Raman Scattering – A Major Roadblock for QKD in Fibre-Optic Networks?

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Current research in deployment scenarios of QKD to use a single, common ITU-T G.652B-compatible fibre for both, data and quantum communications, points to scenarios where system vendors need to control the wavelength plan of all optical signals very accurately [1]. The typical use case is an (inter-) datacenter backup. In contrast, here we discuss a broader approach of the possibilities for QKD to find an appropriate transmission window at fibres already used by telecom systems according to typical transmission standards [2]. Our contribution will continue the assumption to shift the quantum channel to the O-band around 1310nm.

As a premise to reduce cost and attract commercial system vendors, the QKD channel ought to share as much as possible of a given brown-field telecom infrastructure at the physical layer. However, some elements such as DWDM nodes and amplifiers have to be bypassed in order to preserve the weak quantum signal and guarantee the reliable creation of a secure key. The limiting factors for QKD in a single feeder scheme are scattered photons caused by nonlinear effects such as four wave mixing, and Raman scattering. Since the latter is the most dominant source of noise critically influencing the operation of QKD over the entire transmission band it need to be investigated more closely by simulation and experiment. 1511nm

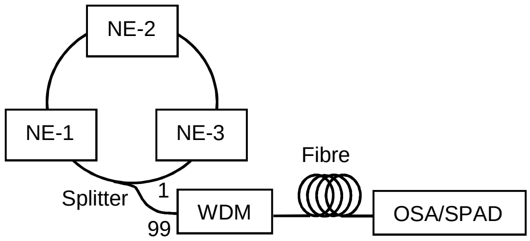

Fig. 1: Three-node DWDM ring network with 99:1 splitter

The presented measurements analyze a 20-channel signal produced by a commercially available ring network (Lucent WaveStar OLS400G, Fig. 1), as it is typical for metro-core networks. The contribution in the O-band is rejected by WDM band splitters. The spectrum of the signal launched in the fibre is shown in Fig. 2 and can be segmented into three parts: (a) A quite weak 1472nm signal, resulting from the leaked pump wavelength of the Erbium-doped fibre amplifier (EDFA) to boost the signal power at the output of each node. (b) The very strong and unavoidable service signal at 1511nm is used for network management related communication between control plane and the nodes and (c) the broadband DWDM data signals in the C-Band.

In contrast to [1] the QKD channel cannot be placed in the C-Band, but even a considerable shift to a lower wavelength remains critical [2].

The presented plots are a combination of spectra obtained by an optical spectrum analyzer (OSA HP71451B) with a noise floor of -90dBm and a SPAD coupled to the optical output of the OSA and calibrated to dBm. With this access to sensitivities as low as -130dBm is gained – which hasn't been investigated up to now.

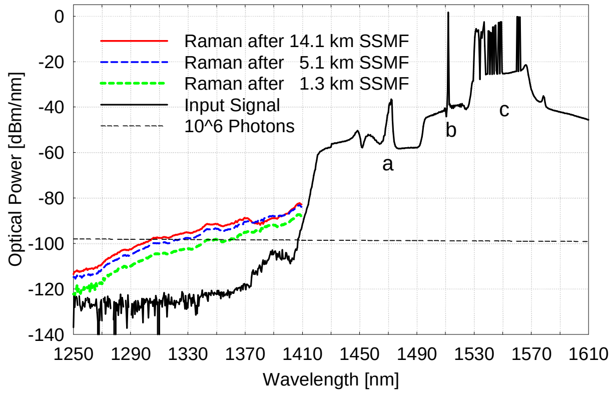

Fig. 2: Spectrum of the WaveStar OLS400G comb signal with rejected O-Band (black) and spectrum of Raman scattering after 1.3km, 5.1km and 14.1km of standard single mode fibre (color).

The Raman contributions generated by the launched radiation (black line) have been measured with SPADs after 1.3km, 5.1km and 14.1km. The generated noise at 1310nm is around 10^6 photons/second and changes by 7.2dB. A length-independent roll-off of 0.2 dB/nm towards shorter wavelengths has been experienced.

These results give bounds and information on where the optimal wavelength of possible QKD channels might be, how much the feeder fibre can be extended and how much loss can be accepted at a QKD add/drop filter. Further development of QKD links with higher ability to withstand uncorrelated noise is needed in order to operate QKD links in such harsh environments.

Acknowledgements

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References

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