

Radiation-Induced Attenuation On Commercial Optical Fibers

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SECOND CNES/ESA FINAL PRESENTATION DAYS

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Defects in SiO₂

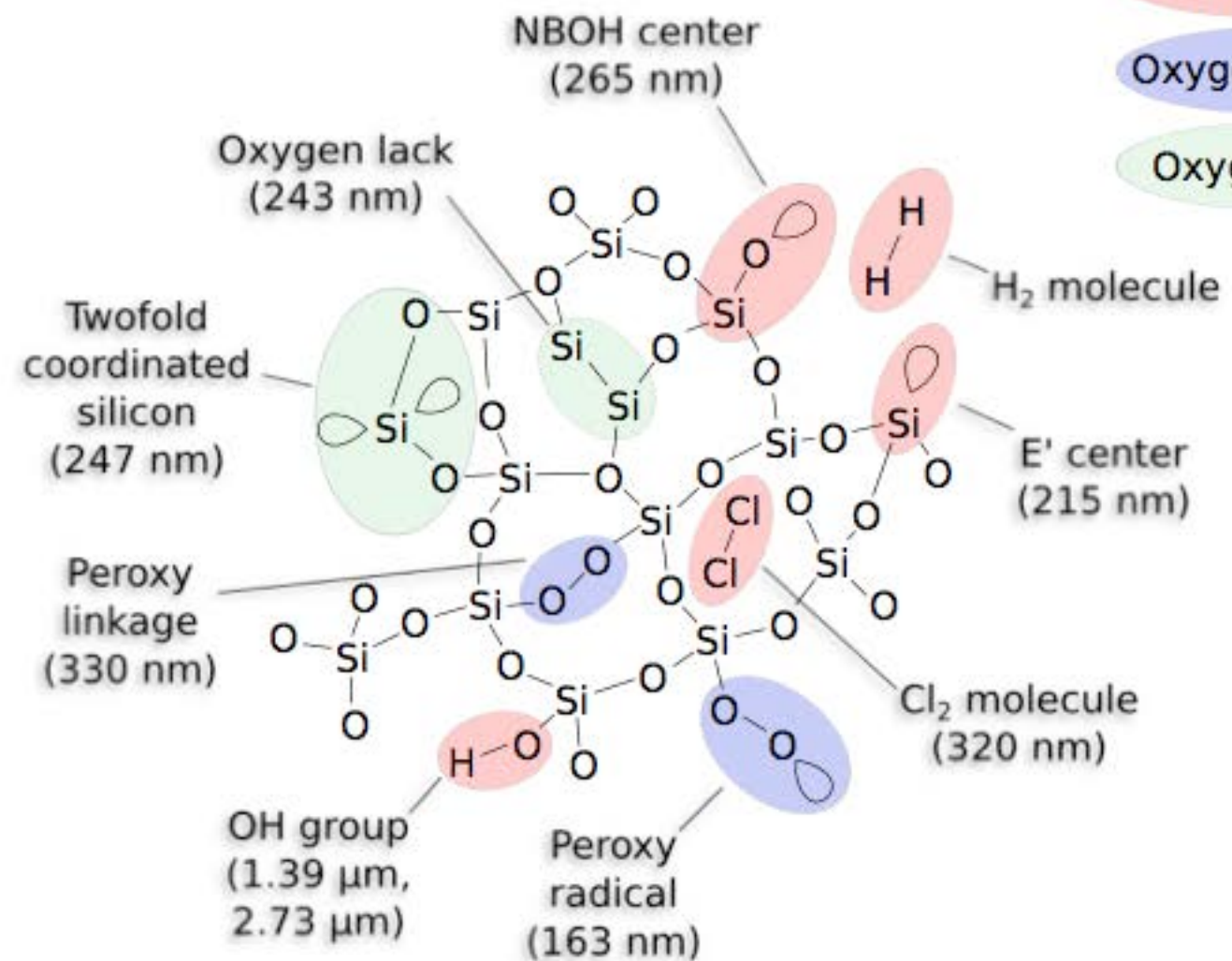
- Pre-irradiation defects

- ✓ *Intrinsic Defects* →

- ✓ *Extrinsic Defects : transition-metal impurities such as Fe, Cu, Co, Ni, Mn, and Cr*

- Radiation-induced defects

- ✓ *Electronic and structural modification*



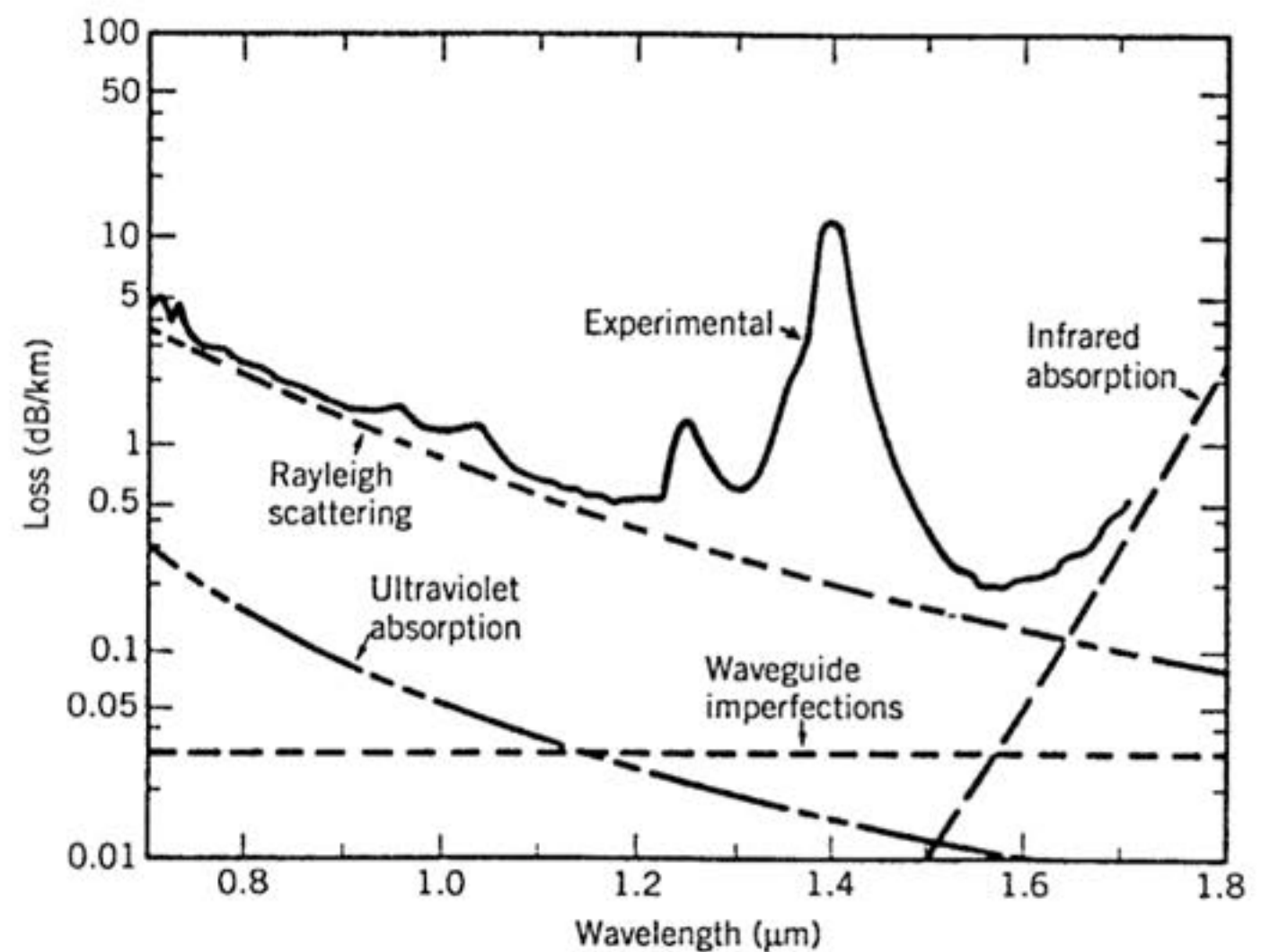
Optical Attenuation in Fibers

Before irradiating

- Material absorption
 - Infrared Absorption (vibrational resonances)
 - UV Absorption (electronic resonances)
 - OH⁻ ion absorption
- Rayleigh Scattering

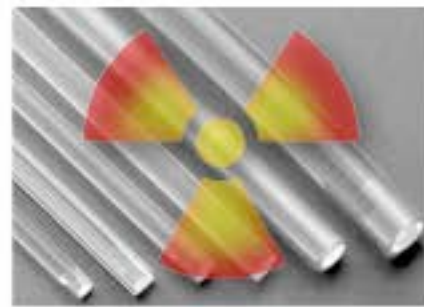
After irradiating

- UV Absorption ↗



Loss spectrum of a single-mode fiber
from T. Miya et al., *Electron. Lett.* 15, 106 (1979)

Finding the Right Component for the Right Use



Problematic

- Different technologies (dopant nature, concentration, profiles) may offer similar ground performance but very different in-flight behaviors.
- Optical fibers : a heterogeneous radiation response.

Contribution

- Development of a test bench.
- Characterize under γ radiation a variety of optical fibers.
- Gather the results in an online database, "RadFiber".

