RADIATION TESTS ON OPTICAL MATERIALS

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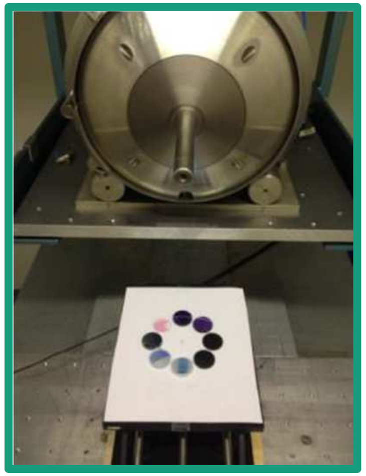

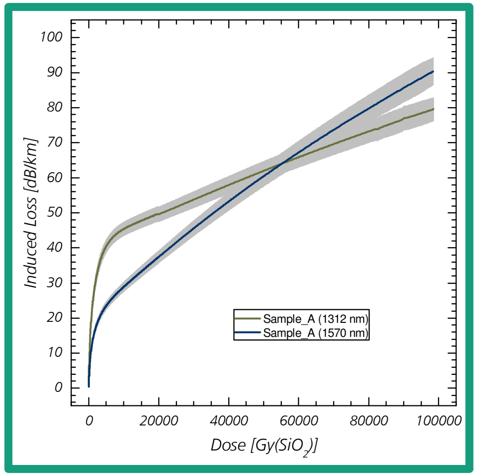

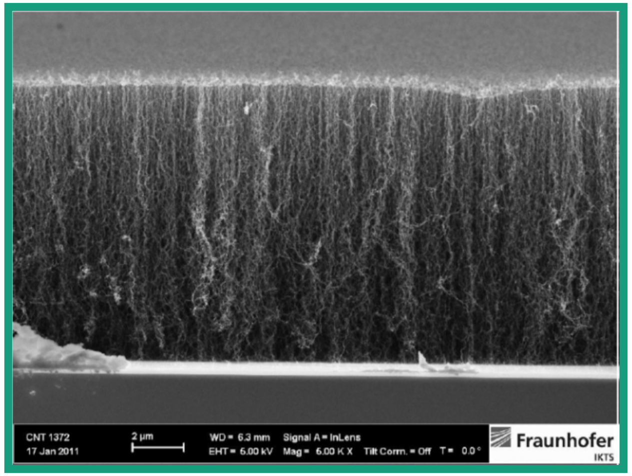

RADIATIONTEST WORKSHOP 2016
SEVILLE – SPAIN 31st MARCH – 1st APRIL

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Radiation Effects in Optical Materials
Overview

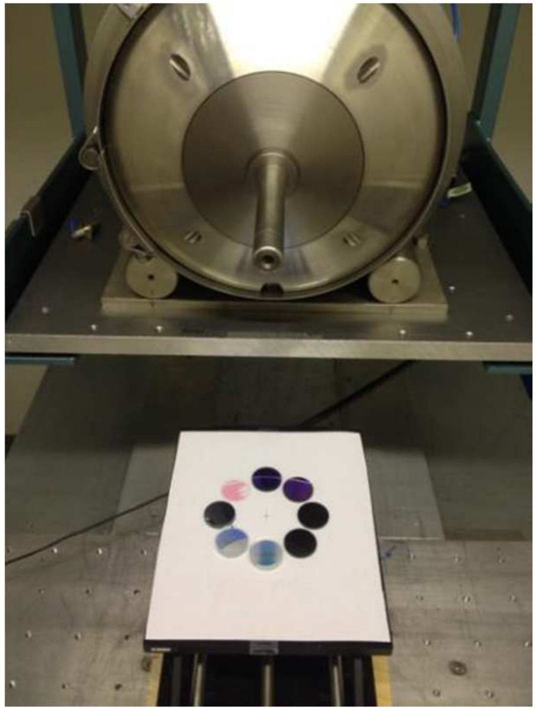
- Induced optical loss by color centers
- Density changes (dilatation or compction)
- Induced stress or stress relaxation
- Changes in polarizability
- All of above can result in changes of refractive index
- Fluorescence, luminescence, scintillation, Cherenkov light
- Dielectric breakdown (Lichtenberg figures)

