Supporting Information

Development of BODIPY based Ratiometric Fluorescence Off-On Dosimeter for Gamma Radiation

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Content

Synthesis and characterization.

All the chemical reactions were carried under argon atmosphere using anhydrous solvents in screw-cap schlenk tube. All the chemical reagents and solvents were purchased from local supplier and were used without any further purification. Thin-layer chromatography was used to monitor the progress of the reactions using commercially available 0.25 mm fluorescent silica plate (F-254) and visualized using a UV-lamp (254 nm and 354 nm wavelength). Compounds were purified by flash chromatography using silica gel (40-63 μm). NMR spectra were recorded in 300 MHz Bruker FT-NMR & 500 MHz Varian FT-NMR instruments. High Resolution Mass Spectrometric (HRMS) analysis was done using 6540 UHD Accurate-Mass Agilent Q-TOF LC/MS instrument.

2,6-Diethyl-4,4-difluoro-1,3,5,7,8-pentamethyl-4-bora-3a,4a-diaza-*s*-indecene (1).[1] ^{1}H NMR: δ 1.03 (t, *J* = 7.6 Hz, 6H), 2.32 (s, 6H), 2.67 (s, 3H), 2.37 (q, *J* = 7.6 Hz, 4H), 2.48 (s, 6H), 2.59 (s, 3H); ^{13}C NMR: δ 12.2, 14.2, 14.8, 16.7, 17.0, 131.5, 132.2, 136.3, 139.8, 151.6; HRMS (ESI-TOF) m/z [M + H^{+}] Calcd. for $C_{18}H_{25}BF_2N_2$: 319.2157. Found: 319.2123.

4,4-Difluoro-1,3,5,7,8-pentamethyl-4-bora-3a,4a-diaza-*s*-indecene (2).[1] ^{1}H NMR: δ 2.40 (s, 6H), 2.52 (s, 6H), 2.56 (s, 3H), 6.05 (s, 2H); ^{13}C NMR: δ 14.4, 16.3, 17.3, 121.2, 132.0, 141.0, 141.4, 153.6; EI-MS m/z (%): 262.0 (100) [M]$^{+}$.

2,6-Diethyl-4,4-difluoro-1,3,5,7-tetramethyl-8-phenyl-4-bora-3a,4a-diaza-*s*-indecene (3).[1] ^{1}H NMR: δ 1.09 (t, *J* = 7.6 Hz, 6H), 1.48 (s, 6H), 2.31 (q, *J* = 7.6 Hz, 4H), 2.87 (s, 6H), 7.01−7.06 (m, 2H), 7.29−7.37 (m, 3H); ^{13}C NMR: δ 11.6, 12.5, 14.6, 17.1, 128.3, 128.7, 129.0, 130.8, 132.7, 135.8,138.4, 140.2, 153.7; EI-MS m/z (%): 380.0 (100) [M]$^{+}$.

4,4-Difluoro-1,3,5,7-tetramethyl-8-phenyl-4-bora-3a,4a-diaza-s-indecene (4).[1] ^{1}H NMR: δ 1.36 (s, 6H), 2.54 (s, 6H), 5.97 (s, 2H), 7.25−7.28 (m, 2H), 7.44−7.48 (m, 3H); ^{13}C NMR: δ 14.2, 14.5, 121.2, 127.9, 128.5, 128.9, 129.1, 131.4, 134.9, 141.7, 143.1, 155.4; HRMS (ESI-TOF) m/z [M + H^{+}] Calcd. for $C_{19}H_{19}BF_2N_2$: 325.1687. Found: 325.1660.

4,4-Difluoro-8-phenyl-4-bora-3a,4a-diaza-*s*-indecene (5).[2] ^{1}H NMR: δ 6.55 (d, *J* = 7.0 Hz, 2H, 6.95 (d, *J* = 7.0 Hz, 2H), 7.50-7.60 (m, 5H), 7.95 (s, 2H); ^{13}C NMR: δ 118.5, 128.4, 130.5, 130.7, 131.6, 133.8, 134.9, 144.1, 147.4; EI-MS m/z (%): 268.1 (100) [M]$^{+}$.

BODIPY dye 6. A mixture of pyrrole (**8**) (18.5 mL, 268.1 mmol), 4-(dimethyl-amino)benzaldehyde (1.0 g, 6.7 mmol) and TFA (4 drops) in CH_2Cl_2 (30 mL) was stirred at 25 ^oC for 12 h. DDQ (1.67 g, 7.37 mmol) was added to the resulting deep colour solution and stirring continued for 4 h. Then, the mixture was treated with Et_3N (5.6 mL, 40.2 mmol) and stirred for another 10 min. Finally, $BF_3.Et_2O$ (4.96 mL, 40.2 mmol) was added into the mixture and the solution stirred at room temperature for 12 h. The resulting dark mixture was washed with aqueous saturated $NaHCO_3$ (50 mL), H_2O (80 mL) and brine (80 mL) and dried. Removal of solvent in vacuum followed by column chromatography of the residue (silica gel, hexane-EtOAc) furnished BODIPY dye **6** (0.61 g, 29%), which was recrystallized from CH_2Cl_2/cyclohexane to afford red crystals. ^1H NMR: δ 3.11 (s, 6H), 6.54 (d, J = 2.0 Hz, 2H), 6.83 (d, J = 8.5 Hz, 2H), 7.04 (d, J = 4.0 Hz, 2H), 7.57 (d, J = 8.5 Hz, 2H), 7.87 (s, 2H); ^{13}C NMR: δ 40.1, 111.4, 117.6, 121.7, 130.7, 133.1, 134.4, 141.6, 148.4, 152.5; HRMS (ESI-TOF) m/z $[M + H]^+$ Calcd. for $C_{17}H_{16}BF_2N_3$: 312.1484; Found: 312.1493.

BODIPY dye 7. A mixture of BODIPY dye **6** (50 mg, 0.16 mmol) and MeI (5 mL) in a sealed tube was heated at 40 ^oC for 3 d. The excess amount of MeI was removed under vacuum and the residue was purified by column chromatography (C-18 silica gel, MeOH) to obtain BODIPY dye 7 (30 mg, 57%) as red powder. ^1H NMR: δ 4.07 (s, 9H), 6.71 (s, 2H), 6.99 (s, 2H), 8.03 (d, J = 8.5 Hz, 2H), 8.08 (s, 2H), 8.43 (d, J = 8.5 Hz, 2H); ^{13}C NMR: δ 58.0, 120.2, 122.0, 132.3, 133.1, 135.5, 136.3, 145.5, 146.2, 149.9; HRMS (ESI-TOF) m/z $[M]^+$ Calcd. for $C_{18}H_{19}BF_2IN_3$: 453.0685; Found: 453.0632.

Photophysical Properties.

Table S1. Photophysical properties of the dyes **6** in chloroform at room temperature.

Dye	λ_{abs} **[nm]**	λ_{em} **[nm]**	ε_{max} **[M^{-1} cm^{-1}]**	Φ_{fl} **[%]**[a]
6	496.0, 540.0	609.0	55700	<1

[a]Determined using Φ_{fl} = 0.88 for Rhodamine 6G in ethanol as the reference.[3]

Experimental details for γ-dosimetry. 2 mL solutions of the dyes **1-7** in organic solvents (~10^{-6} M) were irradiated with specified γ-doses using the Gamma Chamber 5000 (Make: Board of Radiation and Isotope Technology (BRIT), DAE, Mumbai, India; Dose rate: 81.80 Gy/min; Source: ^{60}Co). Then the absorbance and fluorescence were recorded after 5 min of the end of the irradiation of γ-rays.