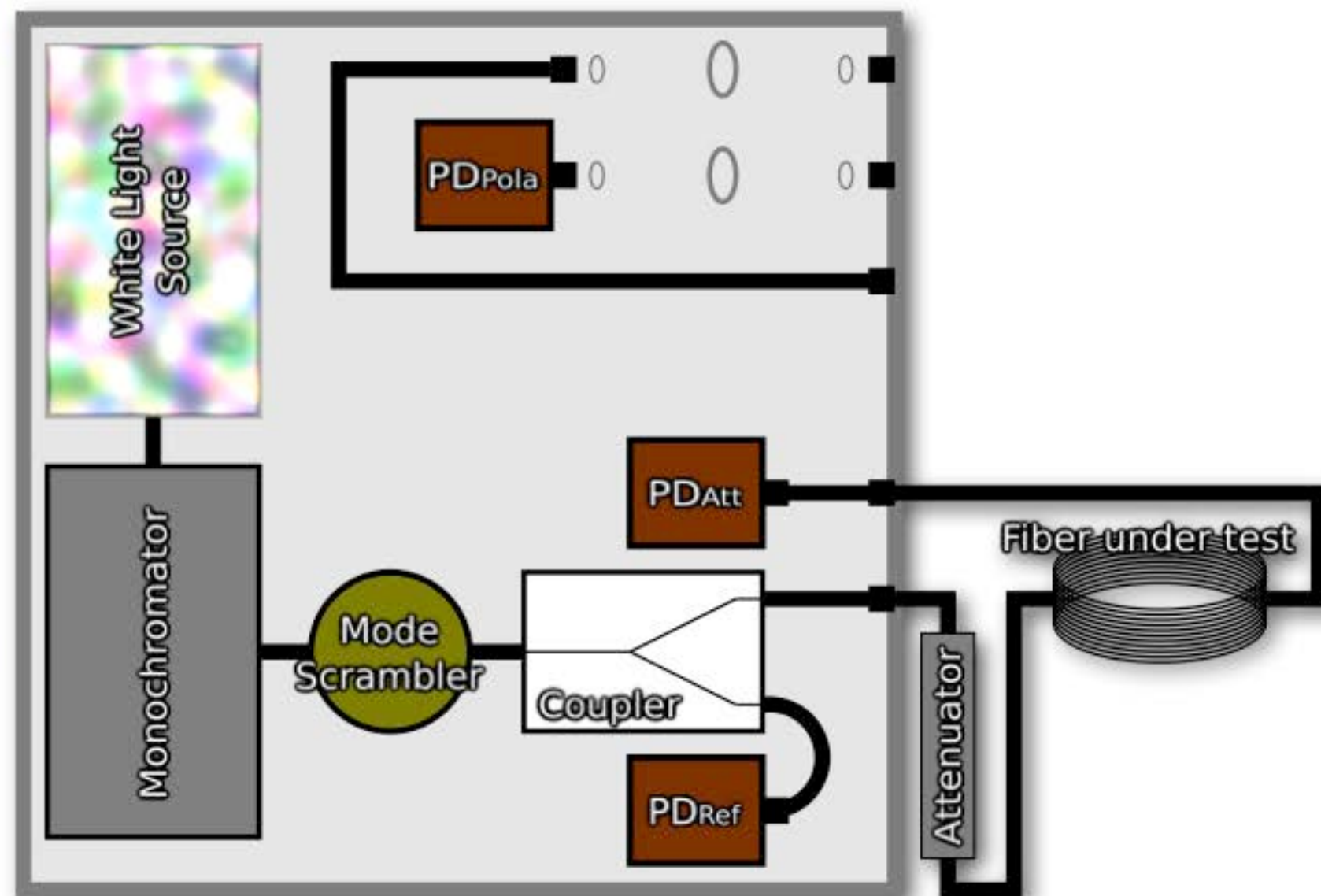
Global Architecture of the Test Bench (attenuation mode)

- **Radiation-Induced Attenuation (RIA)** from 400 nm to 1550 nm.
- Thick black lines : multimode optical patch chords.
- Boxes labeled PD#### contain each a “two-color” photodiode.



