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Hollow-Core Fiber Characterization with Correlation-Optical Time Domain Reflectometry

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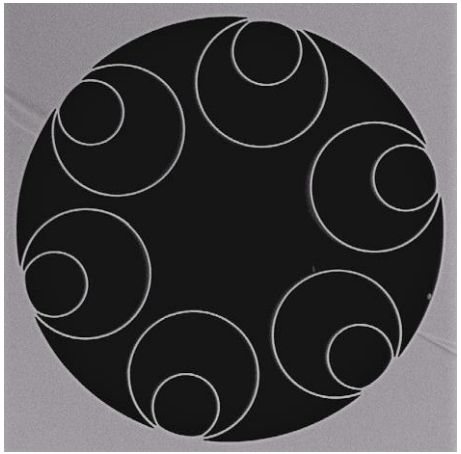
Motivation

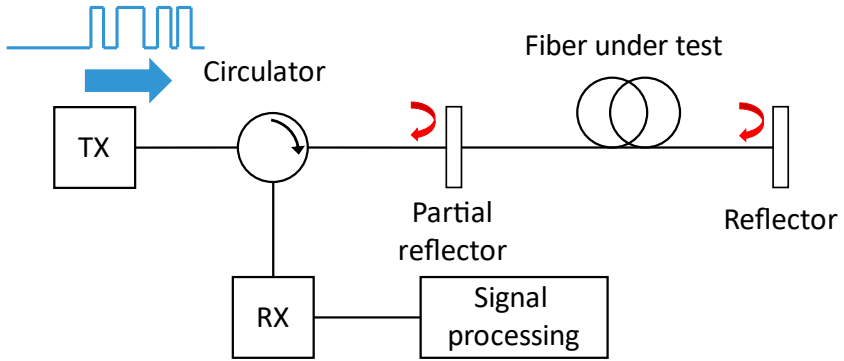


Advantages of Hollow-core fiber (HCF) towards single mode fiber (SMF)

- **Low latency (30 %)**
- **Low thermal sensitivity (up to 20 times)**
- Lower nonlinearities
- Theoretically lower loss in the C-band (no Rayleigh scattering)

[1] Gregory T. Jasion, et al. "Hollow Core NANF with 0.28 dB/km Attenuation in the C and L Bands" OFC 2020, Postdeadline Paper Th4B.4

Application



Correlation-Optical Time Domain Reflectometry (C-OTDR)

- Precise propagation delay measurements of short and long fibers
- 1.5 ps accuracy for short fiber [1]
- 3.9 ps accuracy for long fiber [2]

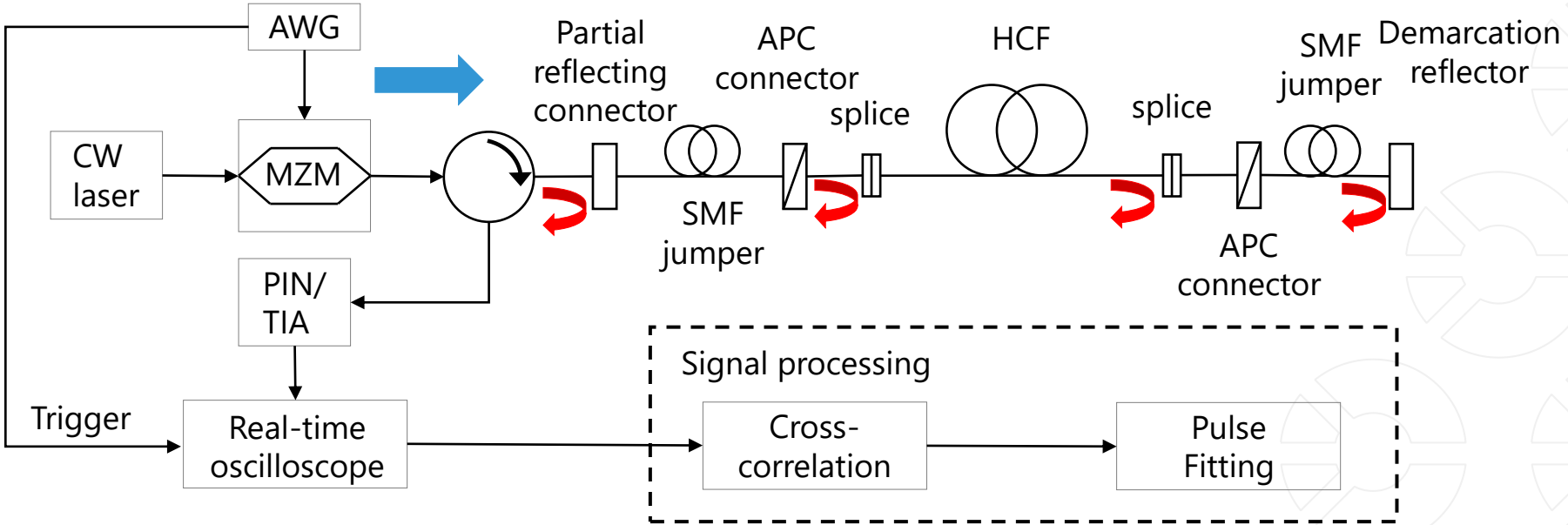
[1] M.H. Eiselt and A. Dochhan, "Single-Ended Fiber Latency Measurement with Picosecond-Accuracy Using Correlation OTDR," OECC 2018, Jeju, Korea, July 2018.