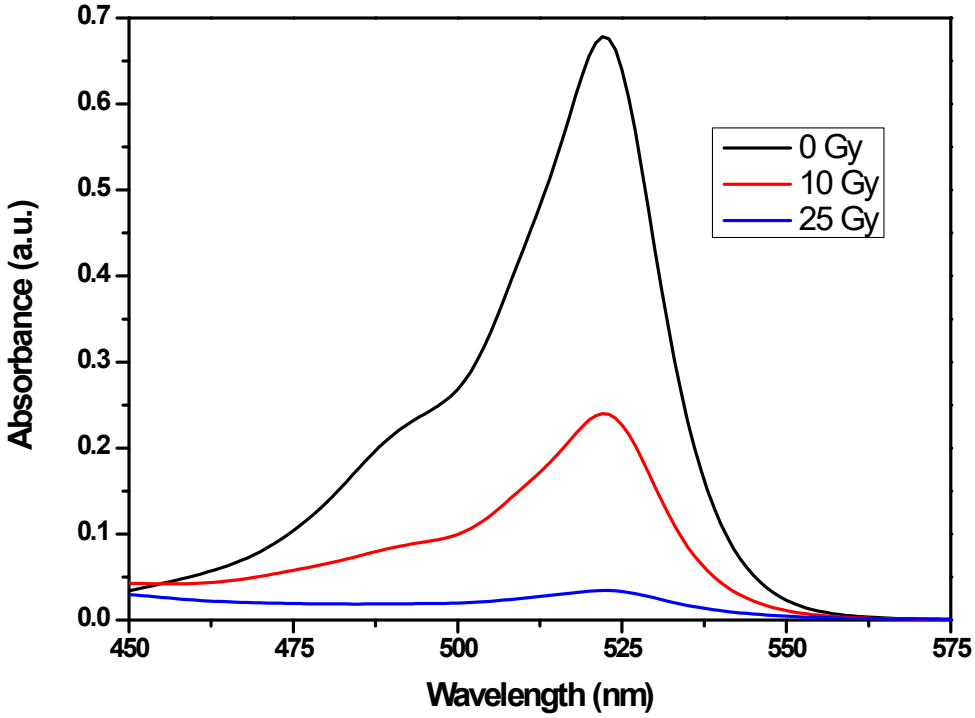


Figure S1. Absorption spectra of dye **1** in chloroform after γ-irradiation with different doses.

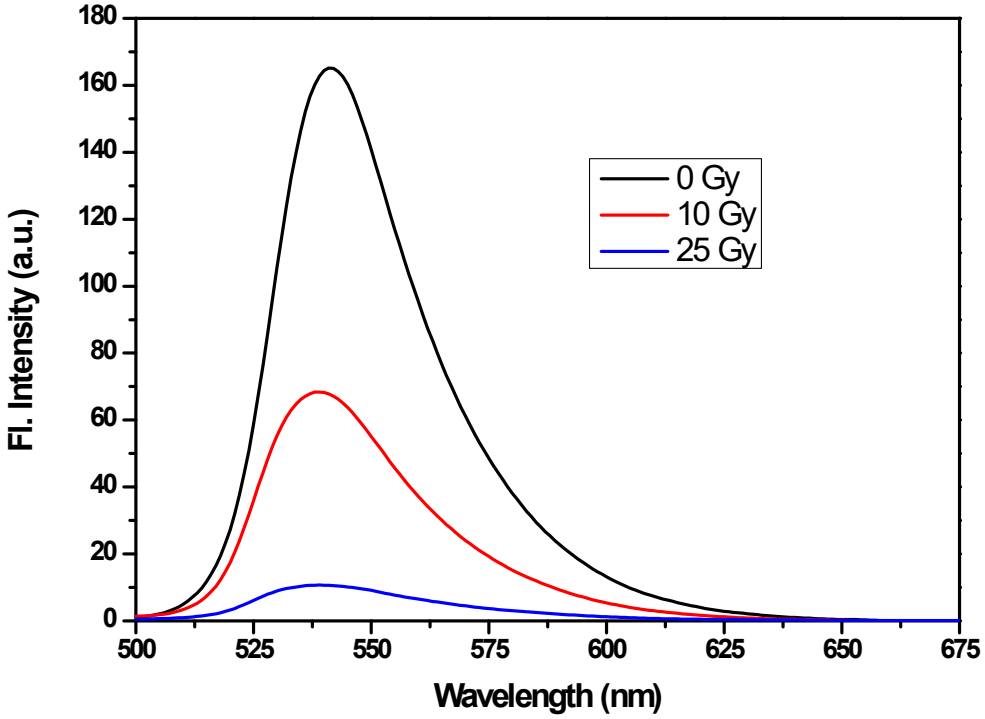


Figure S2. Fluorescence spectra of dye **1** in chloroform after γ-irradiation with different doses.

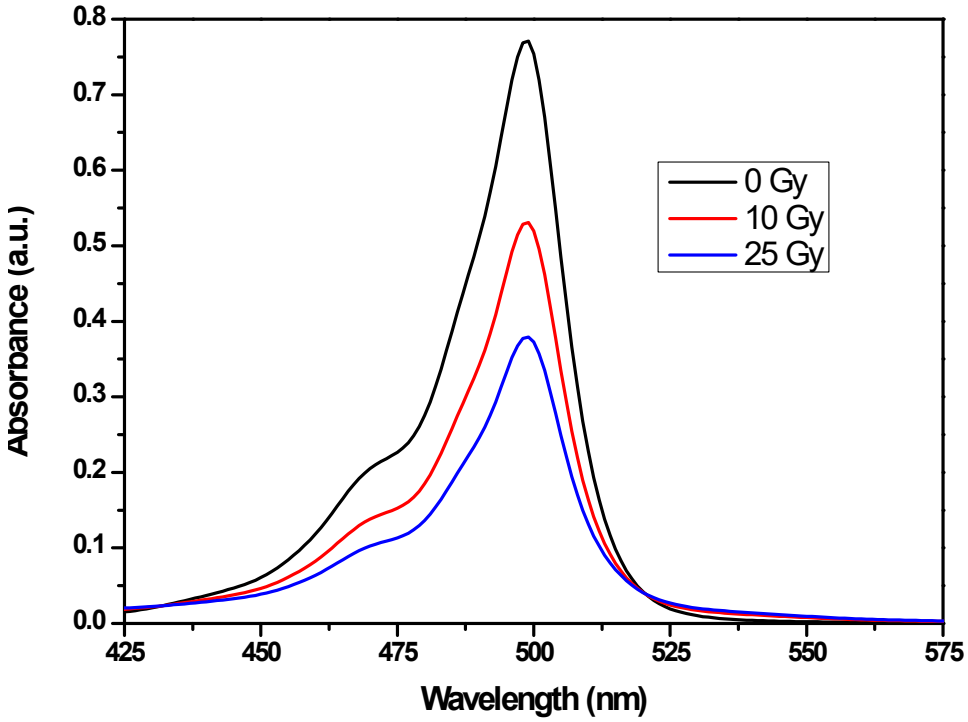


Figure S3. Absorption spectra of dye **2** in chloroform after γ-irradiation with different doses.

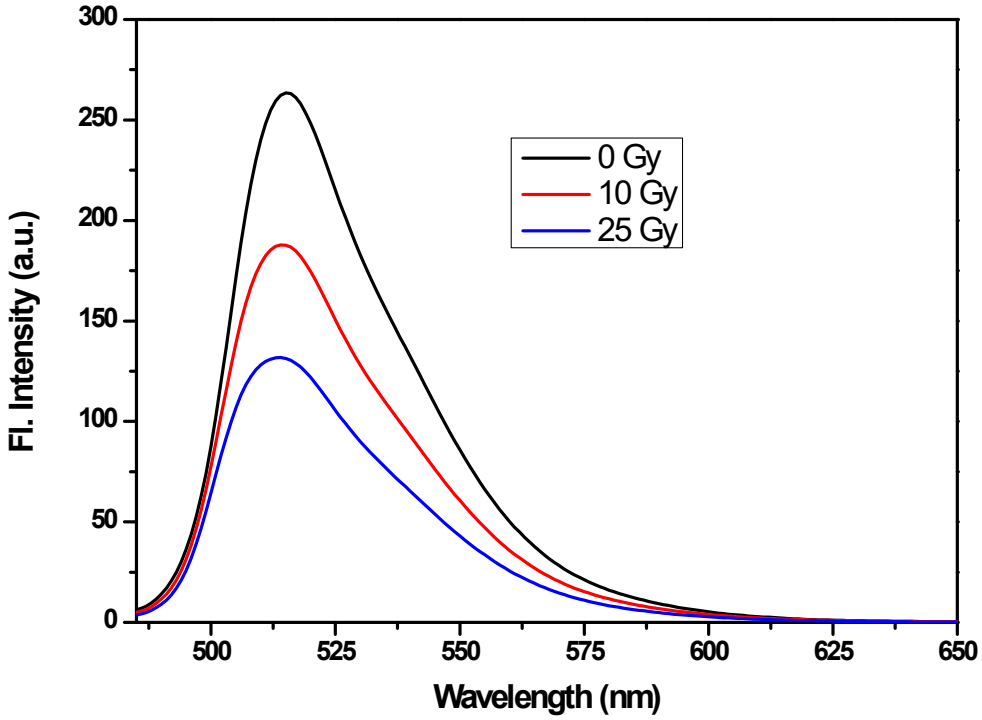


Figure S4. Fluorescence spectra of dye **2** in chloroform after γ-irradiation with different doses.

