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Effect of Ionizing Radiation on Optical Transmission of Actively Pumped Yb-Doped Fiber Amplifiers

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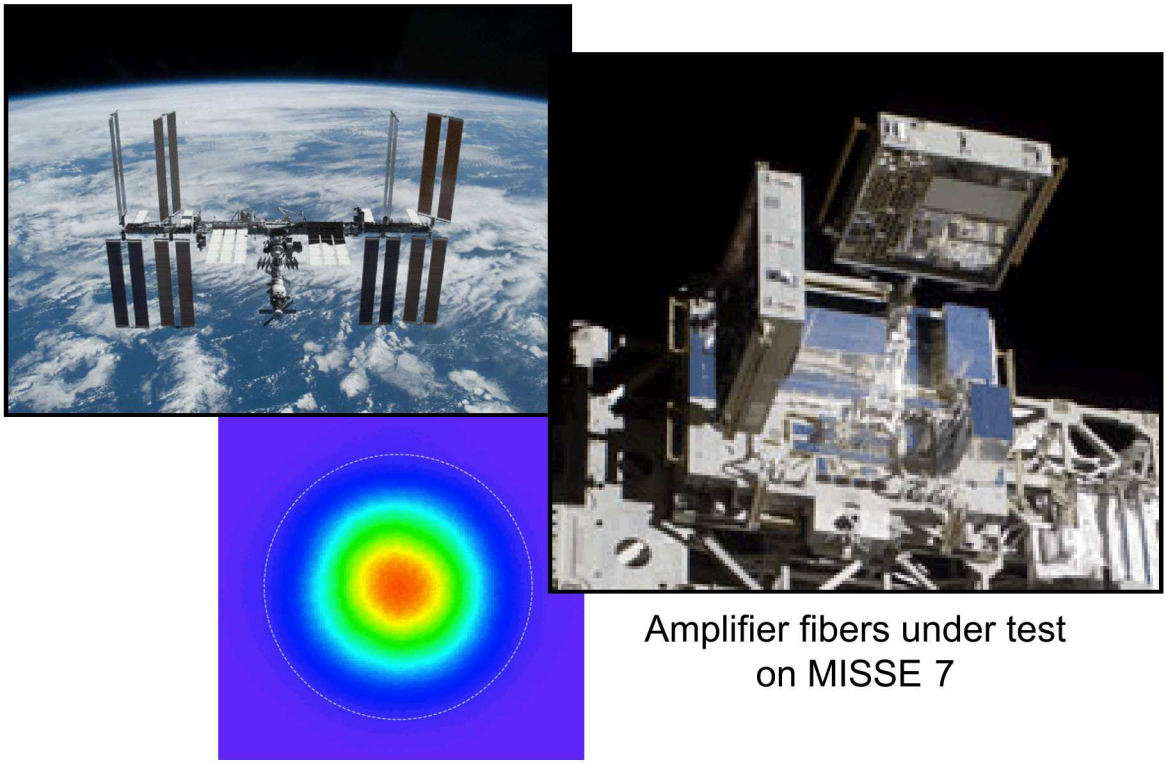
Yb^{3+}-Doped Fiber Amplifiers