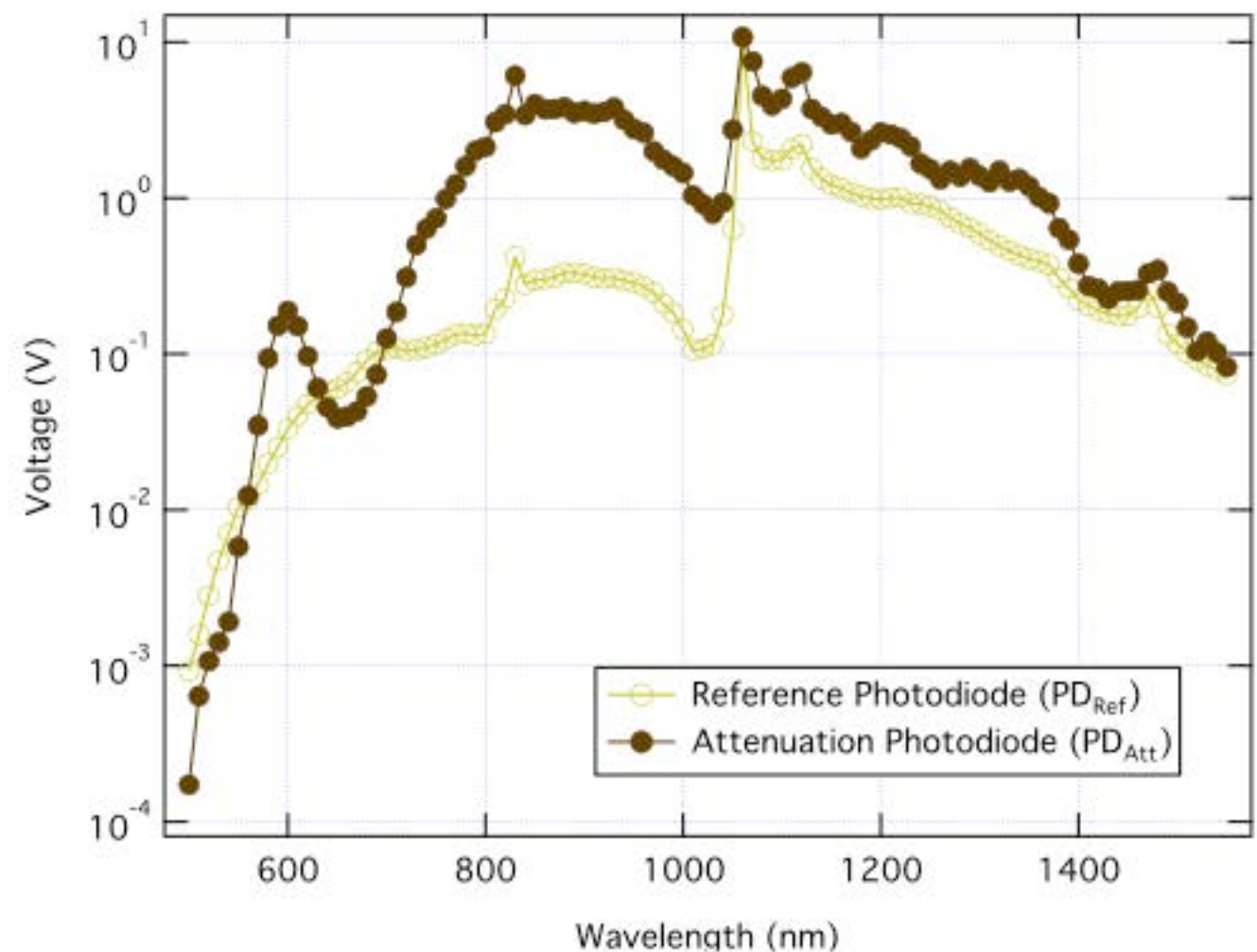
Si

InGaAs



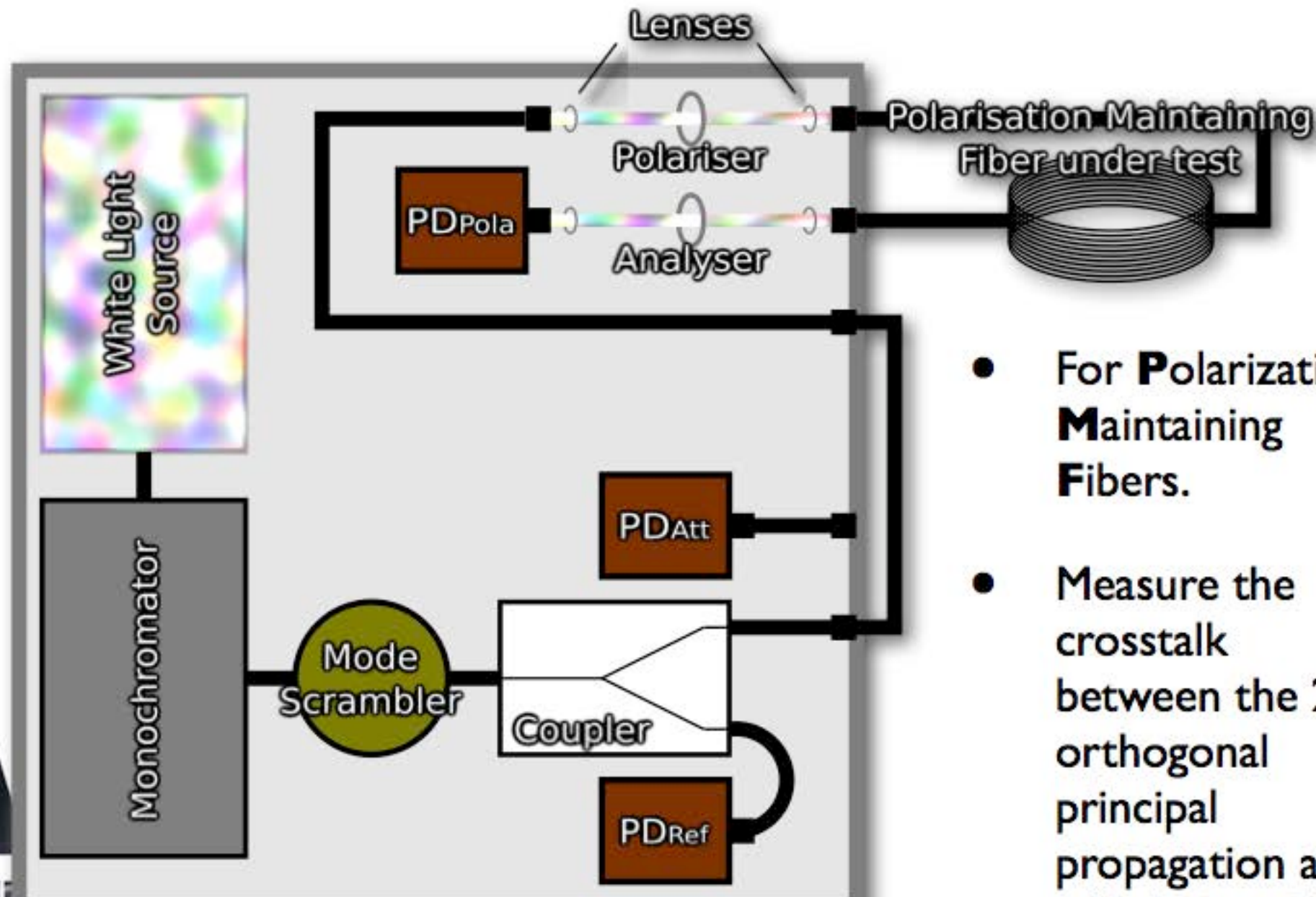
Example of Measurement Showing Two Spectra Obtained from Each Photodiode, PD_{Att} and PD_{Ref}

- Voltage $\propto$ light flux.
 - PD_{Ref} : before the fiber.
 - PD_{Att} : after the fiber.
- Each point = average over 1000 measurements.



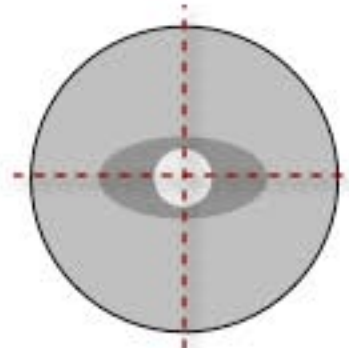
- **Radiation-Induced Attenuation** : $RIA = \frac{(PD_{Att}/PD_{Ref})_{post-irrad}}{(PD_{Att}/PD_{Ref})_{pre-irrad}}$

Global Architecture of the Test Bench (extinction ratio mode)

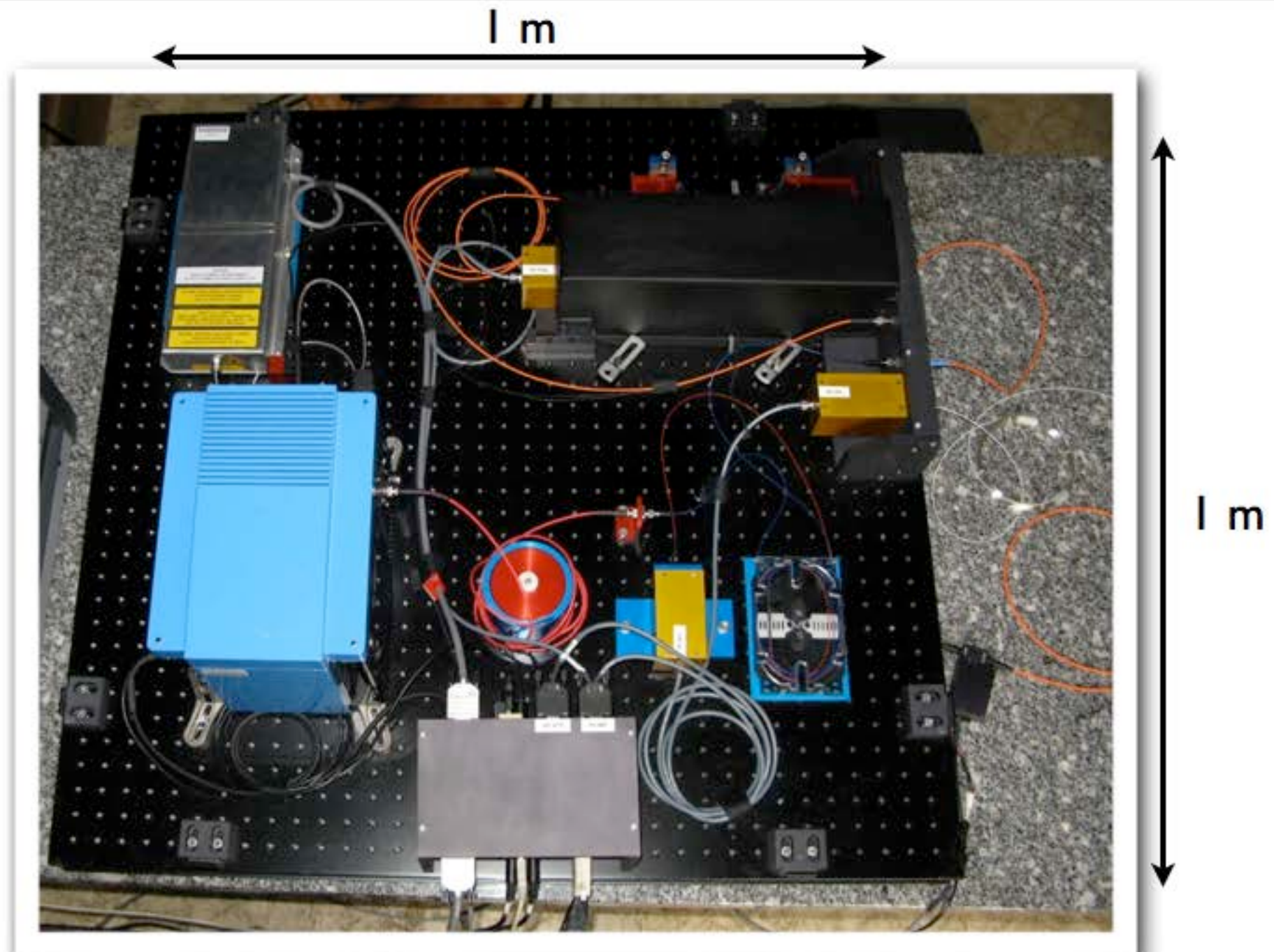


- For **P**olarization **M**aintaining **F**ibers.

- Measure the crosstalk between the 2 orthogonal principal propagation axes of light in a PMF.



Test Bench Close View



Test Bench Overview



- 1 rack case with electronics and power supplies.
- 1 laptop computer.

The Samples And Their Geometry

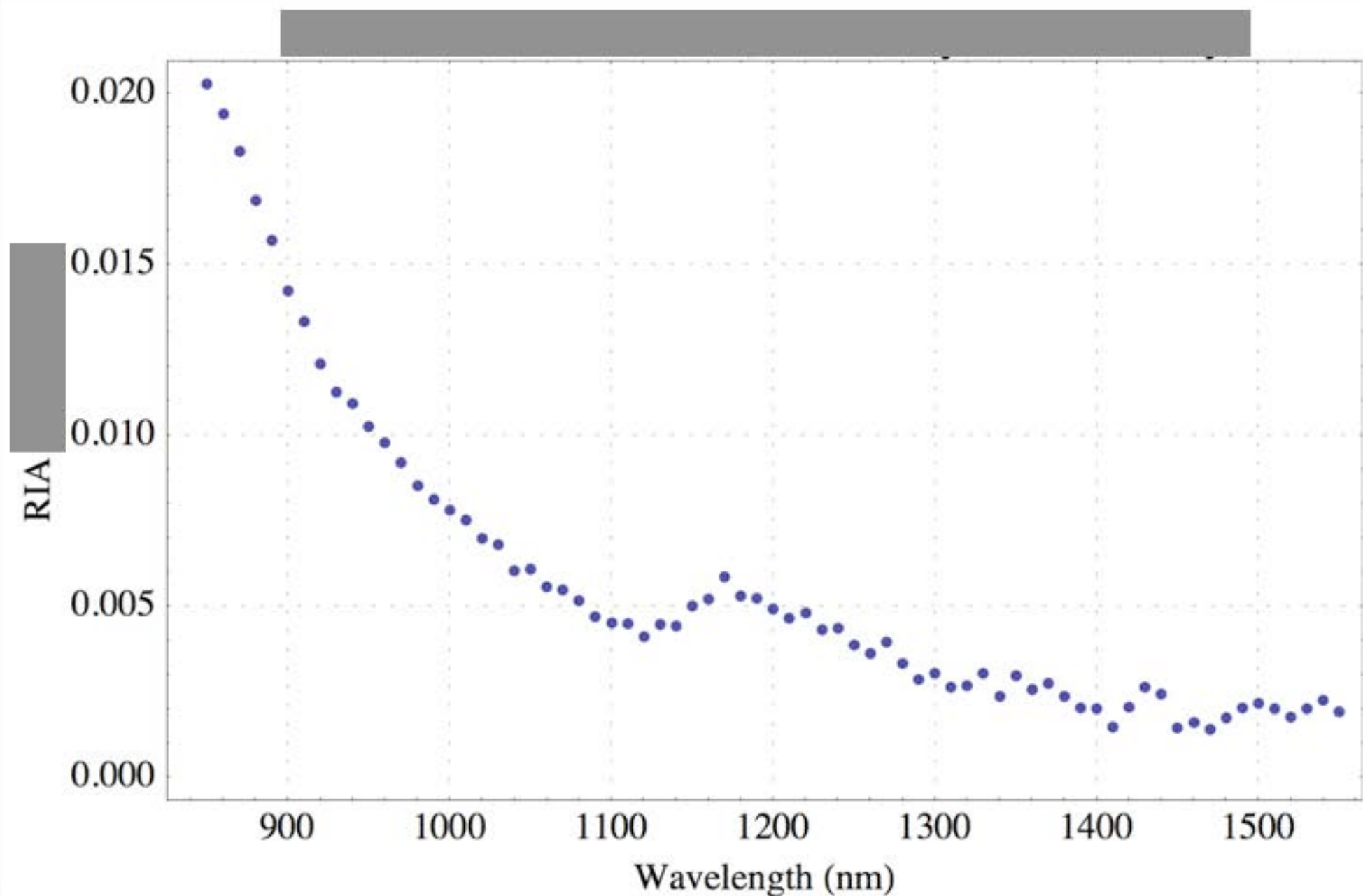
- Fibers are wound on unstressed spools.



