

SPONSORED BY THE



Federal Ministry
of Education
and Research



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

Florian Azendorf^(1,2), Bernhard Schmauss⁽²⁾, Bo Shi⁽³⁾, Eric Numkam Fokoua⁽³⁾, Radan Slavik⁽³⁾, Michael Eiselt⁽¹⁾

(1) ADVA Optical Networking SE, 98617 Meiningen, Germany

(2) LHFT, Friedrich-Alexander-Universität Erlangen/Nürnberg, 91058 Erlangen, Germany

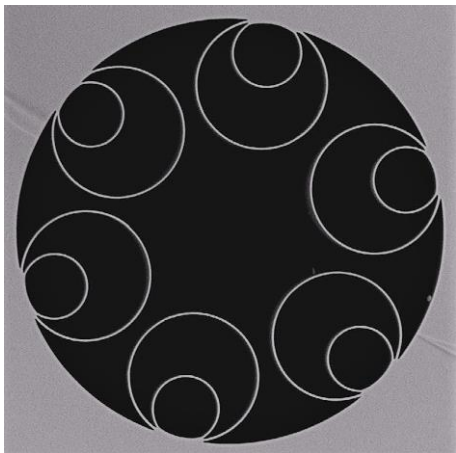
(3) Optoelectronics Research Centre (OCR), University of Southampton, SO17 1BJ Southampton, UK

July 27, 2021



FRIEDRICH-ALEXANDER
UNIVERSITÄT
ERLANGEN-NÜRNBERG

Motivation

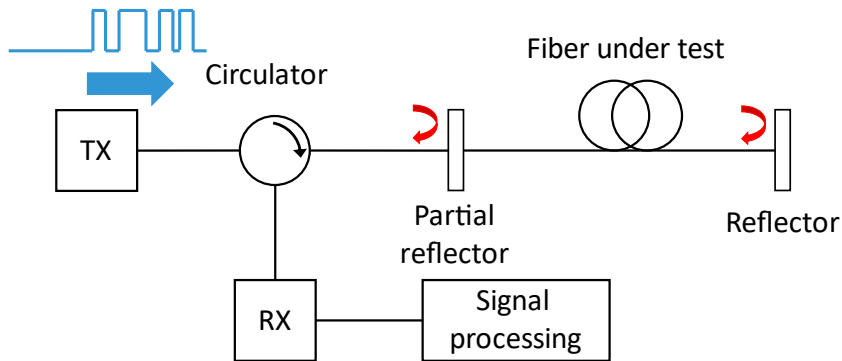


Advantages of Hollow-core fiber (HCF) towards single mode fiber (SMF)

- **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

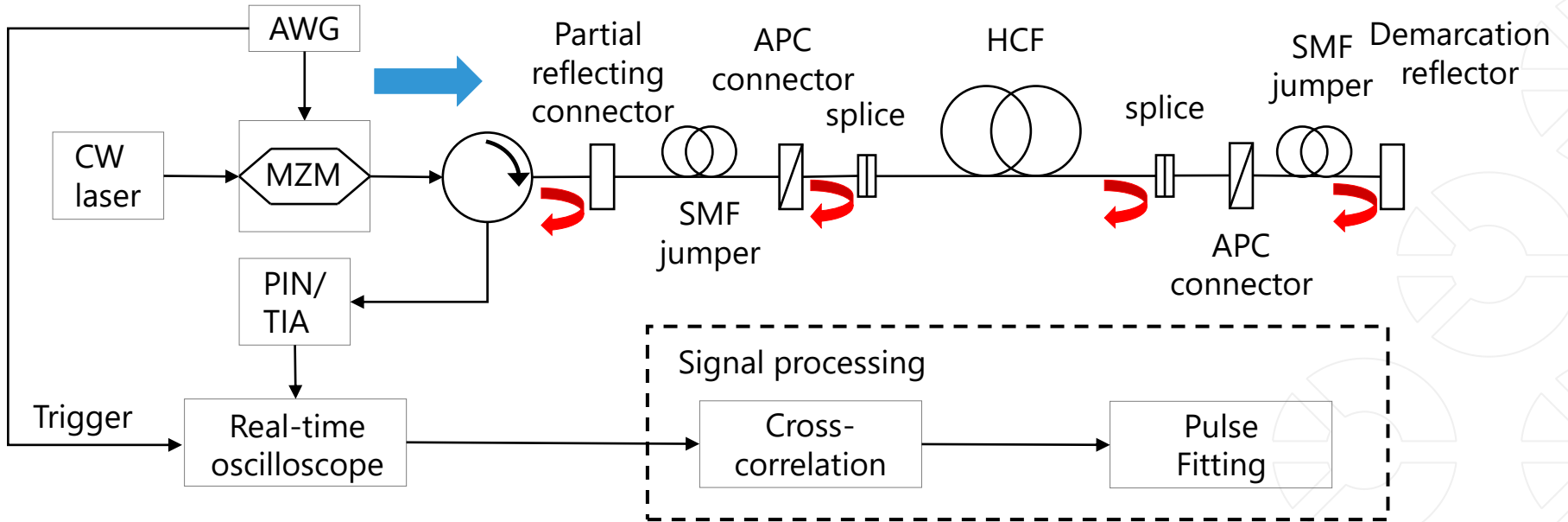
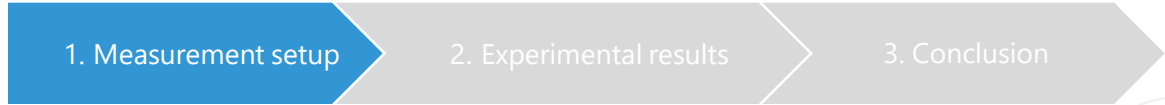
2