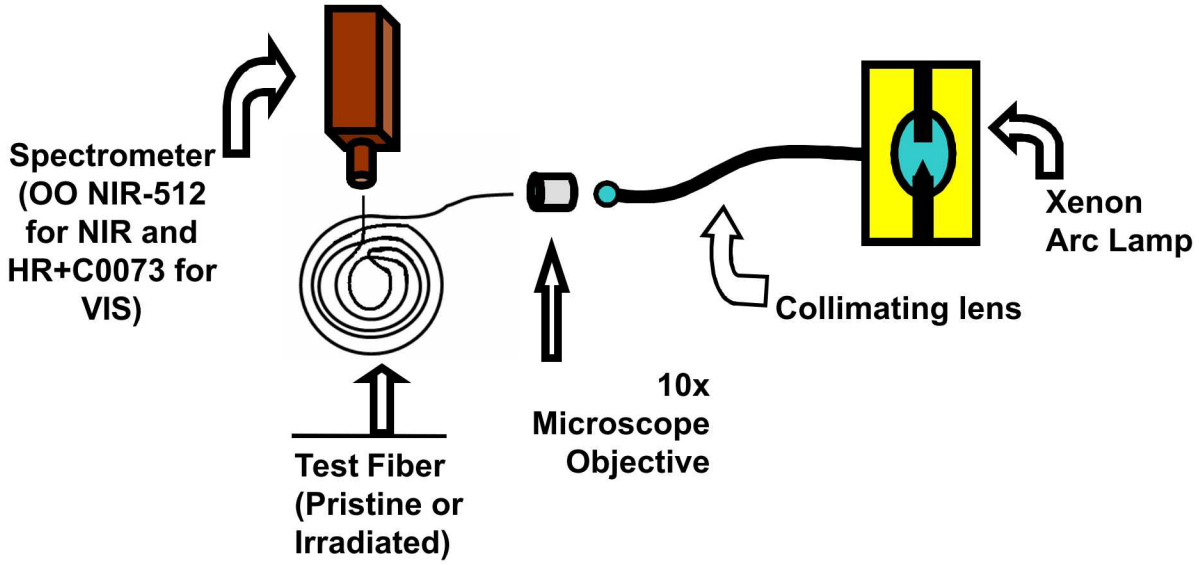
- **Application of doped-fiber amplifiers in space-based systems adds optical functionality in space environments.**



Amplifier fibers under test on MISSE 7

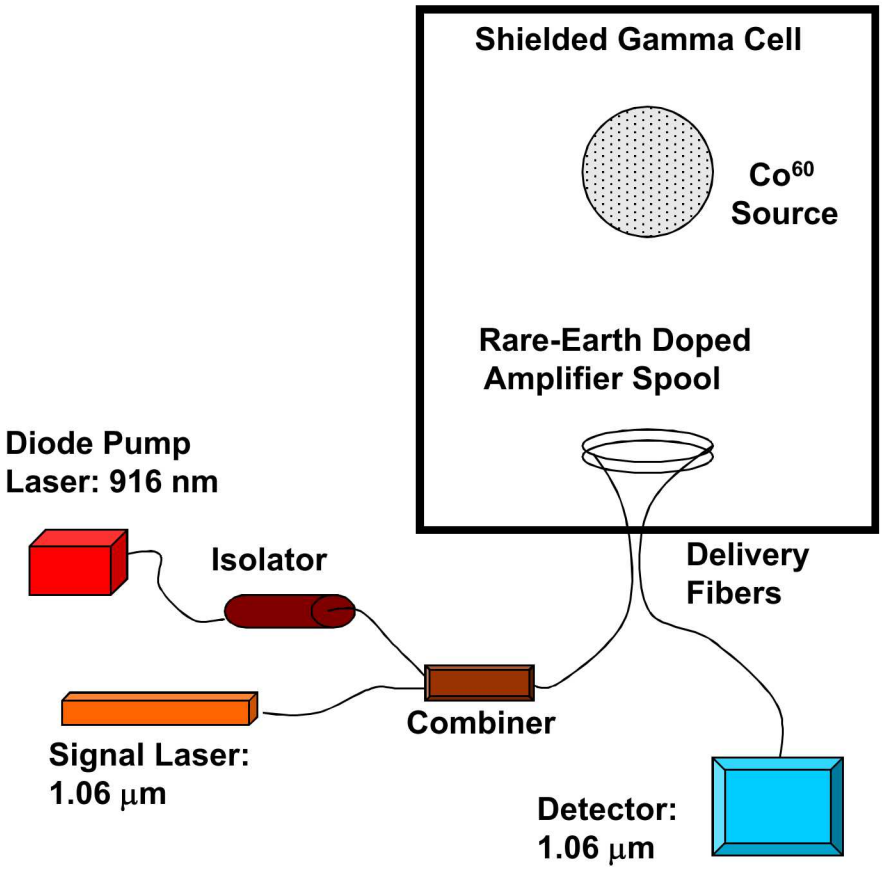
- High reliability through monolithic structure
- High efficiency, low power consumption
- Diffraction-limited beam quality
- Light weight and small volume