- Spool geometry is calculated to minimize dosimetry error.

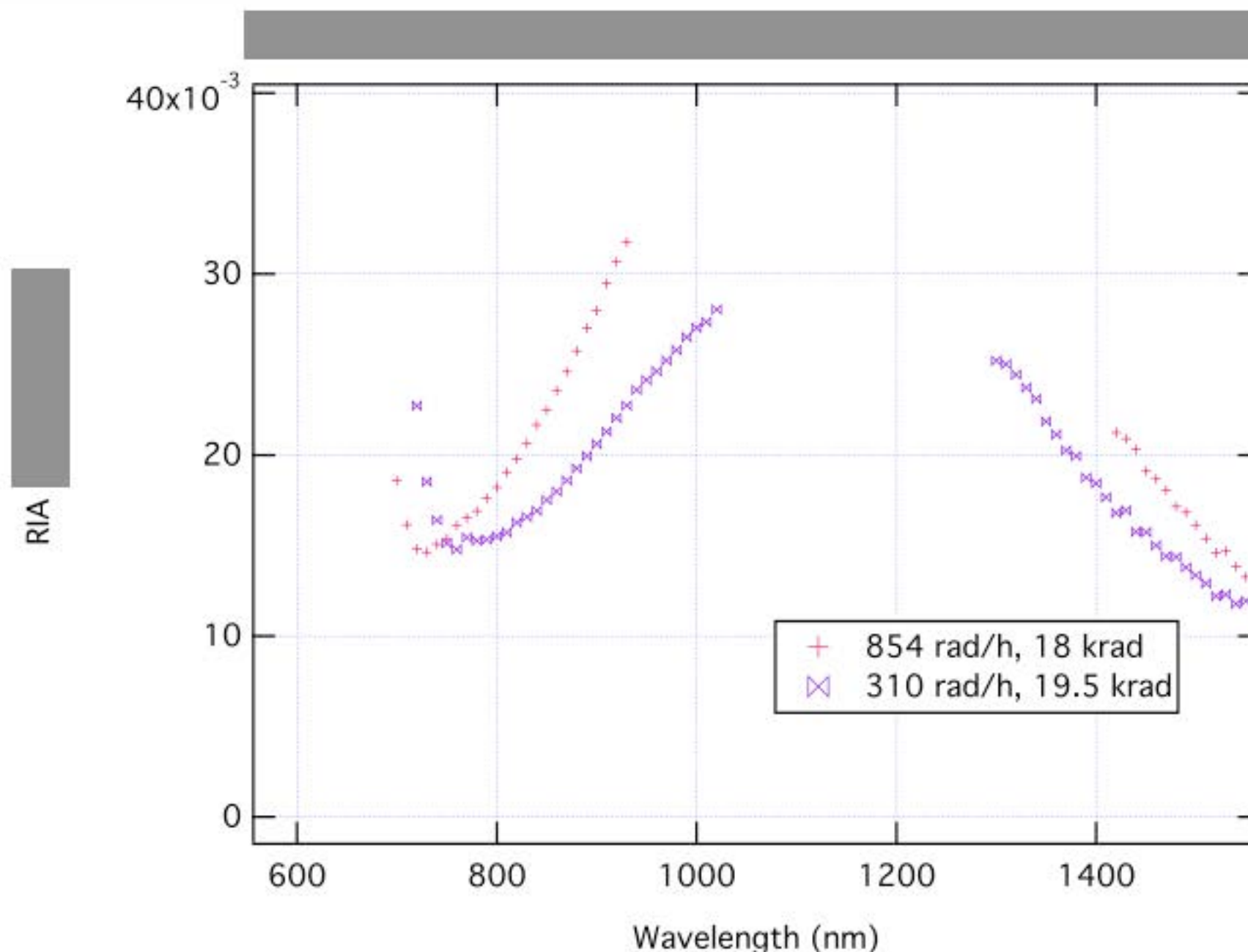
Designation	Fiber type	Remark	Dose rate (krad/h)	Dose steps or range (krad)	Campaign #
MO-01-S3	MOnomode	Rad-Hard	0.716	3, 15.3, 31, 46.6, 48	2
MO-01-S4	MOnomode	Rad-Hard	0.309	44.1, 48	2
MO-02-S1	MOnomode	Rad-Hard	4	16, 28, 48	1
MO-02-S2	MOnomode	Rad-Hard	0.3	48	1
MO-02-S3	MOnomode	Rad-Hard	1	in situ 0-26	3
MO-02-S4	MOnomode	Rad-Hard	1	in situ 0-26	3
MO-02-S5	MOnomode	Rad-Hard	1	in situ 0-26	3
MO-03-S1	MOnomode	Pure Silica Core	0.765	3, 16.2, 33, 46.8	2
MO-03-S2	MOnomode	Pure Silica Core	0.339	19.8, 48.6	2
MO-04-S1	MOnomode	Ultra Low Loss	0.854	18.0	2
MO-04-S2	MOnomode	Ultra Low Loss	0.3	19.5	2
MP-01-S1	Polar. Maintain.		4	16, 28, 48	1
MP-01-S2	Polar. Maintain.		0.3	48	1
MP-02-S1	Polar. Maintain.		4	16	1
MU-01-S1	MUltimode	Rad-Hard	4	16, 28, 48	1
MU-01-S2	MUltimode	Rad-Hard	0.3	48	1
MU-02-S3	MUltimode	Rad-Hard	0.787	13.5, 29.7, 51.3	2
MU-02-S4	MUltimode	Rad-Hard	0.315	18.9, 45	2
MU-03-S1	MUltimode	Power Trans.	0.695	13.5, 27.9, 45.9	2
MU-03-S2	MUltimode	Power Trans.	0.295	18, 43.2	2
MU-04-S1	MUltimode	Power Trans.	0.766	15.3, 30.6, 49.5	2
MU-04-S2	MUltimode	Power Trans.	0.310	20.7, 45.9	2