Experiment & results

3

Conclusion

Measurement schematic



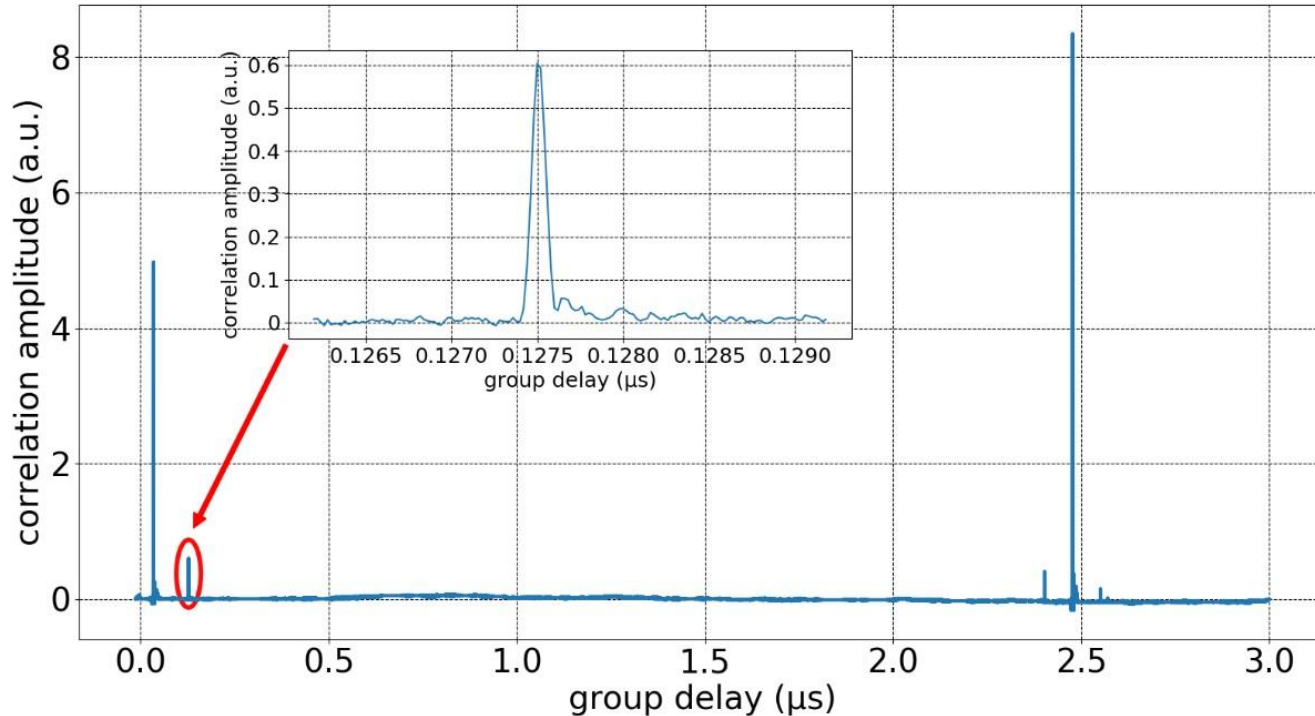
Probe Wavelength	Probe bit rate	Sampling rate	Probe sequence
1550 nm	10 Gbit/s or 5 Gbit/s	50 GS/s or 25 GS/s	128 Bit Golay