[2] F. Azendorf, et al., „Improvement of accuracy for measurement of 100-km fibre latency with Correlation OTDR", ECOC 2019, Dublin, September 2019.

Outline

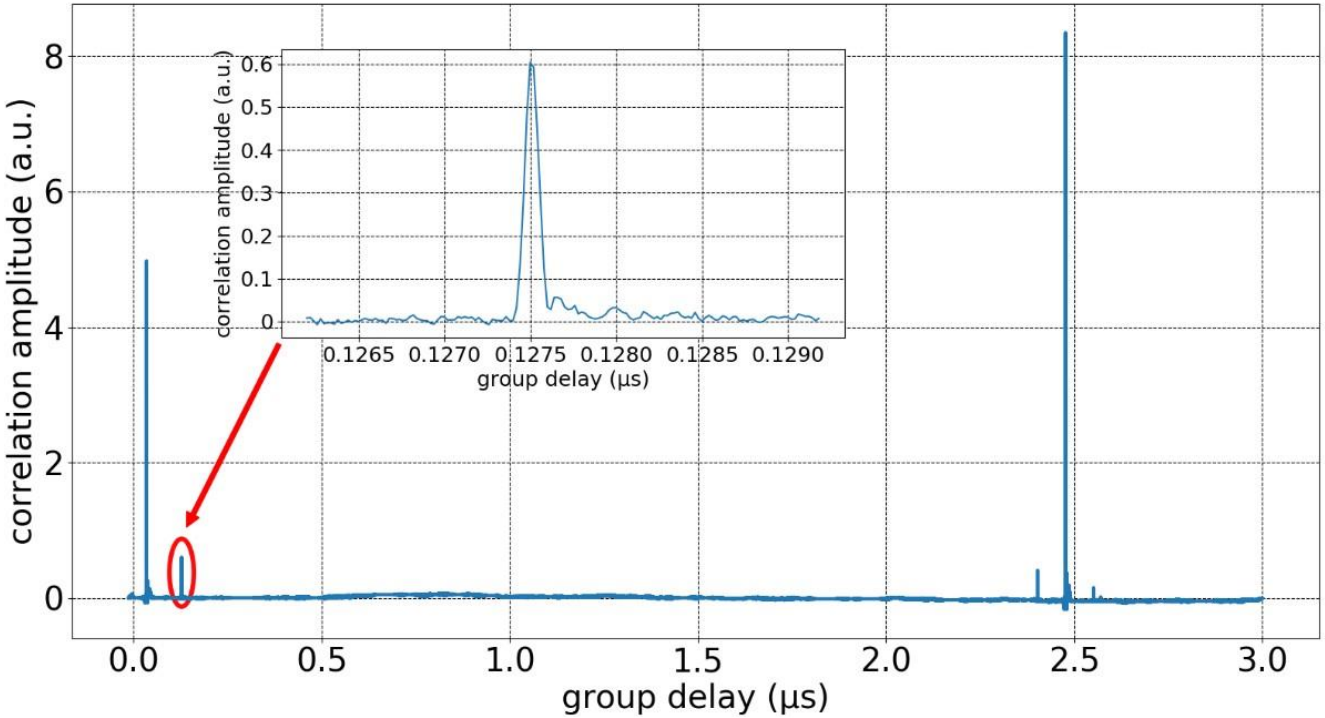
1. Measurement setup
2. Experiment & results
3. Conclusion

