for 1.4 km, 5 km, 7.5 km and 10 km respectively were obtained as shown in fig. 4 (a). Transmission penalty increases with increase in fibre length and bit rate as shown in fig. 4 (b). In a typical network design budget, one might assign some 3-5 dB for up to 25 km to dispersion penalty, indicating that VCSELs are ideal for use in the SKA project. Further transmission with reduced penalty can be achieved over Non Zero Dispersion Shifted Fibre (NZDSF), ITU-T G.655, as dispersion is greatly reduced within the 1550 nm window as compared to ITU-T G.652 Non-Dispersion Shifted single mode fibre that was used in this paper.

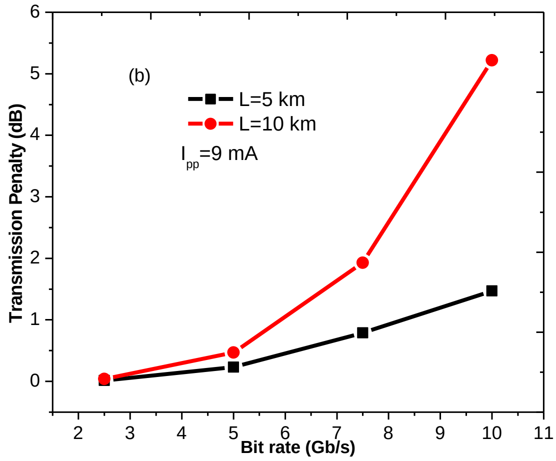

Figure 4 (b): Transmission penalty at various bit rates.

V. CONCLUSION

This work is valuable in providing SKA with VCSELs, an option for extremely high network performance at reasonable cost. Following on this work in progress paper, we are currently building a VCSEL test bed within our lab to experimentally demonstrate the technology for SKA.

VI. ACKNOWLEDGEMENT

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BIOGRAPHY

E. K. Rotich Kipnoo was born in 1984 in Eldoret, Kenya. He obtained a B.Sc. Hons-Physics/Maths degree in 2008 at Moi University and MSc Physics in 2011 at Chepkoilel University College, Eldoret, Kenya. He is currently a PhD student at NMMU, working on SKA fibre Optical network. Research interests; Optical fibre communication optical networking, linear & nonlinear optical effects.