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Regeneration of Phosphosilicate Optical Fiber Dosimeters operating in the Visible Domain

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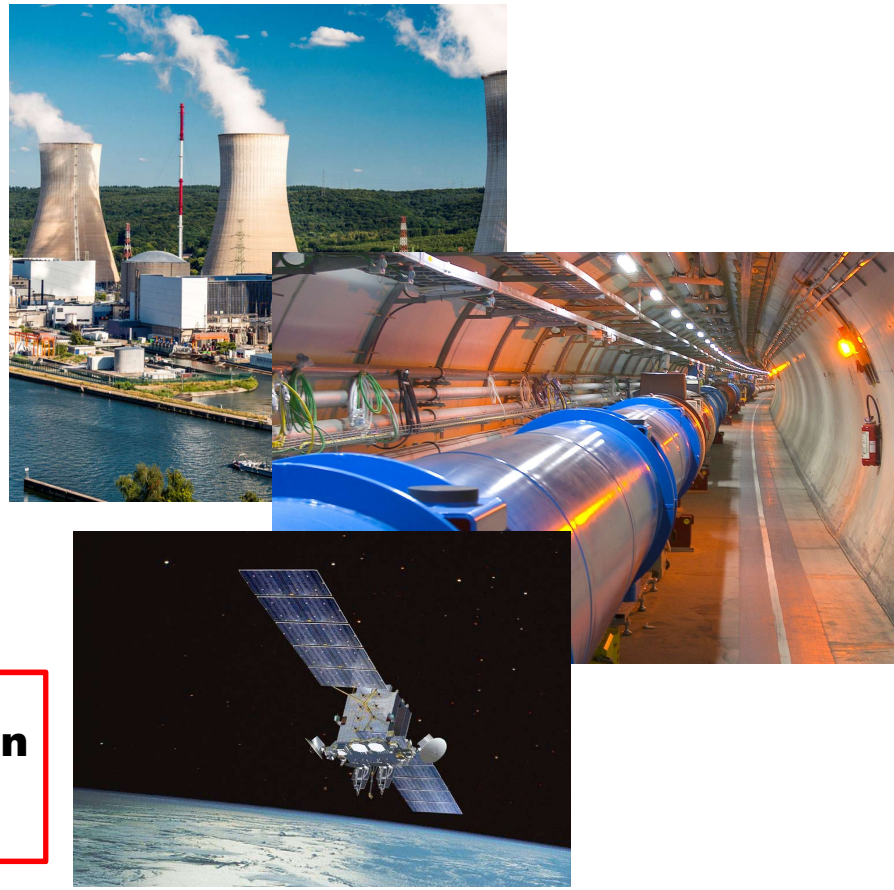
Context – Long term degradation of components and systems in radiation rich environment is a major concern.

- **Optical fibers are part of numerous systems in harsh environment (communication, diagnostics or sensors).**
  - The main risk for these applications is the radiation induced attenuation (RIA).
  - Numerous studies were dedicated to improve radiation toleration of optical fiber-based system (S. Girard et al., J. Opt 2018)
  - Hardly to manipulate or replace in such environment.
- **Space dosimetry using optical fibers has produced excellent results**



We evaluate the capability to retrieve the pre-irradiation performances of a P-doped Optical Fiber.

Context – RIA kinetics is explained by the competition between the generation and the recombination of absorbing point defects.

- **Power and Wavelength of the injected light affects:**
  - The generation efficiency of defects
  - The recombination efficiency of defects

Photobleaching can be define as the potential recombination of a certain amount of radiation induced defects.

The efficiency of the process depends on the composition, length and geometrical properties of the optical fiber, optical power, wavelength…

