RADIATION TESTS ON OPTICAL FIBERS - GOOD AND BAD PRACTICE

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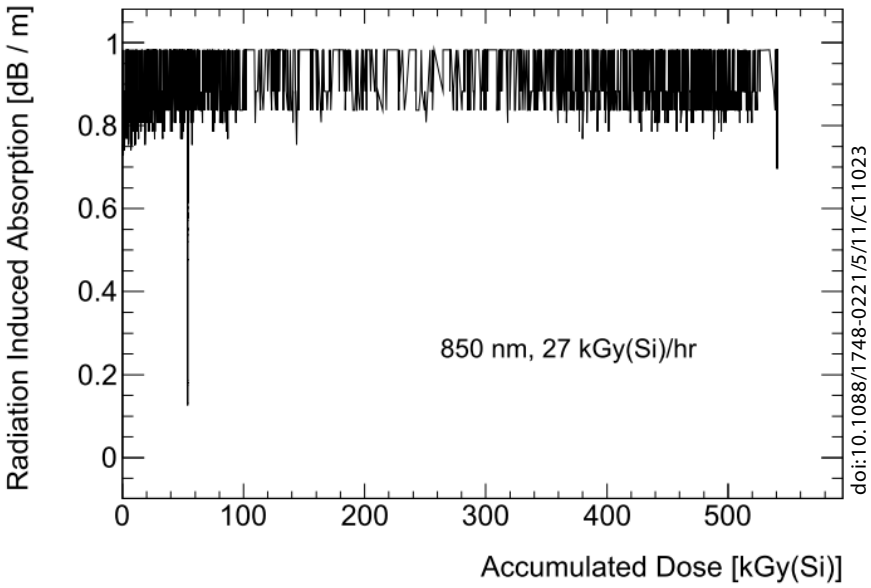
- Introduction
- Overview of parameter dependencies
- Relevant test standards
- Examples of problematic test conditions
  - What is room temperature?
  - Photobleaching – Long gone or worse than ever?
  - Geometry – How to bend the fiber?
  - Exotic influences –
    What does the cladding and coating have to do with the core?

Introduction

- Radiation testing of optical fibers is in principle simple but tricky when it gets to the details
- Common questions regarding optical fiber radiation test (data):
  - Will my product of choice survive conditions xyz?
  - Can I use the data I found in xyz?
  - What do I need to know and do to perform a good radiation test?
  - What is a "good" radiation test?
    - Precise
    - Known uncertainties
    - Reliable
    - Reproducible



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Overview of parameter dependencies
Experimental observed influences listed

Manufacturing influences

- Fibre type (Single mode, graded index, step index)
- Doping of core/
  Doping of cladding
  (for SM fibres)
- Preform manufacturer and used processes
- Core material manufacturer
- OH Content
- Cladding core diameter ratio (CCDR)
- Coating material
- Drawing conditions