Experiment: Optical Transmission



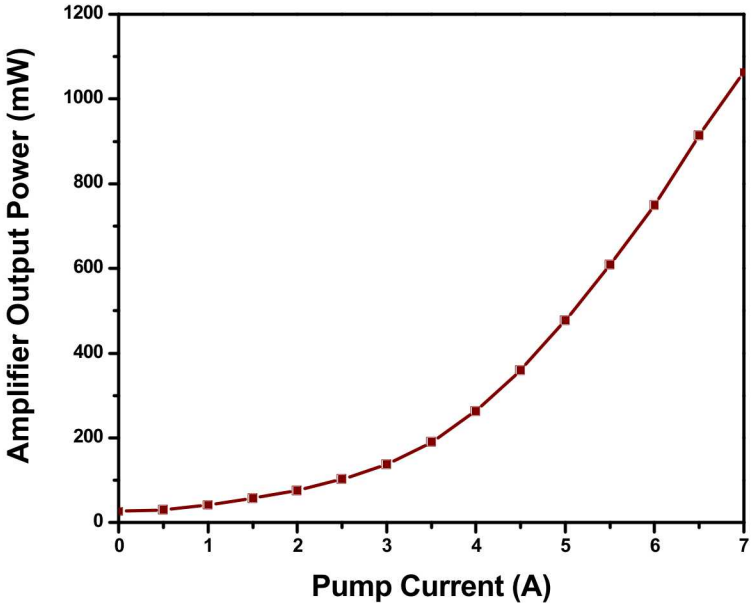
- Fibers tested: Yb^{3+}-doped fiber Liekki (nLight) Yb1200-30/250DC
- Spectroscopy was performed on both pristine and gamma irradiated rare-earth doped fiber samples

Active Fiber Radiation Testing: Setup



- Experiment conducted at the Cobalt-60 cell in the Leach Science Center at Auburn University, AL.
- Yb^{3+}-doped fiber amplifier operated and monitored in-situ during ~419 rad(Si)/hr gamma radiation exposure.
- Figure shows experimental setup with rare-earth-doped fiber spool in the test cell.
- Fibers irradiated both under continuous pumping and intermittent (non-continuous) pumping conditions.