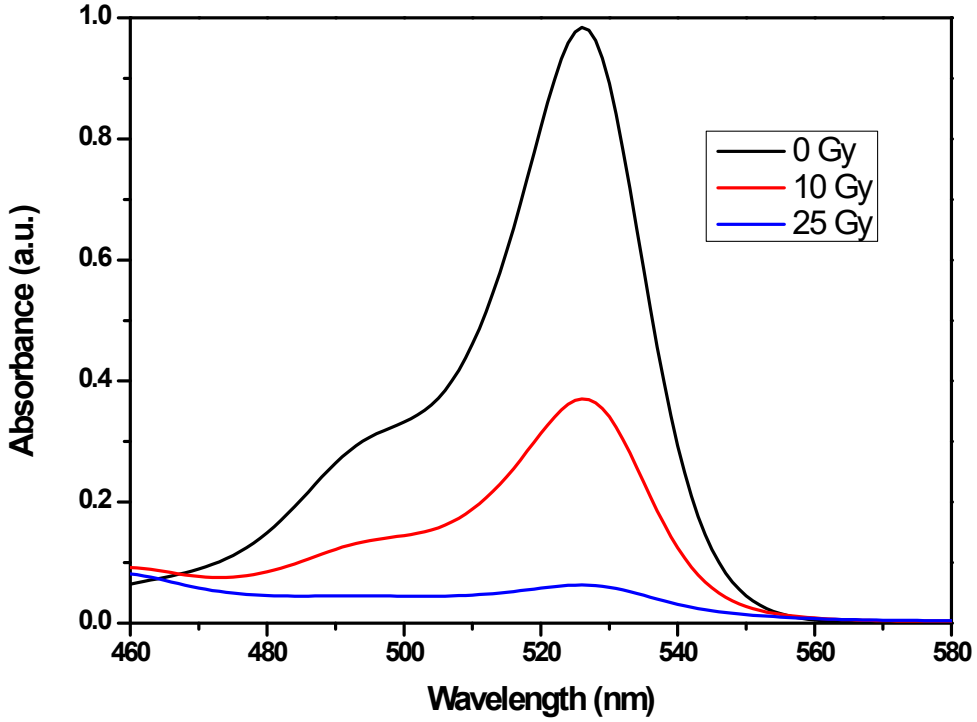


Figure S5. Absorption spectra of dye **3** in chloroform after γ-irradiation with different doses.

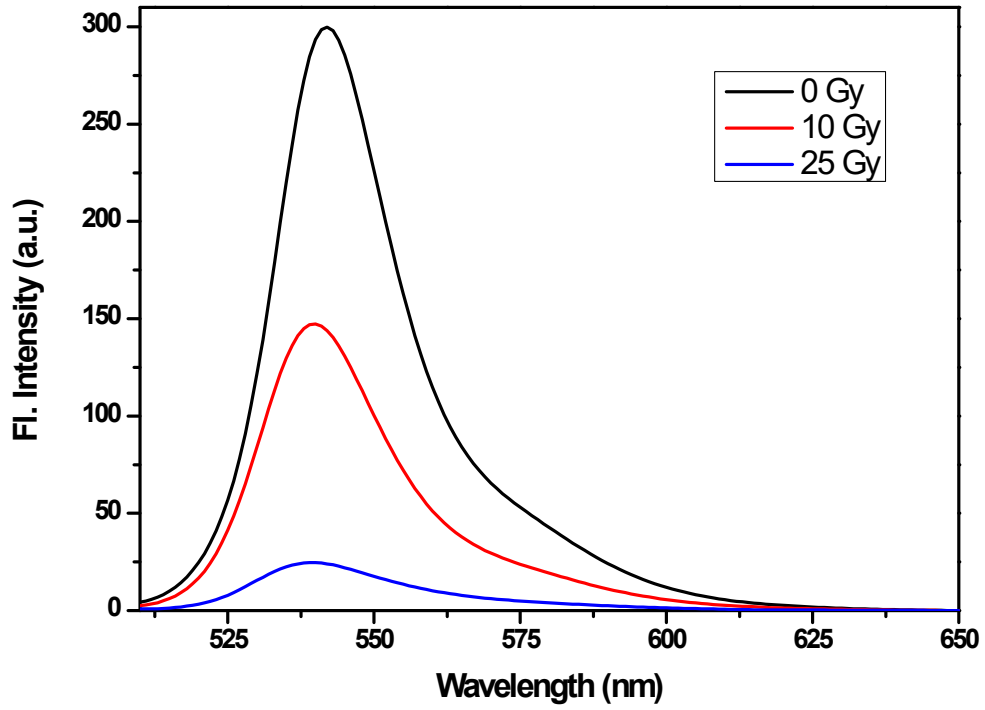


Figure S6. Fluorescence spectra of dye **3** in chloroform after γ-irradiation with different doses.

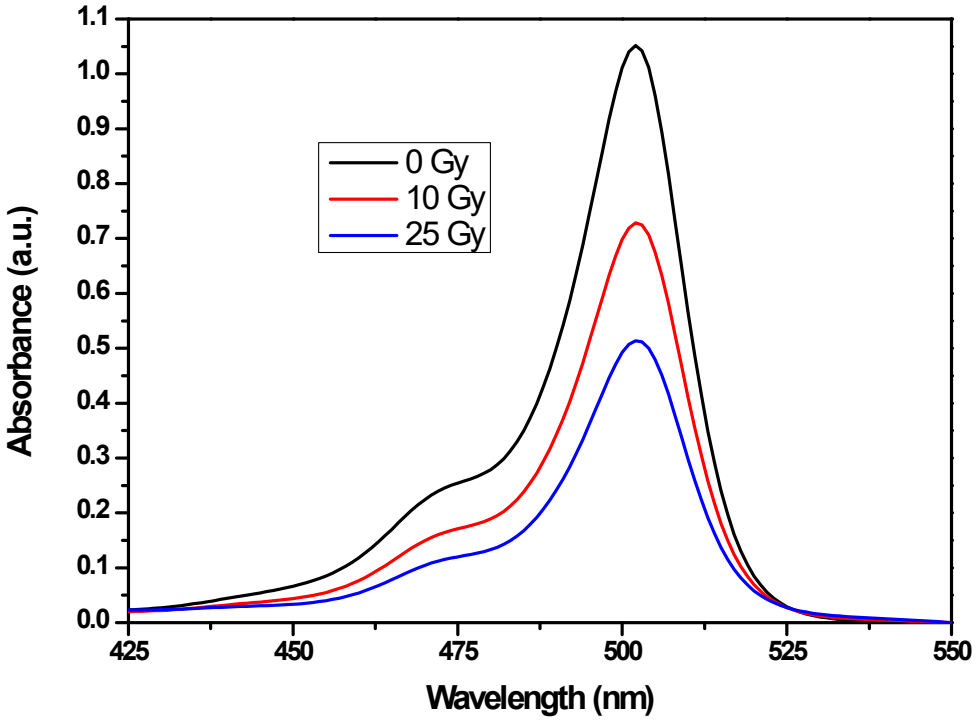


Figure S7. Absorption spectra of dye **4** in chloroform after γ–irradiation with different doses.