Operation conditions

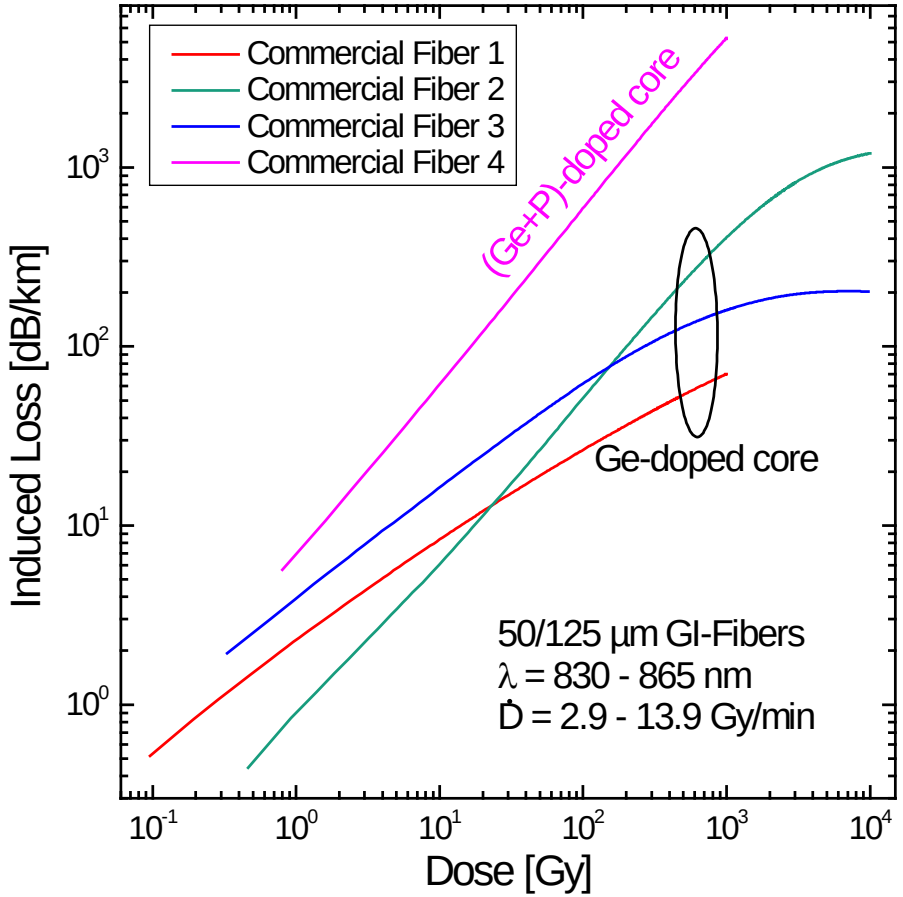
- Wavelength
- Light power
- Launch conditions

Environment

- Total dose
- Dose rate
- Annealing periods / Duty cycle
- Temperature

In combination with each other:
Differences of many orders of Magnitude possible!