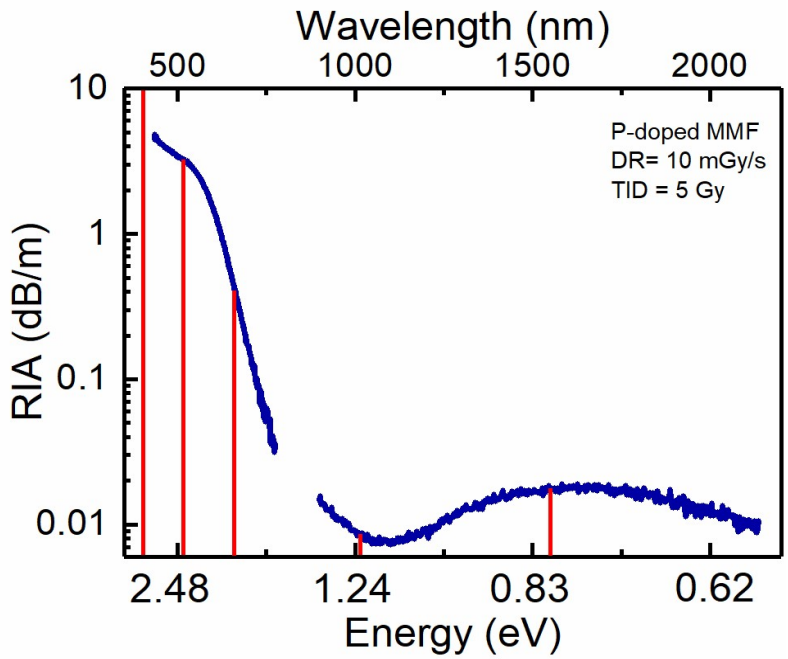
- **Phosphorus doped optical fibers:**

  It was proven that the photobleaching was efficient with the P1 defect (main responsible of the 1550 nm RIA)

  (G. Li Vecchi *et al.*, Opt. Lett. 2020)

  Is it possible to photobleach the various form of POHC defects, which are the major responsible color centers of the RIA in the visible domain ?

Context – Visible domain present interesting characteristics for dosimetry.



- Operation in the visible domain allows reaching coefficients significantly larger than in the infrared.
- …but at the expense of reduced insensitivity to various environmental factors such as dose rate.
- … can reach the RIA saturation quicker than IR dosimeter.
- Need to reset.

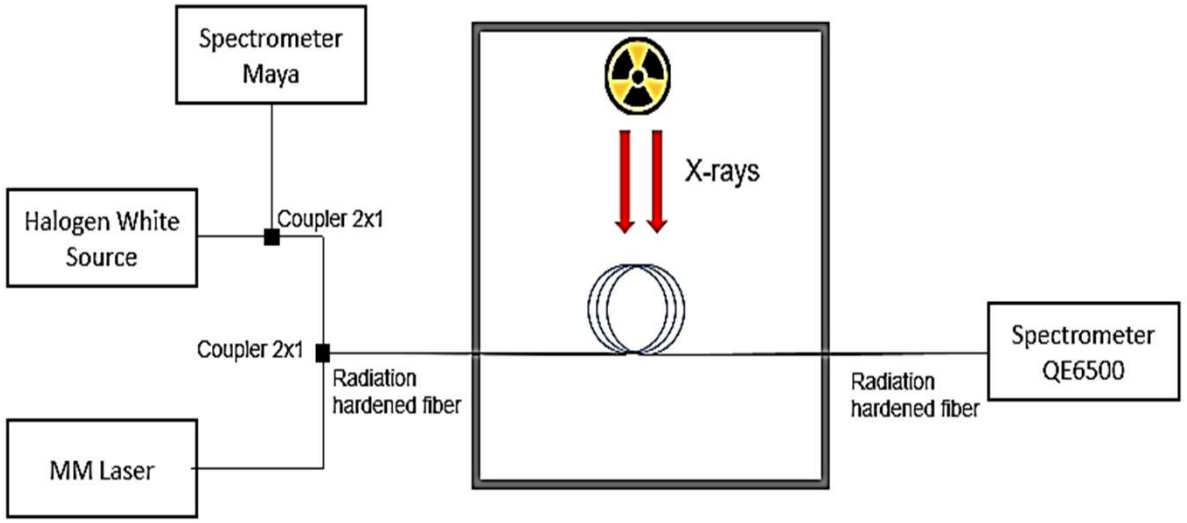
Tools - We measured i*n situ* the RIA kinetics during and after irradiation then after photobleaching process varying the Wavelength of the laser.