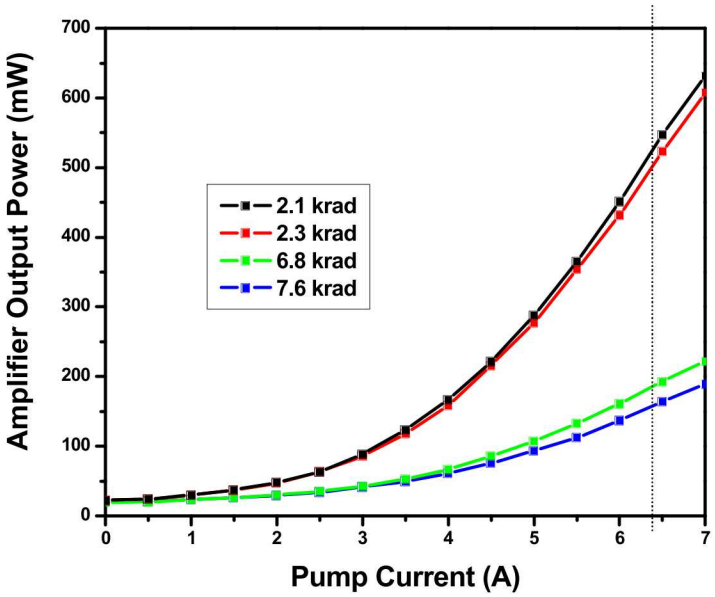
Active Fiber Radiation Testing

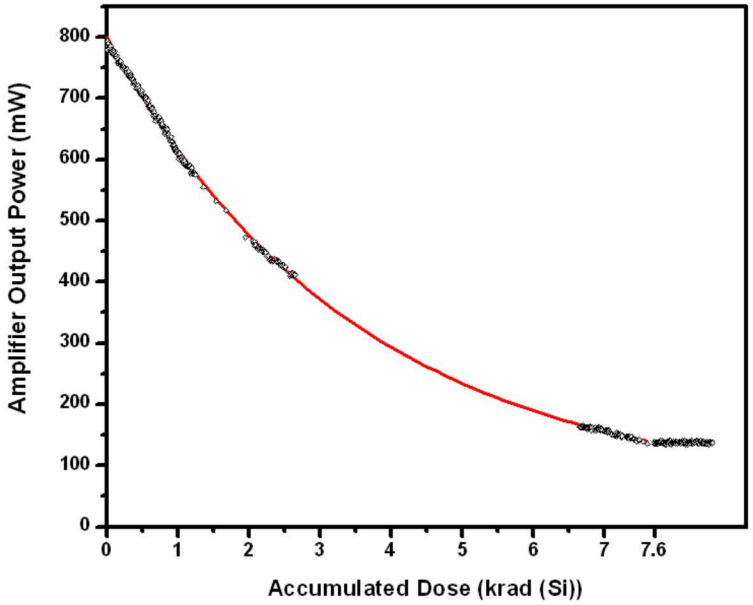


- Amplifier output power measured at the signal wavelength (1.06 μm).
- All power measurements given for output of amplifier routed into gamma-radiation cell.

Plot of power vs. pump current (PI) curve prior to gamma exposure.

Amplifier Irradiation Results with Continuous Pumping

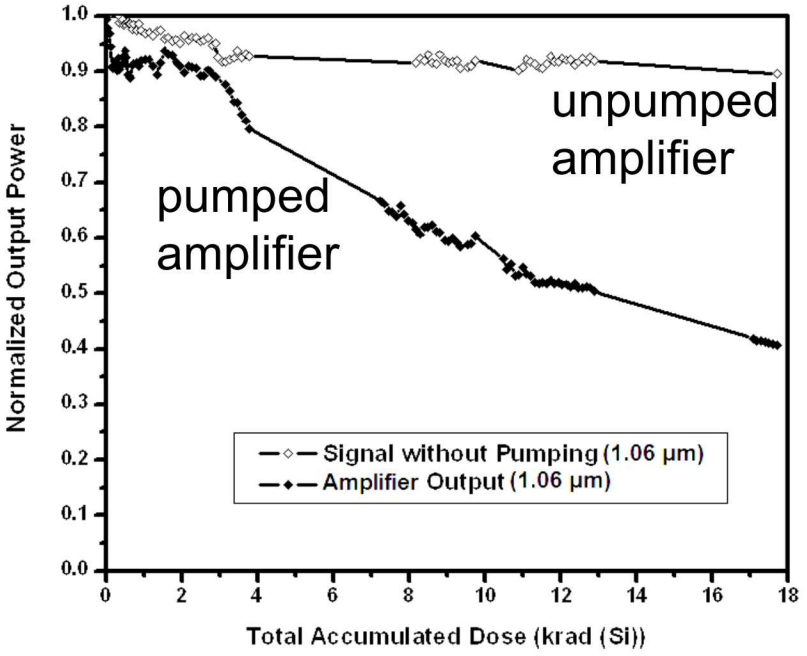




- PI-curve (left) for a range of total accumulated irradiation doses shows decline in amplifier efficiency with gamma exposure.
- Amplifier output power during irradiation (right) up to 7.6 krad(Si) shows significant radiation-induced exponential decay of amplifier output signal (1.06 μm). Amplifier power output after 7.6 krad(Si) is only ~17% of initial.