Radiation-Induced Attenuation of a Rad-Hard Fiber as a Function of Wavelength



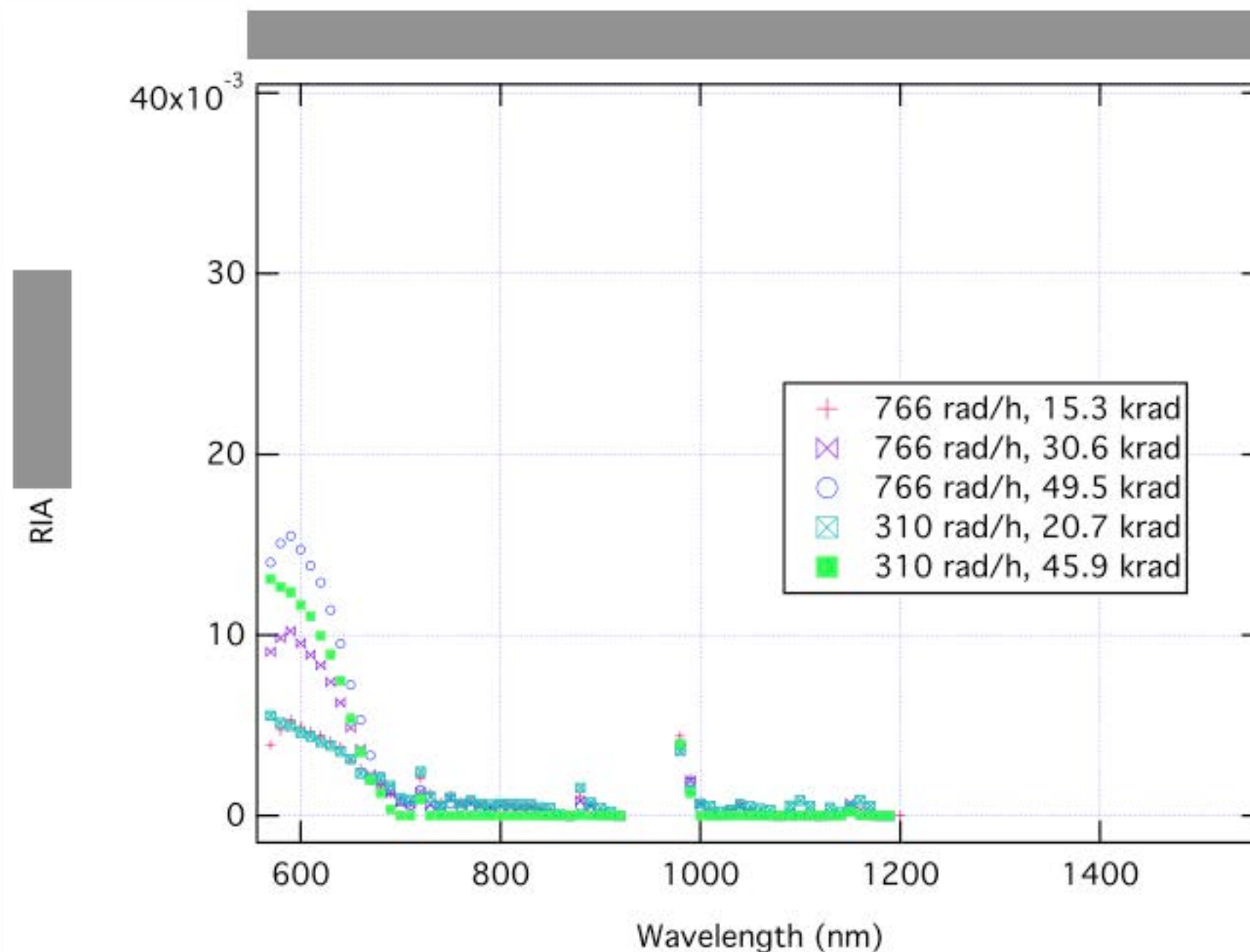
RIA obtained on a commercial Rad-Hard monomode fiber as a function of wavelength.

Radiation-Induced Attenuation of a non Rad-Hard Fiber as a Function of Wavelength



RIA obtained on a commercial non Rad-Hard monomode fiber as a function of wavelength.

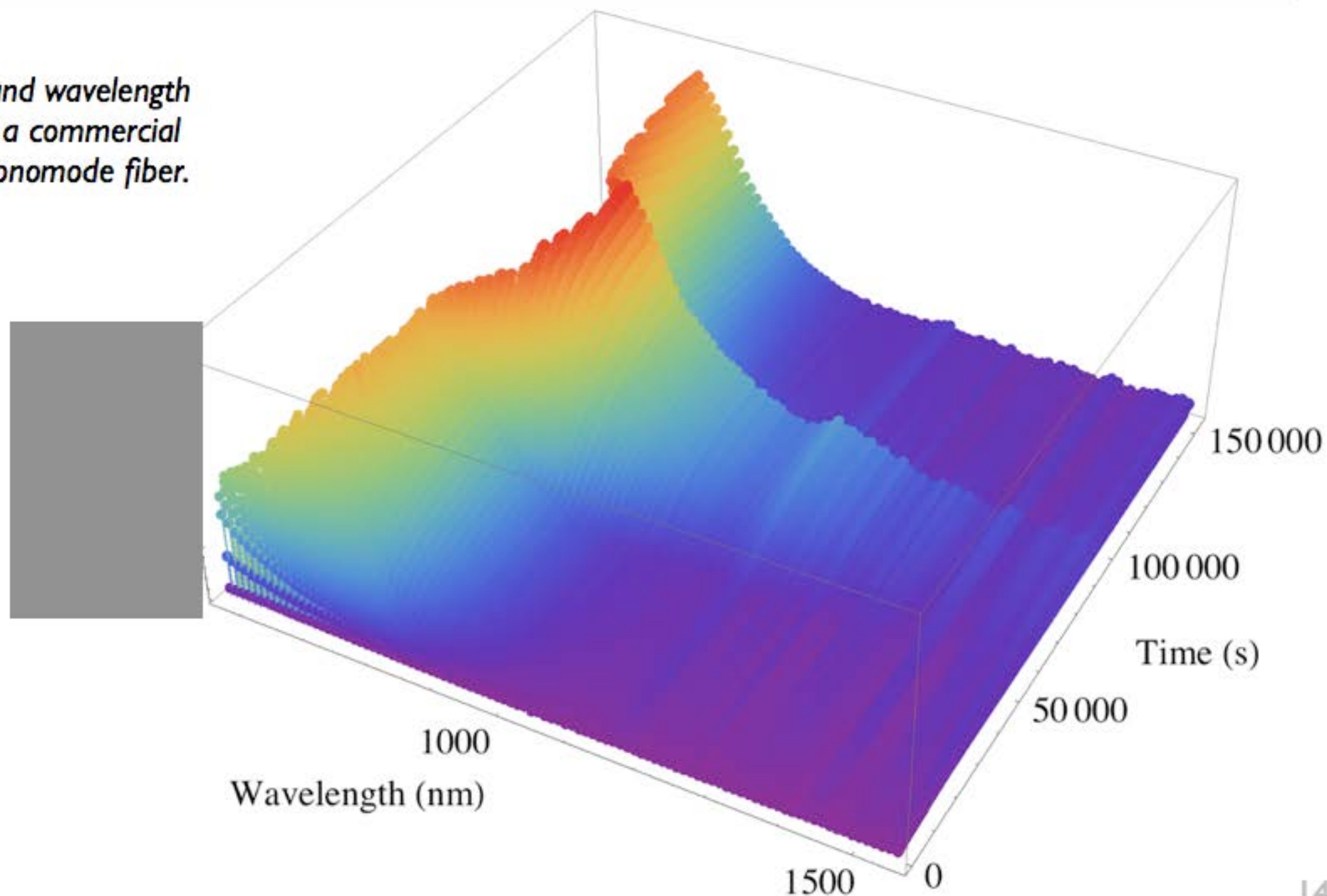
Radiation-Induced Attenuation of a non Rad-Hard Fiber as a Function of Wavelength



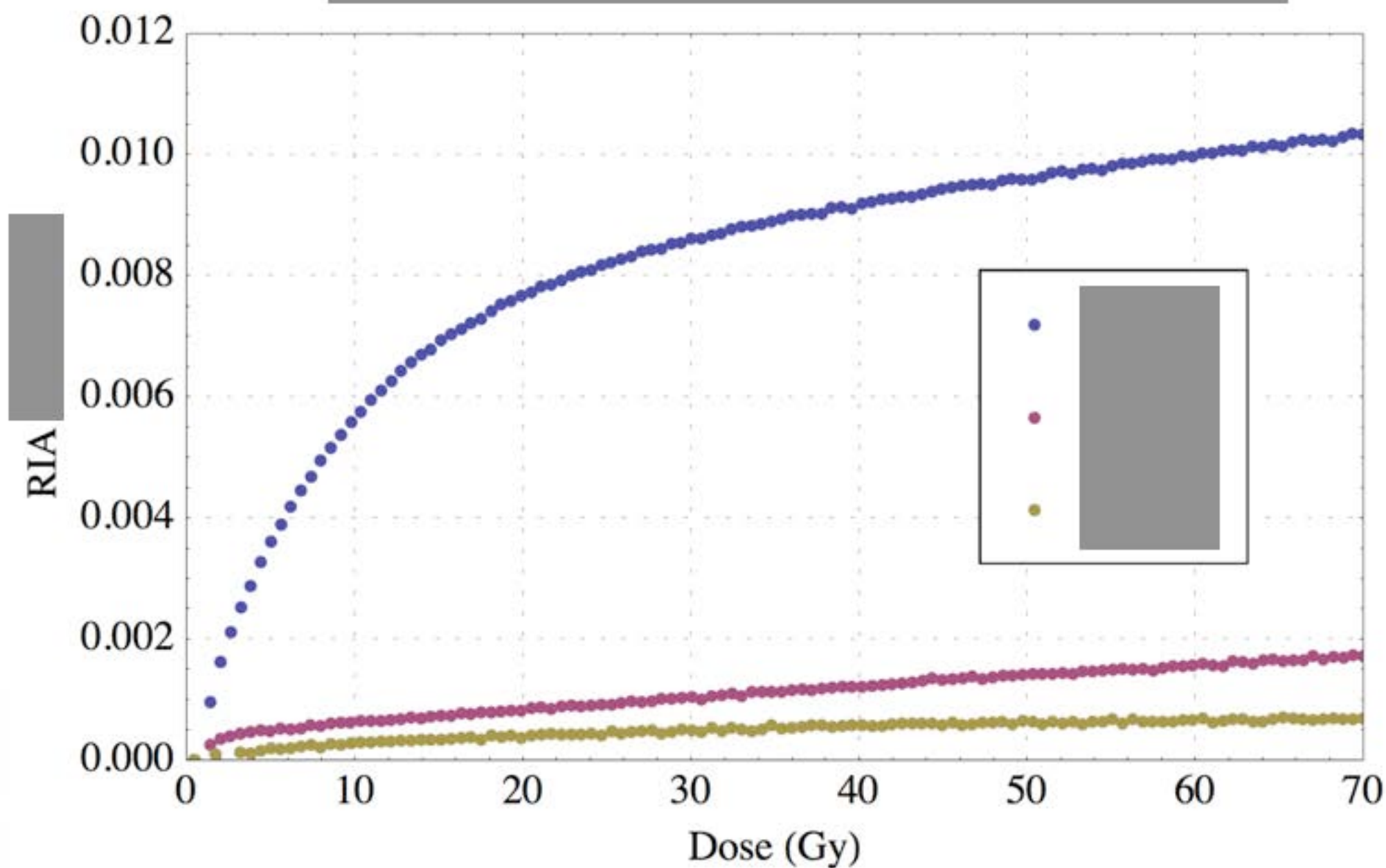
RIA obtained on a commercial non Rad-Hard multimode fiber as a function of wavelength.

