Coexistence analysis of classical channels with DV-QKD over hollow core nested antiresonant nodeless fibre (HC-NANF)

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INTRODUCTION

- The vision behind this work is to provide seamless coexistence of quantum and classical channels without limiting the power of the classical channels.
- Single mode fiber (SMF) limits coexistence due to Nonlinear effects i.e., Raman Scattering and four wave mixing (4WM) and due to the loss of 0.20 dB/km.
- Hollow Core Fibre is considered the ultimate medium for coexistence because it provides ultra low nonlinear effects and the potential of lower loss (10x lower than SMF).

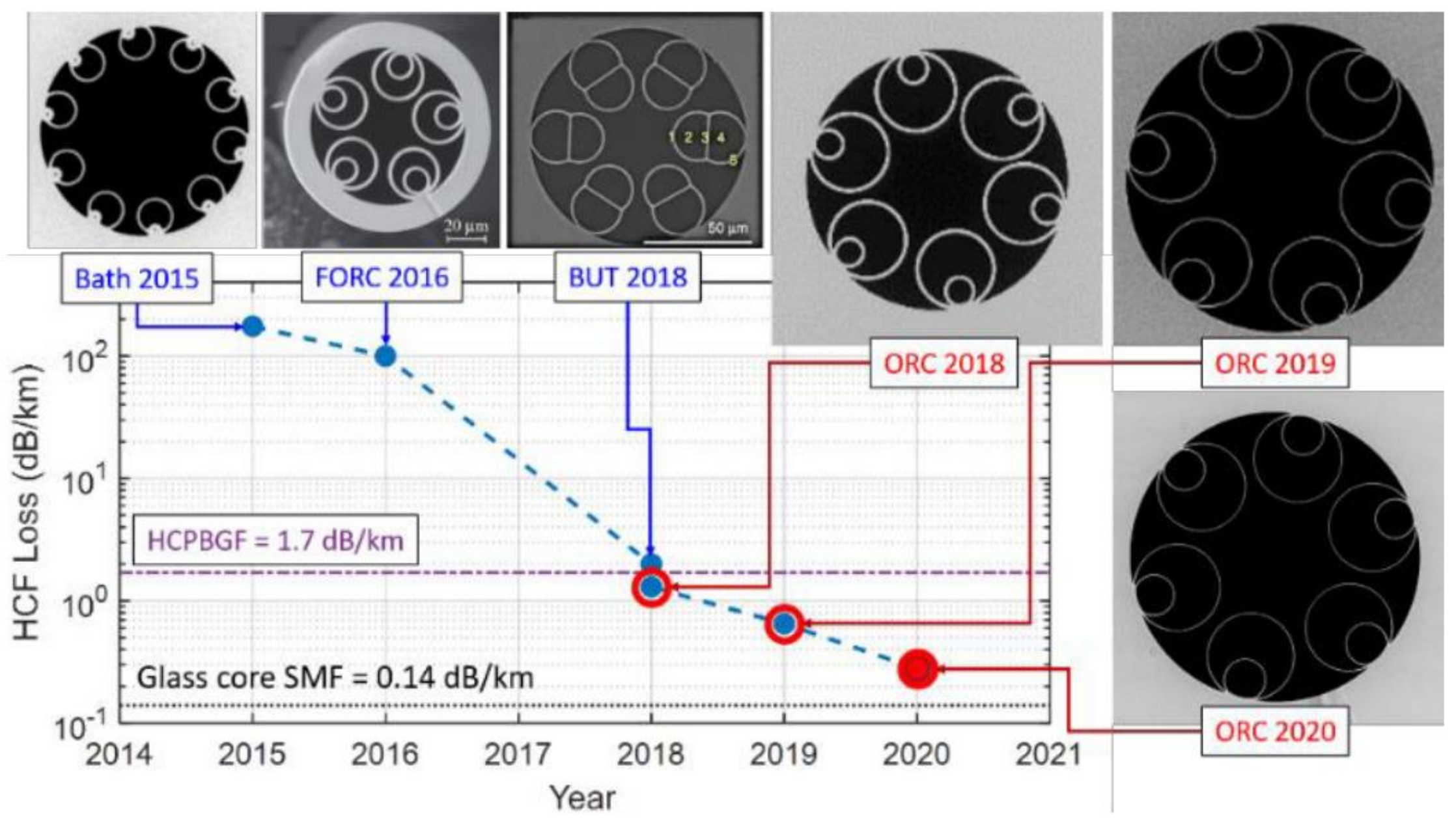
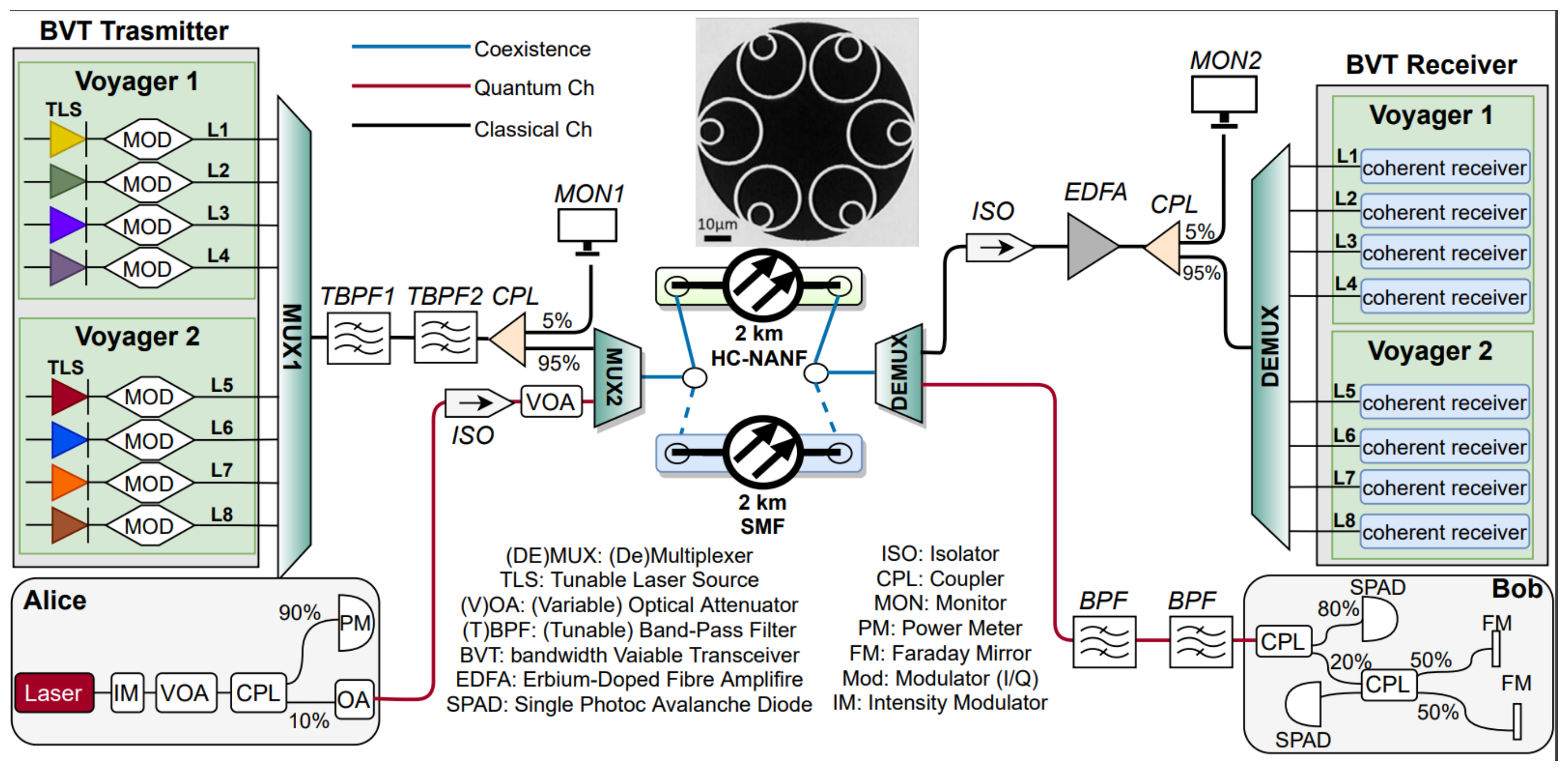


Fig. 1 The loss of NANF fibers over time. For reference we include the loss of solid fiber and the lowest loss HCPBGF 2004.