Effect of Non-Continuous Pumping During Radiation Exposure

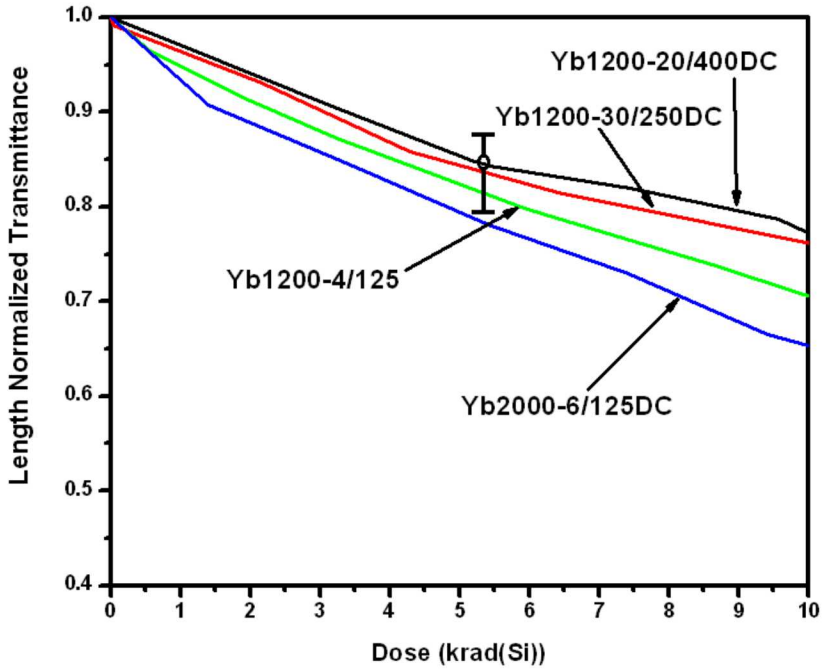
- Yb^{3+}-doped fiber amplifier operated and monitored in-situ during 419 rad(Si)/hr gamma-radiation exposure. Initial power ~800 mW.
- Pumping of amplifier only occurred when measurements were being made.
- Pump laser (915 nm) was turned off during most of the experiment, but signal laser (1.06 μm) was left on.
- Passive loss at signal wavelength (1.06 μm) is ~10 - 15% (similar for both continuous and non-continuous pumping experiments).



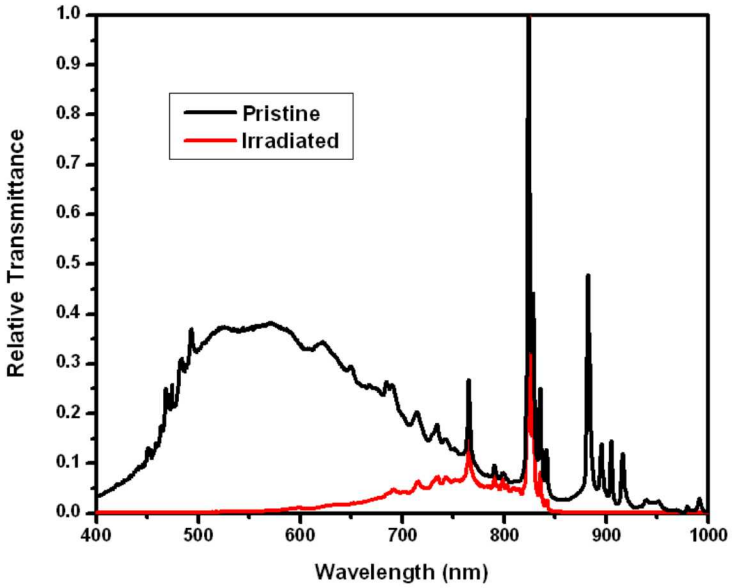
- Approximately linear decay observed for amplifier output (1.06 μm) when pumped non-continuously.
- After 7.6 krad(Si) amplifier performance is ~66% of initial.