Continuous Fiber Monitoring With In Situ Measurements

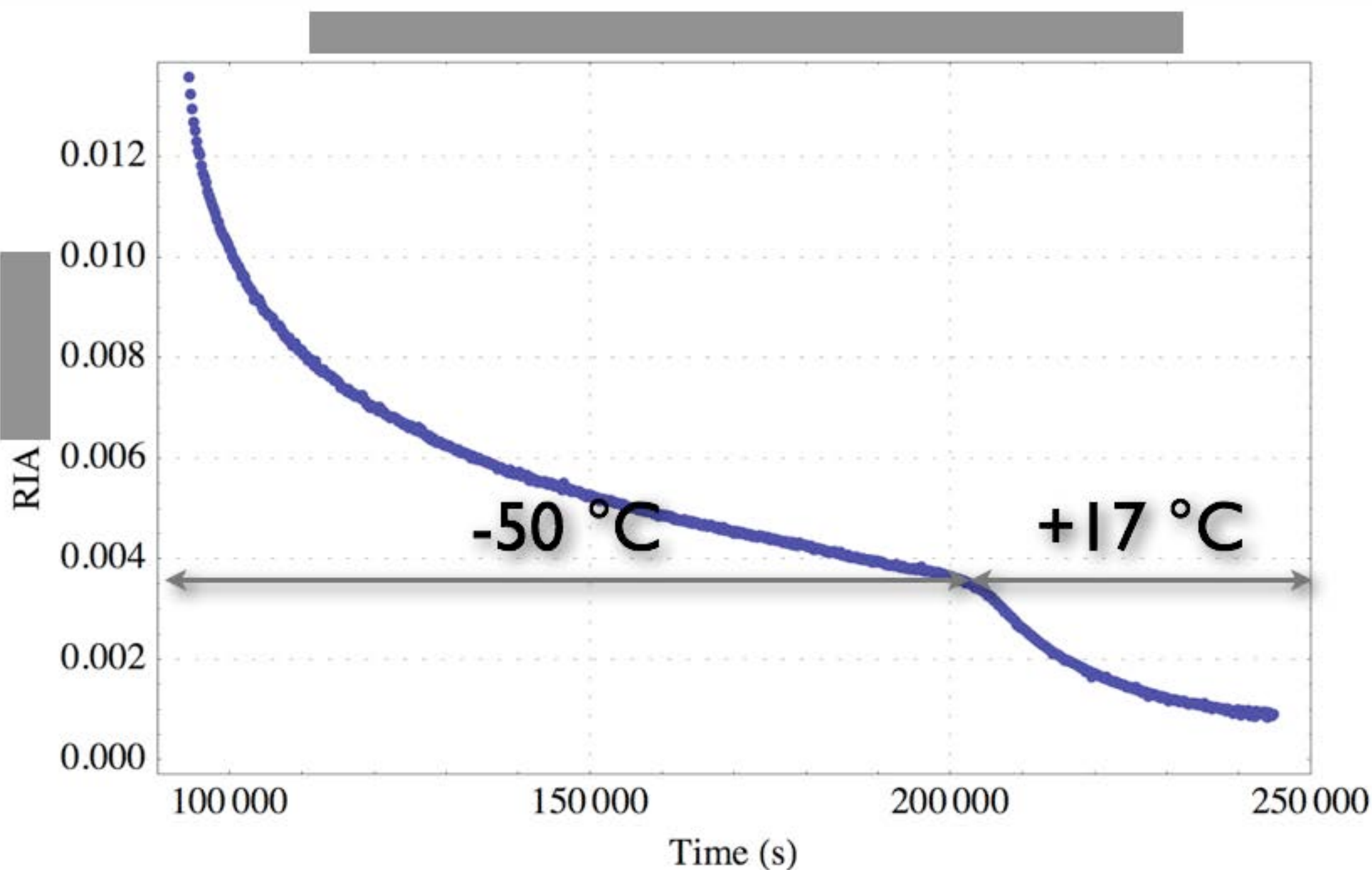
*RIA vs time and wavelength
obtained on a commercial
Rad-Hard monomode fiber.*



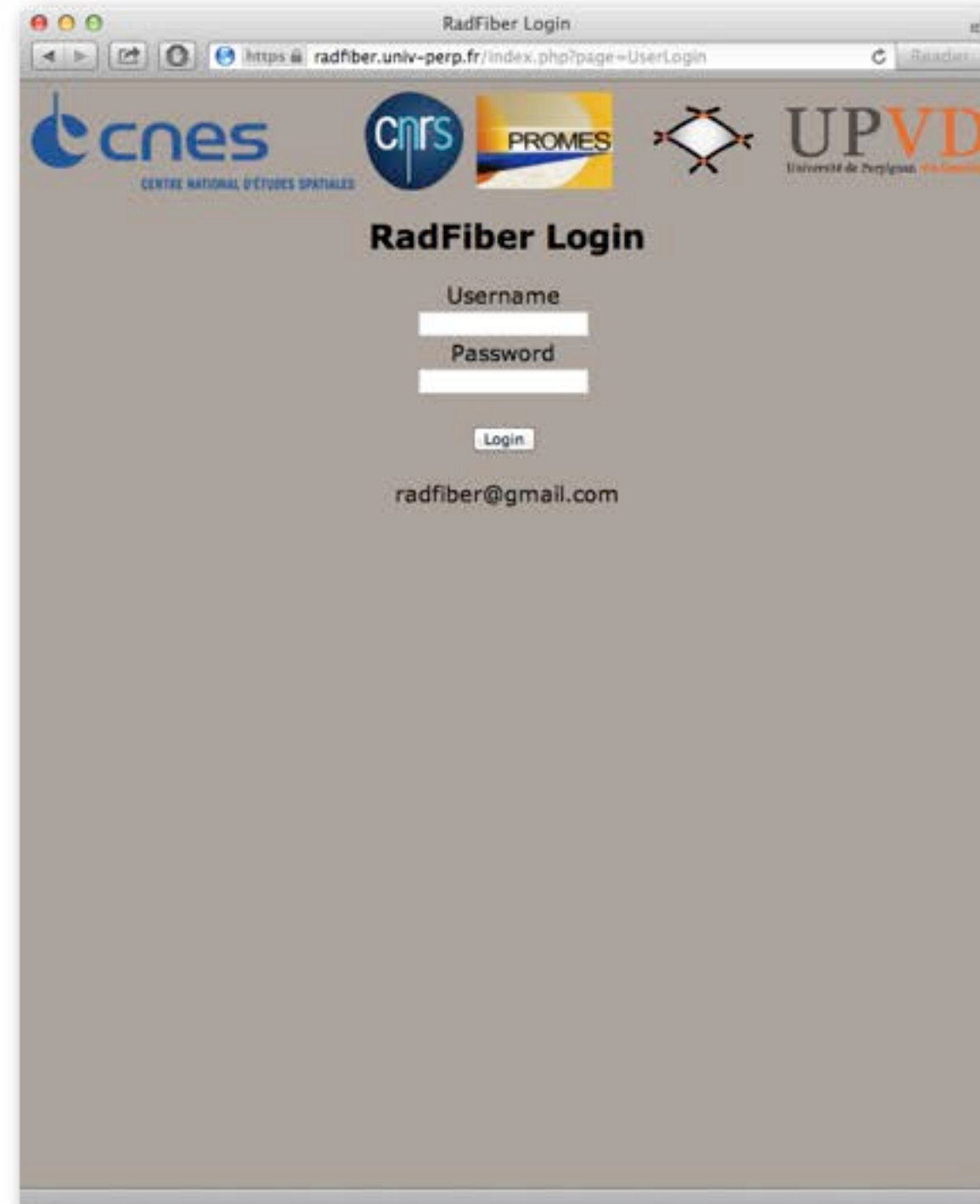
Temperature Effect On RIA



Temperature Effect On Annealing



The Online Database : “RadFiber”



The screenshot shows a web browser window titled "RadFiber Login". The address bar displays the URL "https://radfiber.univ-perp.fr/index.php?page=UserLogin". The page header features logos for CNES (Centre National d'Études Spatiales), CNRS, PROMES, and UPVD (Université de Perpignan). The main content area is titled "RadFiber Login" and contains a login form with the following elements:

- A "Username" label above a text input field.
- A "Password" label above a text input field.
- A "Login" button below the password field.
- A link "radfiber@gmail.com" at the bottom of the form.

Welcome to Radfiber - Optic Fiber Data under Radiation

https://radfiber.univ-perp.fr/index.php?page=Liability Reader

Accord de responsabilite - Liability agreement

Francais : L'utilisation faite du contenu de cette base de donnees et les consequences susceptibles d'en decouler ne sauraient en aucun cas engager les responsabilites du CNES, du CNRS ou de l'Universite de Perpignan. En cliquant sur le bouton OK ci-dessous, je comprends et j'accepte les conditions ci-dessus.

English : The use of this database content and all consequences that may follow cannot in any way involve the liability of the CNES, the CNRS, or the University of Perpignan. By clicking on the OK button below, I fully understand and agree to the conditions above.