Measurement schematic



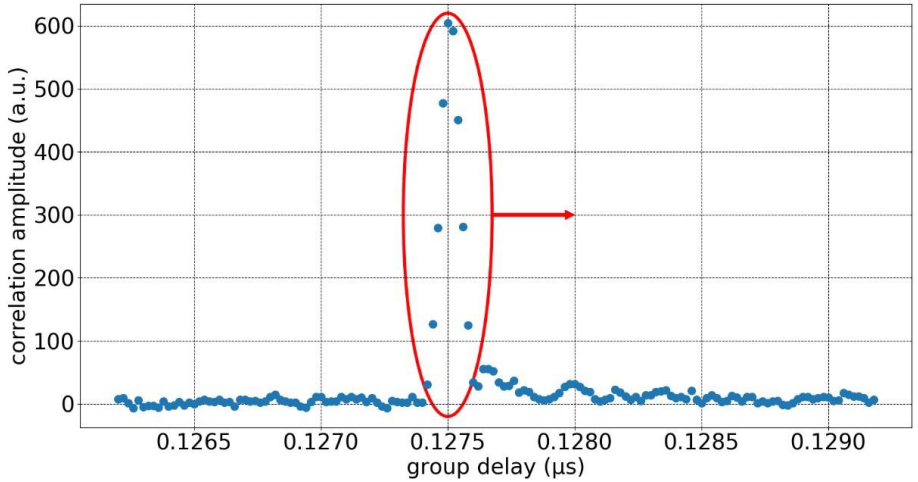
Probe Wavelength	Probe bit rate	Sampling rate	Probe sequence
1550 nm	10 Gbit/s or 5 Gbit/s	50 GS/s or 25 GS/s	128 Bit Golay

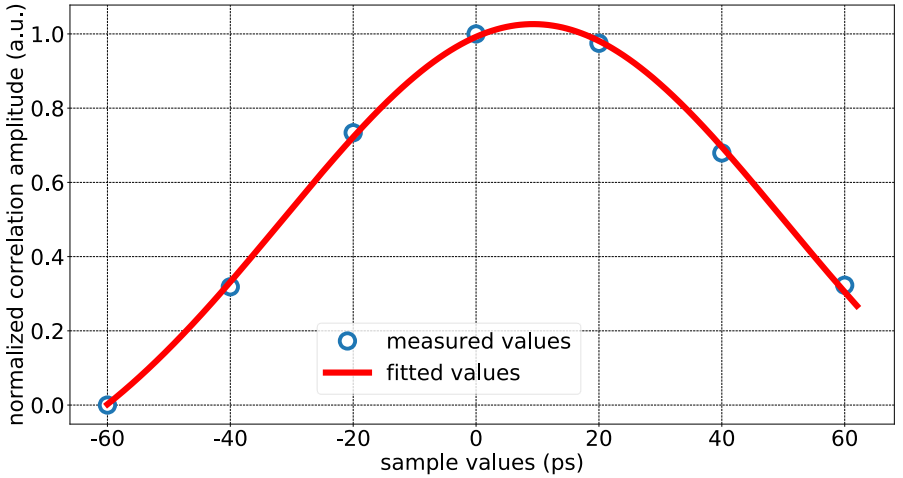
Signal processing - correlation



- Received time signal after 1000 averages
- Correlation of received and transmitted sequence
- Correlation leads to narrow reflection peaks

Signal processing - pulse fitting





- Pulse fitting to improve the timing resolution
- Center of the Gaussian function is taken to calculate the exact time of the reflection peak
- Timing resolution is few picoseconds and better than one sample period (20 ps or 40 ps)