Examples of typical parameter influences
GI fibers from different manufacturers



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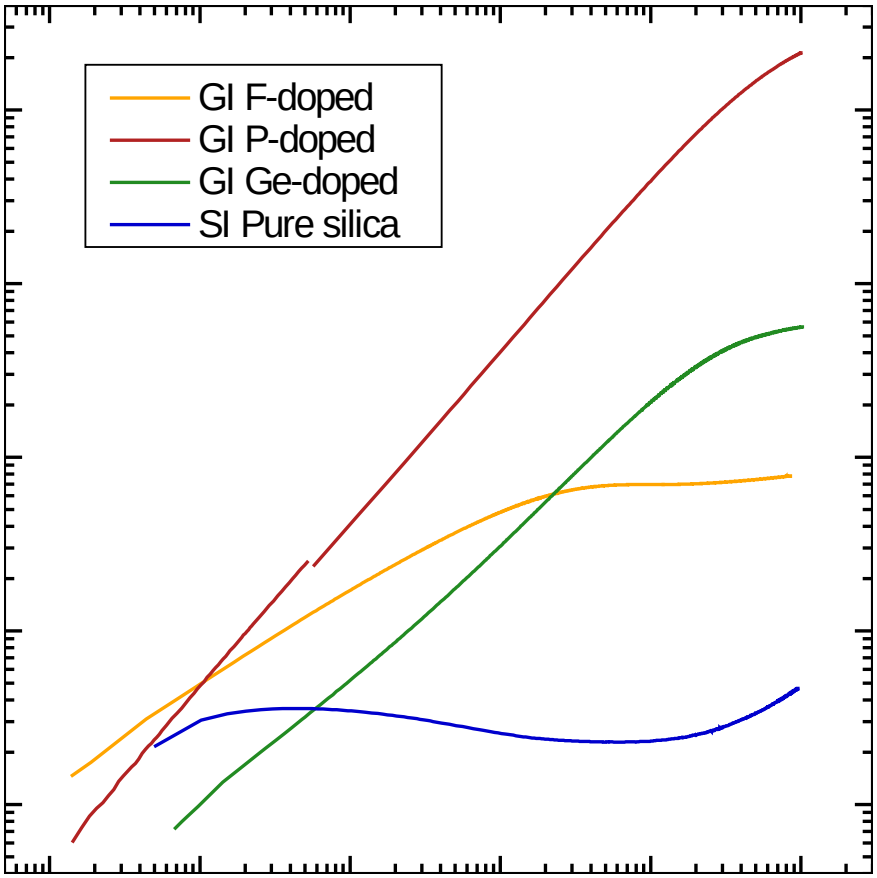
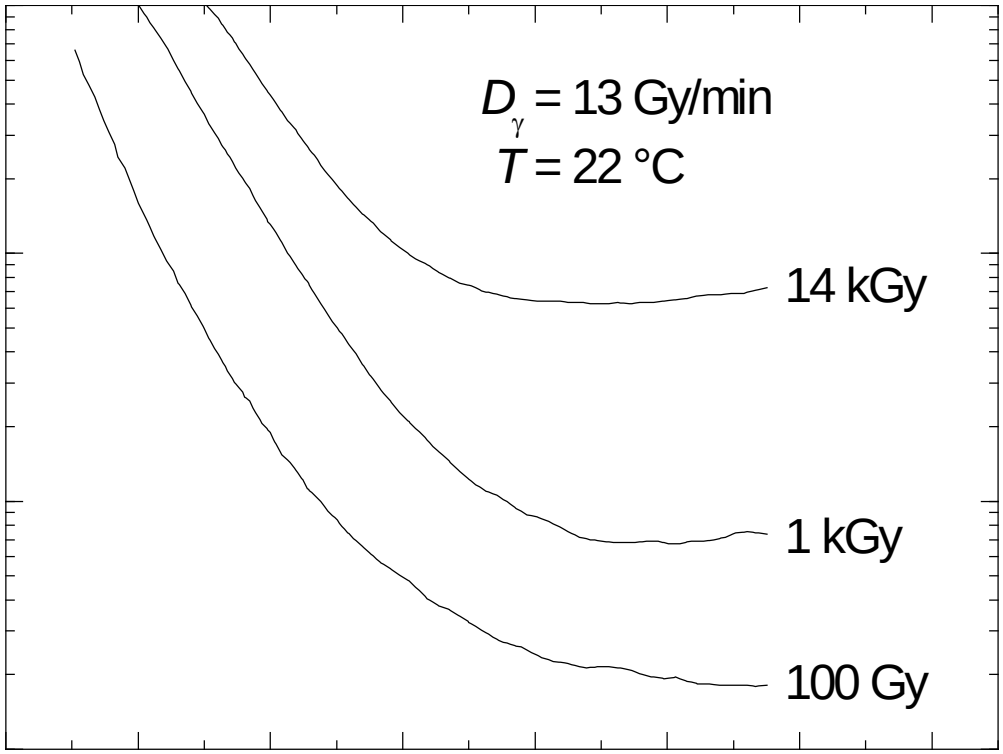
Examples of typical parameter influences

Different fiber types and core dopands



- What does that mean for injected light of 1 mW:
  - Wavelength: ~830 nm
  - Fibre length: 100 m
- Pure silica fibre: 0.89 mW
- F-doped fibre: 0.17 mW
- Ge-doped fibre: $3 \cdot 10^{-6}$ mW
- P-doped fibre: 10^{-200} mW