Ok Log Out

Welcome to Radfiber - Optic Fiber Data under Radiation

https://radfiber.univ-perp.fr/index.php?page=Home

Reader

RadFiber Database

[Information](#)
[Data](#)

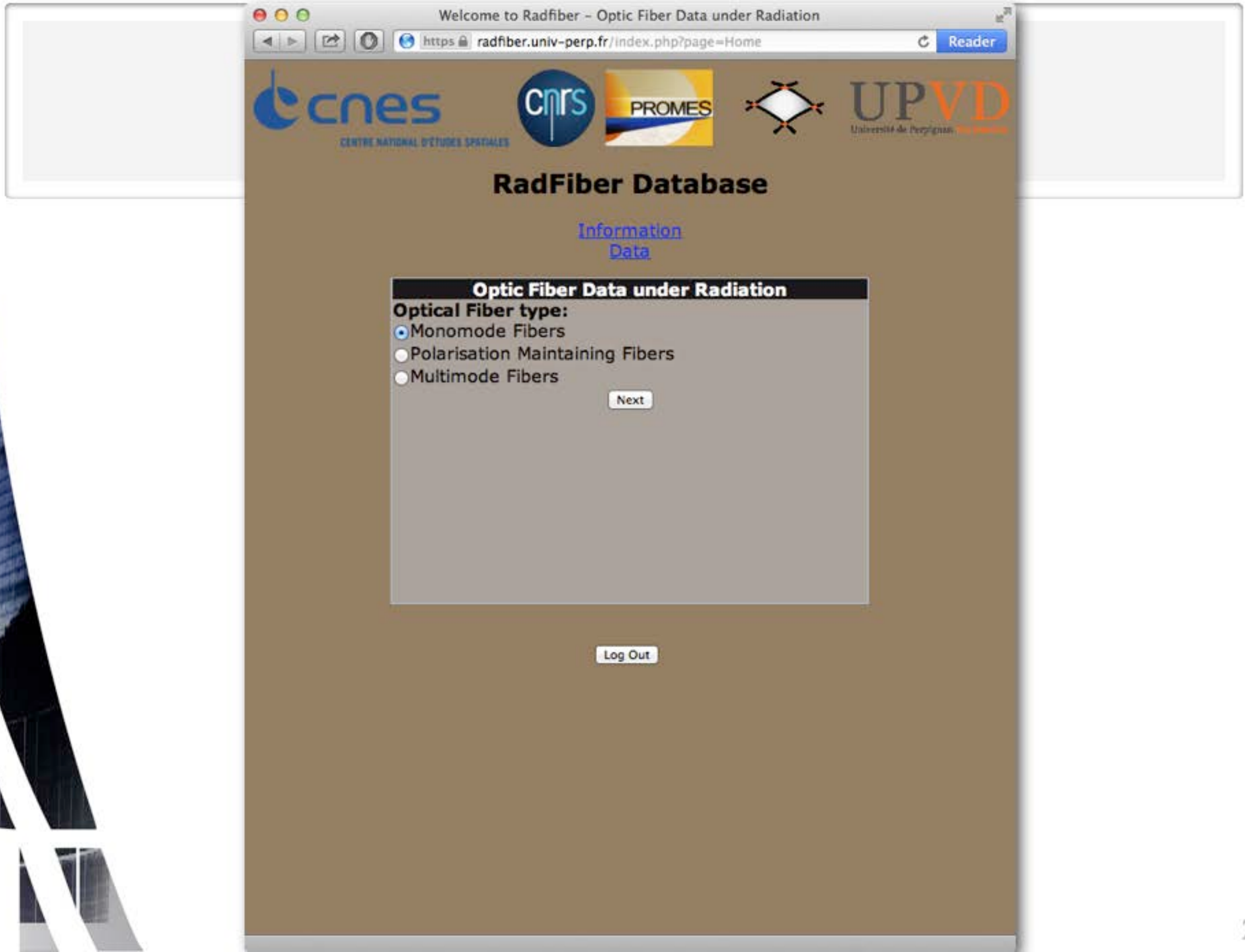
The Radiation Induced Attenuation (RIA) of optical fibers is stored for various experimental conditions in terms of dose, dose rate and wavelength. Measurements have been carried out after the gamma irradiation. The wavelength domain ranges from 400 nm up to 1550 nm .

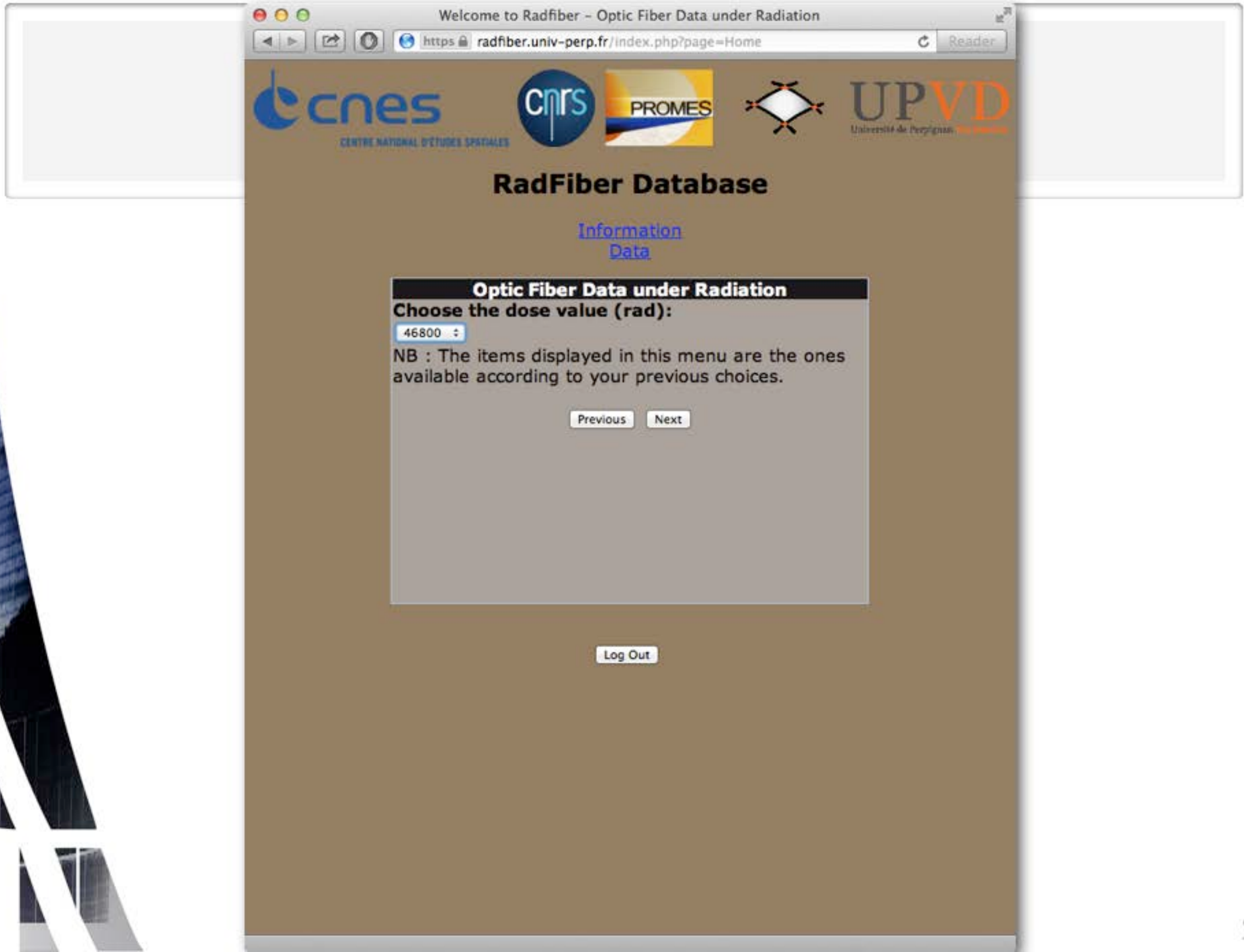
At a given wavelength, a RIA equals to zero means that the radiation effects on the fiber was too small to be measured by the experimental setup.

At a given wavelength, a RIA not available is due to a fiber degradation too high to be measured, i.e. the sample became too darkened.

Click on the "Data" link above to access the tool.