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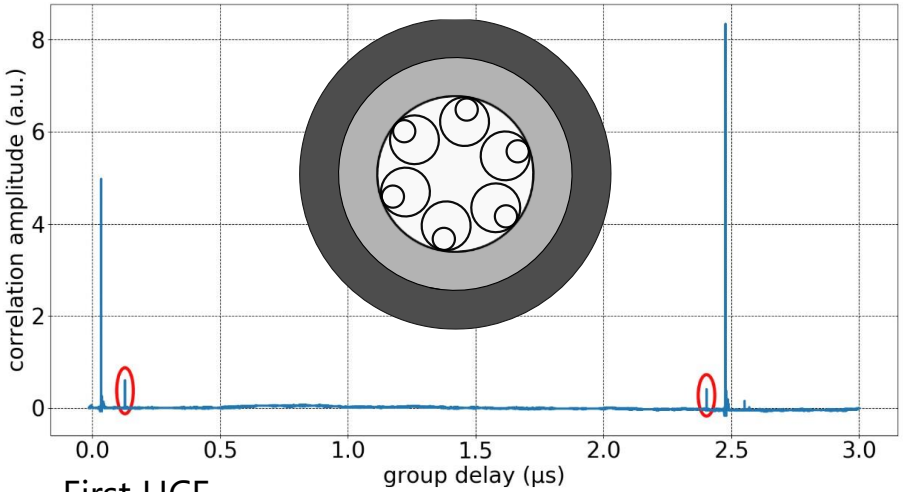
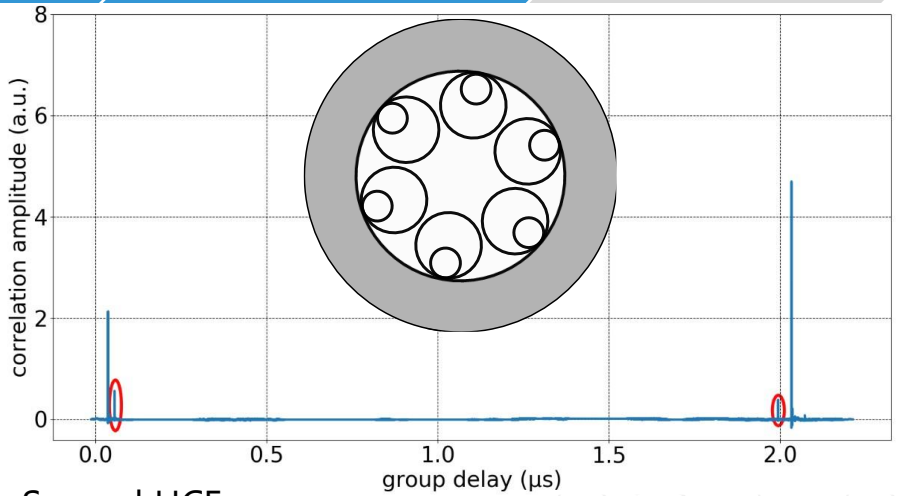
Correlation signal HCF



First HCF

- 340 m
- Double coating
- Group refractive index: n = 1.003
- Measured group delay (RTT): 2.275 µs

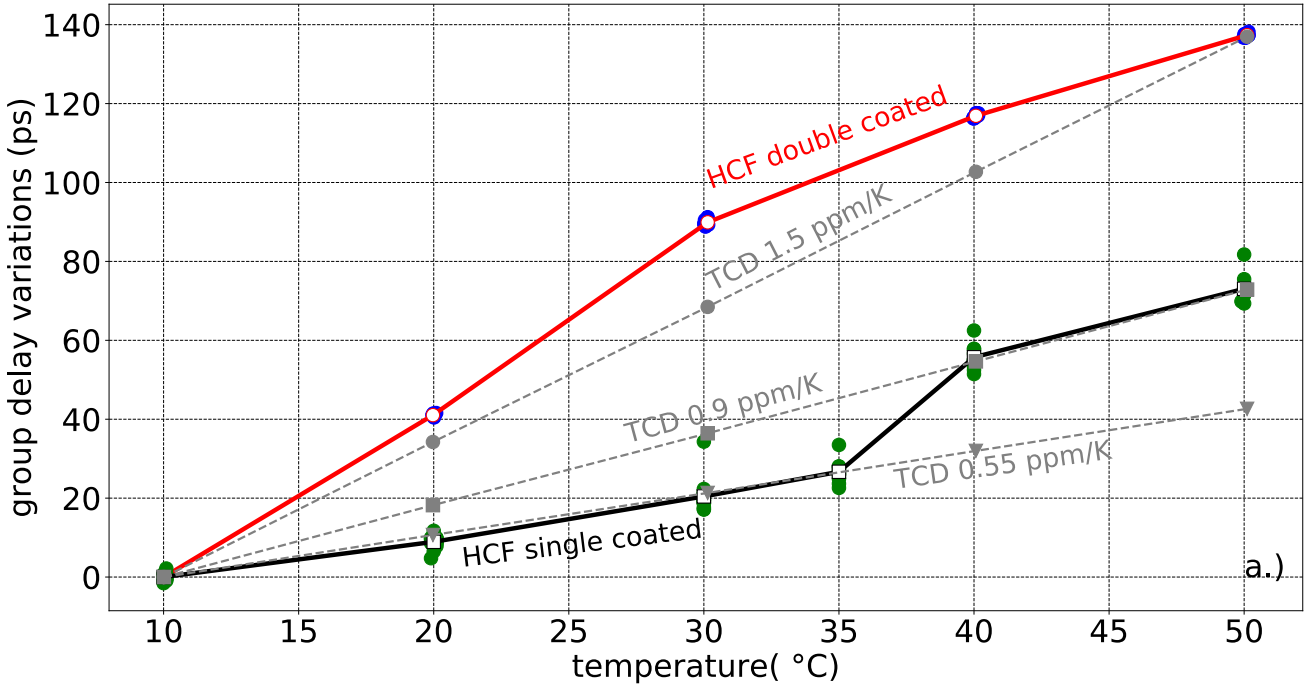


Second HCF

- 289 m
- Single coating
- Group refractive index: n = 1.005
- Measured Group delay (RTT): 1.938µs

