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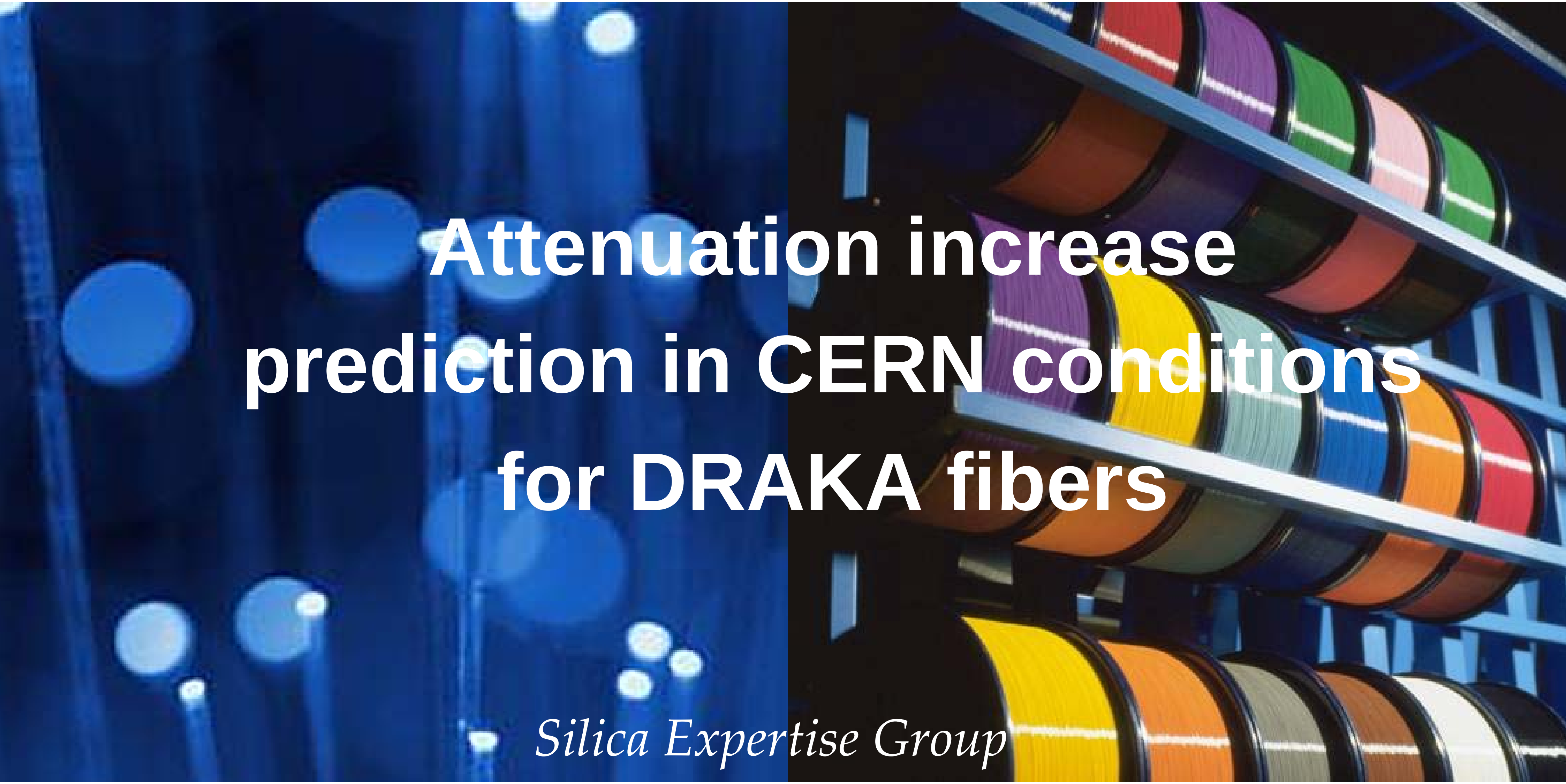

Attenuation increase prediction in CERN conditions for DRAKA fibers

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Purpose:

Predict Radiation Induced Attenuation (RIA) at low dose-rate, over a large period (CERN conditions), based on RIA-measurements performed at higher dose-rates (Fraunhofer Institute).

Problem:

- RIA is not linear with dose / exposure time.
- high dose-rates measurements cannot be directly extrapolated to low dose-rates

$\Rightarrow$ The understanding of RIA phenomena is very important

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Kinetic modelling of radiation induced attenuation (RIA)

- Time dependence for defect generation <u>without annealing</u>: $$\frac{dn_1}{dt} = a_1 \dot{D}$$

$\Rightarrow$ solution: $\boxed{n_1 = a_1 \dot{D} t}$ or $n_1 = a_1 D$

D: total dose
$\dot{D}$: dose-rate
a_1: probability of defect generation

Non-reversible mechanism

- Time dependence for defect generation with finite lifetime:

$$\frac{dn_2}{dt} = a_2 \dot{D} - \frac{n_2}{\tau_2}$$

$\dot{D}$: dose-rate, n_2: defect concentration, τ_2: lifetime, a_2: probability of defect generation

$\Rightarrow$ solution of saturating exponential type: $$\boxed{n_2(t) = a_2 \dot{D} \tau_2 [1 - \exp(-\frac{t}{\tau_2})]}$$

Reversible mechanism

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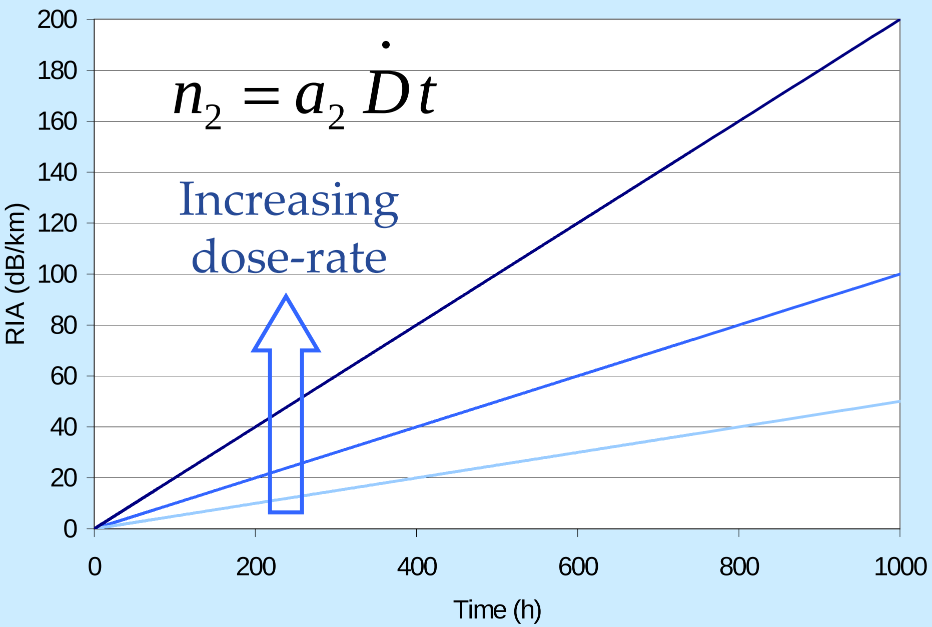
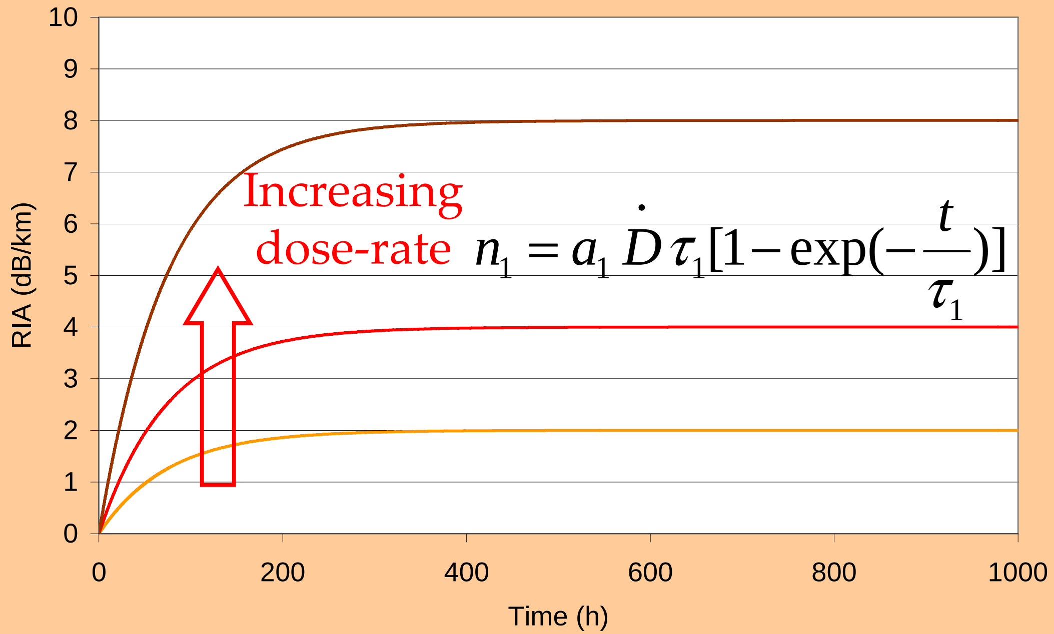
Non-reversible mechanism