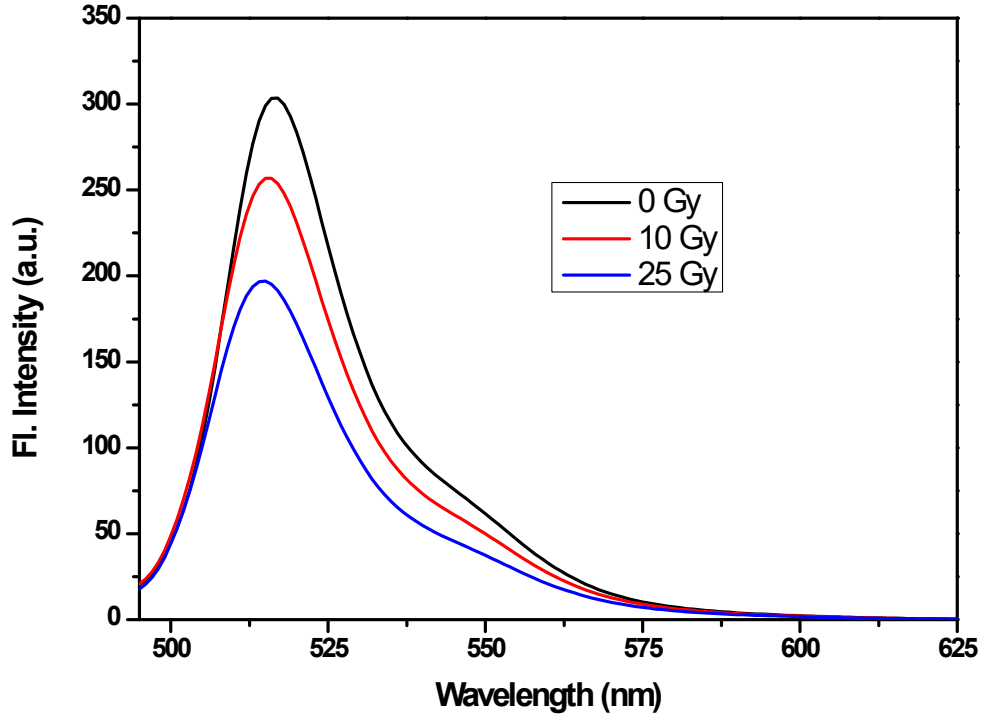


Figure 8. Fluorescence spectra of dye **4** in chloroform after γ–irradiation with different doses.

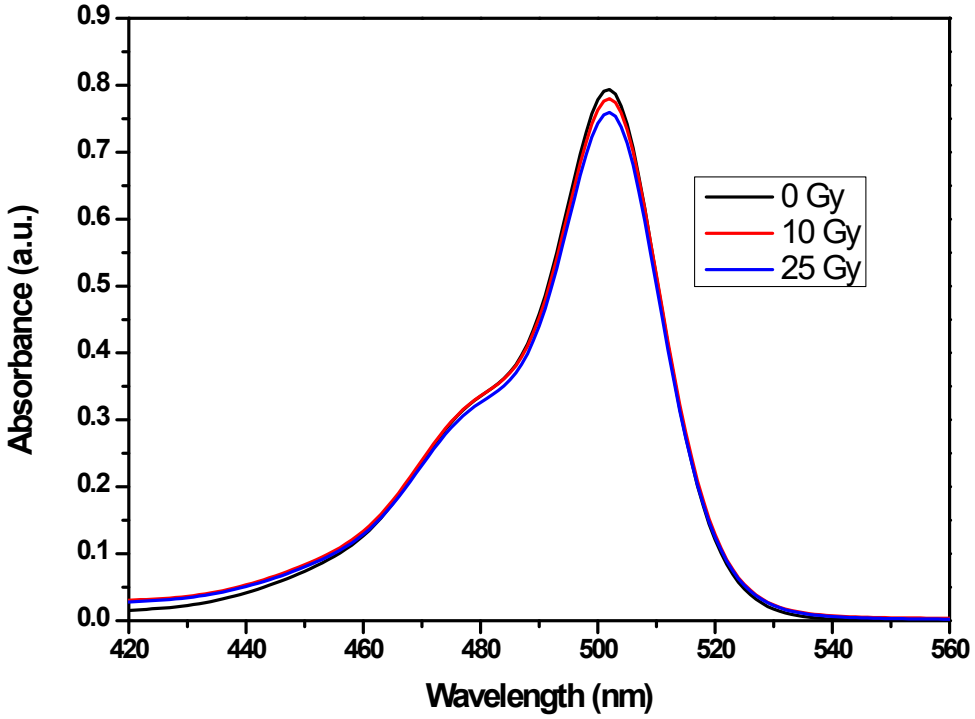


Figure S9. Absorption spectra of dye **5** in chloroform after γ-irradiation with different doses.

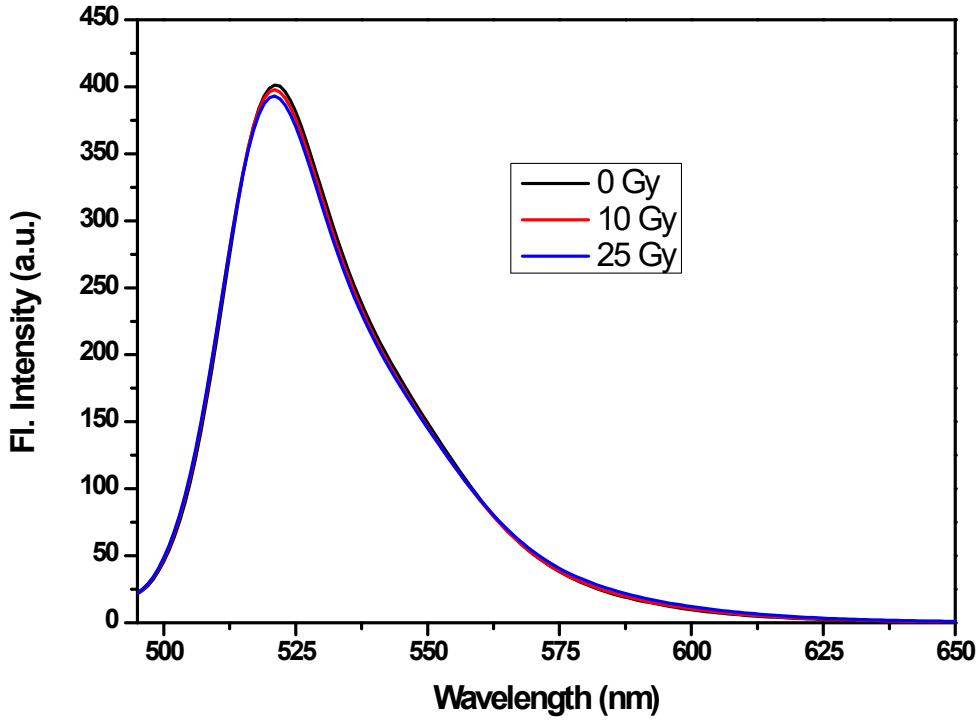


Figure 10. Fluorescence spectra of dye **5** in chloroform after γ-irradiation with different doses.