Signal processing - correlation

1. Measurement setup

2. Experimental results

3. Conclusion



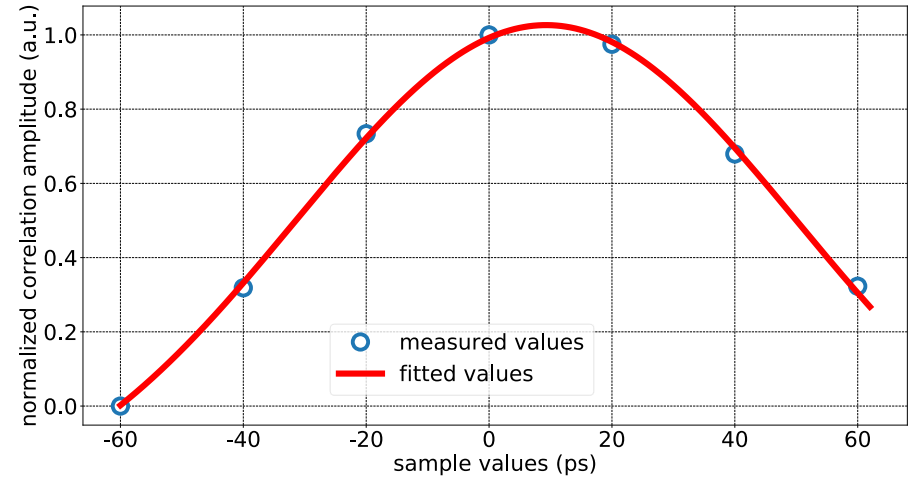
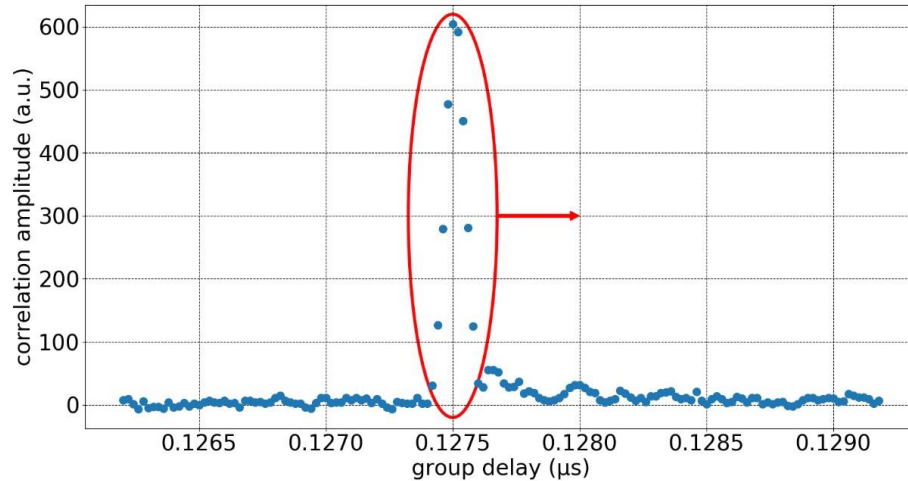
- Received time signal after 1000 averages
- Correlation of received and transmitted sequence
- Correlation leads to narrow reflection peaks

Signal processing - pulse fitting

1. Measurement setup

2. Experimental results

3. Conclusion



- 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)