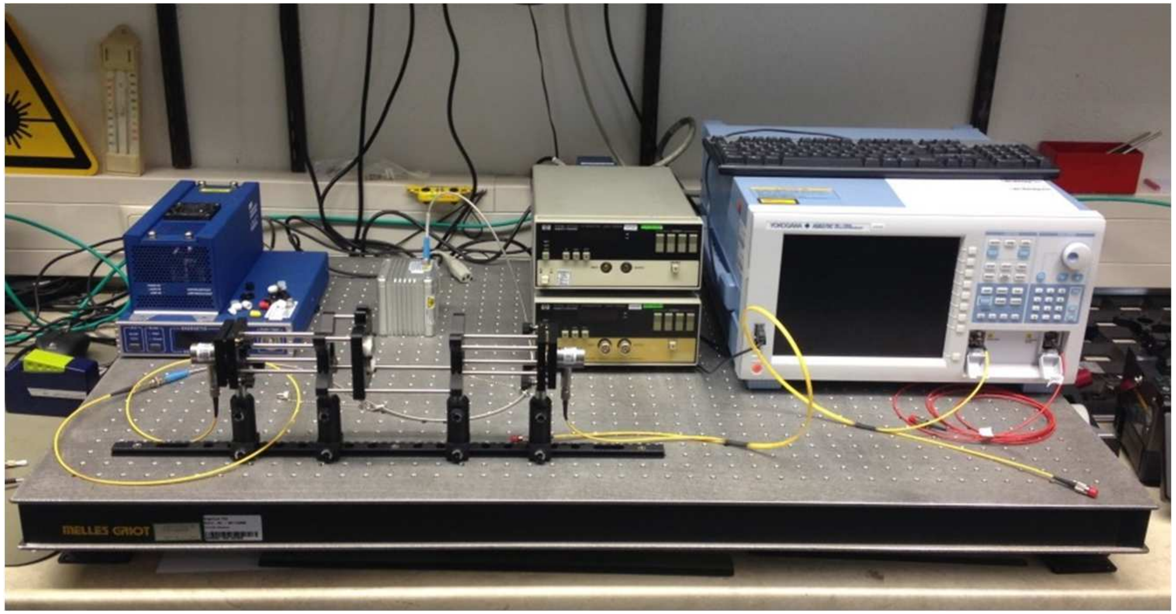
Quelle: NASA JPL

Bulk Optical Materials
Introduction

- Testing usually done step-stress e.g. optical measurements are done outside the irradiation chamber
- Testing of induced absorption sometimes done by irradiation lab. For more specialized measurements
  - Bring your own setup. (might not be feasible)
  - Have the samples sent to optical lab (might need more samples, problem with annealing)
- No irradiation standard for optics, but ISO 15856 covers materials in general
  - Use protons with 2 MeV to 200 MeV and electrons > 0.5 MeV (electrons can be substituted by Co-60 which has no ESD problem)
  - Some materials (e.g. transparent polymers) are very sensitive to oxygen. Irradiate in vacuum (max 10^{-2} Pa) or inert gas