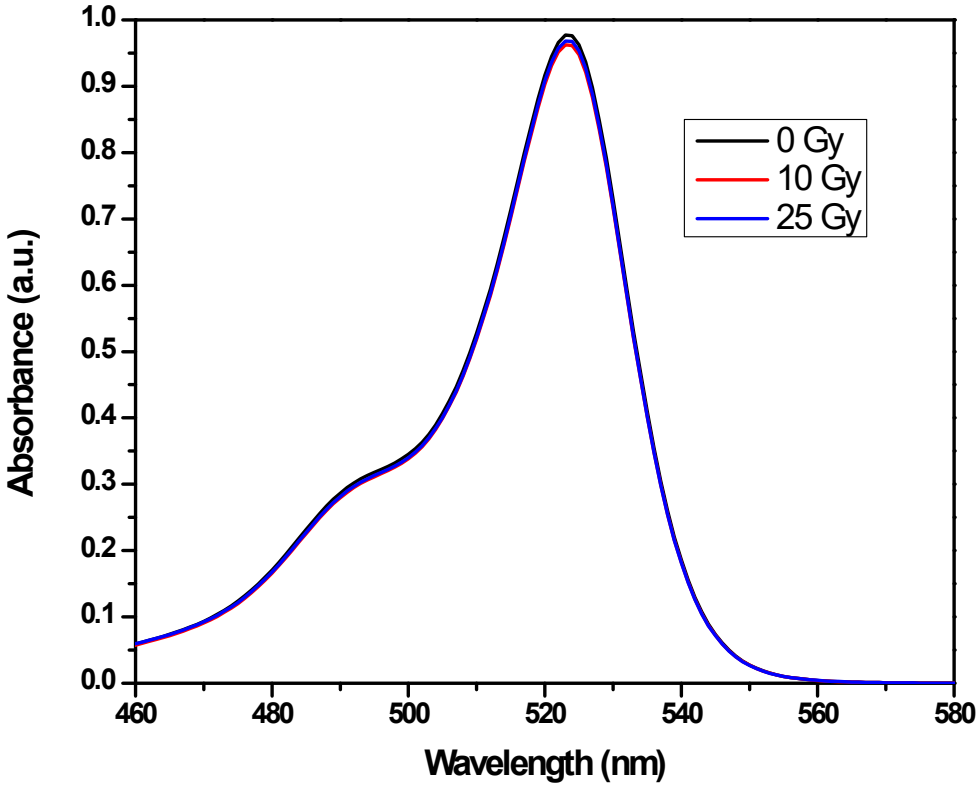


Figure S11. Absorption spectra of dye **3** in tetrahydrofuran after γ-irradiation with different doses.

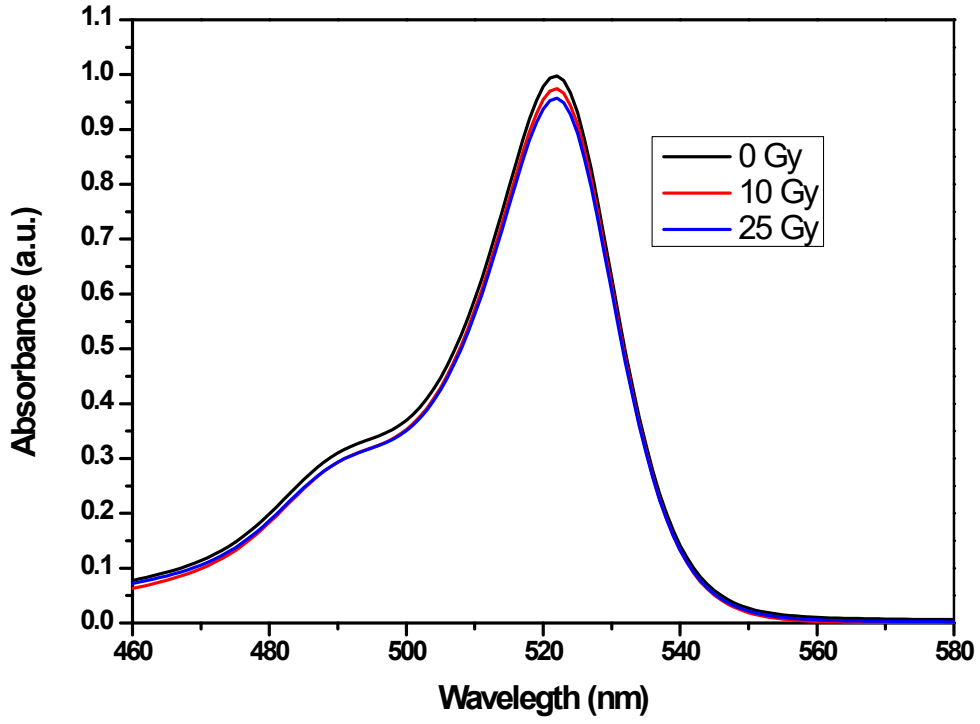


Figure S12. Absorption spectra of dye **3** in ethyl acetate after γ-irradiation with different doses.

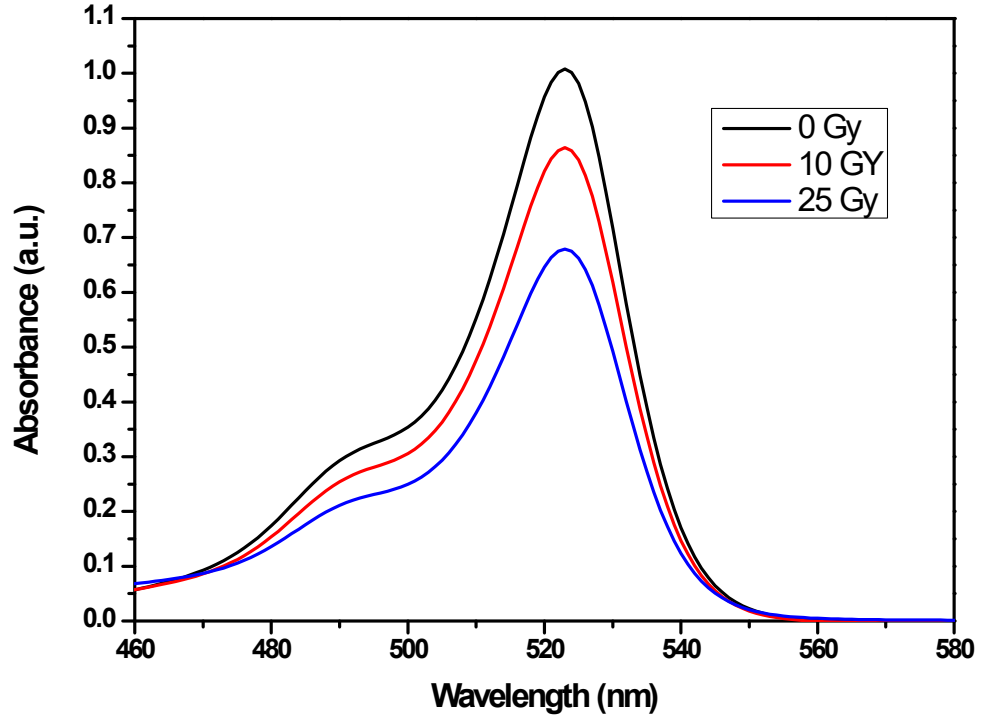


Figure S13. Absorption spectra of dye **3** in ethyl acetate/chloroform (3:1) after γ-irradiation with different doses.

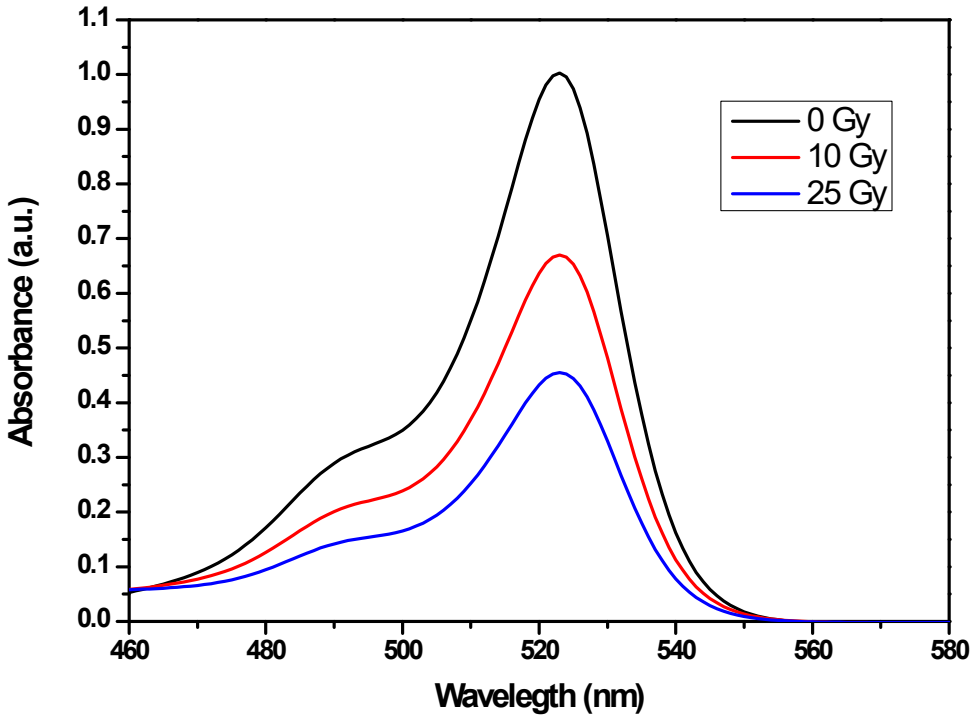


Figure S14. Absorption spectra of dye **3** in ethyl acetate/chloroform (1:1) after γ-irradiation with different doses.