Hollow Core Nested Antiresonant Nodeless Fibre (HC- NANF) losses went down from over 100 dB/km in 2015 to 0.22 dB/km in 2021 (10% higher than SMF)

Testbed



(DE)MUX: (De)Multiplexer
TLS: Tunable Laser Source
(V)OA: (Variable) Optical Attenuator
(T)BPF: (Tunable) Band-Pass Filter
BVT: bandwidth Vaiable Transceiver
EDFA: Erbium-Doped Fibre Amplifire
SPAD: Single Photoc Avalanche Diode

ISO: Isolator
CPL: Coupler
MON: Monitor
PM: Power Meter
FM: Faraday Mirror
Mod: Modulator (I/Q)
IM: Intensity Modulator

Fig. 2 Experimental Testbed for the Coexistence of 1.6 Tbps classical channels and DV-QKD channel over 2km HC-NANF and SMF. Inset: scanning electron micrograph (SEM) of the HC-NANF cross section.

- For the classical channels, two optical packet DWDM platforms are used with bandwidth-variable transponders.
- For the quantum channel, IDQuantique DV-QKD systems are used (Clavis3 QKD Platform). These systems are implemented to run with the COW (Coherent One-Way) protocol.

Tab. 1 PARAMETERS FOR HC-NANF COEXISTENCE TESTBED.

Parameters	Value
Classical Channels	
Number of Channels	8
Classical Channel Frequencies scenario 1	193.50 THz, 193.45 THz, 193.40 THz, 193.35 THz, 193.30 THz, 193.25 THz, 193.20 THz, 193.15 THz
Classical Channel Frequencies scenario 2	192.70 THz, 192.65 THz, 192.60 THz, 192.55 THz, 192.50 THz, 192.45 THz, 192.40 THz, 192.35 THz
Grid Spacing	50 GHz
Modulation Format	16-QAM
Optical Signal-to-Noise Ration (OSNR)	20 dB
Capacity per Channel	200 Gbps
Total Capacity	1.6 Tbps
Pre-FEC Level	15%
Detector sensitivity*	-26 dBm
Quantum Channel	
DV-QKD Wavelength	1547.72 nm
DV-QKD Frequency	193.70 THz
QKD Protocol	COW
Maximum Distance	80 km @ 16 dB loss
Optical Band Pass/Rejection Filter (OBRF)	
Insertion loss band pass port	0.5 dB
Center wavelength band pass port	1547.72 nm
Bandwidth band pass port	100 GHz

**Corresponding to 16-QAM Modulation @200 Gbps and back-to-back.*

We consider two scenarios

- Sc1 best case scenario with 200 GHz (1.6 nm) spacing between quantum and classical channels.
- Sc2 worst case scenario with 1 THz (8 nm) spacing between quantum and classical channels.