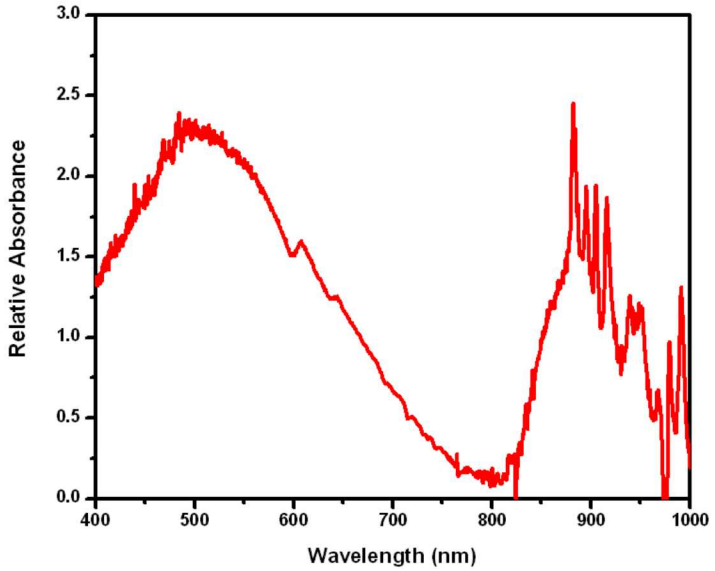
Transmission of Unpumped Gamma-Irradiated Yb^{3+}-Doped Fibers at 1.06 μm

- Plotted on the right are the results of previous unpumped irradiation of Yb^{3+}-doped fiber compositions at the lasing wavelength of 1.06 μm.
- The length normalized transmittance decrease after an accumulated dose of ~7 krad (Si) is on the order of 15% for the 30/250DC fibers in these experiments.
- Similar response seen in these passive fiber experiments as in the passive, intermittently pumped fiber amplifiers.



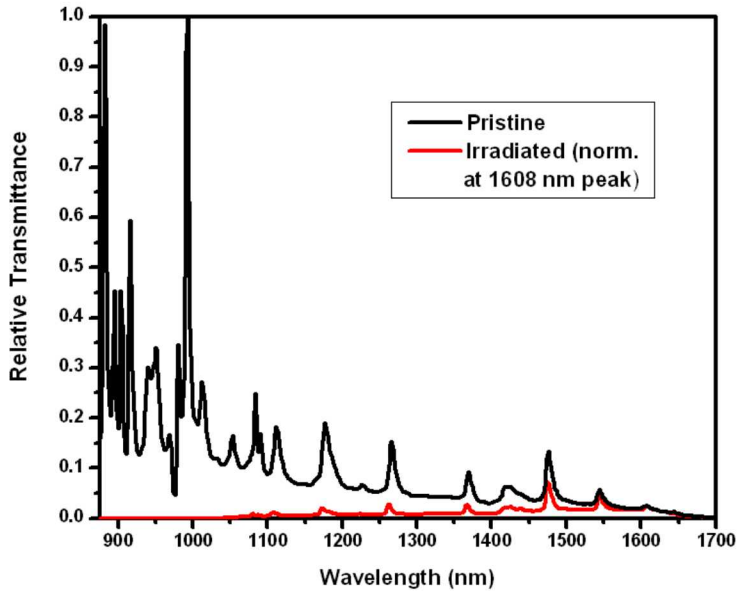
Visible Spectroscopy of Yb^{3+}-Doped Fiber Material

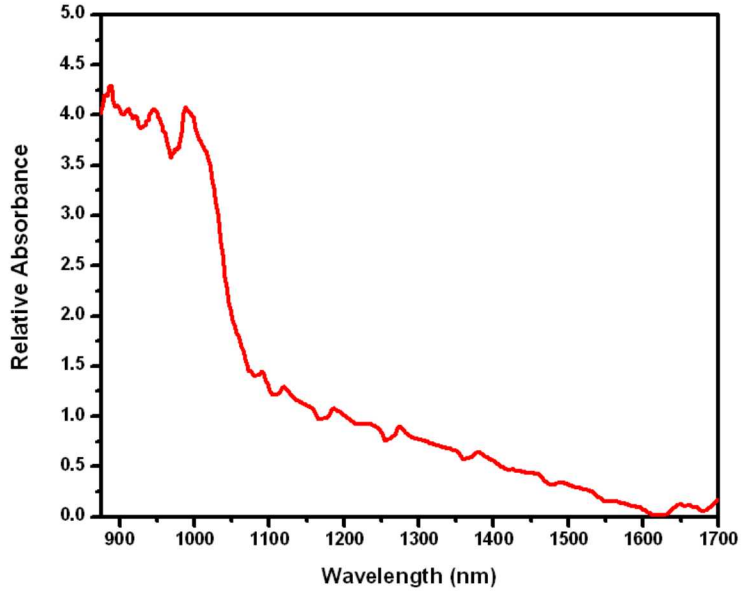




- Visible spectroscopy was conducted on pristine and gamma irradiated (16.9 krad (Si) total dose) fiber samples.
- Large, radiation-induced absorption over 400 - 700 nm range. Further absorption is observed at wavelengths greater than ~850 nm.
- Consistent with previously found Al-related color centers (such Al oxygen-hole centers).