Bulk Optical Materials
Typical Test Setup





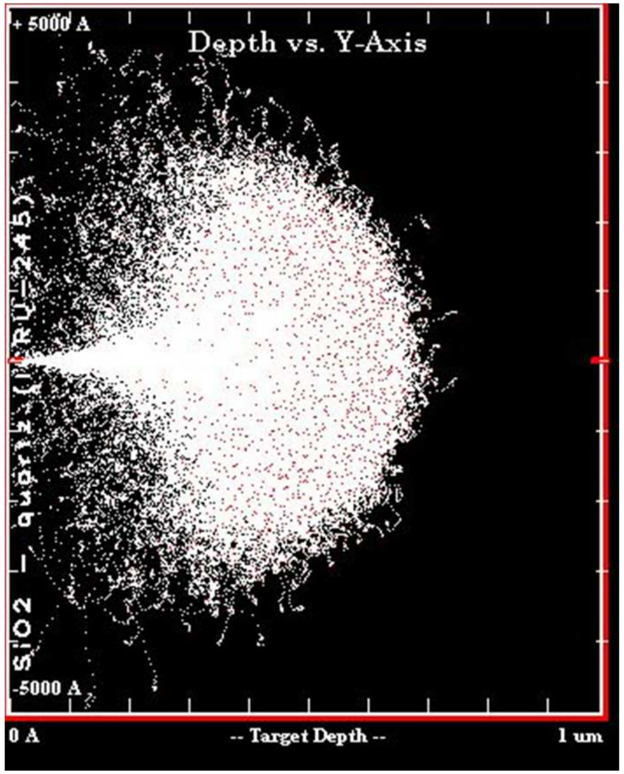
Bulk Optical Materials
Typical Results

TIE-42, Schott AG

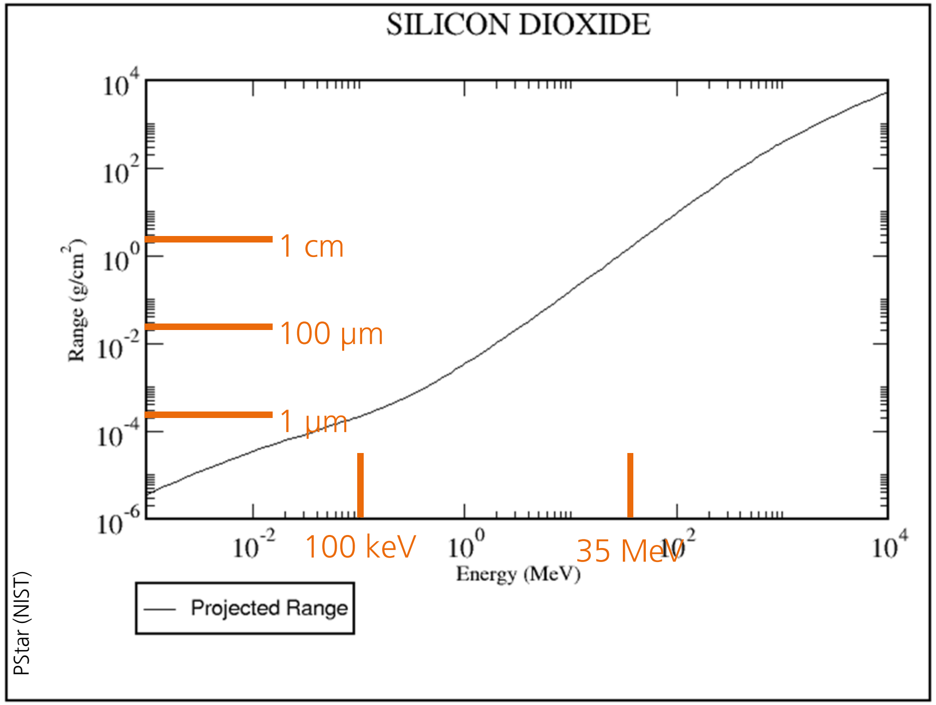
Surface Effects
Introduction

- ISO 15856 classifies surface effect up to 4 mg/cm² (about 18 µm SiO_2)
- Surface effects are a problem in environments with high fluxes of low energy particles (e.g. radiation belts)
- Proposed particles protons with energies of 10 keV to 1 MeV and electrons from 10 keV to 500 keV, no Co-60!
- Problem for thin optical films, especially when directly exposed to space

Surface Effects
Irradiation planning for protons



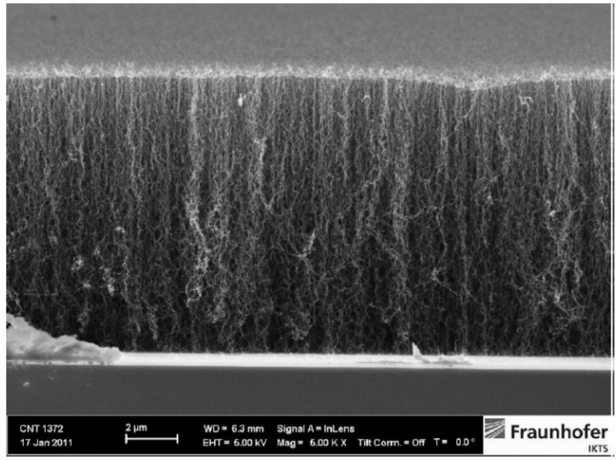
50 keV protons

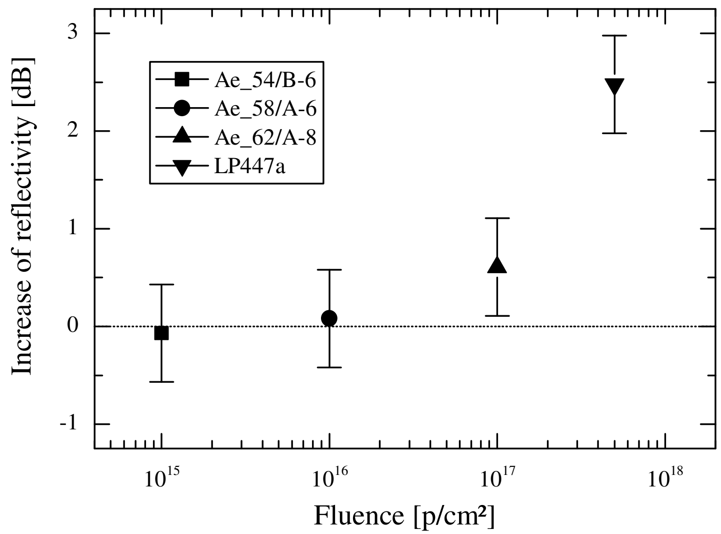


Surface Effects

Example: Vertically Alligned Carbon Nano Tubes

- VA-CNTs are very effective absorber
- Reflectivities of < 1% are possible over very broad wavelength spectrum (typical black paint has 2% to 4% reflectivity)
- Functionality is dependent on structural integrity of the nano tubes and their surface quality.
- Irradiation up to 1.2 Grad showed no measurable effect (though done with Co-60!)
- Test with 150 keV protons showed effect on reflectivity