Depends only on total dose
(or dose-rate x irr. time)

Reversible mechanism

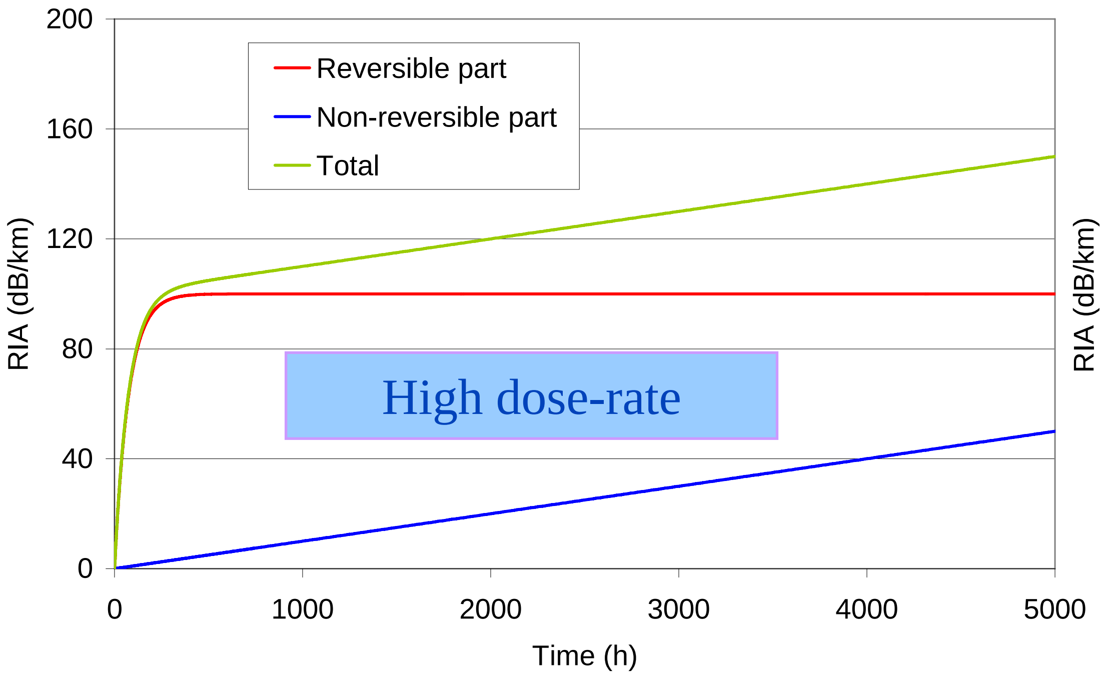


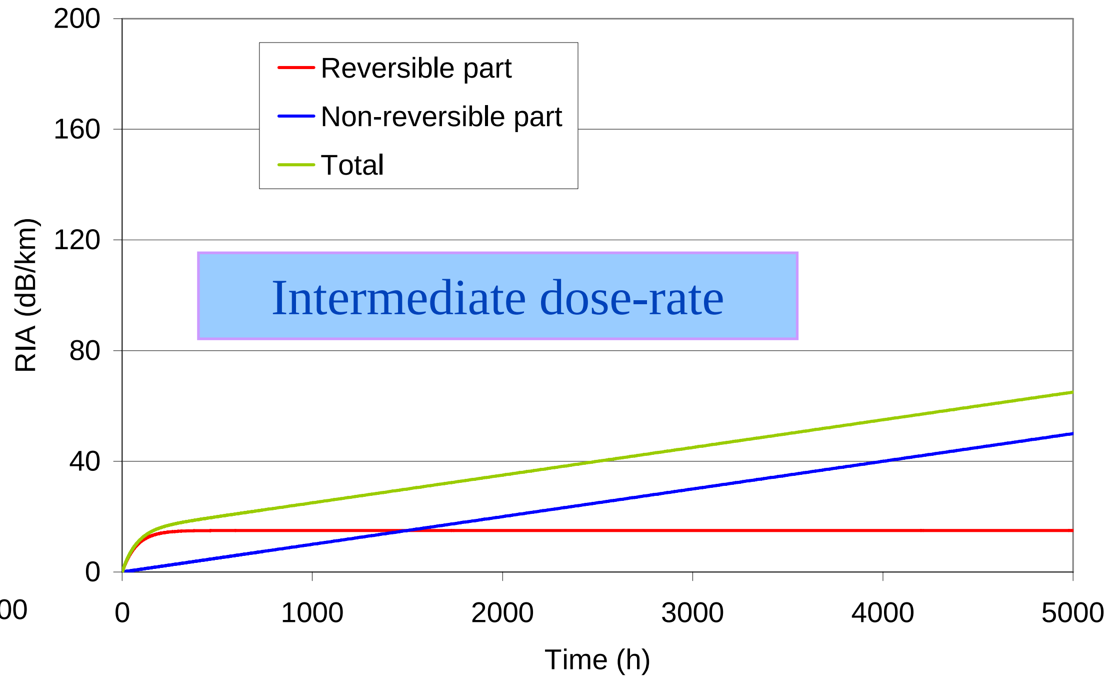
Depends on both total dose AND on dose-rate

$\Rightarrow$ becomes negligible for very low dose-rates

Total RIA = sum of both components

Kinetic model





In order to predict RIA, it is essential to well-determine both:

- the non-reversible component

- the dose-rate dependency of the reversible component

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General

- Our prediction is based on kinetic model
  - reversible component (dose-rate dependent)

  Mainly determined from Fraunhofer Institute’s measurements at 4 different dose-rates