Examples of typical parameter influences
Wavelength dependence



Relevant test standards for optical fiber radiation tests

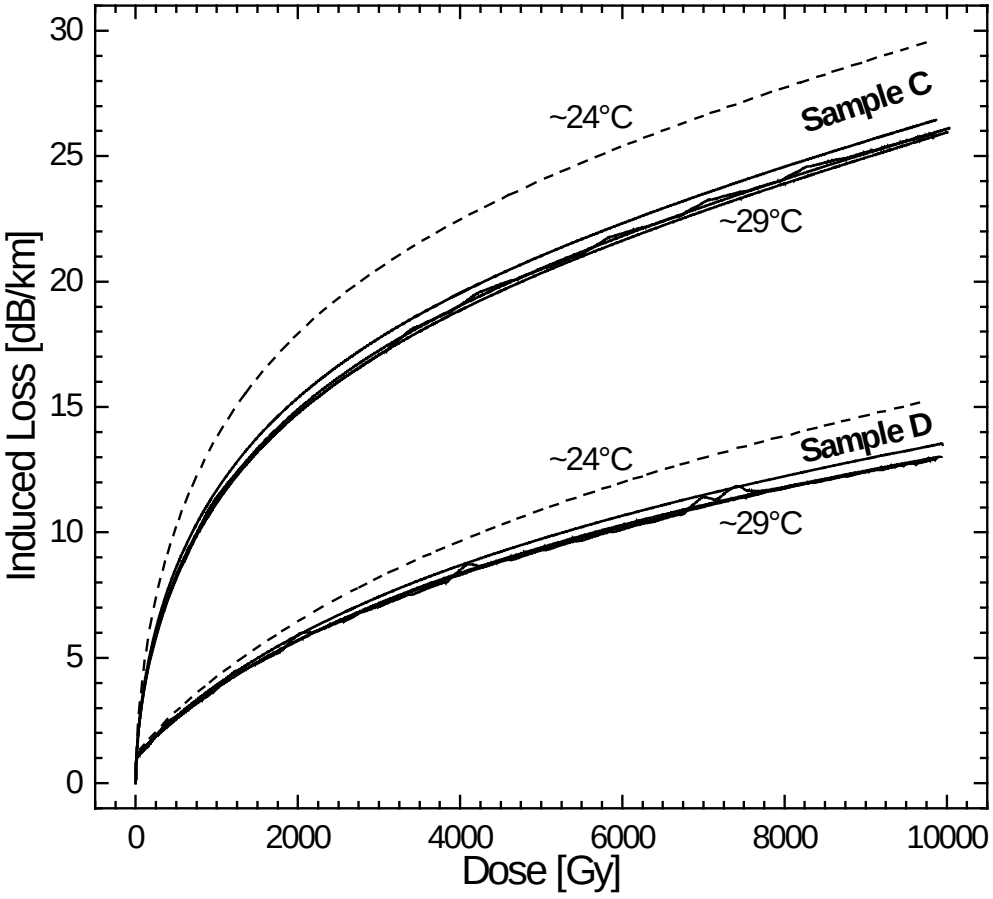
- List of test standards for radiation tests on optical fibers
  - IEC 60793-1-54 ed. 2.0 (2012)
  - ASTM E 1614 - 94 (2013)
  - TIA/EIA-455-64: FOTP 64 (2002)
  - IEC 62283 TR ed. 2.0 (2010) – no standard
  - DIN EN 61300-2-31 (1998) – not active
  - IEEE Std. 1682 (2011) – general description
  - NATO Nuclear Effects Task Group: NRL/MR/6505-92-6963 – outdated
  - ESCC 22900 Issue 4 (2010) – Not intended for fibers

Overview of some key standards
Differences in specifications

Parameter	FOTP-64	IEC 60793-1-54	ASTM E1614
Wavelength [nm]	850,1310,1550±20	x±20, 3 dB width	250 – 2100
Light power	1 µW	1 µW (avoid PB)	n. a.
Irradiation Source	γ, n, X, e^-	Co-60	α, β, γ, p >500 keV
Irradiation Time	7.7 min – 100 min	1000 h	77 min – 167 h
Dose rate	0.05 Gy/s – 1.6 Gy/s	0.27 Gy/s	0.2 Gy/s – 1.6 Gy/s
Annealing	> 1000 s	> 15 min	> 3600 s
Sample length	100 m	250 m (or shorter)	50 m

Problematic test conditions
What is room temperature?