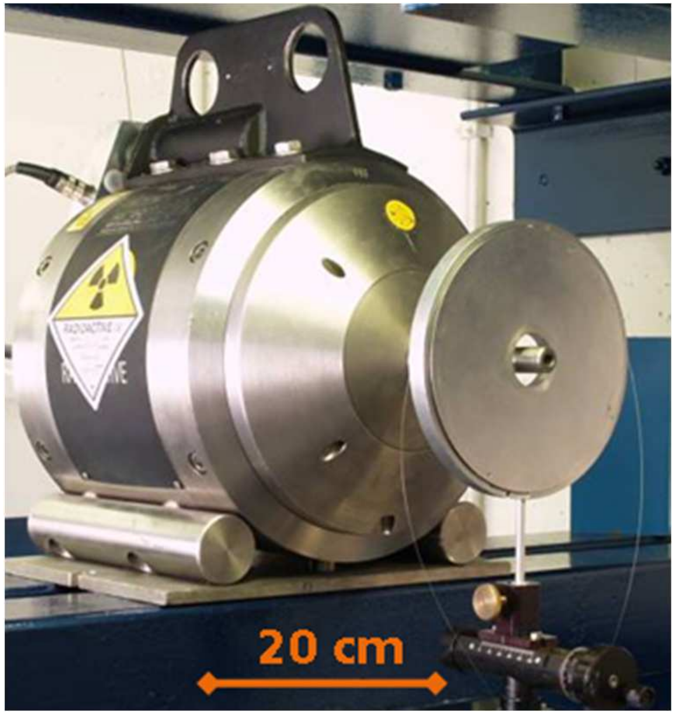


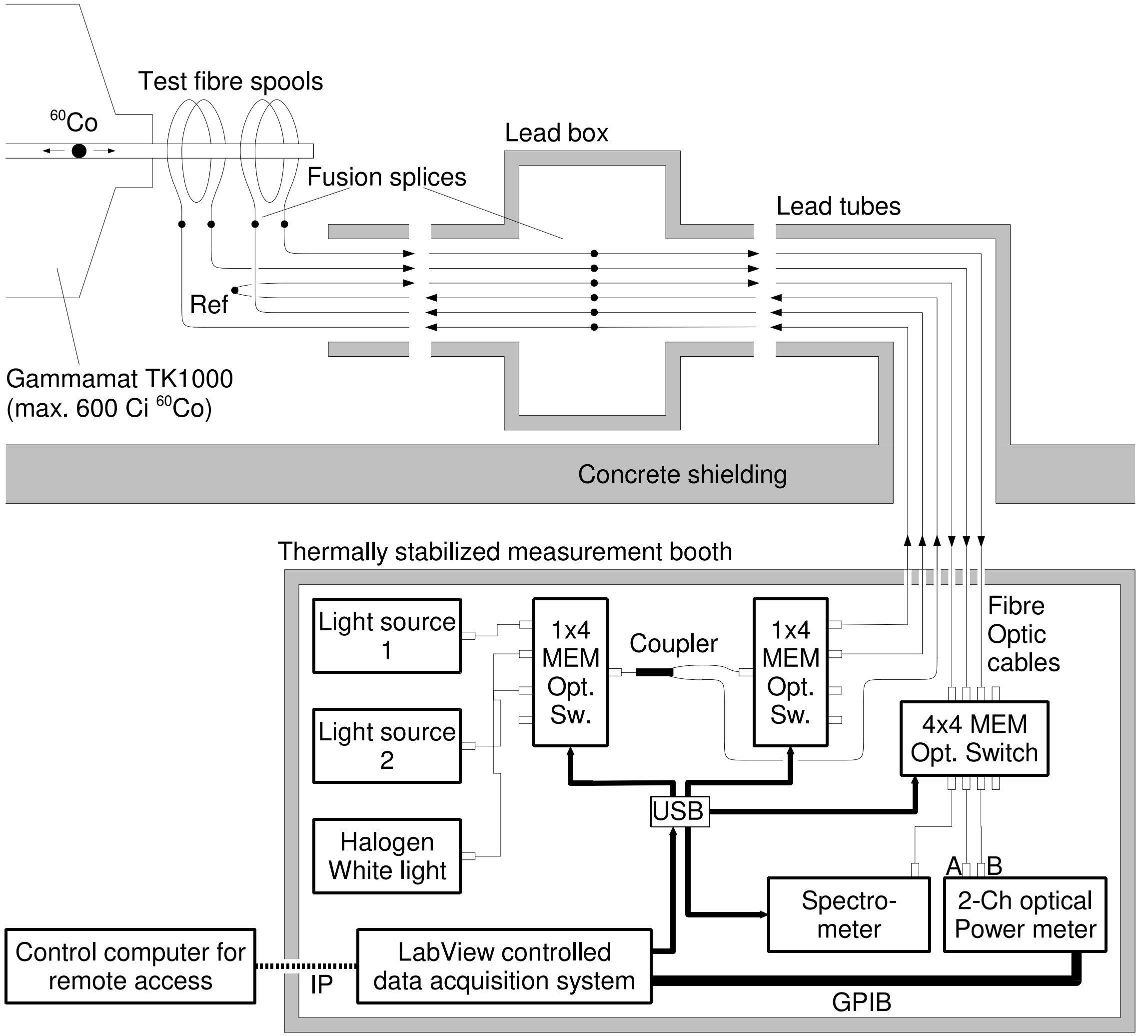
Optical Fibers
Differences to Bulk Glasses

- Optical fibers are optimized for ultra low absorption to guide the light over large distances ⟶ small changes in transmission may get significant.
  - Example: 100 m optical fiber @ 800 nm after 1 Mrad.
    - Pure silica fiber: 1 mW ⟶ 0.89 mW
    - P-doped fiber: 1mW ⟶ 10^{-200} mW