  - non-reversible component

  Determined from both:

  - annealing curves measured at Fraunhofer Institue and

  - spectral attenuation measurements after total annealing

- Our prediction is valid for
  - $\lambda = 1310$nm
  - for DRAKA SMF and Sample 4

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Model for RIA prediction

CERN conditions: Dose-rate = 0.002 Gy/s, Time = 1 year (~ 3.10^7 s)

Reversible part

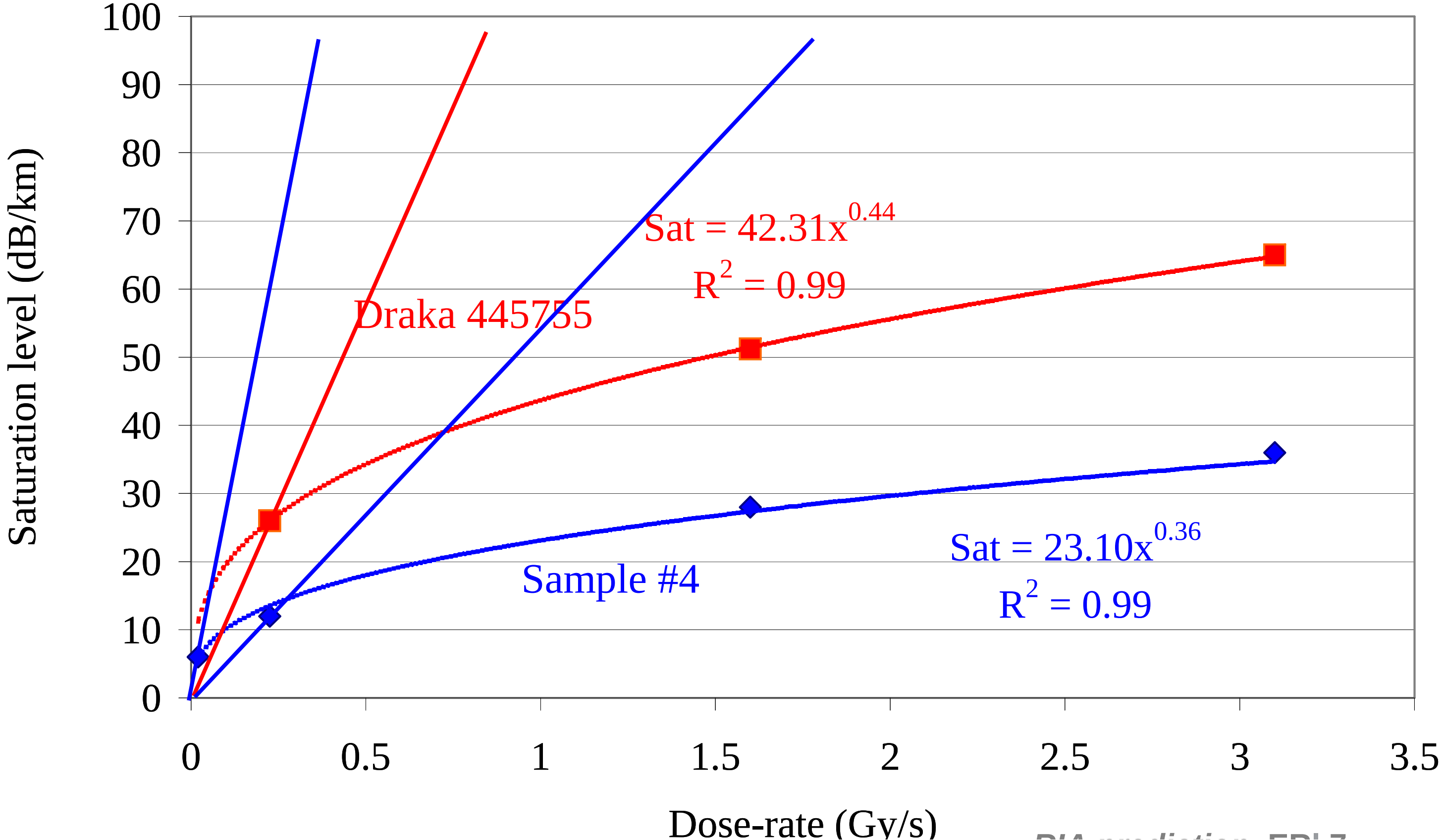
⇒ irradiation time >> τ_2

⇒ Only the saturation level is important

$$RIA_{saturation} = a_2 \dot{D} \tau_2 = C_2 \dot{D}$$

Not a linear behavior

$$RIA_{saturation} = C_2 \dot{D}^{\gamma}$$



$\gamma = 0.44$ for Draka SMF

$\gamma = 0.36$ for Sample 4

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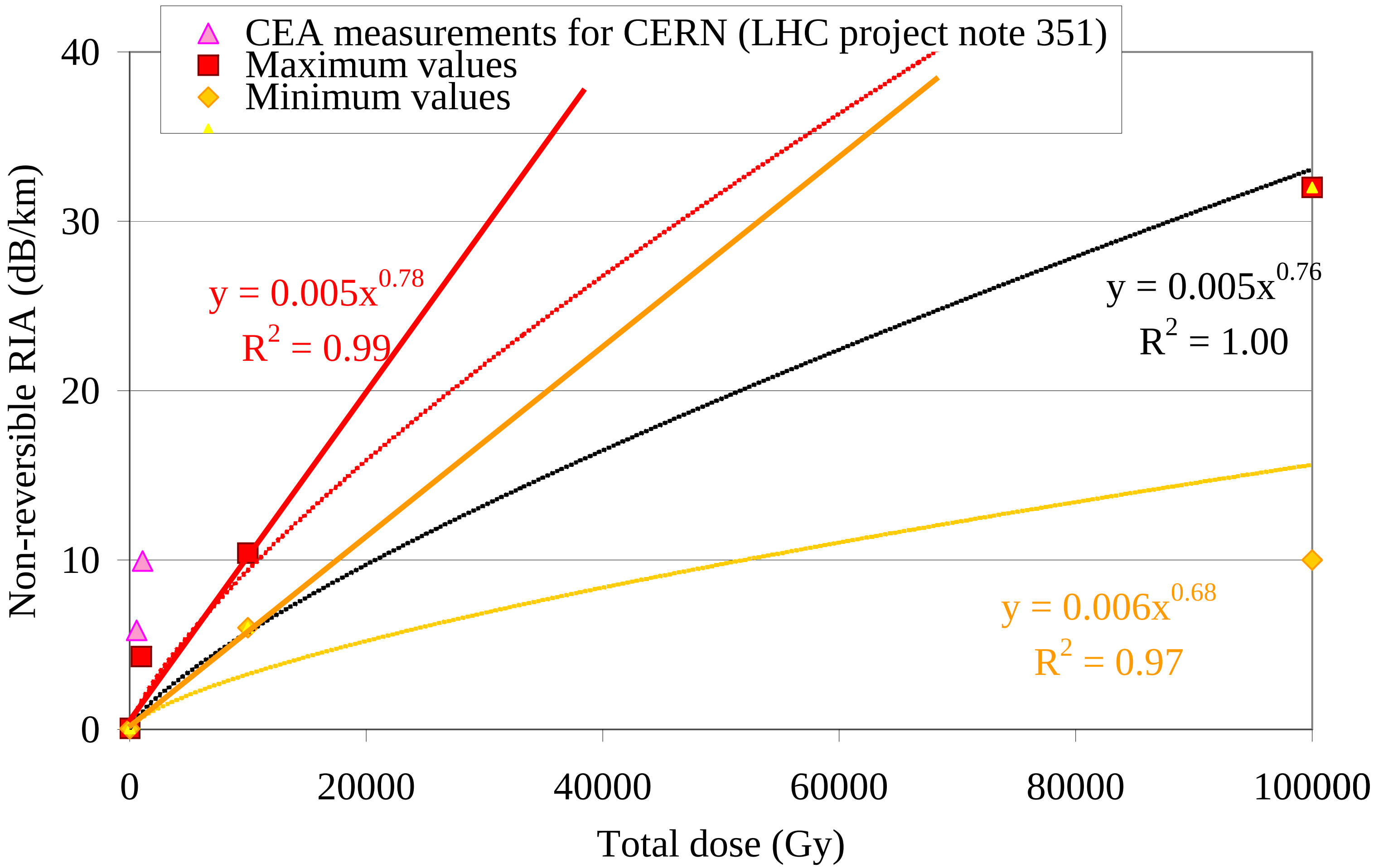
Model for RIA prediction