- Phosphorus doped multimode optical fiber (from exail)

1 Gy = 100 rad

- 100 kV X-Ray irradiation up to 5 Gy (The fibers are only sensitive to Total Ionizing Dose (TID)) (S. Girard et al., J. Optics, 2018)
- **Length of the Optical fiber = 5 m**
- Dose rate = 10 mGy/s
- Optical power = **4 mW**
- **Room temperature**

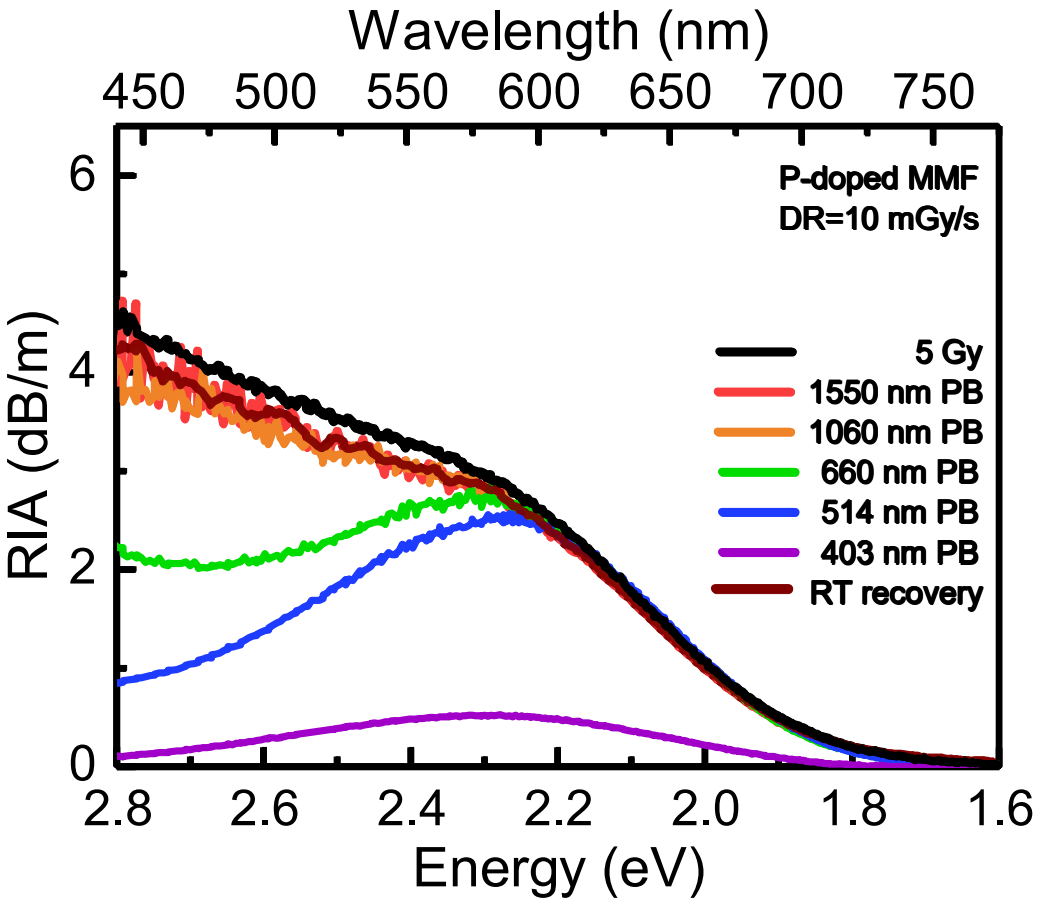
Experimental Setup



➢ Tested Photobleaching Wavelengths:

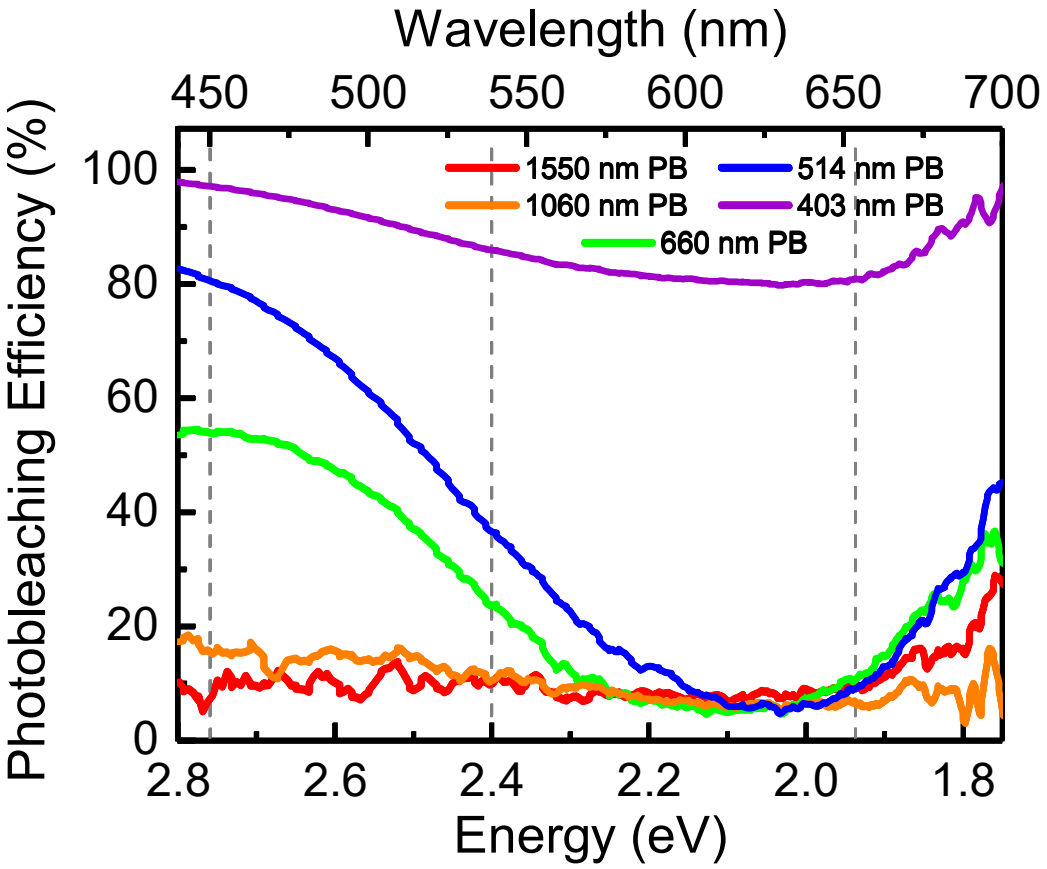
1550 nm **1060 nm** **660 nm** **514 nm** **403 nm**

Results– 403 nm is the most efficient photobleaching wavelength



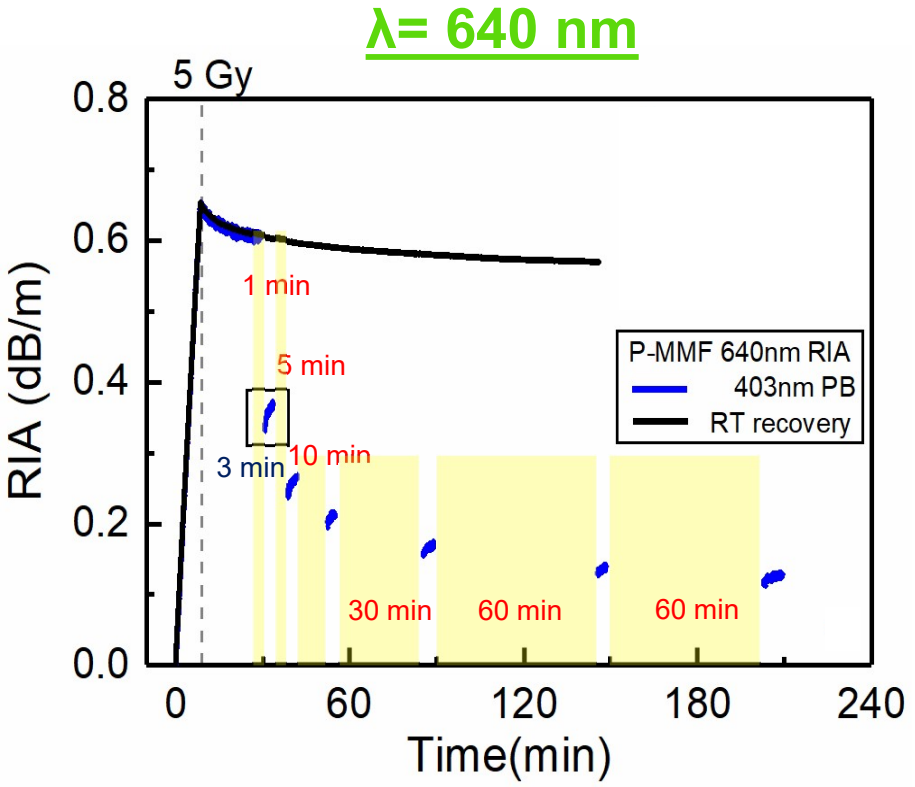
- **After 2 hours of photobleaching**
- NIR wavelengths are inefficient for photobleaching.
- Only the higher energy photons can photobleach the radiation induced losses from 1.8 eV to 2.8 eV.
- 660 nm and 514 nm lasers have only an impact on the RIA at lower wavelengths.
- The RIA caused by the Gaussian absorption band of s-POHC centered at 2.28 eV remains mostly unaffected by this 4 mW laser injection.