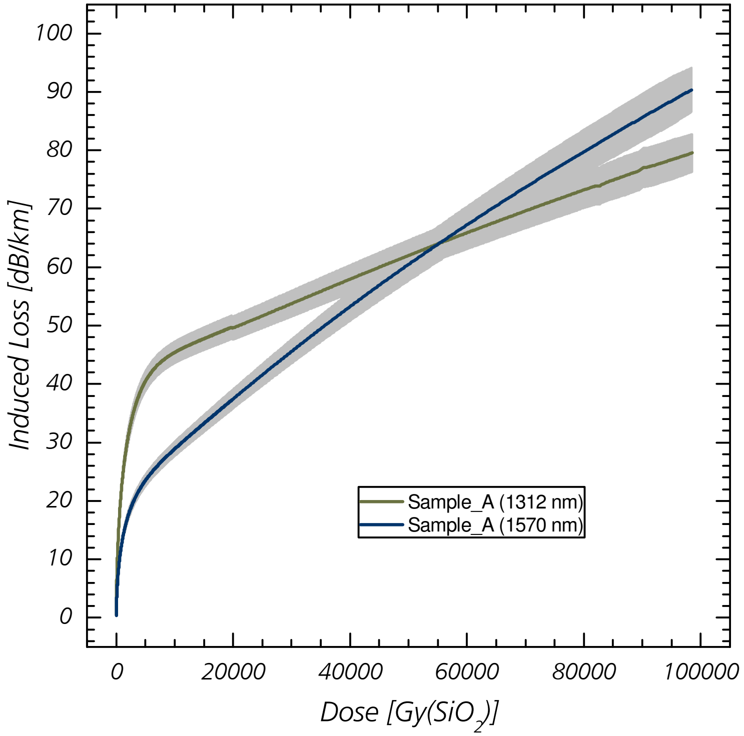
- Testing is usually done online
  - Need for highly stable equipment and environment
  - Need to irradiate exclusively

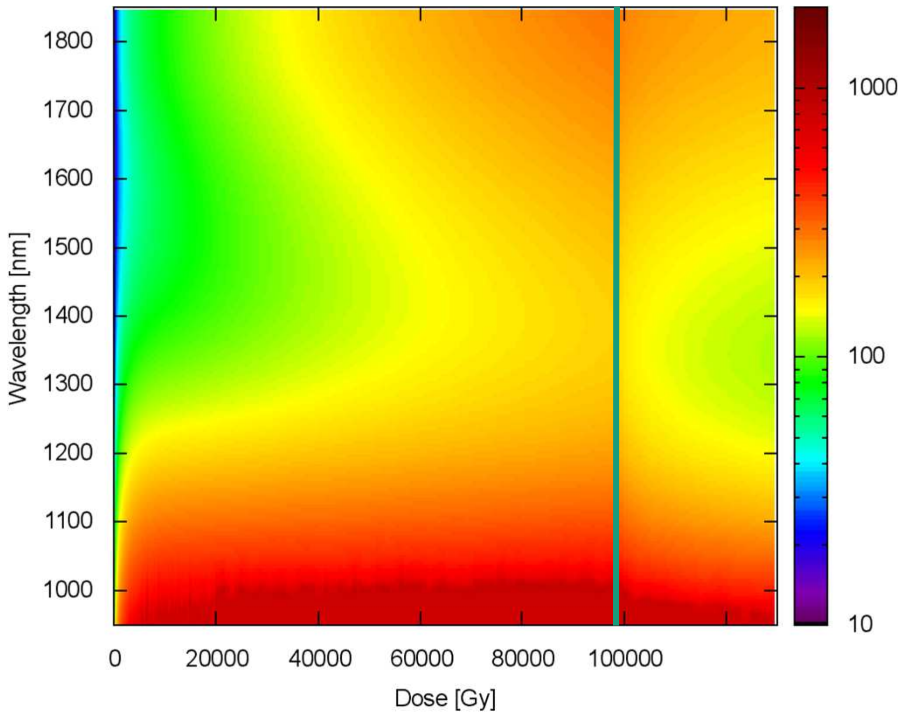
Optical Fibers
Typical Irradiation Setup