CERN conditions: Dose-rate = 0.002 Gy/s, Time = 1 year (~ 3.10^7 s)

Non-reversible part



$$RIA_{non-rev} = a_1 \dot{D} t = C_1 D$$

$$RIA_{non-rev} = C_1 D^{\beta}$$

+ see also [Kyoto – 1992]

0.68 < β < 0.78 for Draka SMF

0.47 < β < 0.52 for Sample 4

[Kyoto – 1992], JLT Vol 10, 3, pp289-294

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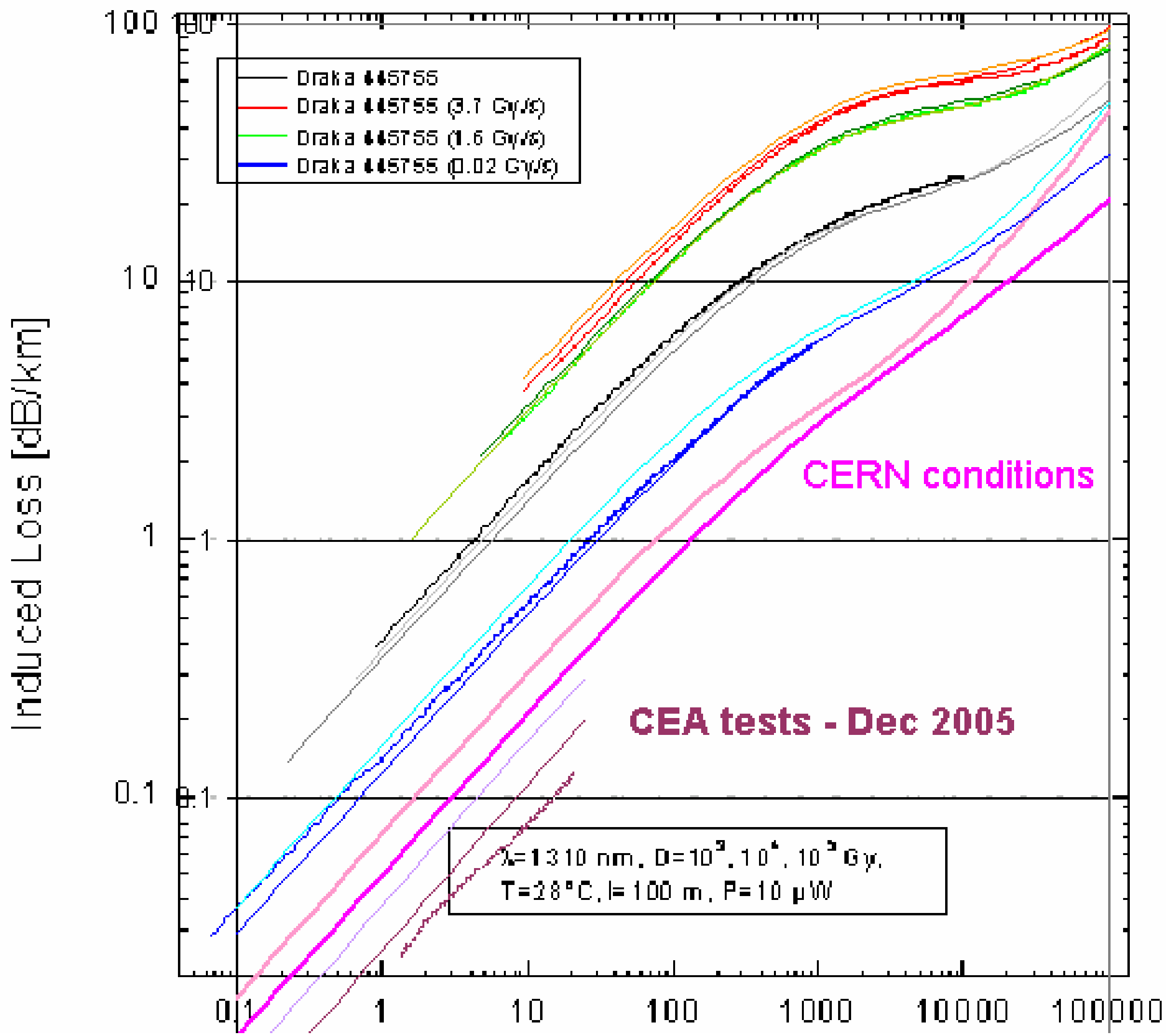
RIA prediction for Draka SMF (Sample #445755)