Outline

1

Measurement setup

2

Experiment & results

3

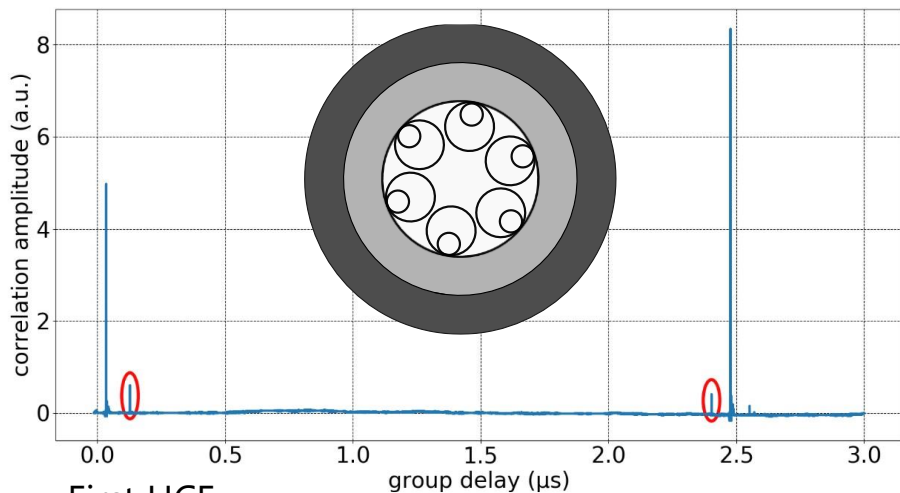
Conclusion

Correlation signal HCF

1. Measurement setup

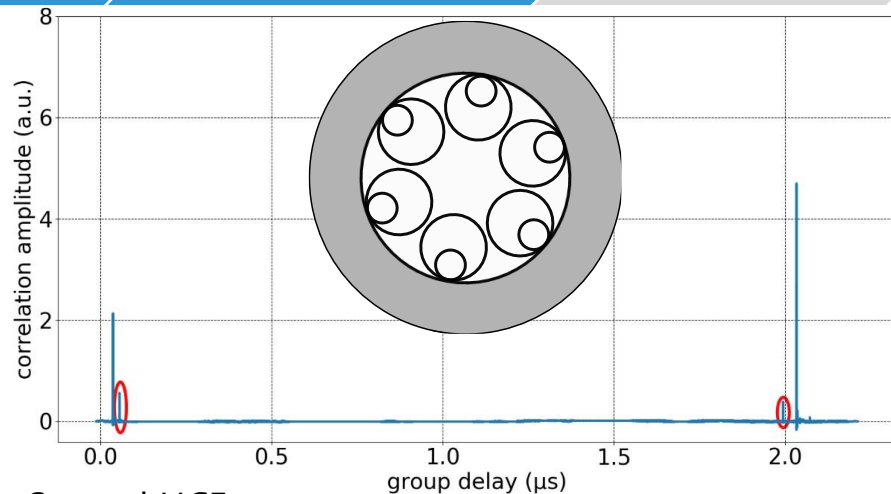
2. Experimental results

3. Conclusion



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): 1.938 μs

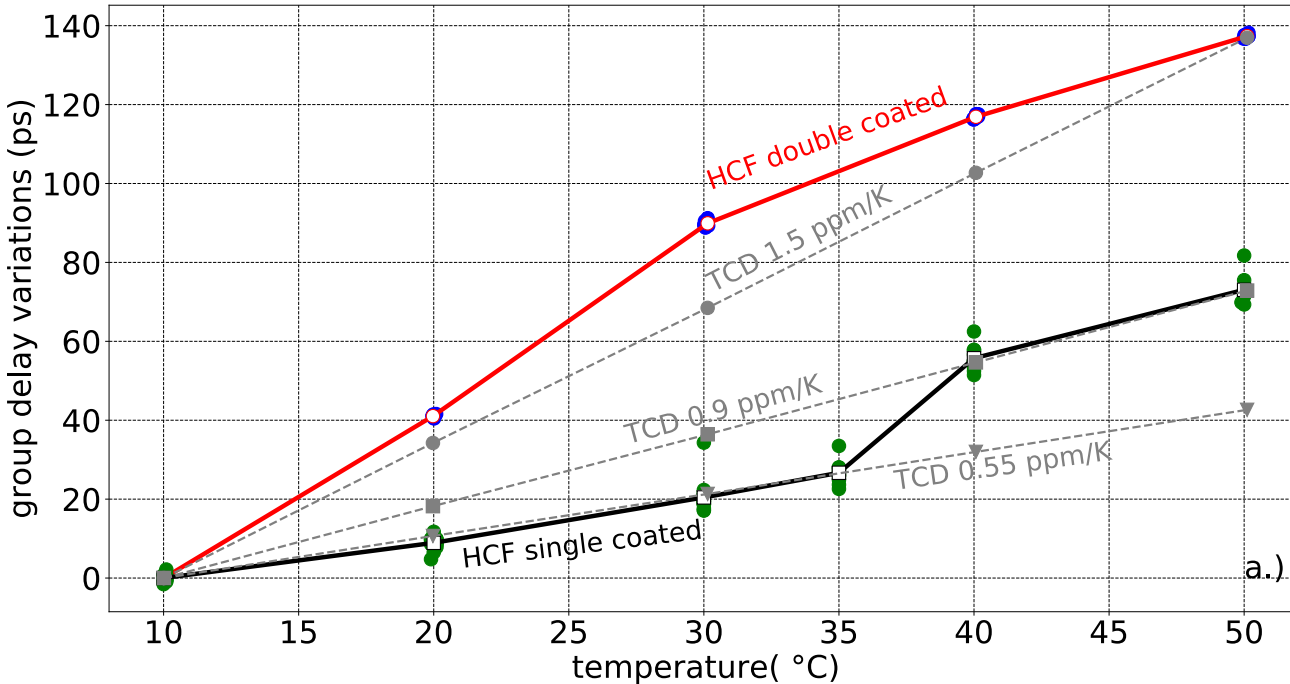
For a SSMF ($n=1.47$) with similar length we would obtain 3.334 μs and 2.834 μs RTT