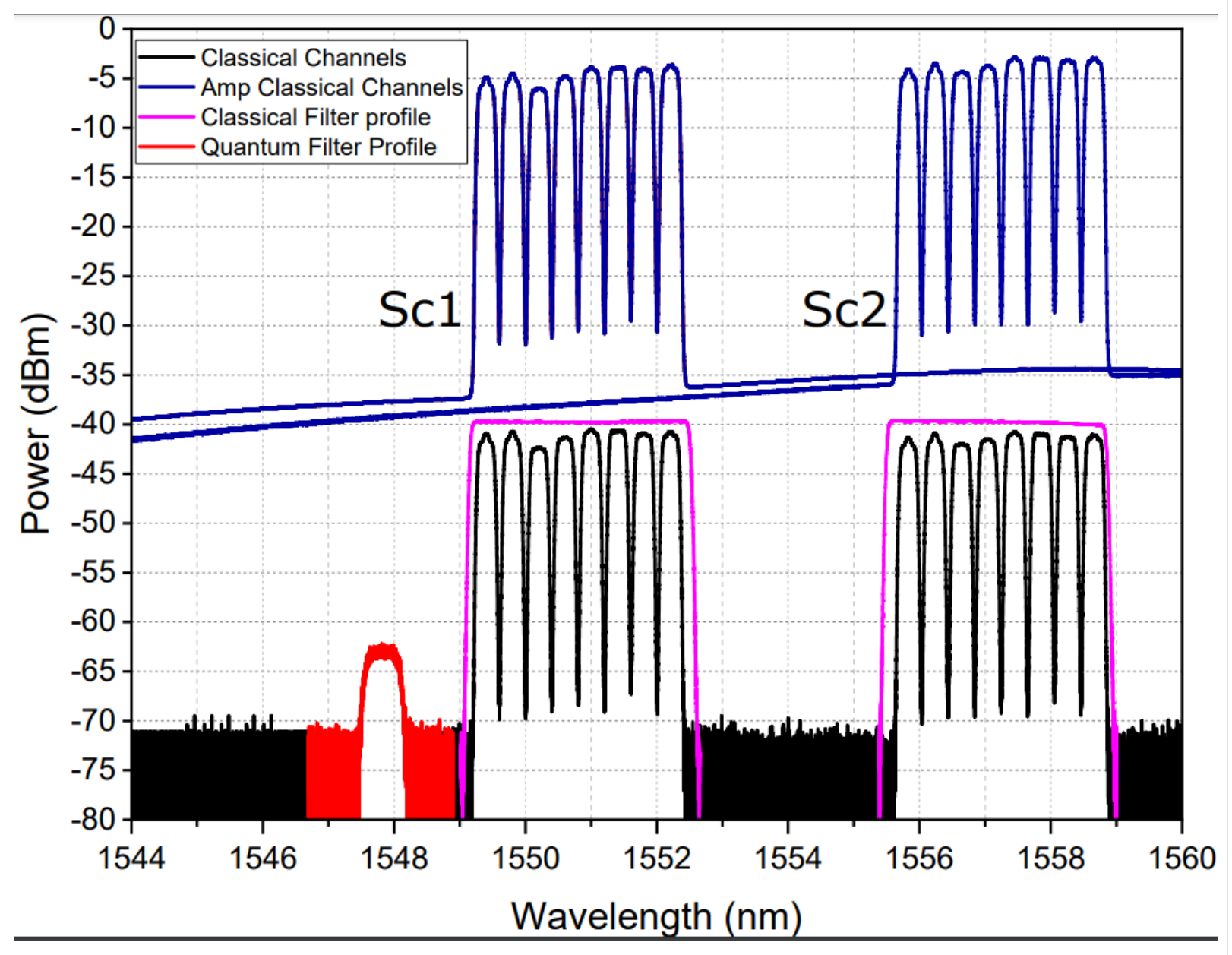


Fig. 3 Spectrum of the combined transmission of quantum and classical channels with optical filter profiles of both scenarios.

Channel Spacing/Position for Quantum/Classical Coexistence

- We consider both Raman scattering and four-wave-mixing (FWM) in the calculation .
- The photon counts for Raman noise and FWM noise in the special case of classical band spacing equal to 200 GHz (1.6 nm) are also shown in the figure.

