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Comparative neutron irradiation effects on structural (B/Ge) and rare-earth (Er/Yb) doped silica fibers: Photoluminescence and application specific performance analysis

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Saidin, Norazlina [a] ; Baba, Tamana [a] ; Muzafar, Nurul Addeeni [a] ;
Farid, Raja Zarith Batrisyia Raja Ahmad [a] ; Shaharuddin, Siti Shafiqah Ahmad [b] ; +3 authors

[a] Department of Electrical and Computer Engineering, Kulliyyah of Engineering, International Islamic University Malaysia, Kuala Lumpur, 53100, Malaysia

Abstract

The resilience of optical fibers in radiation-rich environments is increasingly critical for applications in space communications, nuclear facilities, and high-power photonics. While extensive studies have been conducted on either structurally doped fibers or rare-earth doped fibers, comparative insights across these two fundamental classes remain limited. This work systematically investigates the effects of neutron irradiation on Boron- and Germanium-doped fibers (structural dopants) alongside Erbium- and Ytterbium-doped fibers (rare-earth dopants). Photoluminescence (PL) spectroscopy was employed as a universal diagnostic probe to evaluate radiation-induced modifications in optical properties, while application-specific performance metrics were separately analyzed: reflectivity and Bragg wavelength shifts for Boron and Germanium, and the output power and amplified spontaneous emission (ASE) for Erbium and Ytterbium. The results reveal distinct radiation responses: Boron-doped fibers exhibit strong PL quenching and pronounced Bragg wavelength shifts, highlighting their potential as sensitive radiation dosimeters; Germanium-doped fibers display moderate PL variation and minimal wavelength shifts, underscoring their spectral stability; Erbium-doped fibers suffer

severe ASE degradation ('40 dB loss), reflecting poor radiation tolerance; while Ytterbium-doped fibers retain emission stability with modest losses (15–20 dB), demonstrating structural resilience. By unifying the analysis of structural and rare-earth dopants, this study bridges a critical gap in fiber radiation research and provides a comprehensive framework for tailoring dopant selection according to both optical response and application-specific performance in harsh environments. © 2026 Elsevier Ltd.

Author keywords

Boron; Erbium-doped fiber; Germanium; Neutron irradiation; Photoluminescence spectroscopy; Ytterbium-doped fiber

Indexed keywords

Engineering controlled terms

Doping (additives); Dosimeters; Erbium; Neutrons; Optical waveguides; Radiation effects; Rare earth-doped fibers; Silica; Spectrum analysis; Ytterbium

EMTREE drug terms

boron; erbium; germanium; lanthanide; silicon dioxide; ytterbium

Engineering uncontrolled terms

Amplified spontaneous emissions; Application specific; Boron-doped fibers; Bragg wavelength shift; Erbium-doped fibers; Germanium doped fiber; Germaniums (Ge); Optical-; Rare earth dopants; Ytterbium doped fibers

EMTREE medical terms

amplified spontaneous emission; Article; Bragg Wavelength Shift; comparative study; Fiber Bragg Grating; irradiation; Monte Carlo method; neutron radiation; performance; photoluminescence; radiation exposure; radiation induced attenuation; radiation induced attenuation; radiation response; reflectivity; refraction index; spectroscopy; thermal equilibration; X ray

Engineering main heading

Boron; Germanium; Neutron irradiation

Device trade names

Commercial names given to devices, used for branding and differentiation in the market, commonly referenced in scientific and clinical research.

Horiba LabRAM; PUSPATI TRIGA Mark II

Chemicals and CAS Registry Numbers

Unique identifiers assigned by the Chemical Abstracts Service (CAS) to ensure accurate identification and tracking of chemicals across scientific literature.

boron	7440-42-8
erbium	7440-52-0
germanium	7440-56-4
silicon dioxide	10279-57-9, 14464-46-1, 14808-60-7, 15468-32-3, 60676-86-0, 7631-86-9
ytterbium	7440-64-4

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Corresponding authors

Corresponding author	N. Saidin
Affiliation	Department of Electrical and Computer Engineering, Kulliyyah of Engineering, International Islamic University Malaysia, Kuala Lumpur, 53100, Malaysia
Email address	norazlina@iium.edu.my