CEA tests were performed at RT, power ~ 0.5mW,

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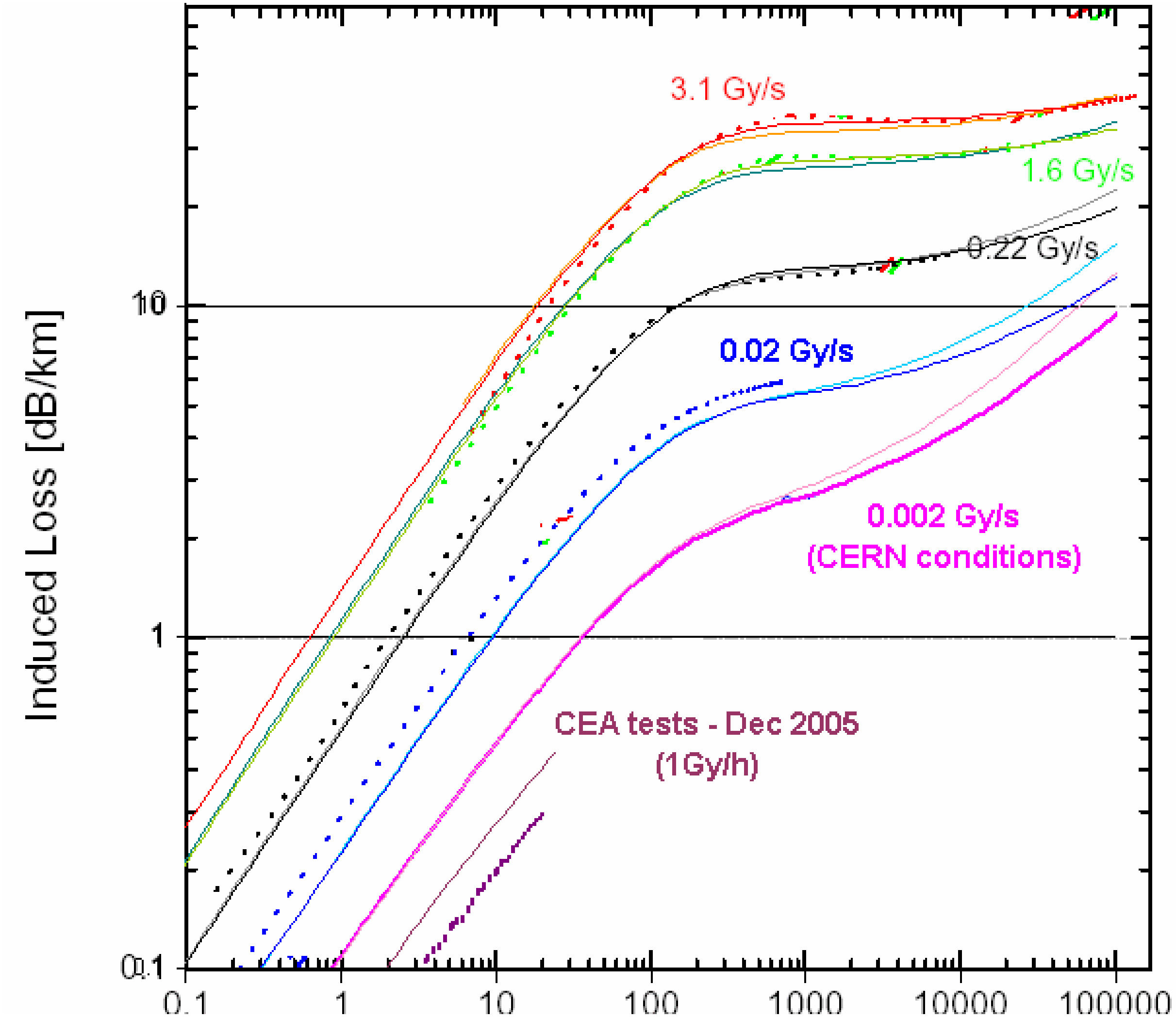
RIA prediction for Sample 4



CEA tests were performed at RT, power ~ 0.5mW,

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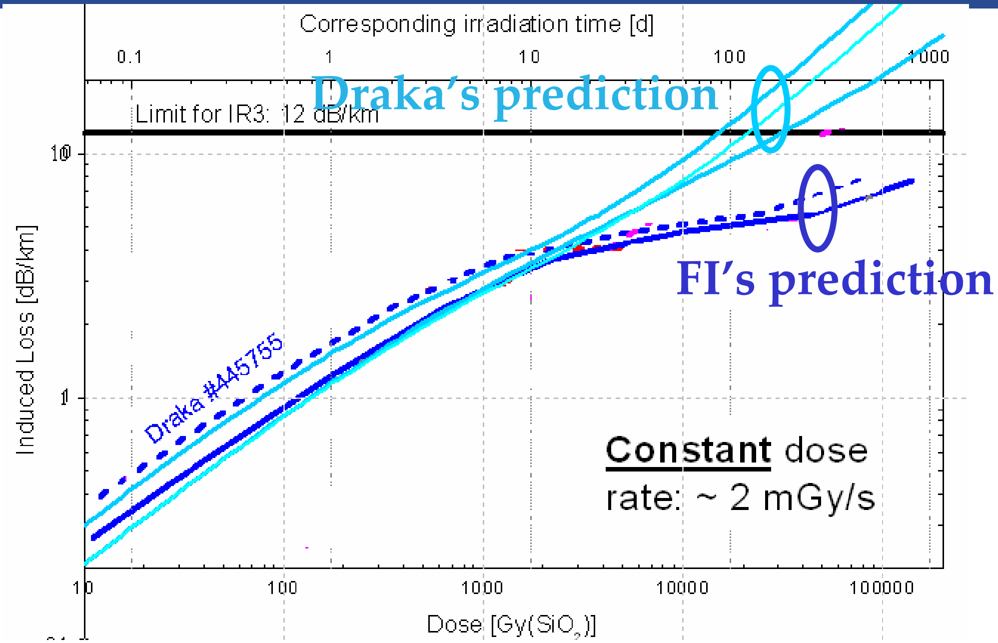
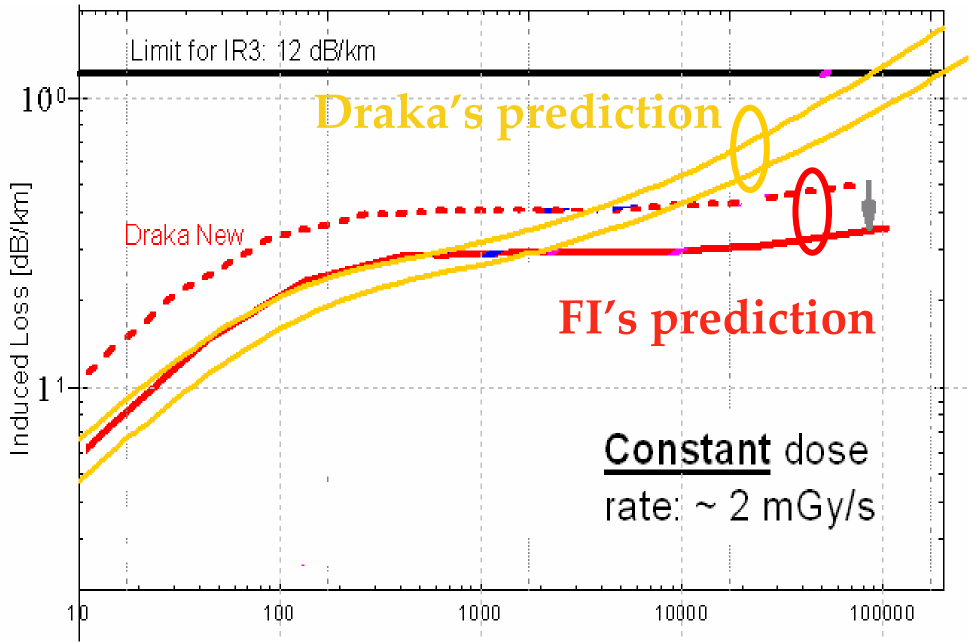
Prediction for CERN conditions (mean dose-rate = 0.002 Gy/s)



RIA(Draka SMF)> 12 dB/km for doses > 16 000 to 33 000 Gy

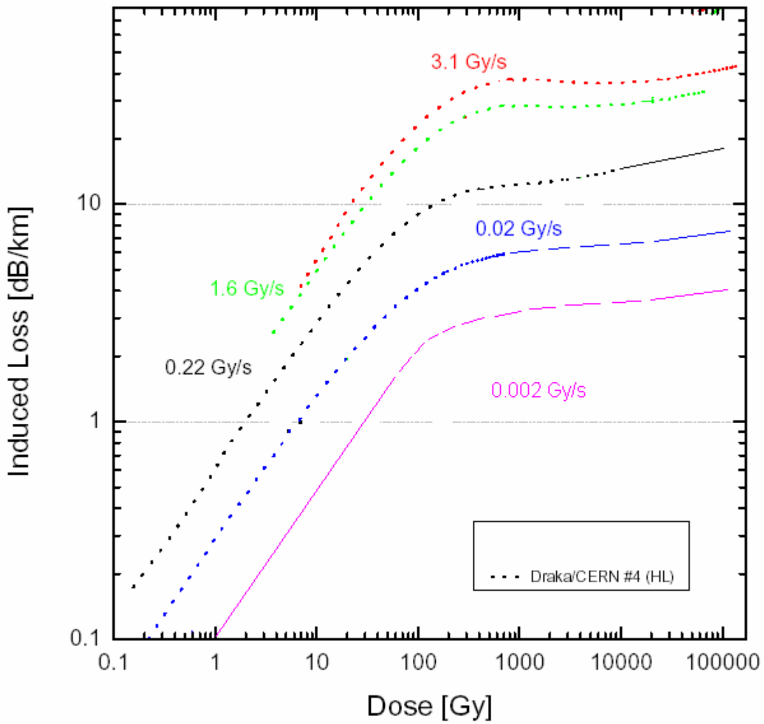
=> The fiber has to be changed every 1 or 2 years.