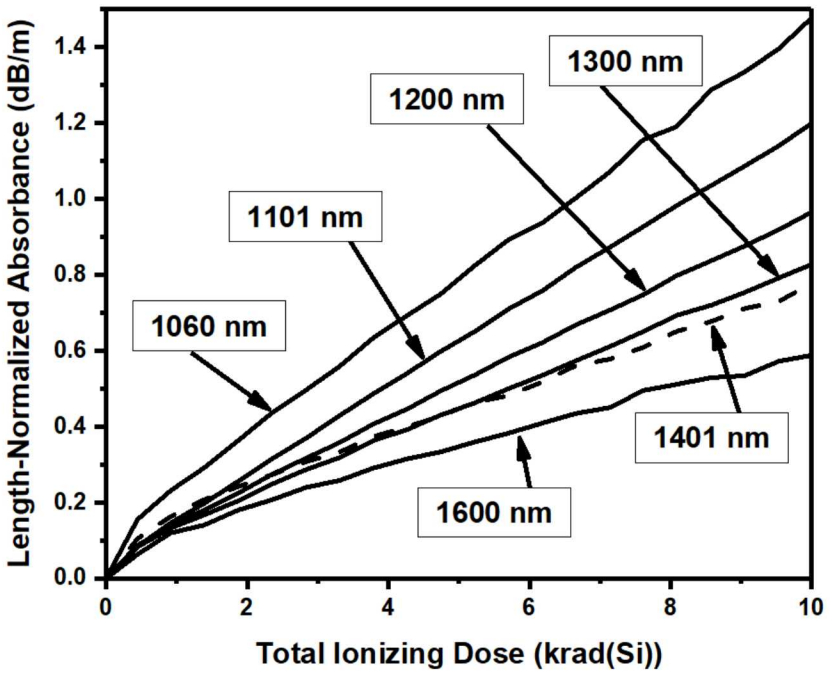
NIR Spectroscopy of Yb^{3+}-Doped Fiber Material