Optical Fibers
Typical Results





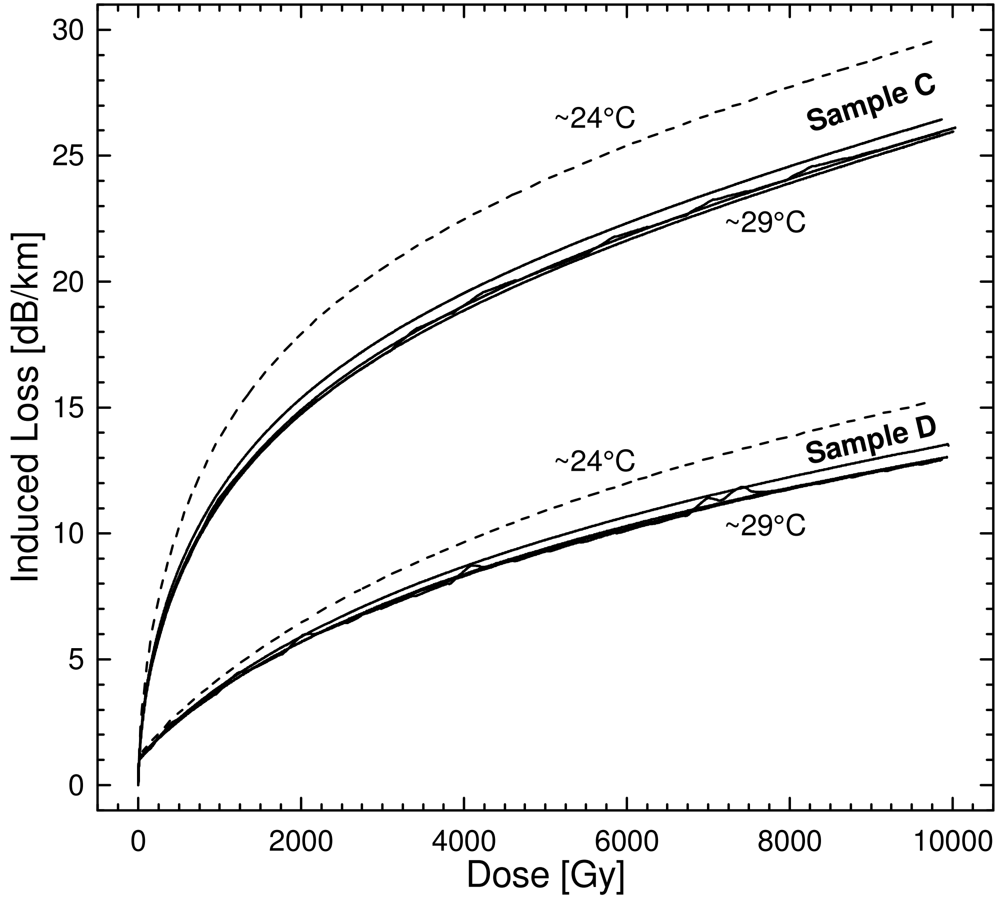
Optical Fibers
Different Test Standards

Parameter	FOTP-64	IEC 60793-1-54	ASTM E1614
Wavelength [nm]	850,1310,1550±20	x±20, 3 dB Breite	250 – 2100
Light Power	1 µW	1 µW	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
Doserate	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
Fiber Length	100 m	250 m (or shorter)	50 m

(*) deleted 2012

Optical Fibers
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
- Is the difference significant?
- Yes! Because small differences of 5 °C can produce a 15% different RIA.



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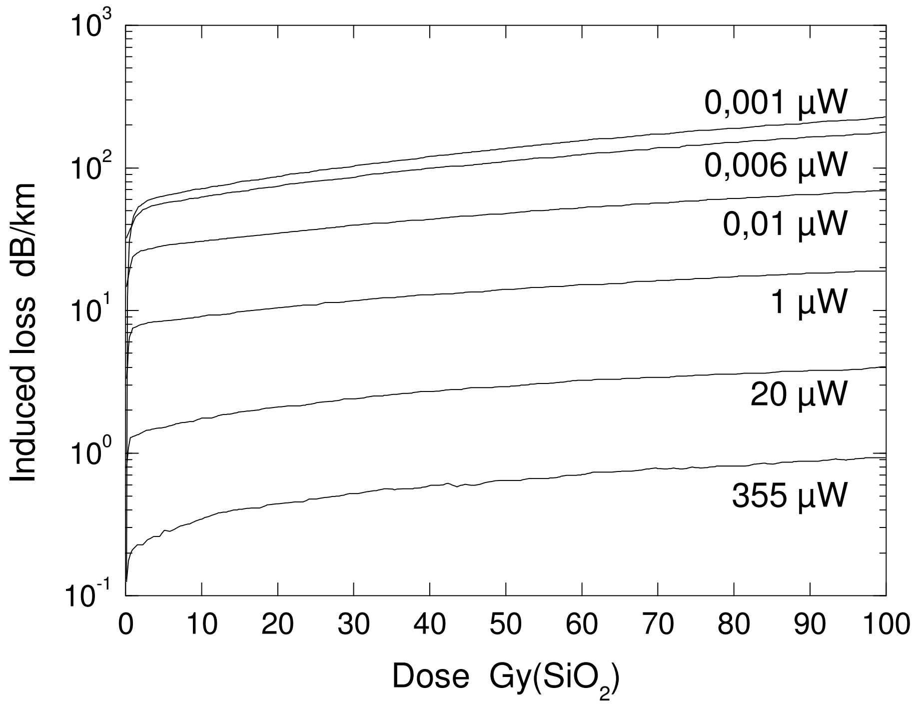
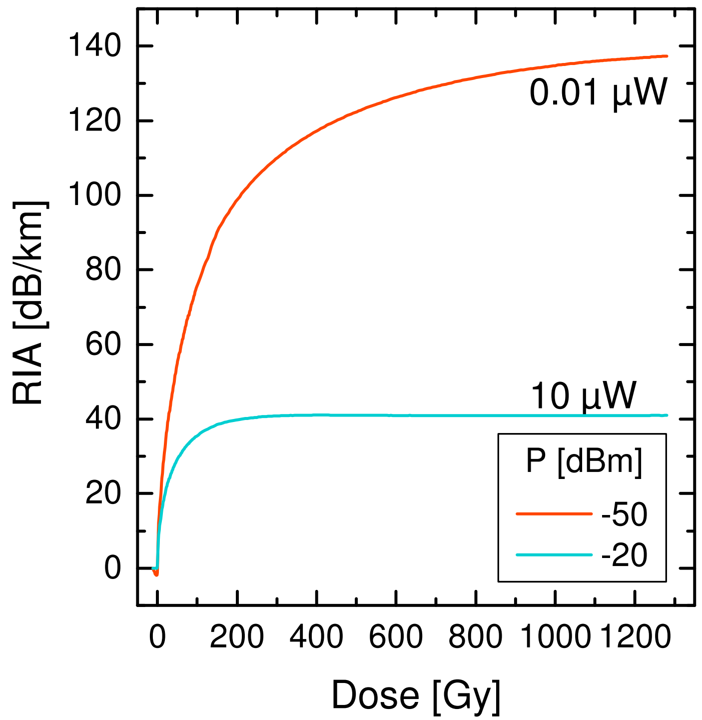
Optical Fibers
Photobleaching – Still an Issue?