- Standards:
  - FOTP: 21°C – 25°C
  - IEC: 20°C – 30°C
  - ASTM: 21°C – 25°C
  - ESCC: 10°C – 30°C
- From this it seems that a wide range is possible, but does it make sense?
- No, because already small variations (5°C) lead to significant variations of RIA (15%)



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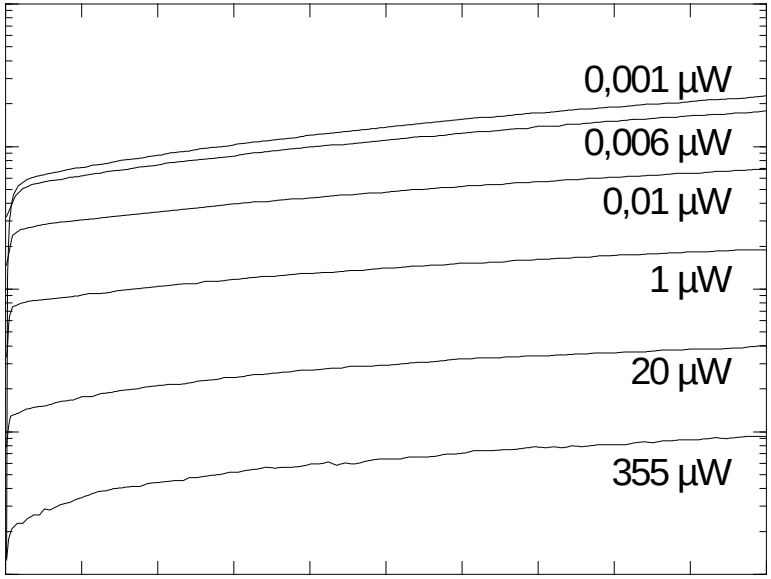
Problematic test conditions

Photobleaching – Long gone or worse than ever?



- Henschel showed strong effect of photo-bleaching in pure-silica core step-index fibers

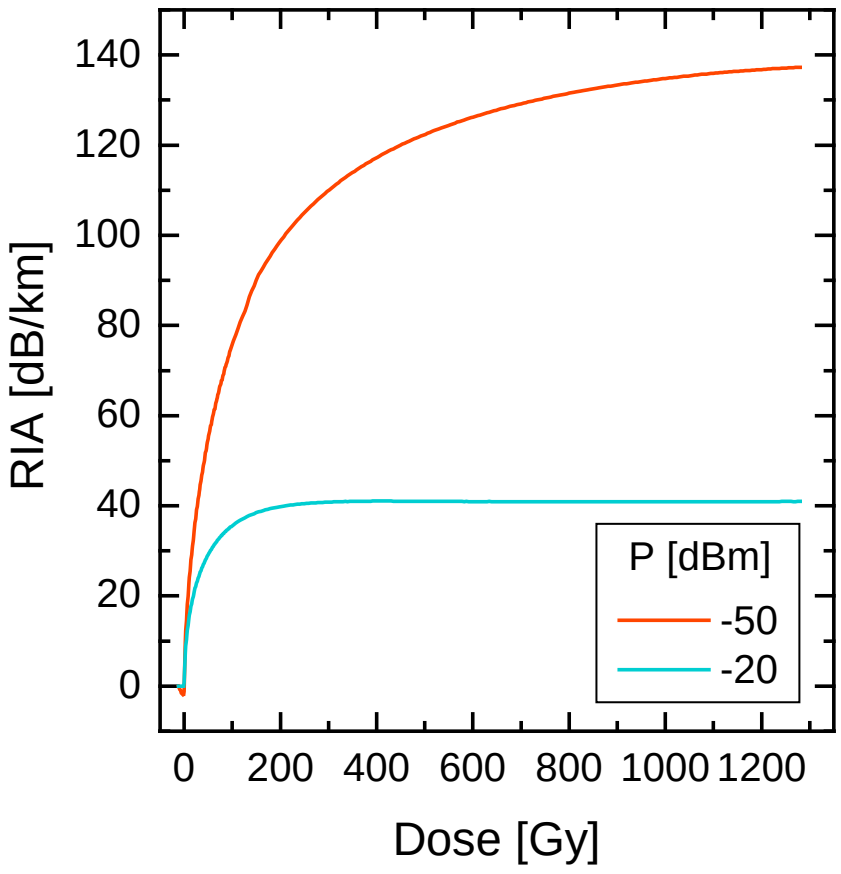
more photo-bleaching for light powers < 1 µW!

"Classical" photo-bleaching for light powers > 1 µW

- Using light powers of ~1µW does not avoid photo-bleaching!
- One reason named was the quality of the fibers in the 90s.
- So no problem any more?