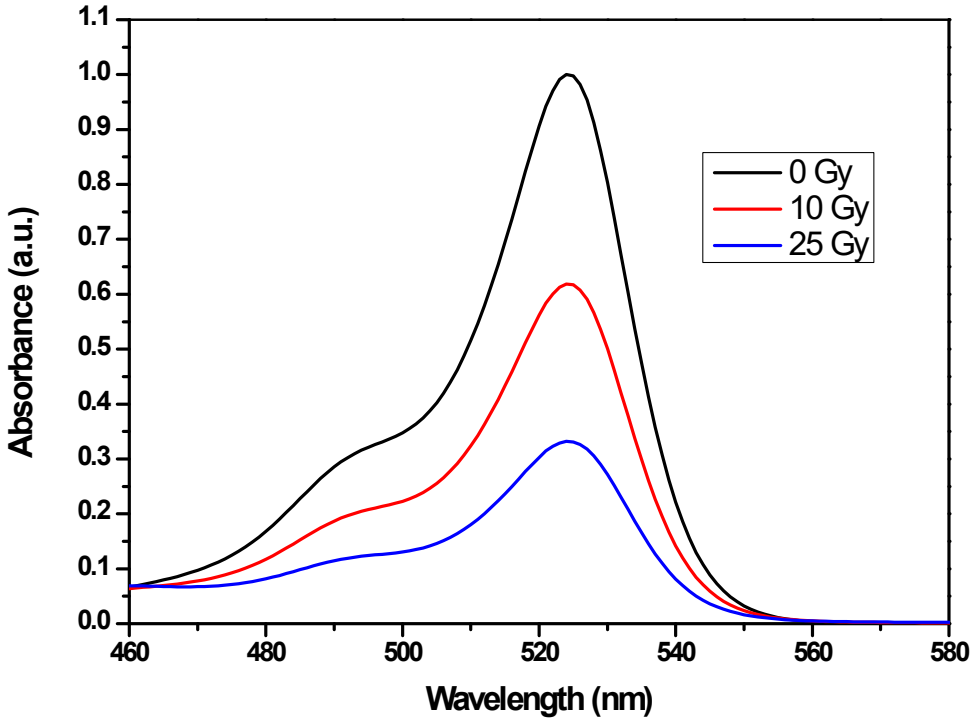


Figure S15. Absorption spectra of dye **3** in ethyl acetate/chloroform (1:3) after γ-irradiation with different doses.

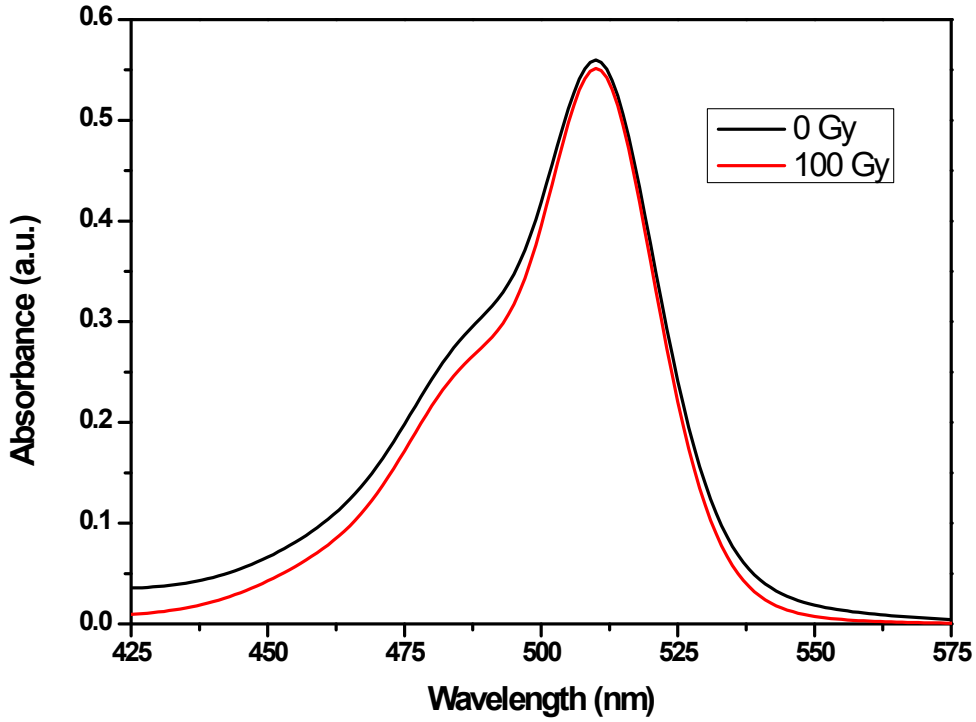


Figure S16. Absorption spectra of dye **7** in chloroform before and after γ-irradiation (100 Gy).

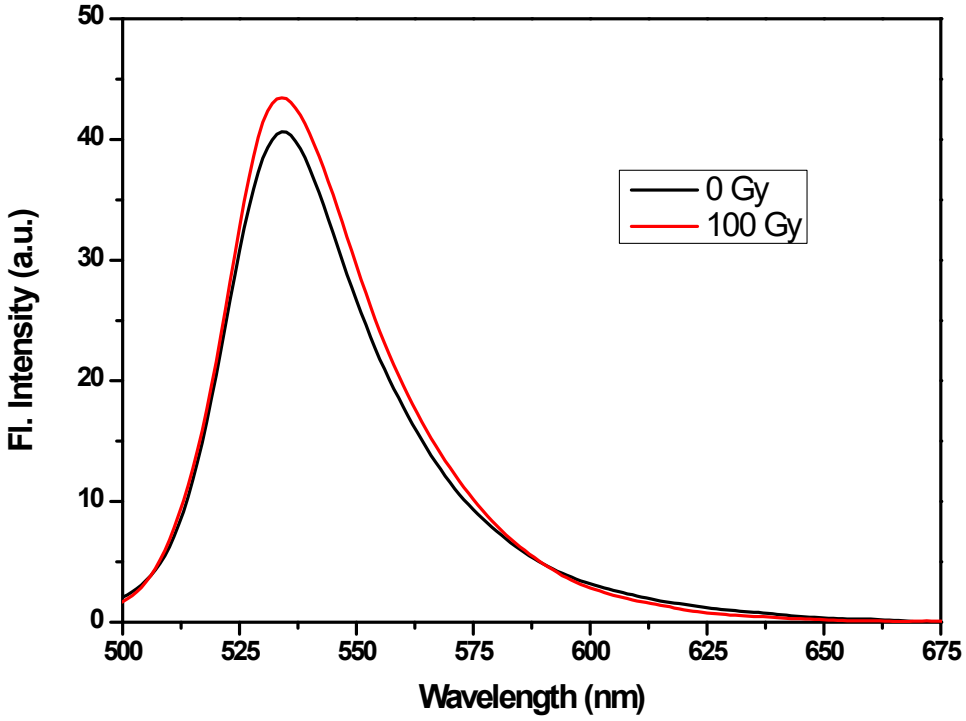


Figure S17. Fluorescence spectra of dye **7** in chloroform before and after γ-irradiation (100 Gy).