Results– 403 nm is the most efficient photobleaching wavelength



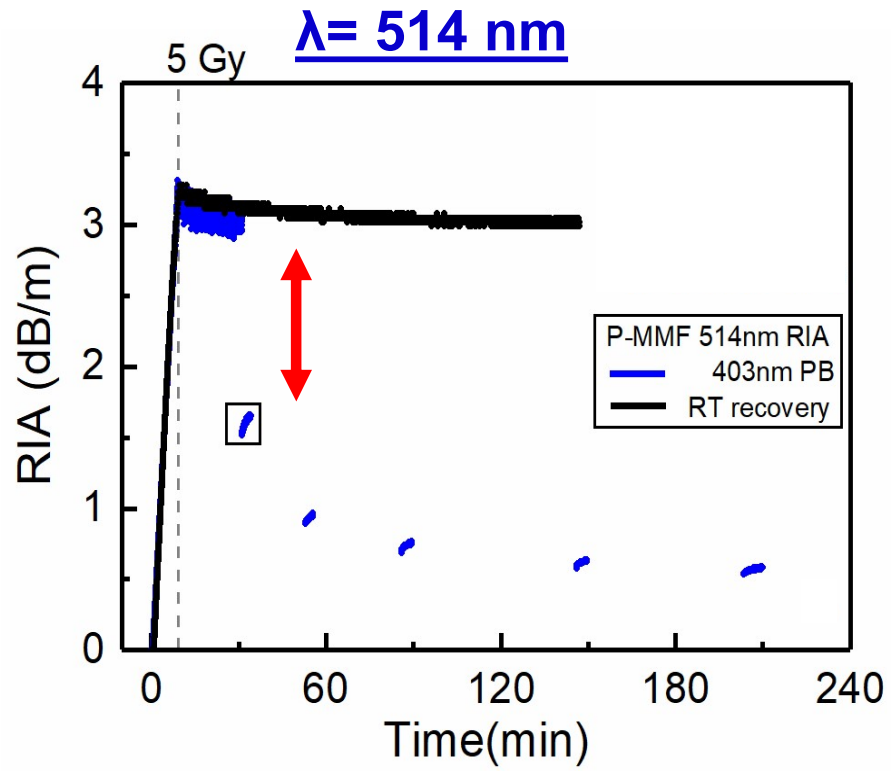
- **After 2 hours of photobleaching**
- The closer the ratio is to **100%**, the more efficient was the photobleaching at the reported wavelength.
- The 403 nm PB efficiency : we recovered at least 80 % of the pre-irradiation transmission capacities over the visible spectrum.
- The 403 nm laser demonstrates a particular efficiency: four and eight times better than 514 nm PB at 2.28 eV and 2.1 eV respectively.
- **Focus on 403 nm photobleaching results**