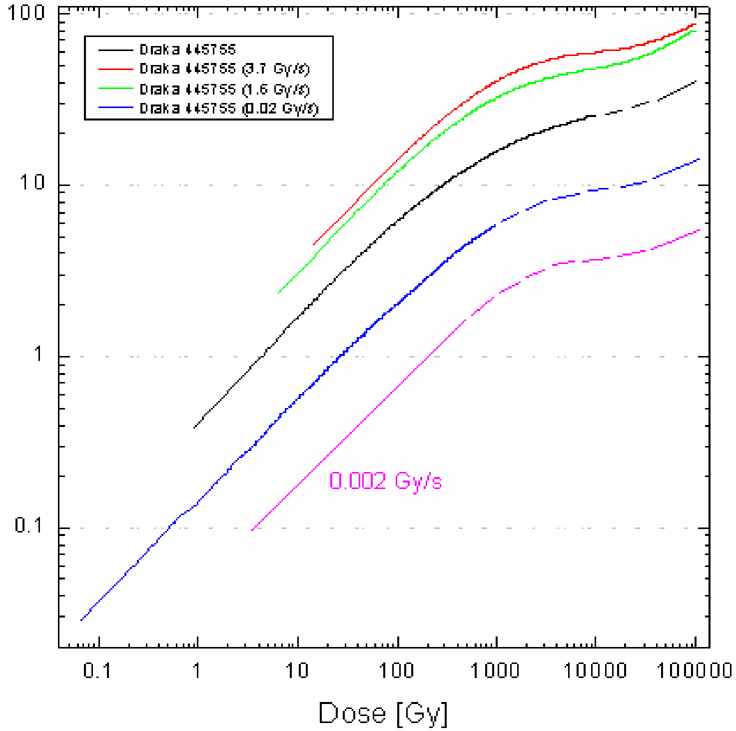


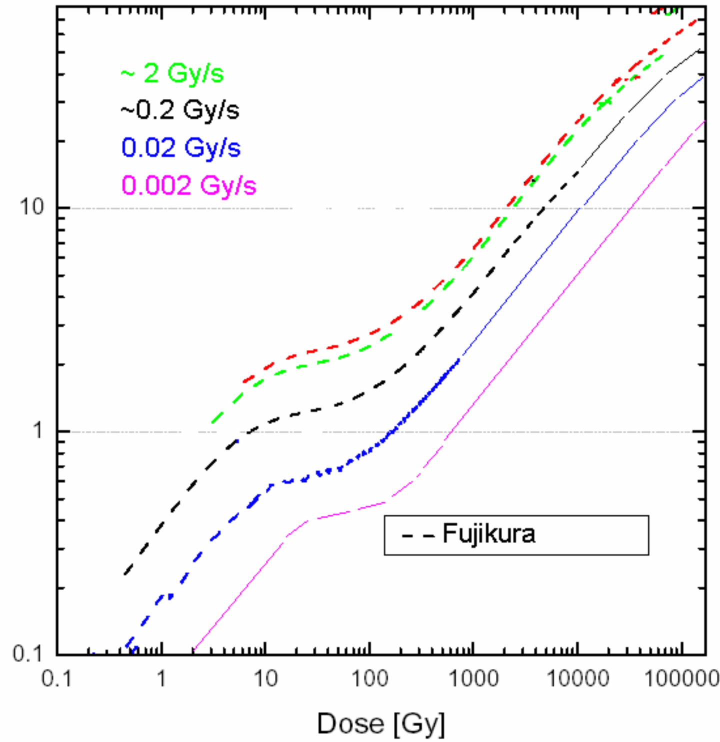
RIA(Sample 4)> 12 dB/km for doses > 100 000 Gy at least

=> The fiber does not need to be changed for 4 to 8 years.

Rough extrapolation based on RIA curves shifting (FI extrapolation)







⇒ Parallel RIA curves (in log scale) mean that the difference between curves obtained at different dose-rates increases with increasing doses.

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Experimental results at high doses / diff. dose-rates

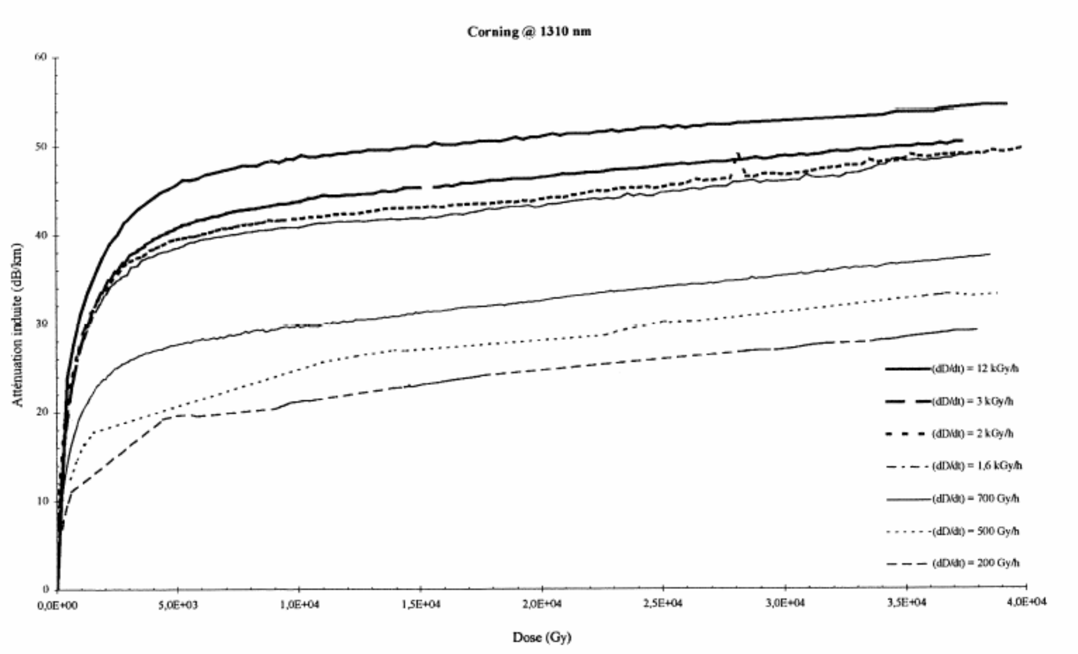

Figure 4.14: Atténuation induite dans la fibre Corning à 1310 nm en fonction de la dose totale, pour différents débits de dose.