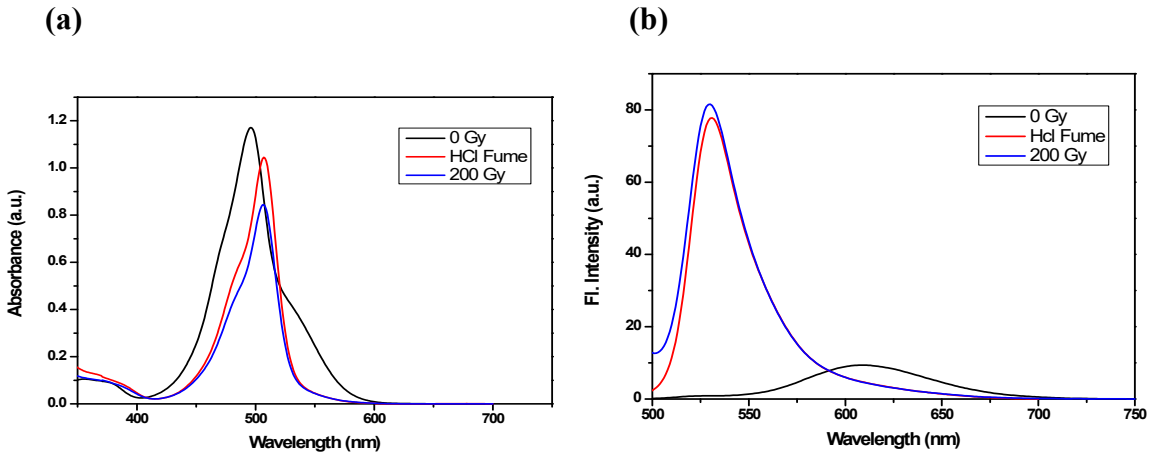


Figure S18. (a) Absorption and (b) fluorescence spectra of BODIPY dye **6** in chloroform, and after exposure with HCl fume and 200 Gy of γ–radiation.

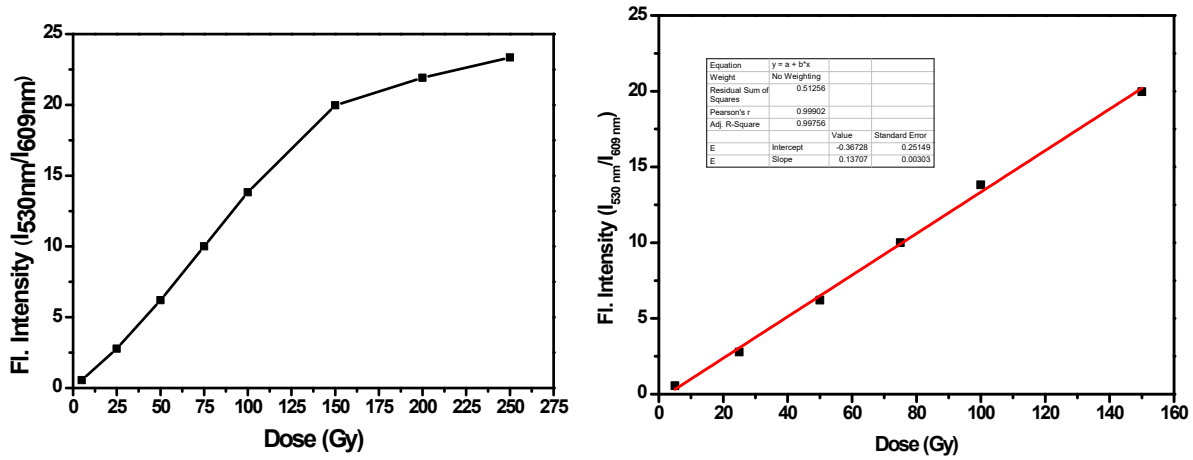


Figure S19. Fluorescence intensity ratio ($I_{530\ nm}/I_{609\ nm}$) changes of dye **6** with γ-irradiation doses.

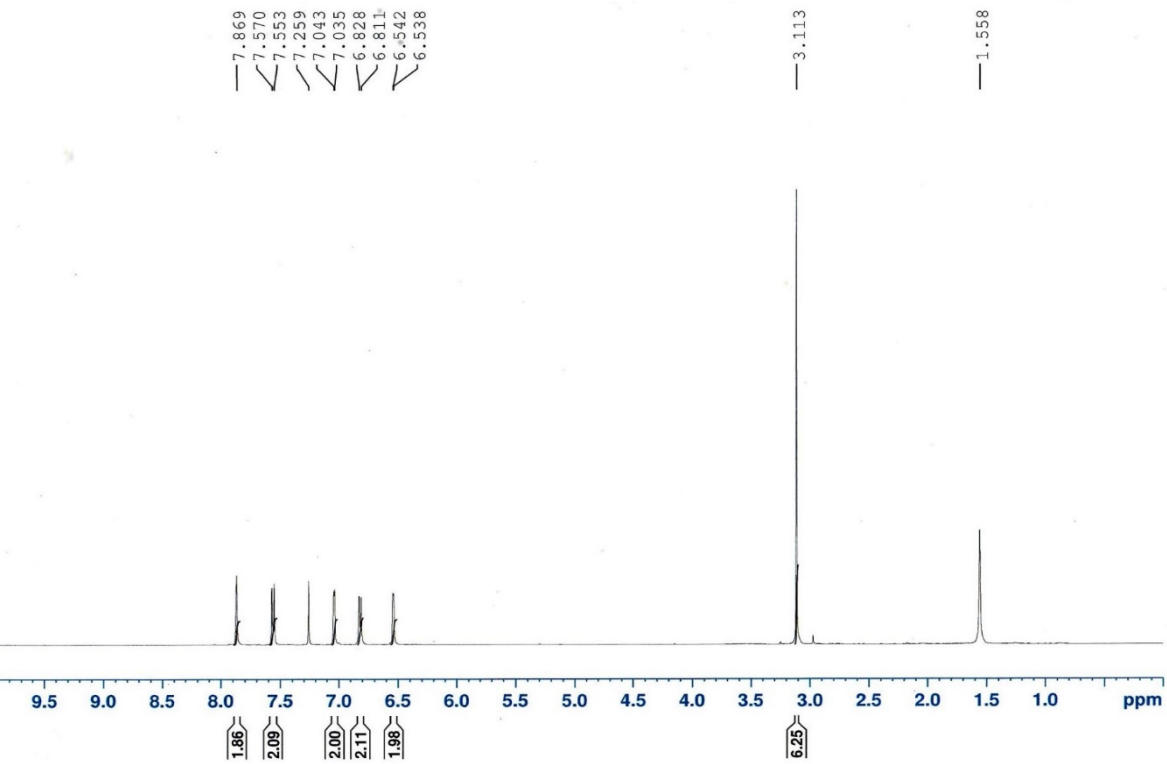
Calculation of LOD: LOD was calculated as per the IUPAC protocol using the formula 3σ/S where S is the slope of the calibration curve and σ is the standard deviation of the fluorescence response of the blank, determined by recording 10 consecutive fluorescence measurements of the dye at identical condition.

LOD = (3 x 0.025165) / 0.13707

= 0.55 Gy

Table S2. Measurement of unknown γ–dose using dye **6** in chloroform.

Dose measured by Fricke dosimetry (Gy)	**Dose measured by fluorescence dosimetry -Our method (Gy)**
84.92	84.55



I NMR spectrum
e **6**.

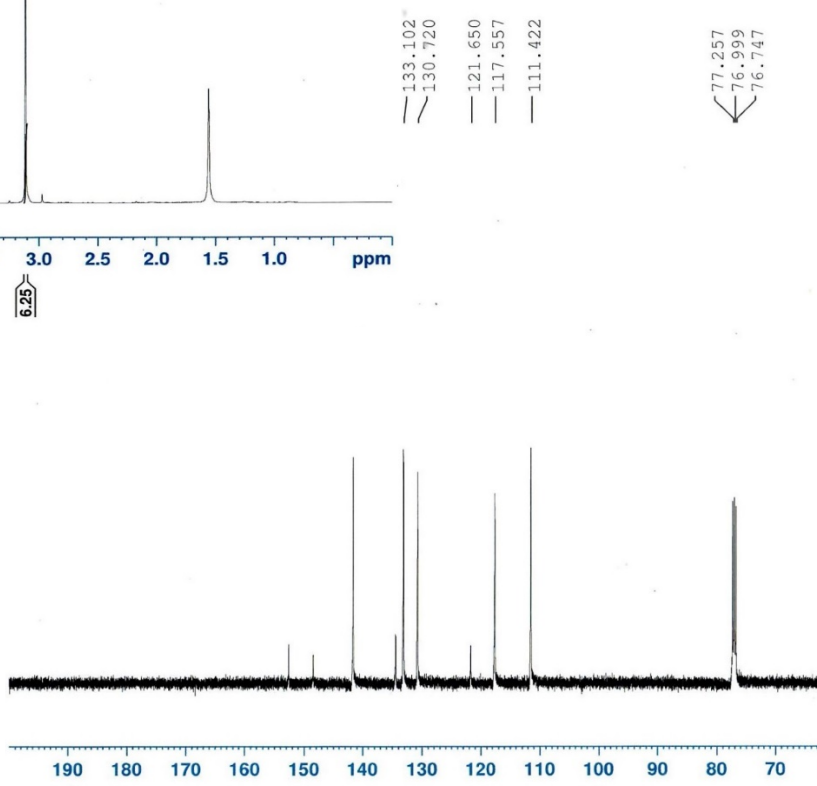


Figure S20. ^{13}C NMR spectrum of BODIPY dye **6**.