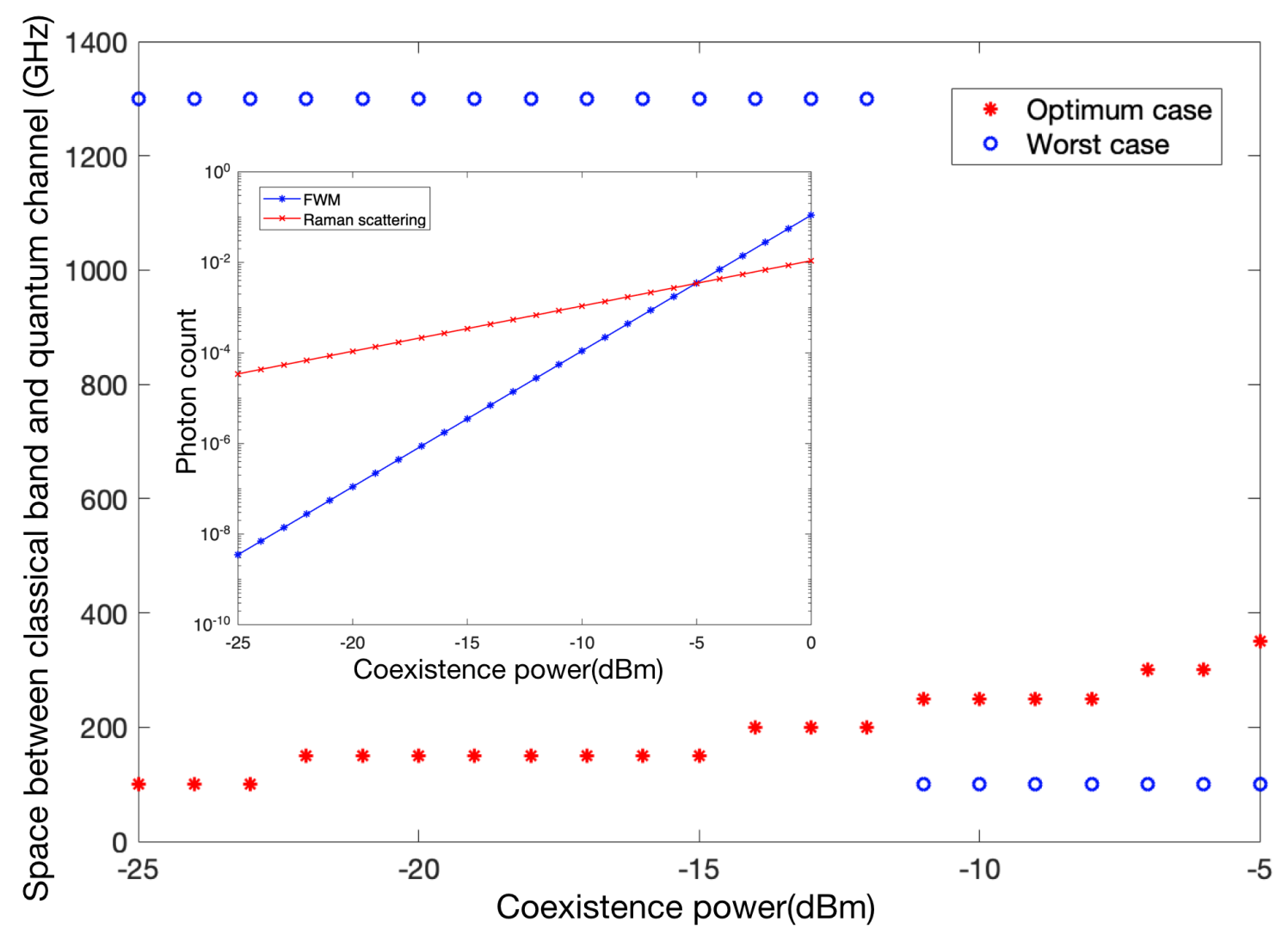


Fig. 4 Best- and worst-case scenarios for the classical band spacing, considering different values for the coexistence power in the SMF.