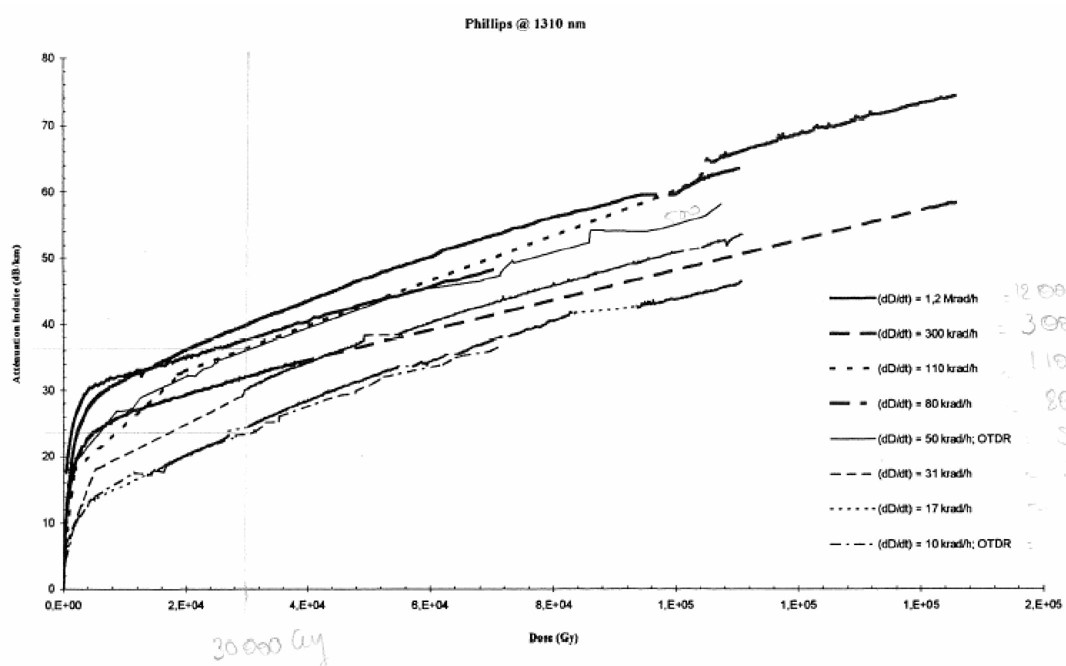

Figure 4.17 : Atténuation induite dans la fibre Philips à 1310 nm en fonction de la dose.

Figures issued from M. Van Uffelen's PhD report

⇒ According to M. Van Uffelen's results, RIA curves are parallel in linear scale. That means that the differences between curves obtained at different dose-rates is constant.

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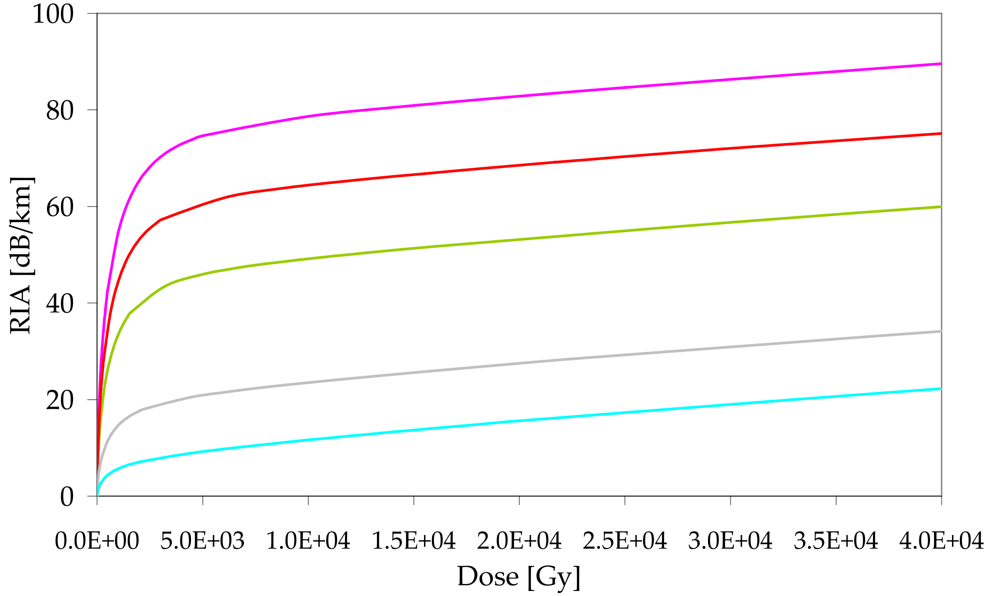
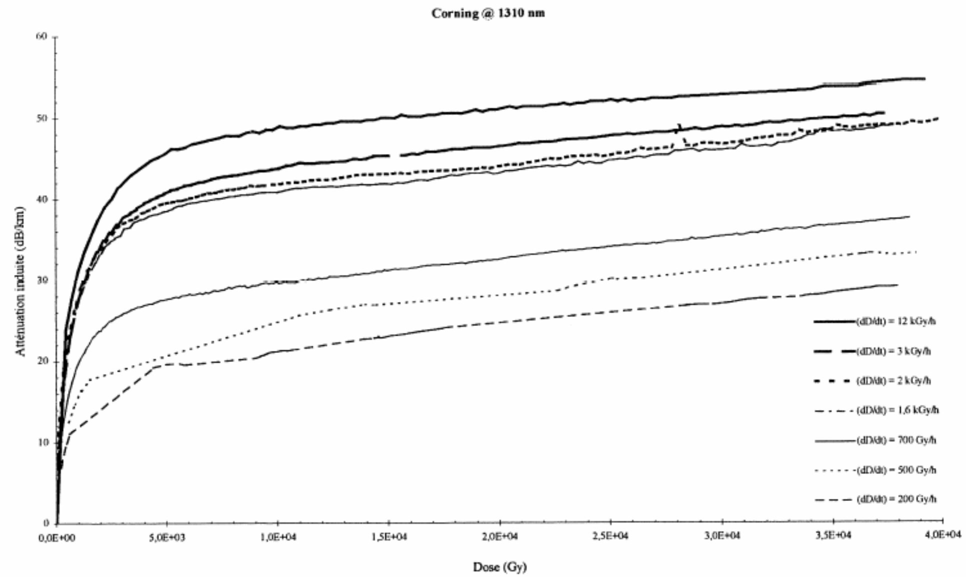
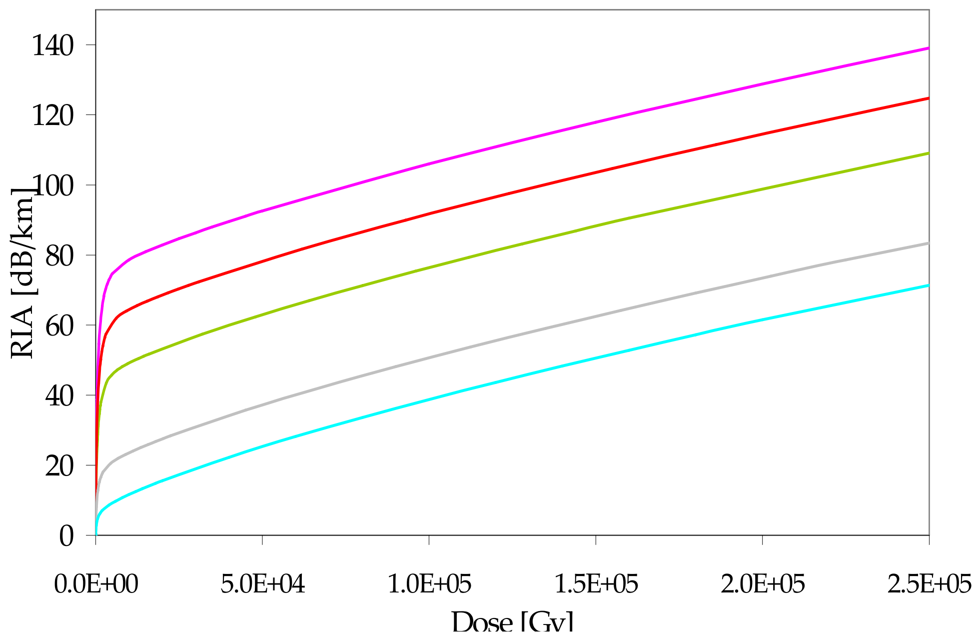
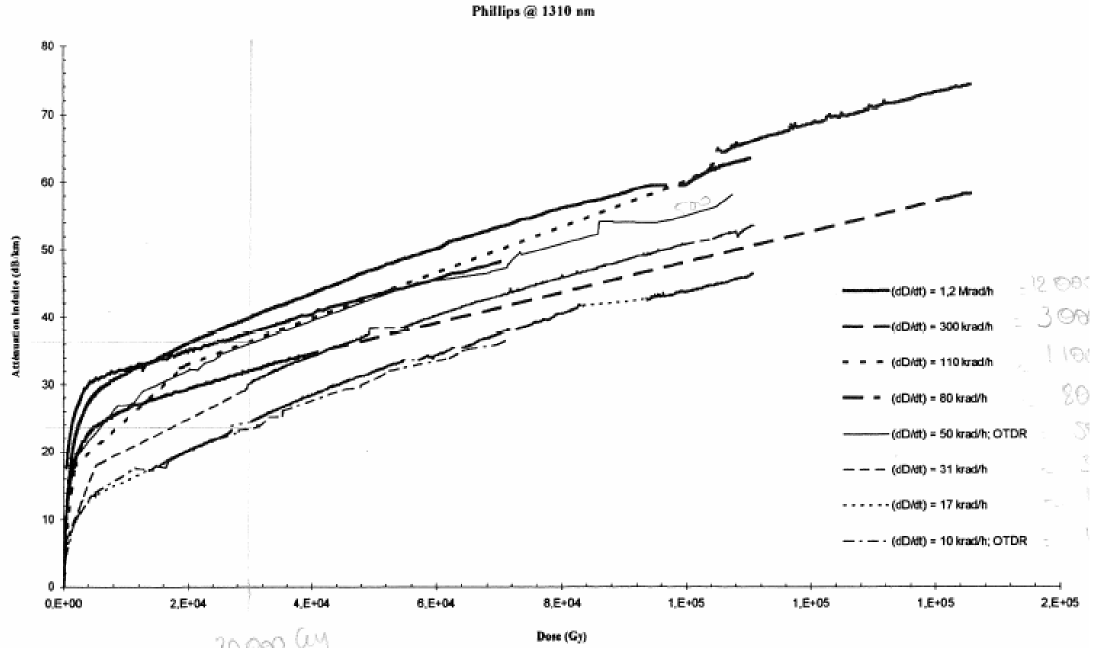
Comparison Draka's model / experimental results at high doses