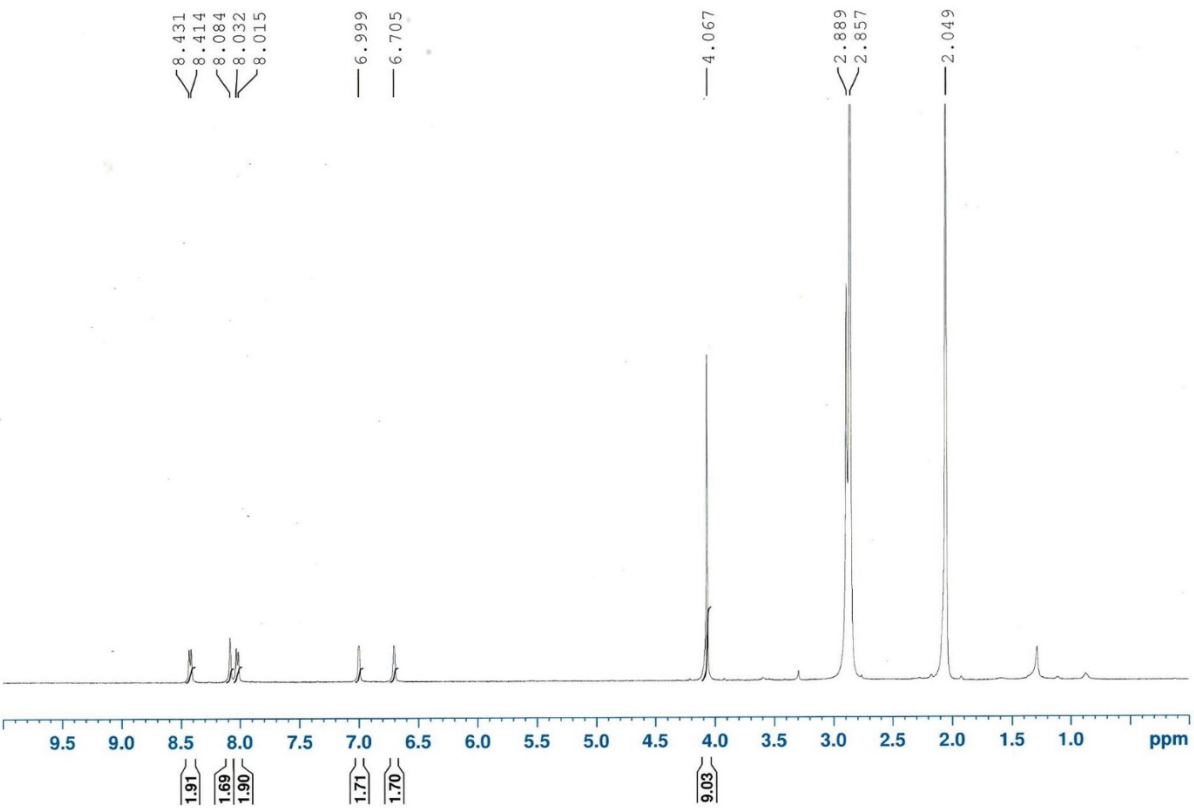


Figure S21. ^{1}H NMR spectrum of BODIPY dye **7**.

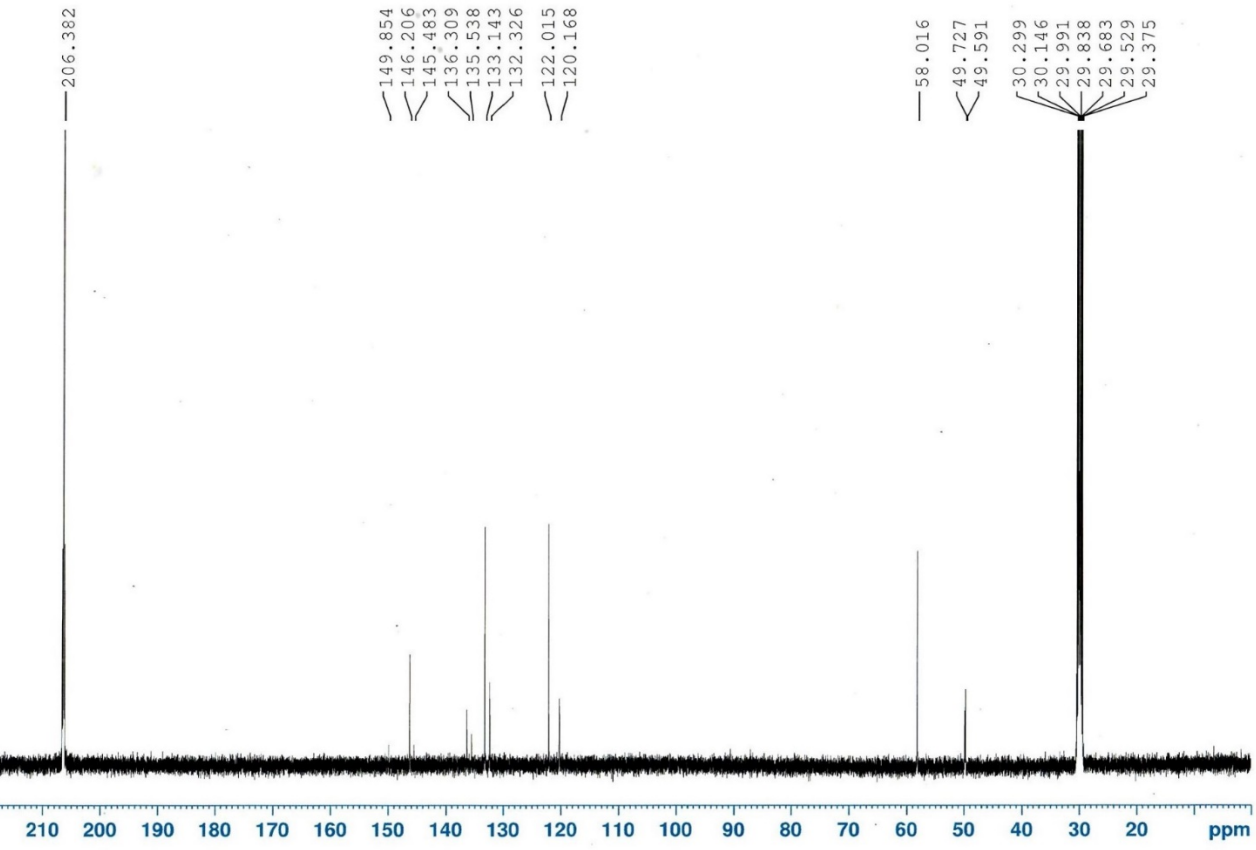


Figure S22. ^{13}C NMR spectrum of BODIPY dye **7**.

References.

1. (a) S. Mula, A. K. Ray, M. Banerjee, T. Chaudhuri, K. Dasgupta and S. Chattopadhyay, *J. Org. Chem.* 2008, **73**, 2146-2154; (b) A. B. More, S. Mula, S. Thakare, S. Chakraborty, A. K. Ray, N. Sekar and S. Chattopadhyay, *J. Lumin.*, 2017, **190**, 476-484; (c) A. B. More, S. Mula, S. Thakare, N. Sekar, A. K. Ray and S. Chattopadhyay, *J. Org. Chem.*, 2014, **79**, 10981-10987.

2. R. W. Wagner and J. S. Lindsey, *Pure Appl. Chem.*, 1996, **68**, 1373-1380.
3. J. Olmsted, *J. Phys. Chem.*, 1979, **83**, 2581-2584.