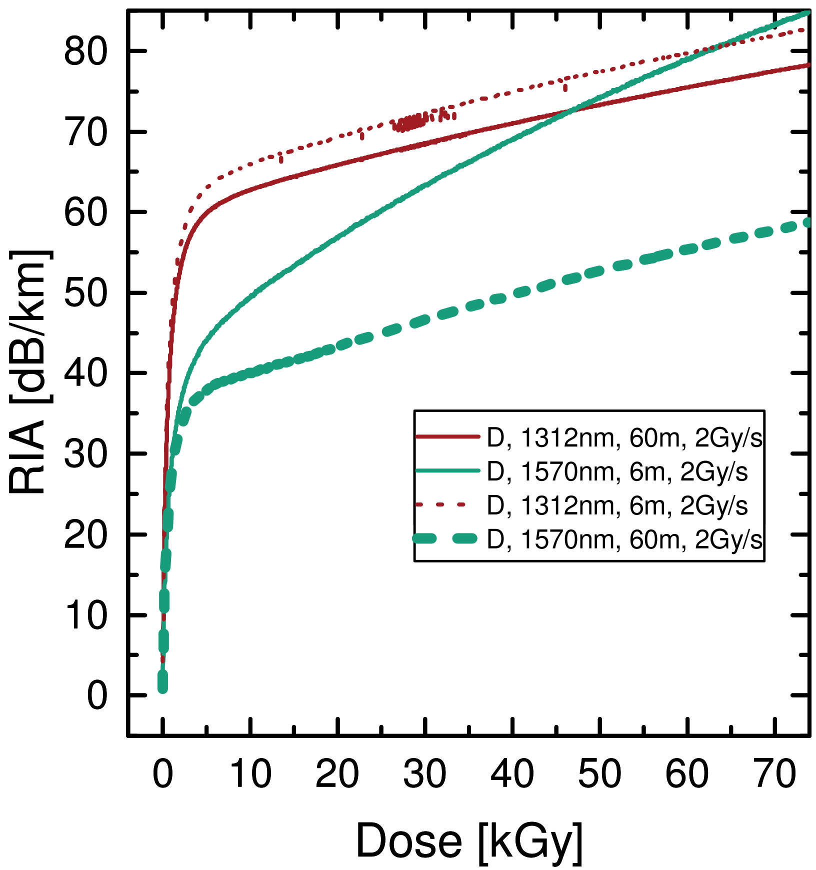
Old measurements form Henschel 20 years ago



