Xtera

91 nm bandwidth low-noise amplifiers enable 120 Tbit/s on a single fibre

During the last few months Xtera and University College London (UCL) have worked together to explore how large capacities can be achieved based on technology which can be industrialised. Using hybrid EDFA / Distributed Raman Amplifiers, the result is a record breaking capacity of 120 Terabit/s on a single fibre, over 9 spans of 70 km.

More details of the experiment are available on the arXiv platform: http://arxiv.org/abs/1804.01845.

To ensure that the design could be industrialised the amplifiers used were based on the hybrid Raman-EDFA design that Xtera currently uses for subsea amplifiers, with the bandwidth increased by adding extra Raman pumps. The high order modulation (256QAM) and sophisticated adaptive FEC are both technologies which, while more complex than those used in existing commercial modules, don’t require a major jump in technology. Accordingly, Xtera and UCL believe that we have demonstrated a practical route to the higher capacities that will be demanded in the future.

Authors (of the referenced paper)

L.Galdino[1,*], A.Edwards[2], M.Ionescu[2], J.James[2], W.Pelouch[3], E.Sillekens[1], D.Semrau1, D.Lavery[1], R.I.Killey[1], S.Barnes[2], P.Bayvel[1] and S.Desbruslais[2]

1 Optical Networks Group, Dept. of Electronic & Electrical Engineering, University College London, UK

2 Xtera, Bates House, Church Road, Harold Wood, Essex, UK

3 Xtera, 500 West Bethany Drive, Allen, Texas, USA

* l.galdino@ucl.ac.uk

Copyright and confidentially

A summary with a little more detail is provided on the next page.

CAPACITY LIMITS

The capacity of an optical communication system is limited by a combination of noise (generated by optical amplifiers & transceiver modules), distortion caused by optical fibre nonlinearity and overall optical bandwidth.

Advances in digital signal processing (DSP), modulation formats [1], high speed electronics, single-mode fibres and broadband optical amplification, have resulted in recent landmark transmission results, with demonstrations of capacities exceeding 70 Tbit/s over transatlantic distances [2] and an overall capacity record of 115.9 Tbit/s over 100 km [3]. They are summarised in the following figure.

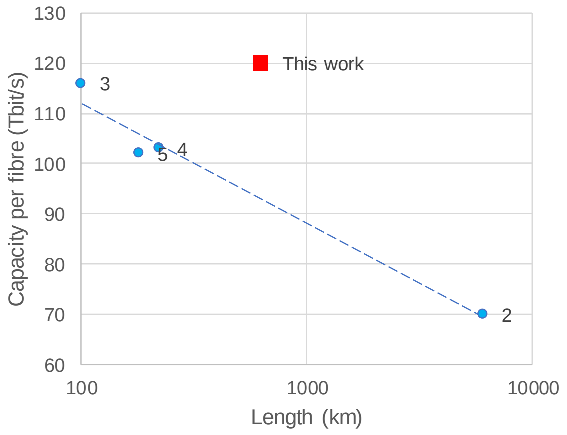

Figure 1 – Recent capacity records

AMPLIFIER TECHNOLOGIES USED

The previous record [3] was 115 Terabit/s over 100 km, using a Semiconductor Optical Amplifier (SOA), while other recent results have used parallel C-band and L-band Erbium Doped Fibre Amplifiers (EDFAs).

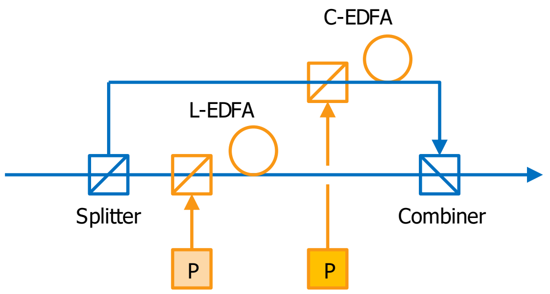

Figure 2 – Simplified schematic of C+L

The C+L configuration needs splitter / combiner components which add loss and also create a small gap in the transmission bandwidth, which is limited to around 75 nm.

While the SOA offers continuous amplification, it has relatively high noise figure, so system performance decreases rapidly with distance.

The hybrid EDFA / Distributed Raman Amplifier, pumps the transmission fibre, creating Raman gain in what would otherwise be a lossy fibre and extending the bandwidth beyond that of an EDFA.

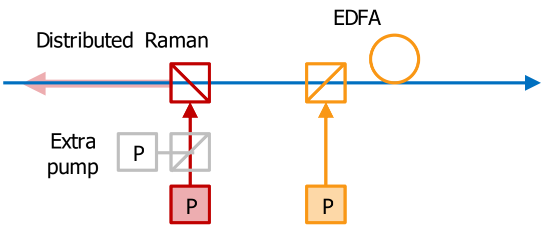

Figure 3 – Simplified schematic of C+L hybrid EDFA / Distributed Raman Amplifier

This results in a very low noise figure; the amplifiers used for this experiment achieved 3 dB at 1525 nm and -0.5 dB at 1616 nm. By contrast EDFAs offer a noise figure of 4-5 dB. All-Raman, as used in [4] and [5] also gives very low noise, but requires more power than the hybrid solution.

The architecture shown above is very similar to that used in Xtera’s subsea repeaters, with additional Raman pumps (at longer wavelengths) extending the bandwidth to 91 nm.

LINE DESIGN AND OTHER FACTORS

To minimise non-linear penalties, power density must be controlled, which is usually achieved by the use of large core fibres. However, for Raman gain, a standard core fibre is desirable, to maximise the pump power density. To achieve both objectives, each span consisted of large core (Sumitomo Z+150) fibre at the launch and 80 micron core (Sumitomo Z) at the receive end.

This combination has the benefits of using a relatively standard and economical fibre for a significant fraction of system. And while cabling a mix of fibres might seem complicated for the terrestrial world it has been a norm in submarine cables for many years.

The 256QAM format (made possible by the high SNR) allowed the transmission of more capacity: for comparison, references [4] and [5] used

64QAM.

REFERENCES

[1] S. Chandrasekhar et al., “High-spectral-efficiency transmission of PDM-256QAM with Parallel Probabilistic Shaping at Record Rate-Reach Trade-offs, Proc. ECOC, PDP Th3C.1 (2016).

[2] T-X. Cai et al., “70.46 Tb/s over 7,600 km in in C+ L Band Using Coded Modulation with Hybrid Constellation Shaping and Nonlinearity Compensation, Proc. OFC, PDP Th5B.2 (2017).

[3] J.Renaudieretal.,“First100-nmContinuous-BandWDMTransmissionSystemwith115Tb/sTransportover100kmUsingNovelUltra-Wideband Semiconductor Optical Amplifiers,” Proc. ECOC, PDP (2017).

[4] A. Sano et al., “102.3-Tb/s C-band extended L-band all Raman transmission over 240 km using PDM-64QAM single carrier FDM with digital pilot tone,” Proc. OFC, PDPSC.3 (2012).

[5] D.Qianetal.,“101.7-Tb/s(370x294-Gb/s)PDM-128QAM-OFDMTransmissionover3x55-kmSSMFusingPilot-basedPhaseNoiseMitigation,” Proc. OFC, PDPB.5 (2011).