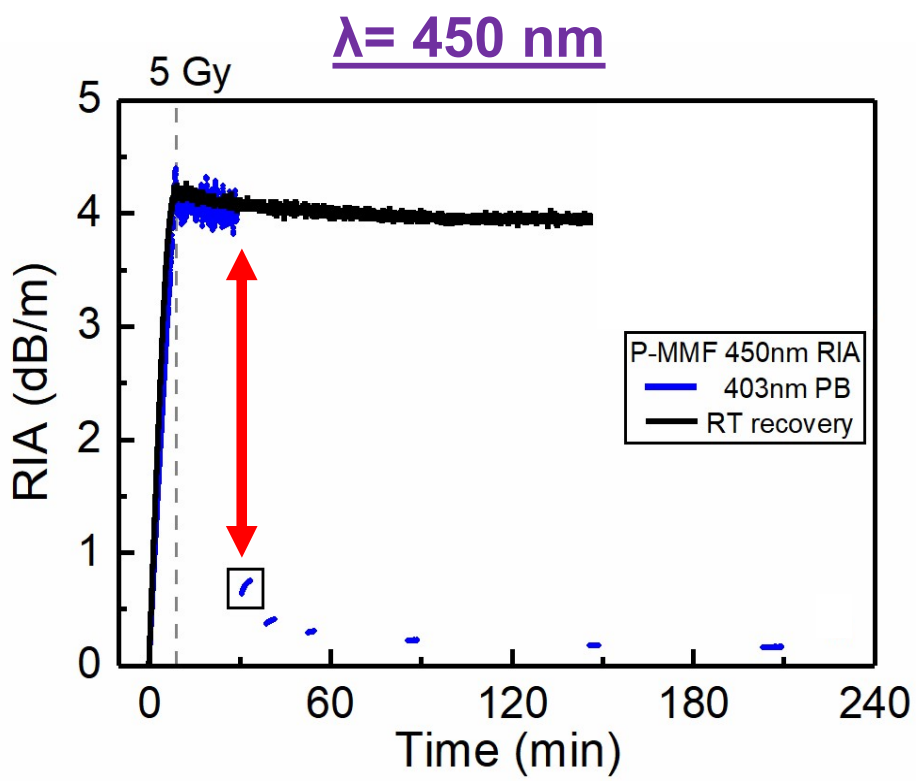
Results– With different photobleaching timing, we investigate Time efficiency.



- Different timings of photobleaching :
  1 min 5 min 10 min 30 min 60 min 60 min
- Room temperature recovery is noticeable.
- **By increasing the PB treatment duration**, we recover more of the transmission capability.

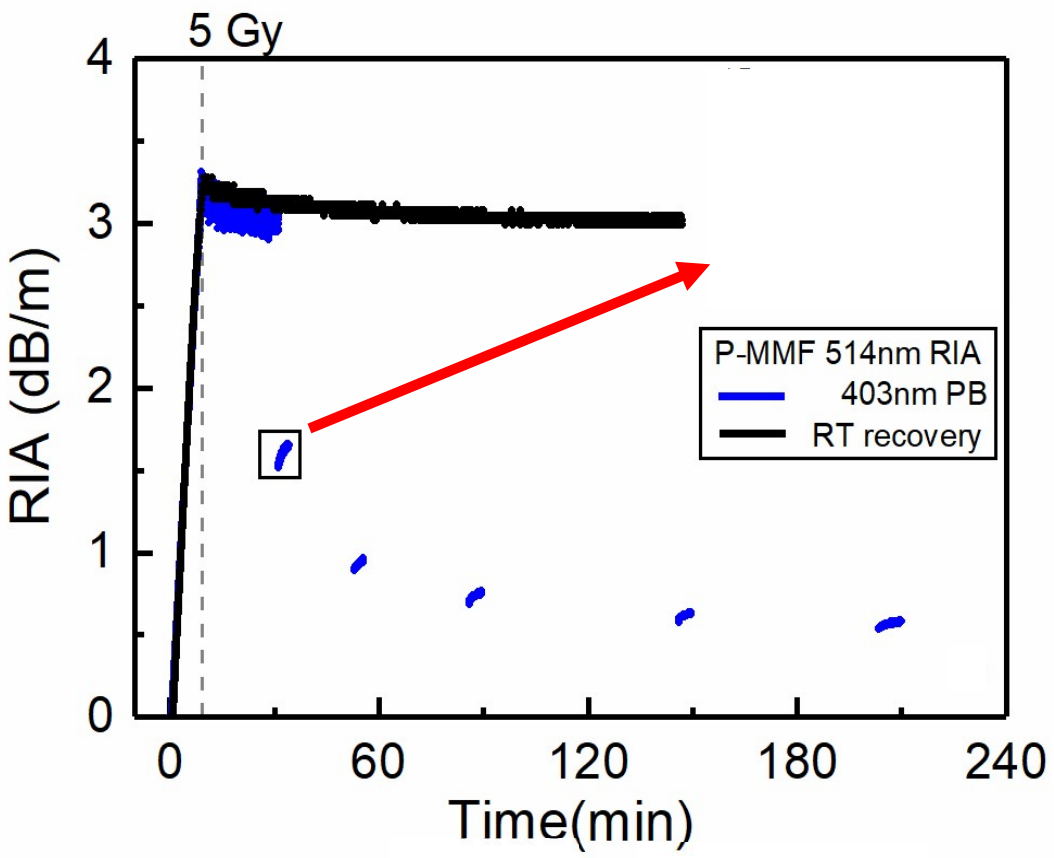
Results– The PB is more effective during the first minutes than in the long term.