Log Out





Welcome to Radfiber - Optic Fiber Data under Radiation

https://radfiber.univ-perp.fr/index.php?page=Home

RadFiber Database

[Information](#)
[Data](#)

Optic Fiber Data under Radiation

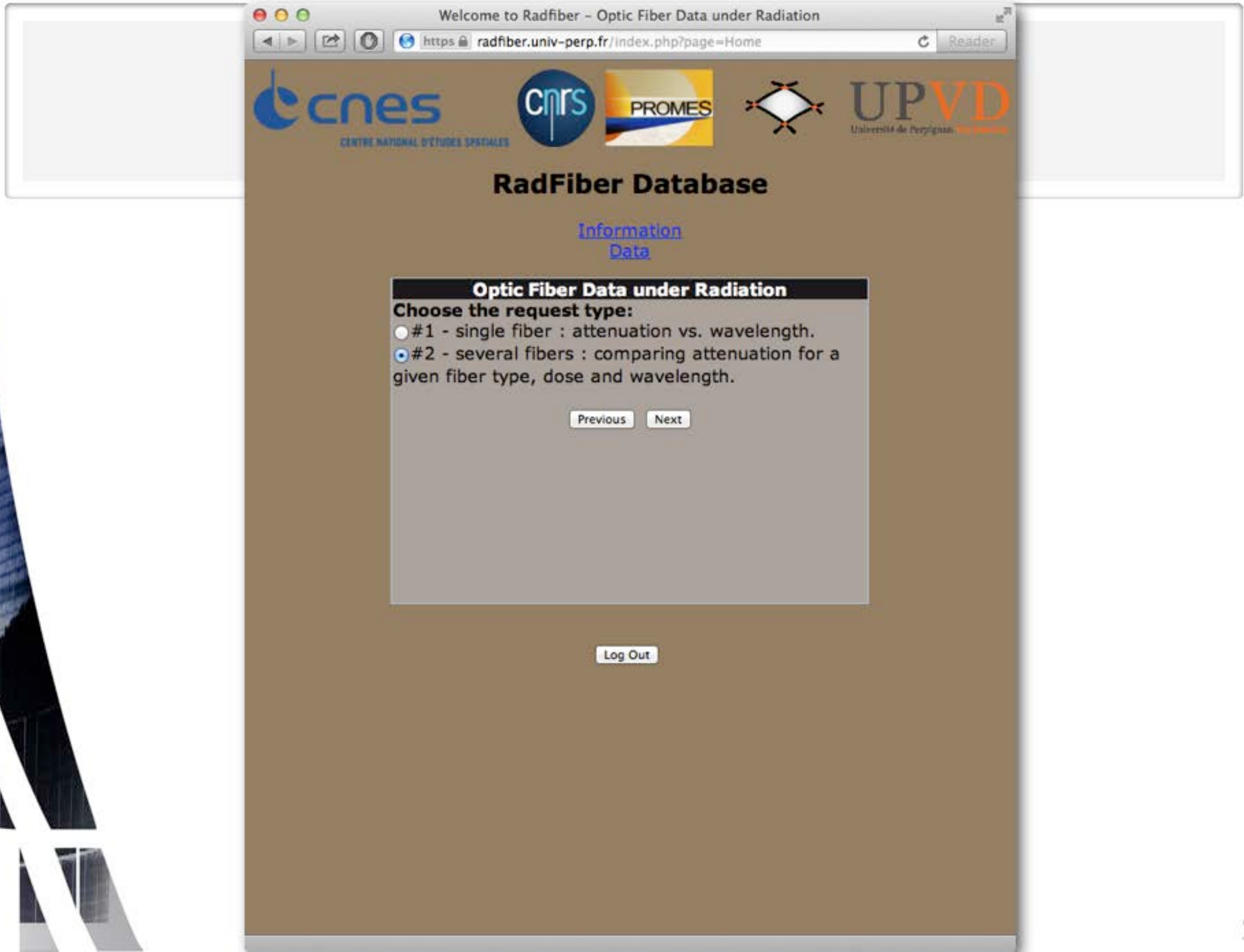
Choose the dose value (rad):

46800 ±

NB : The items displayed in this menu are the ones available according to your previous choices.

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 https://radfiber.univ-perp.fr/index.php?page=Home







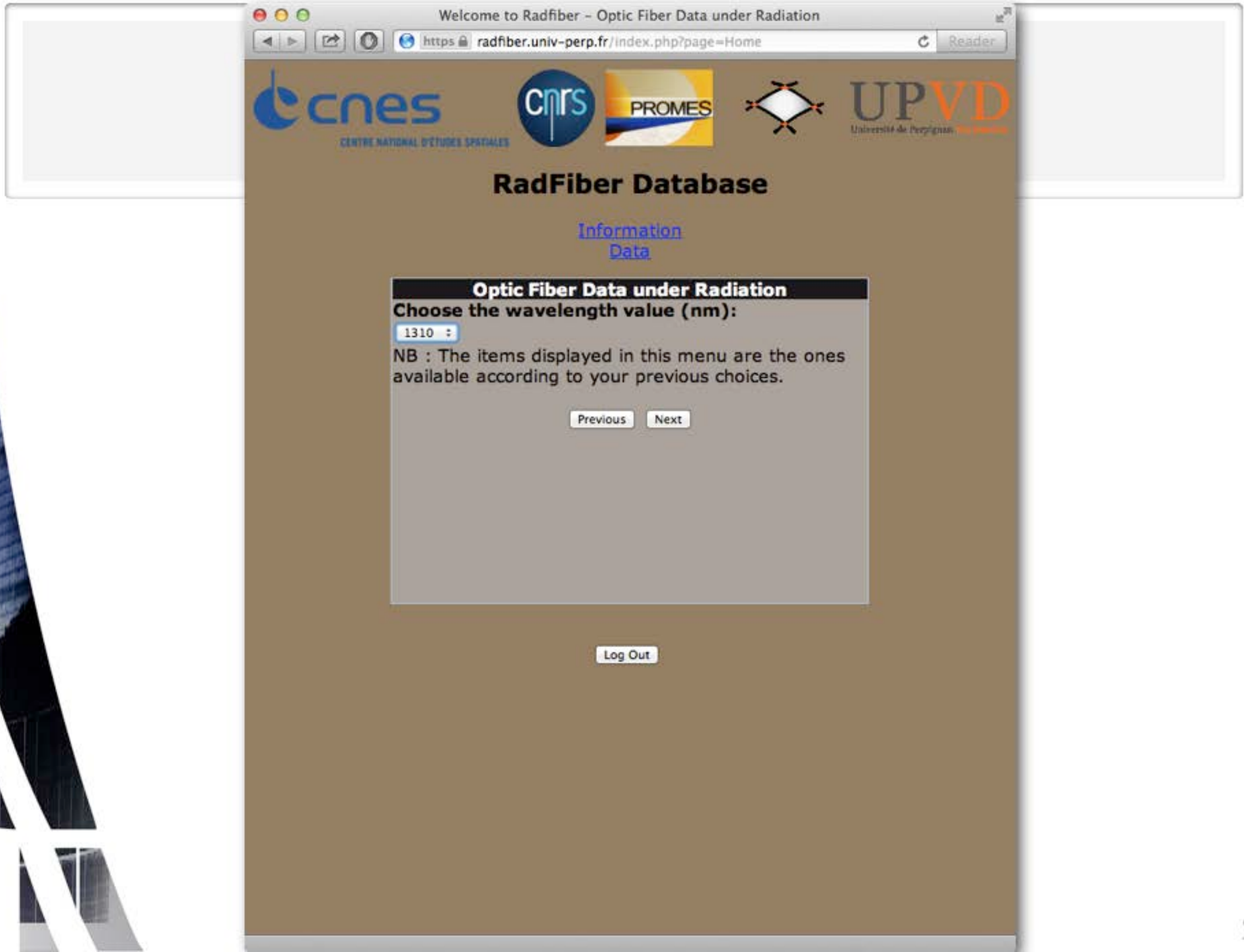
RadFiber Database

[Information](#)
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Optic Fiber Data under Radiation

Choose the request type:

☐ #1 - single fiber : attenuation vs. wavelength.
☒ #2 - several fibers : comparing attenuation for a given fiber type, dose and wavelength.



Welcome to Radfiber - Optic Fiber Data under Radiation

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RadFiber Database

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Optic Fiber Data under Radiation

Choose the wavelength value (nm):

1310 :

NB : The items displayed in this menu are the ones available according to your previous choices.

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Optic Fiber Data under Radiation

Summary and numerical data
 Fiber type : MOnomode
 Wavelength : 1310 nm
 Dose(s) : 46800 rad (+ or - 15%). NB: Doses are sorted according to increasing values.

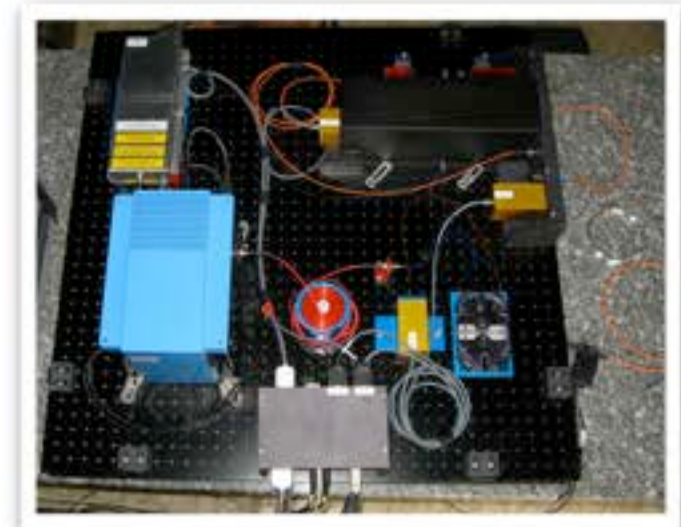
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Commercial Designation of the Fiber	Attenuation (dB/m)	Dose rate (rad/h)	Dose (rad)
	0.00549491	341	44100
	0.00201991	705	46630
	0.00574626	761	46800
	0.0250164	300	48000

Conclusion

- Irradiations with in situ measurements at various temperatures.
- At certain wavelengths non rad-hard devices can be harder than rad-hard fibers.
- Results gathered in an online database which
 - allows to extract specific data according to user choices and
 - permits to compare the performances of numerous fibers in order to select the right one for a given space mission.



Perspectives

- Use of optical switches to test several fibres simultaneously.
- Make the database bigger and opened to everyone through collaborations with manufacturers, industries and agencies.