RESULTS

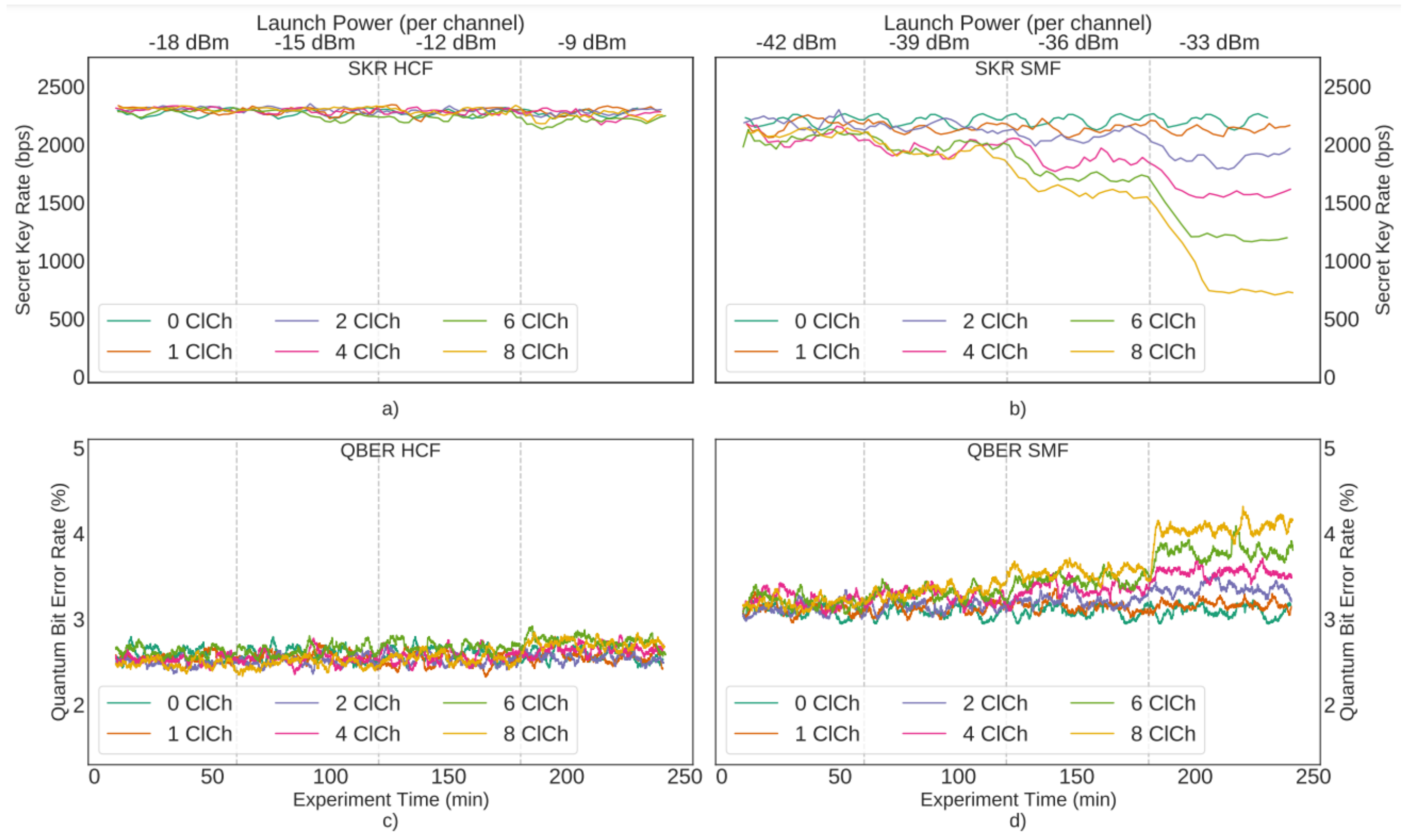


Fig. 5 a) Average SKR versus launch optical power using HC-NANF. b) Average SKR versus launch optical power using SMF. c) Average QBER versus launch optical power using HC-NANF. d) Average QBER versus launch optical power using SMF; 200 GHz spacing between quantum and classical channels.