New measurements from Kuhnhenn 2013



Optical Fibers
Bending Radius of Fiber Spools

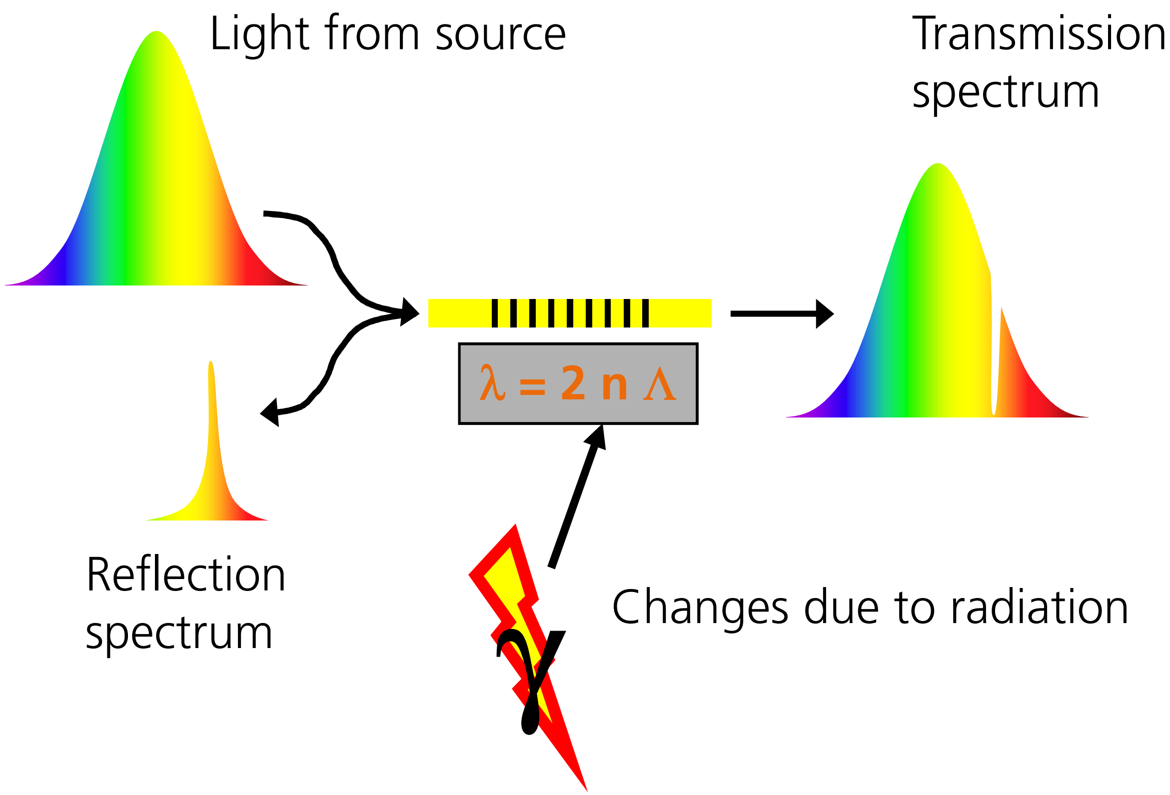


- Corning SMF28e
- 1 Gy/s ⇔ Spool ∅ 6 cm
- 2 Gy/s ⇔ Spool ∅ 4 cm

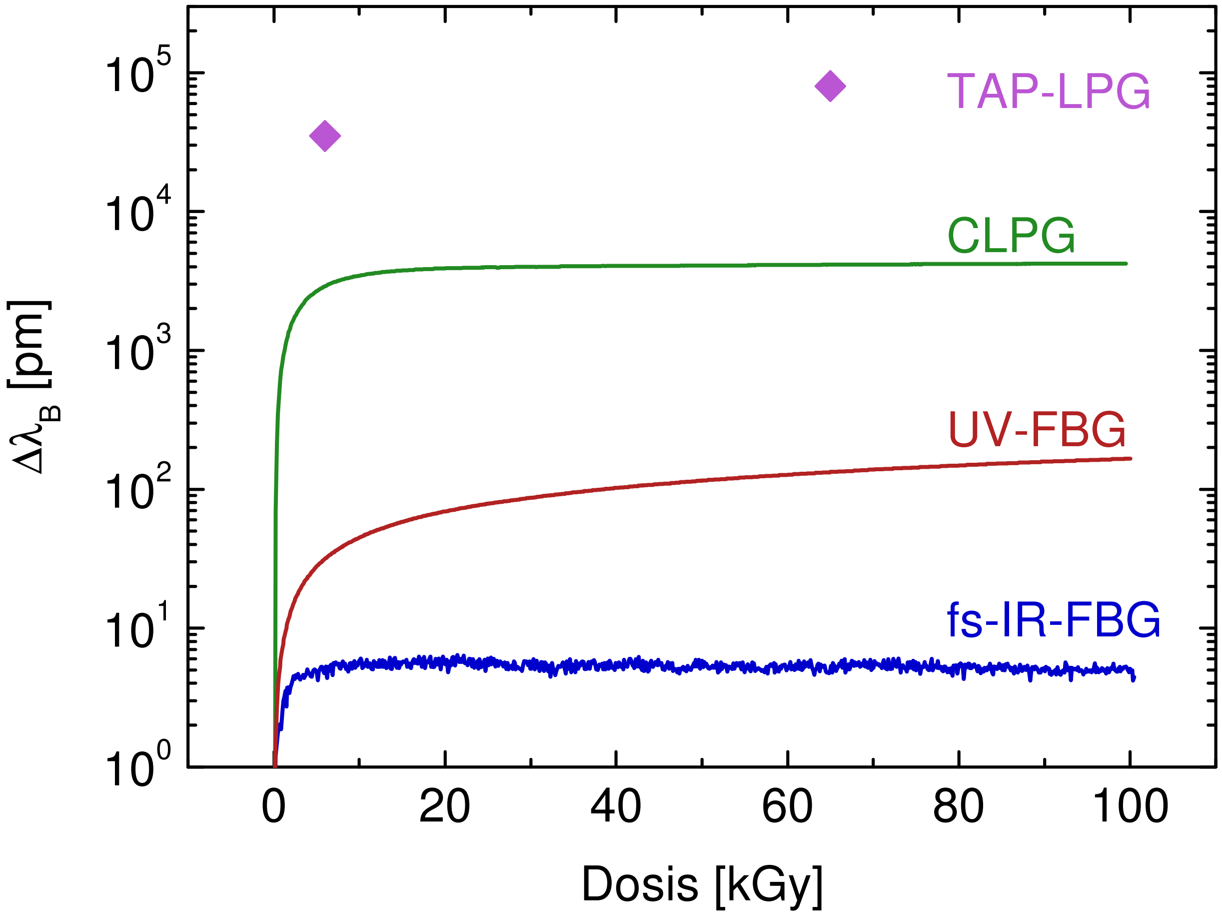
- Strong influence of bending radius on RIA
- OTDR-Messungen showed no significant influence of bending radius before irradiation!

Fiber Bragg Gratings (FBG)
Introduction

- Applications of FBGs:
  - Temperature sensors
  - Strain sensors
  - „Mirrors“ for fiber lasers



Fiber Bragg Gratings (FBG)
Examples of Different Technologies



Fiber Bragg Gratings (FBG)
Test Challenges

- Irradiations are done online, as with fibers
- There might be statistical variations from grating to grating due to fluctuations in manufacturing
- Possibility to test large number of FBGs due to multiplexing
- FBGs are strain sensors ⟶ strain free setup necessary during irradiation
- FBGs are temperature sensors ⟶ irradiate in environment as temperature stable as possible, correct for remaining variations

Thank you for your attention!

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