Group delay variations for both HCFs

1. Measurement setup

2. Experimental results

3. Conclusion



Measurement results:

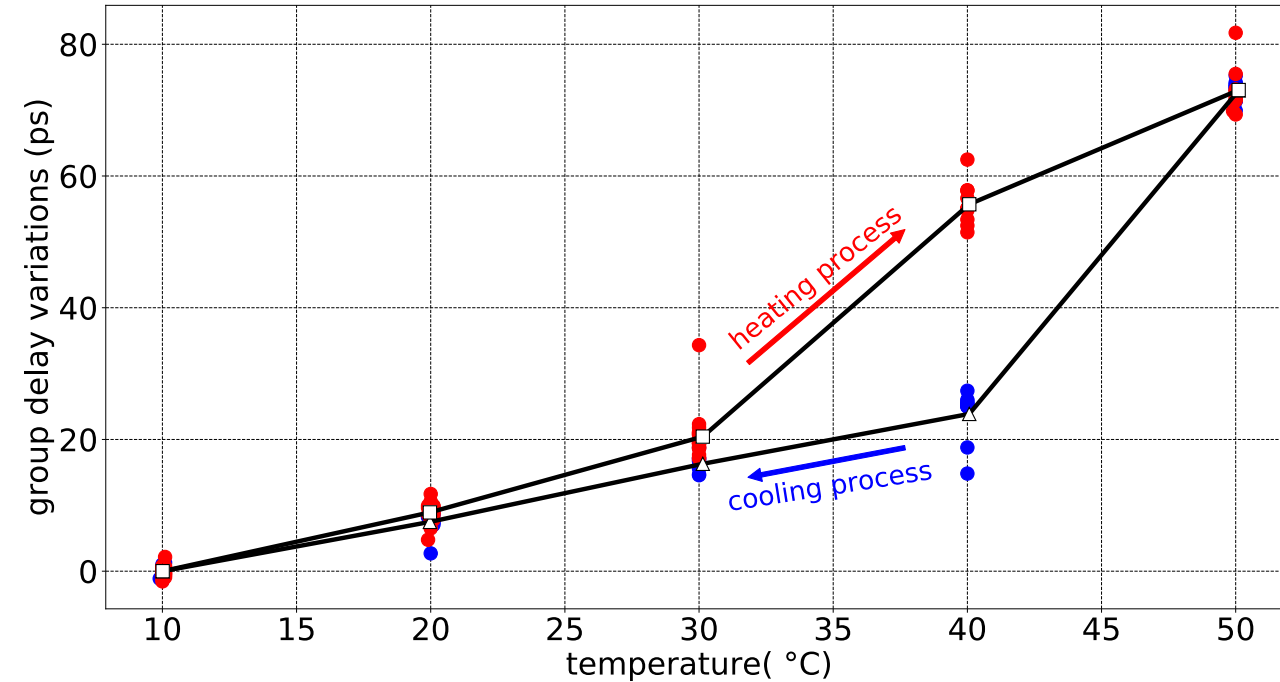
- 1.5 ppm/K -> 5.02 ps/K/km
- 0.55 ppm/K -> 1.67 ps/K/km
- Nonlinear behavior is caused by material properties of the coatings
- The step might be explained by tight spooling of the fiber

Single coated HCF hysteresis

1. Measurement setup

2. Experimental results

3. Conclusion



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

1. Measurement setup

2. Experimental results

3. 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



SPONSORED BY THE



Federal Ministry
of Education
and Research



OptiCON



Thank you

fazendorf@adva.com



IMPORTANT NOTICE

The content of this presentation is strictly confidential. ADVA is the exclusive owner or licensee of the content, material, and information in this presentation. Any reproduction, publication or reprint, in whole or in part, is strictly prohibited.

The information in this presentation may not be accurate, complete or up to date, and is provided without warranties or representations of any kind, either express or implied. ADVA g shall not be responsible for and disclaims any liability for any loss or damages, including without limitation, direct, indirect, incidental, consequential and special damages, alleged to have been caused by or in connection with using and/or relying on the information contained in this presentation.

Copyright © for the entire content of this presentation: ADVA.