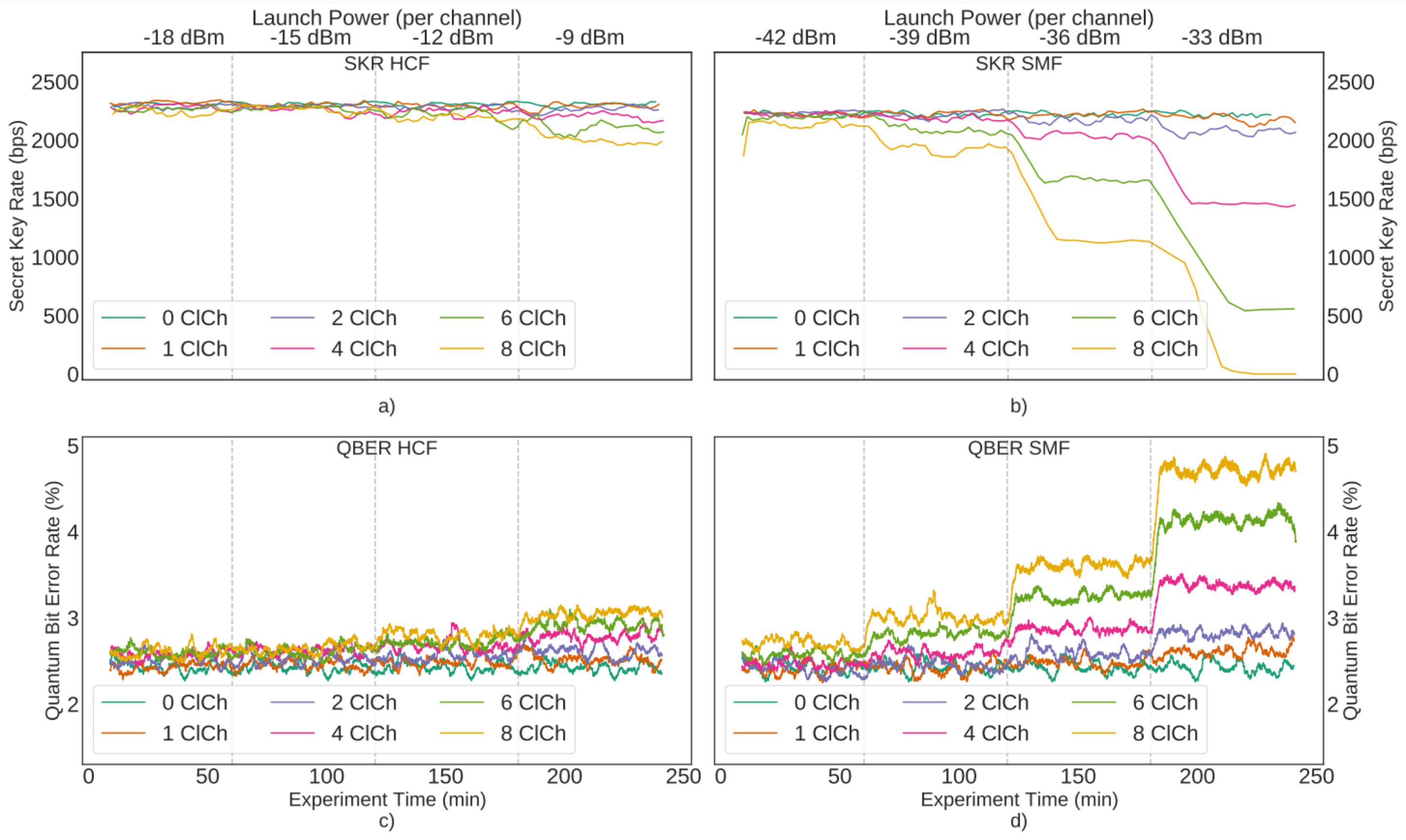


Fig. 6 a) Average SKR versus launch optical power using HC-NANF. b) Average SKR versus launch optical power using SMF. c) Average QBER versus launch optical power using HC-NANF. d) Average QBER versus launch optical power using SMF; 1 THz spacing between quantum and classical channels.

CONCLUSIONS

The coexistence of a DV-QKD channel and 8 × 200 Gb/s classical channels was successfully demonstrated over a 2-km long HC-NANF. In the best-case scenario (200~GHz spacing between the quantum and classical channel) at -24 dBm coexistence power in SMF, the SKR dropped 73%, whereas, at 0 dBm coexistence power in HC-NANF (250 times higher than the power used in SMF), the SKR was preserved.