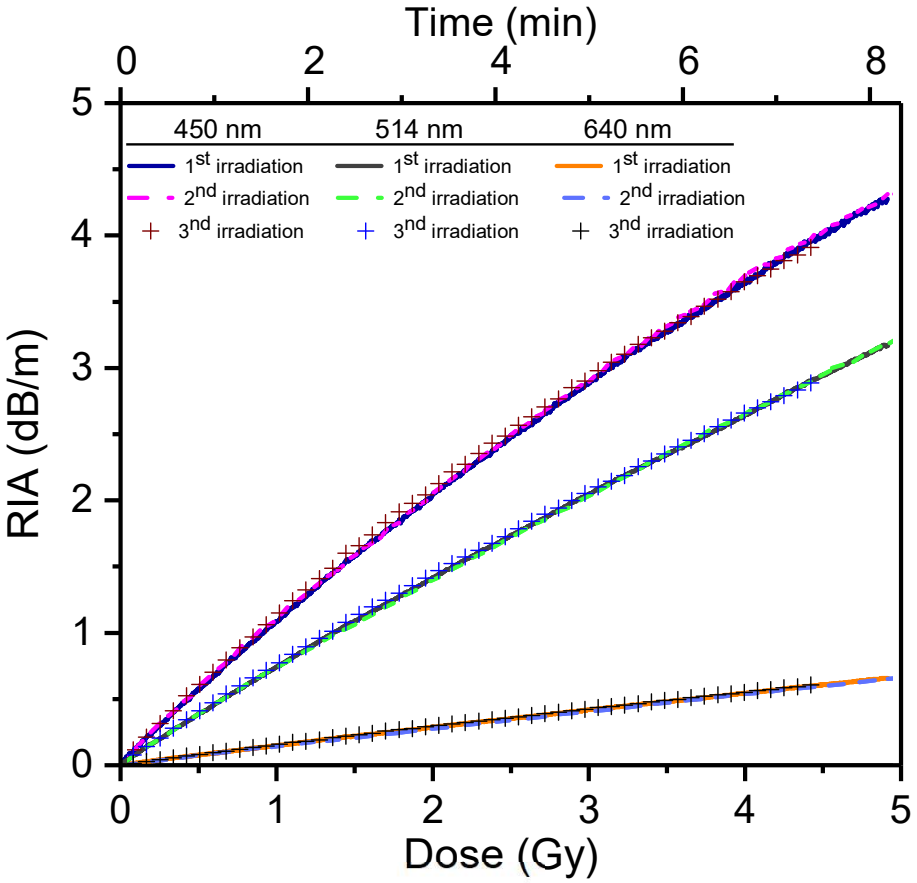
- **5 min laser photobleaching** allows **recovering 50% of the transmission performance** regarding on the remaining RIA compared to the **80% after 1 min laser at 450 nm.**

Results– Another observation : the surprising fast and limited RIA regrowth after the PB action.



- After the short PB period, the RIA level slightly increases.
  - Radiation induced defects absorbing in the visible are again generated, but without irradiation.
- From a practical point of view, the RIA level has to be considered after few minutes.

Results– Re-use of the dosimeter, does the RIA kinetic remain the same ?



- We irradiate the same sample three times and photobleached it 2 times, during 3 hours.
- At 640 nm, 514 nm and 450 nm: The fiber response remains the same
  - **The reset does not change the dosimeter response.**
- From a practical dosimeter point of view, the dosimeter calibration remains unchanged after a full photobleaching session.