For a SSMF (n=1.47) with similar length we would obtain 3.334 µs and 2.834 µs RTT

Group delay variations for both HCFs



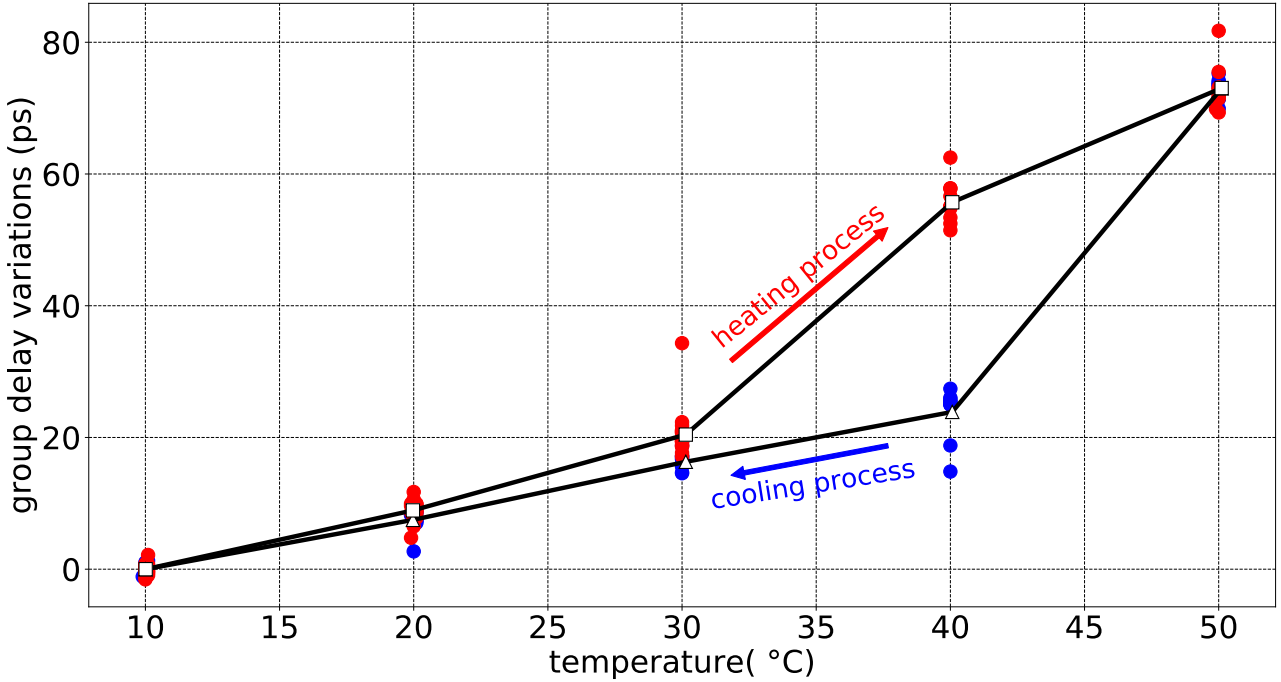
Measurement results:

- 1.5 ppm/K -> 5.02 ps/K/km
- 0.55 ppm/K ->1.67 ps/K/km

- Nonlinear behavior is caused by material properties of the coatings

- The step might be explained by tight spooling of the fiber

Single coated HCF hysteresis



Measurement results:

- Negative hysteresis was observed
- The group delay drops between 40 °C and 50 °C in the cooling process
- Such a behavior was also observed with SMF jumper

Conclusion

- Two NANF HCF were characterized with Correlation OTDR
- Results show that the HCF has a 6 to 20 times lower sensitivity to temperature changes as compared to standard single-mode fiber
- Correlation-OTDR has precise timing resolution to measure the temperature changes of a signal propagating in an HCF
- We measured group delay changes of 5.02 ps/K/km, 3.01 ps/K/km, and 1.67 ps/K/km
- The coating material properties affect the propagation delay in an HCF

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