Problematic test conditions

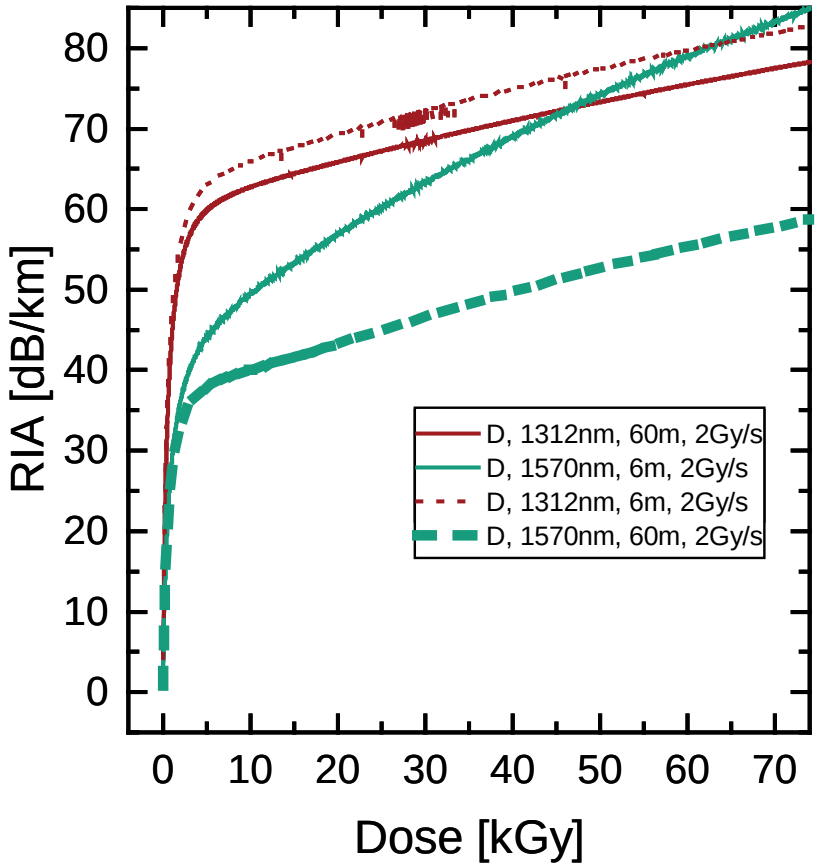
Photobleaching – Long gone or worse than ever?



- The graph shows results obtained with a commercial optical fiber
- Light power was varied between 10 µW and 0.001 µW
- Strong photo-bleaching effect is observed which would underestimate the radiation-induced loss in low-power applications dramatically
- Problem still exists and needs careful attention while designing a test

Problematic test conditions

Geometry – How to bend the fiber?



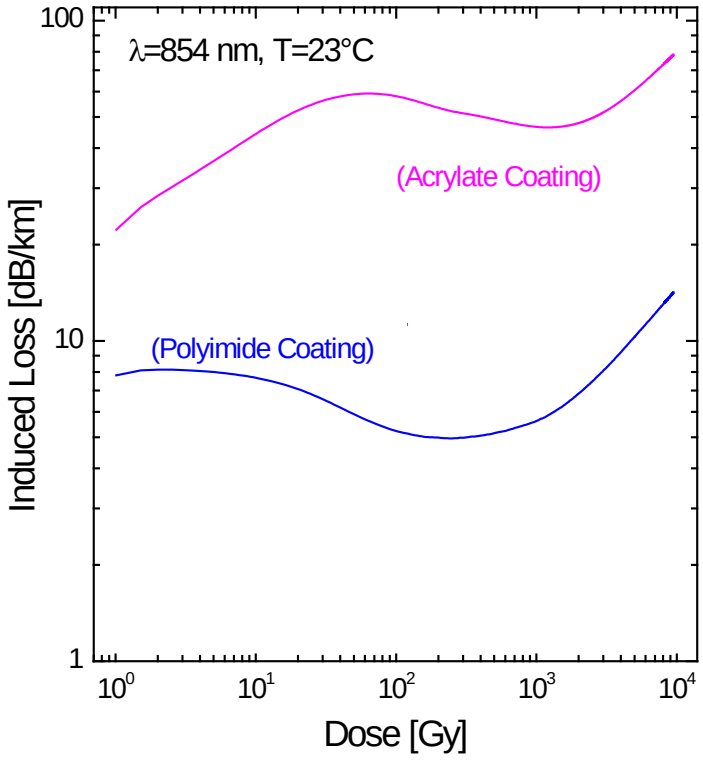
- Corning SMF28e
- 1 Gy/s ⇔ Spool ∅ 6 cm
- 2 Gy/s ⇔ Spool ∅ 4 cm