Weak points of Draka model

- The model is valid only for λ=1310nm, at RT.

- We have a big uncertainty on the non-reversible part (a factor 3 for dose = 100 000 Gy).

- Some fibers may have several reversible components.

- The model has to be adjusted for each fiber type => to do that, a few experimental data are needed.

- How to reduce the uncertainty on the non-reversible part?

⇒ attenuation measurement at 1310nm for 3 different doses (10, 10^3, 10^5 Gy), after total annealing.

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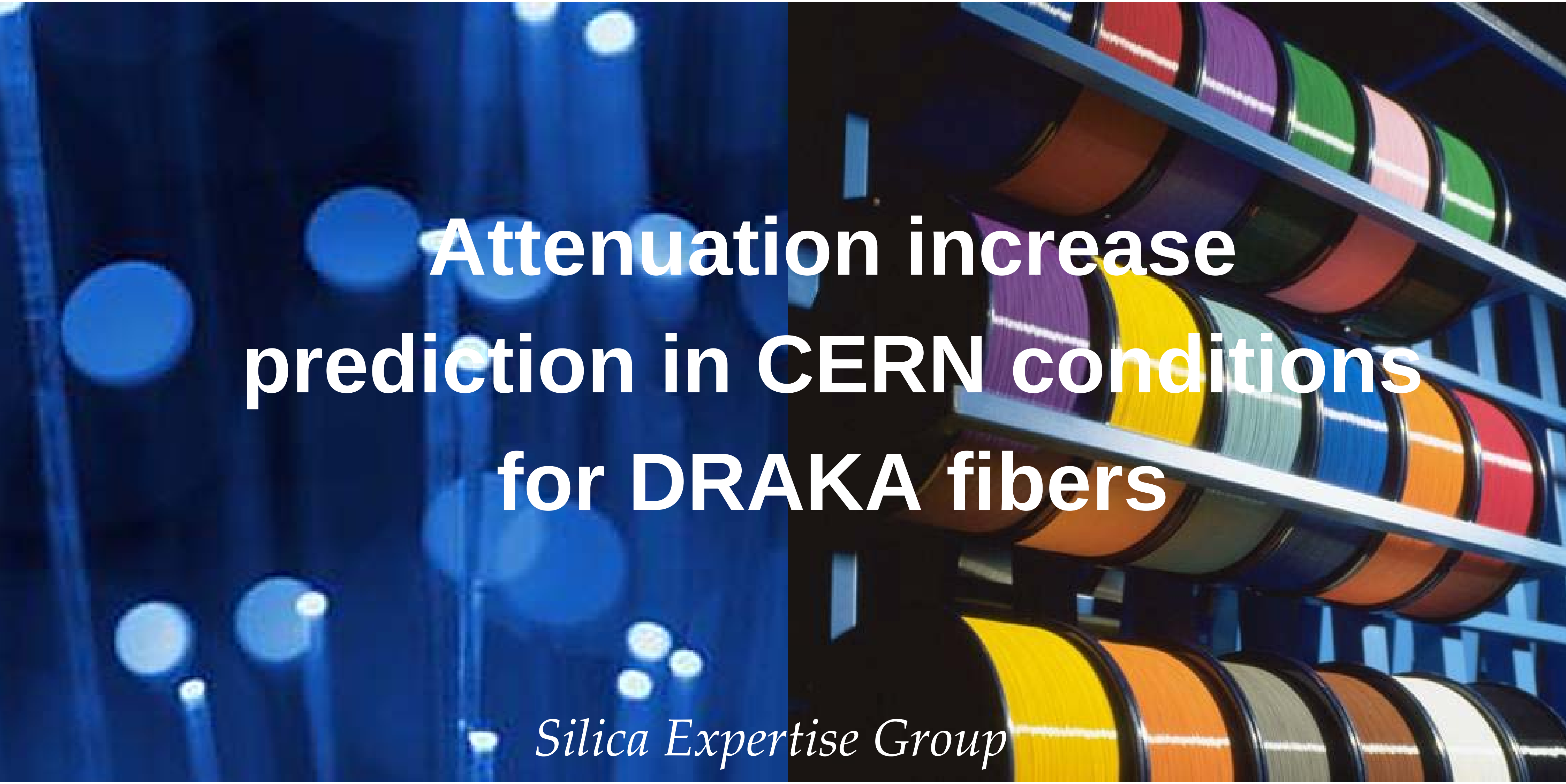
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