Conclusion

❑ Regeneration of a phosphorus doped optical fiber dosimetry operating in the visible domain :

5 Tested photobleaching wavelengths : **1550 nm** **1060 nm** **660 nm** **514 nm** **403 nm**

➔ **Limited** photobleaching effects on RIA with NIR wavelengths.
➔ **403 nm is the most efficient.**

Different photobleaching timing were investigated

➔ By increasing the PB treatment duration, we recover more of the transmission capability.
➔ The first minute of PB is the most productive.
  ➢ Imagine quick time of recovery for dosimetry system.

Untouched dosimetry caracteristics

➔ The dosimeter calibration remains unchanged after a full photobleaching session.

Photobleaching optimization

➔ Optimizing the PB configuration (power, length, duration) should allow to recover the transmission performances in a shorter time.

Thank you for your attention!

Any questions?

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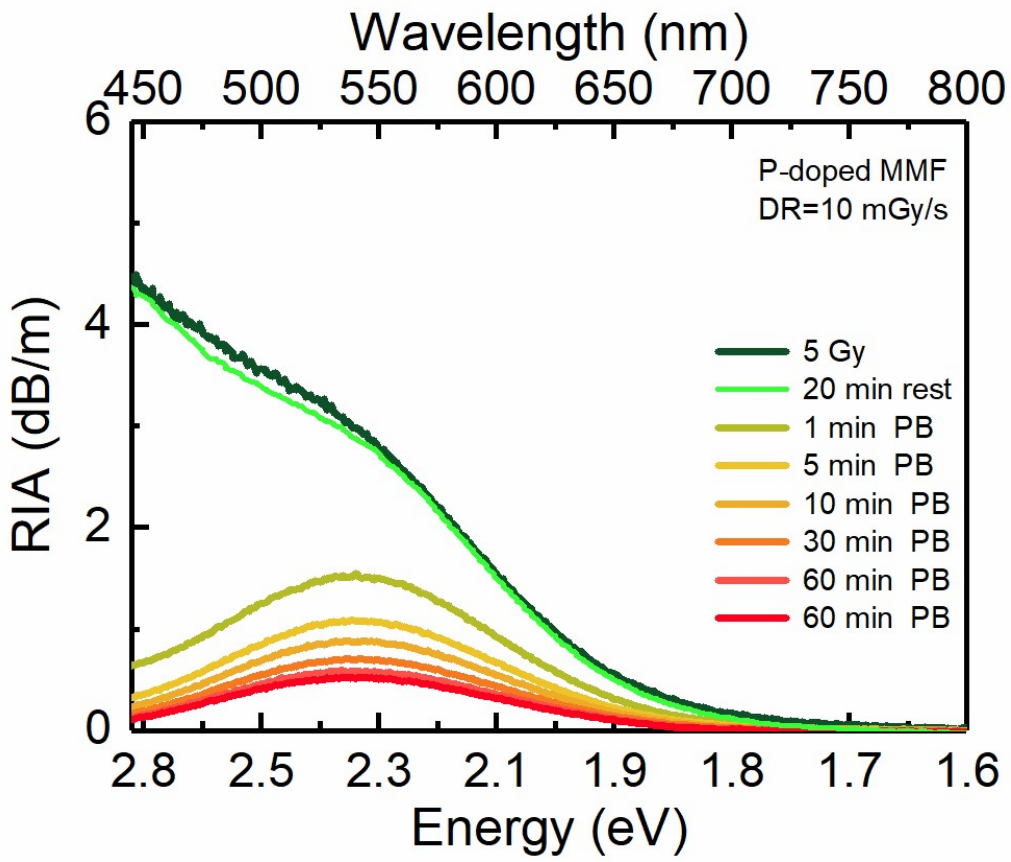
Results– Generalized results of the 403 nm Photobleaching over the Visible spectra



- After the 403 nm PB treatment, the remaining RIA consists in a Gaussian-like absorption centered at 2.3 eV (540 nm)
  - seem to be associated to s-POHC defects.
- 1 min of 403 nm laser PB allows reducing by a factor 2 the losses at 640 nm and 514 nm.
- 85% of transmission performance recovery for the 450 nm RIA.