- Strong effect of bending radius on RIA as a function of wavelength
- OTDR-Measurements showed no noticeable bending loss!

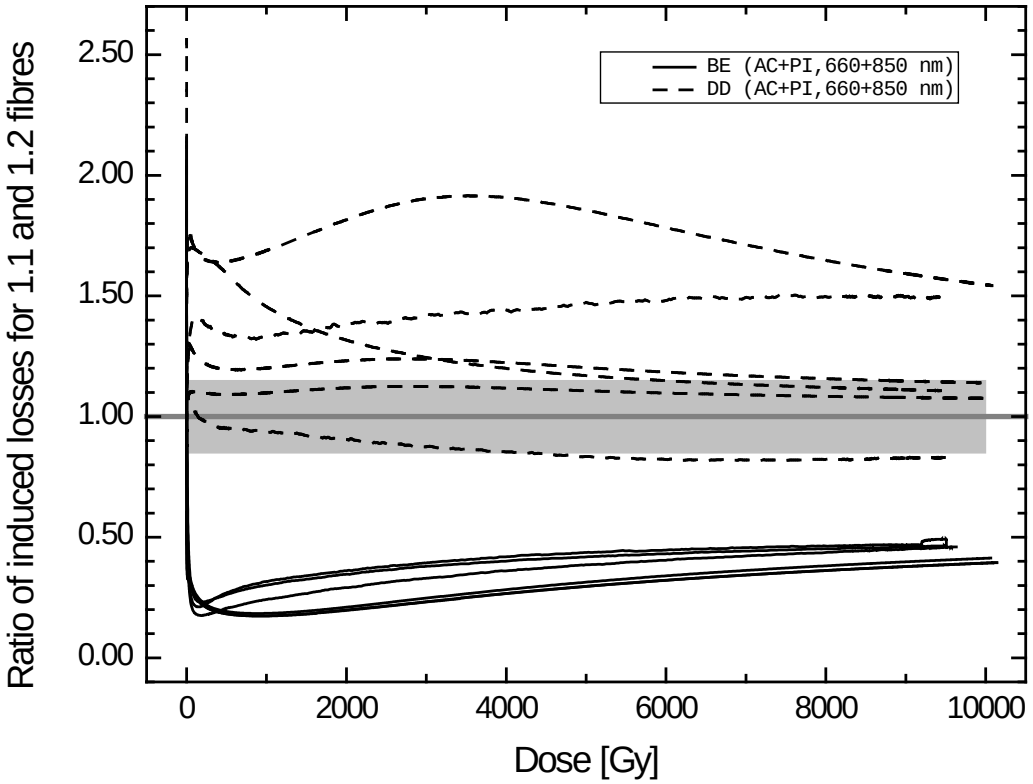
Problematic test conditions

Exotic influences – What does the cladding and coating have to do with the core?

- Influence of coating material



- Influence of core-cladding ratio



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Conclusions

- Well known and not so well known influences on the radiation-induced loss in optical fibers were presented
- Overview of relevant standards and their differences was given
- Not covered (but possible topics for panel discussion):
  - Evaluation of uncertainties
  - Influences of experimental equipment
  - Quality assurance
  - Comparison of different laboratory test data
  - Testing of speciality fibers (photonic crystal, PM, active)
- Take-home message:
  Radiation testing of optical fibers is not simple, but experience and careful planning and design leads to reliable and useful test results

Last slide

Thank you for your attention!

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