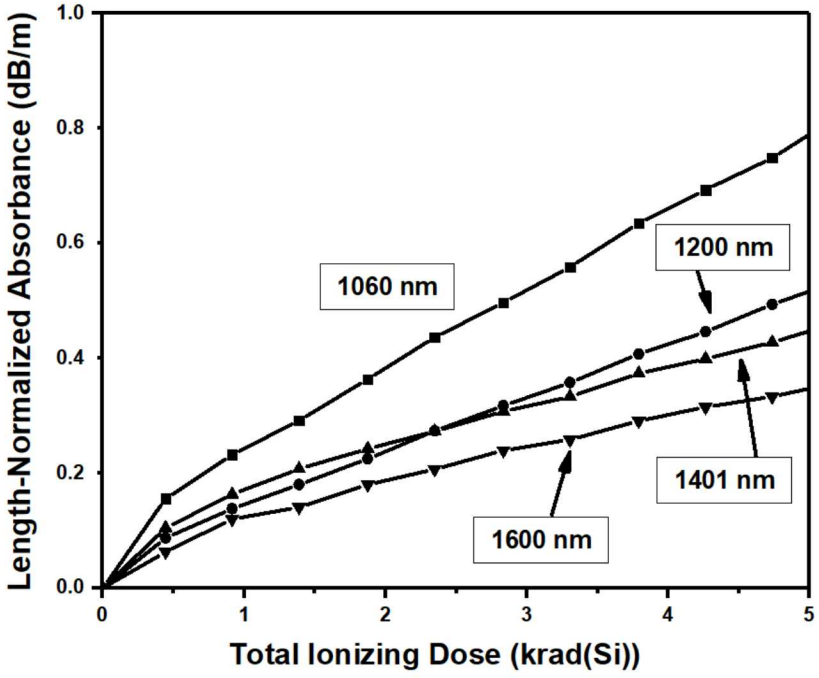


- NIR spectroscopy was conducted on pristine and gamma irradiated (16.9 krad (Si) total dose) fiber samples.
- Irradiated fiber shows absorption band tails in the NIR due to color centers in the visible part of the spectrum, possible NIR bands, consistent with the literature.

Dose Dependence of NIR Absorbance

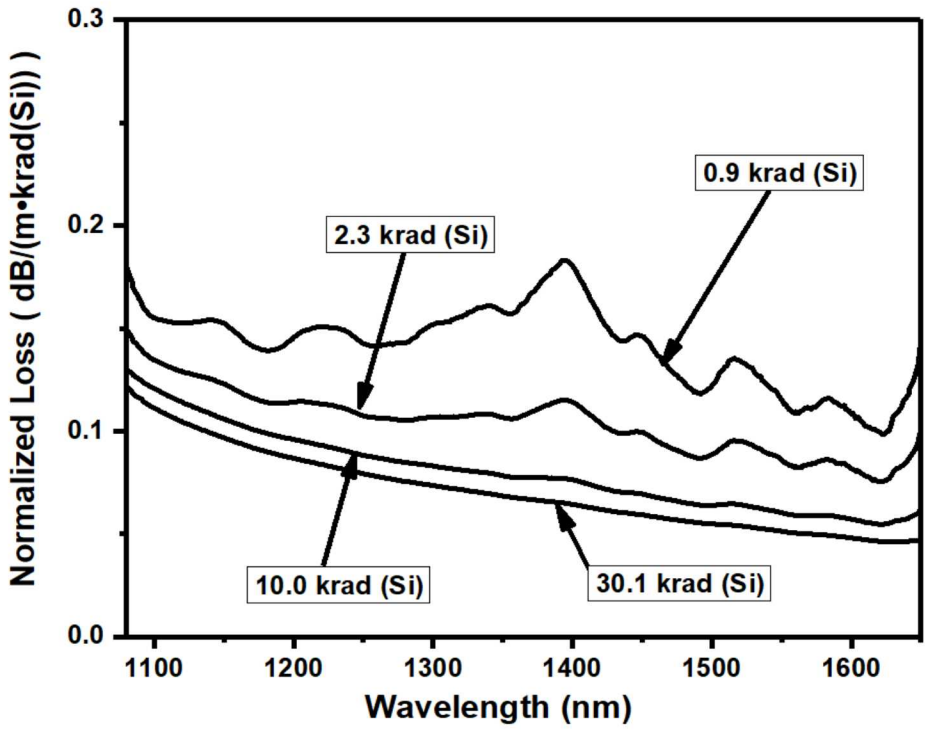


Close investigation of IR data show that longer wavelengths experience a greater radiation-induced absorption than shorter wavelengths at low total doses.



Dose Dependence of NIR Absorbance

- Larger dose-normalized losses observed at low total doses.
- Anomalously large induced absorption at 1400 nm for low total doses. Can be linked to prior reports identifying self-trapped hole centers.
- stable normalized loss, consistent with the interpretation of color center tailing from the UV and visible portion of the spectrum, is realized around 10-30 krad(Si)



Fiber Amplifier Conclusions I

- Significant degradation in amplifier performance exhibited in actively-pumped, gamma-irradiated Yb^{3+}-doped fiber.
- The continuously-pumped amplifier experienced an exponential decrease in output power, while the non-continuously-pumped amplifier experienced a roughly linear decrease in power. The former configuration showed greater radiation-induced absorption than the latter (~17% amplifier efficiency vs. ~66% amplifier efficiency after ~7.6 krad(Si)).
- Large radiation-induced loss in the visible spectrum suggests depletion of the pump by radiation-induced color centers as one possible source of amplifier loss.

Acknowledgements

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