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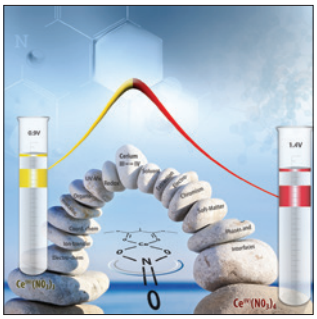

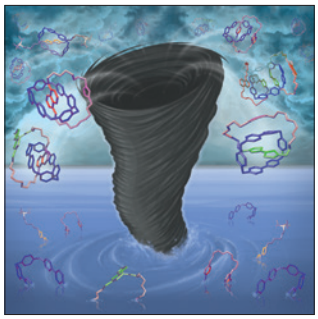

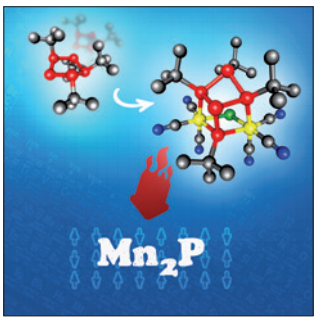

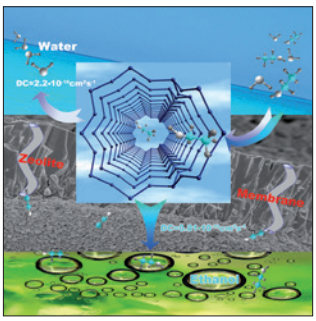

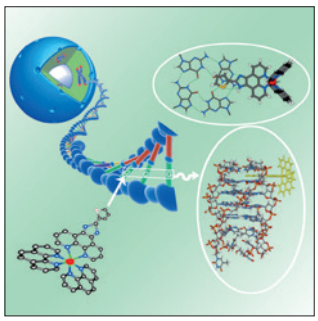


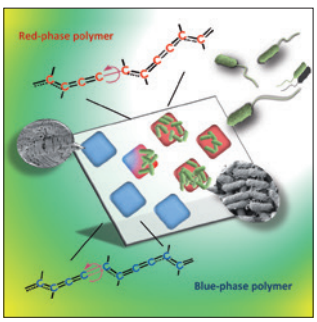

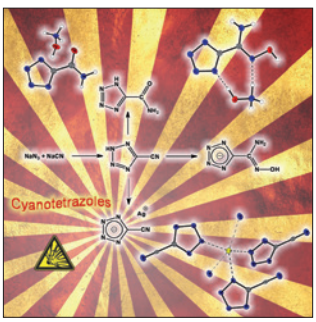

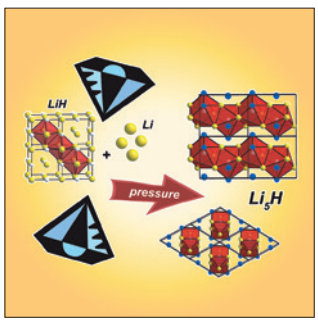

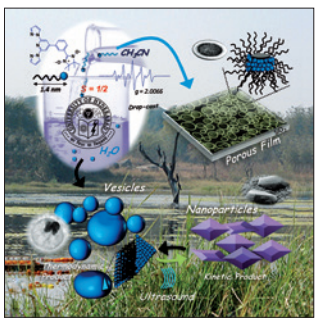


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# Two-Photon Absorption Properties and Structures of BODIPY and Its Dyad, Triad and Tetrad

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A series consisting of a dyad, a triad and a tetrad containing either two, three and four BODIPY units, respectively, has been synthesized and fully characterized and compared to two mono-BODIPY analogs (used as references). The one- and two-photon photophysical properties have been measured and the X-ray structures of four of the BODIPY derivatives have been determined. In the 700–900 nm range, the two-photon absorption (TPA) cross sections range from 30 GM to 160 GM for these compounds.

## Introduction

Difluoroboraindacene, also known as "BODIPY", is an excellent type of fluorescent dye that have been used for a wide variety of applications.[1] Among examples, fluorescent probes,[2] photodynamic therapy,[3] biological labeling[4] and solar cell design[5] are some of the key areas where BODIPYs have so far been found to be useful. Since the first synthesis of BODIPY in 1968, their importance in various fields of applied chemistry stay in constant growth. More recently, BODIPYs have found new and interesting applications in biology with the rapid development of fluorescence-based techniques such as non-linear, super-resolution or multiplexed microscopies.[6] The particular physico-chemical and photophysical properties of BODIPYs such as high luminescence quantum yield, narrow emission spectra, thermal stability and chemical stability in various conditions of pH combined with a high sensitivity of these properties to small modification of the molecule backbone (Figure 1) have rapidly afforded a wild variety of new dyes which many of them being now commercially available for use e.g. in fluorescent microscopy. BODIPYs can also be easily functionalized to strength their two-photon absorption (TPA) activity.[7]

Of particular interest, modifications leading to an extension of the conjugated system at the *meso* or pyrrolic positions induced a red shifted absorption and emission, in the near IR region of the electromagnetic spectrum. This shift to the near IR is of crucial importance in particular for *in-vivo* applications in live animals. An interesting point is that a such red shift in the absorption is also possible using a non-linear excitation such as two-photon absorption. This non-linear phenomenon intrinsically brings also other key features of great interest in biological applications, for example a 3D confinement of the excitation in a femtoliter range volume, even deep in tissues.[8] In addition to these structural modifications in the BODIPY core, multichromophoric assemblies were also explored. For example, dimers and trimers have been reported showing interesting two-photon absorption properties.[9]

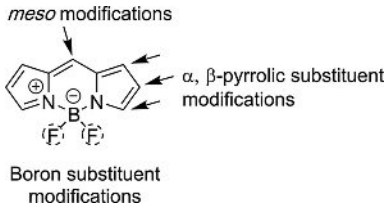


**Figure 1.** BODIPY core modifications leading to finetuning of the photophysical properties.

In the present work, we report the synthesis of fluorescent probes using BODIPY as the common fluorophore but with different geometry ($C_{2v}$, $C_{3v}$ and $T_d$) and different substituents at the *meso*-position. **Ph-BODIPY-1** and **$Ph_3N$-BODIPY-1** were used as references and their photophysical properties are well described.[10] **BODIPY-2**[11] is for the first time studied for its two-photon absorption properties. **BODIPY-3** was built based upon a truxene central unit, a two-photon active chromophore.[12] Truxene is very attractive due to its exceptional solubility, high thermal stability and easy poly-functionalization.[12–13] Interestingly, truxene core can efficiently enhance TPA activity, as was reported by Xiao *et al.*[14] **BODIPY-4** was incorporated on a tetrahedron unit allowing the addition of four BODIPY units. Tetraphenylmethane is a valuable precursor for the construction of molecules with tetrahedral geometry. Such tetrahedral building block have been successfully incorporated in supramolecular networks like porous crystalline polymers

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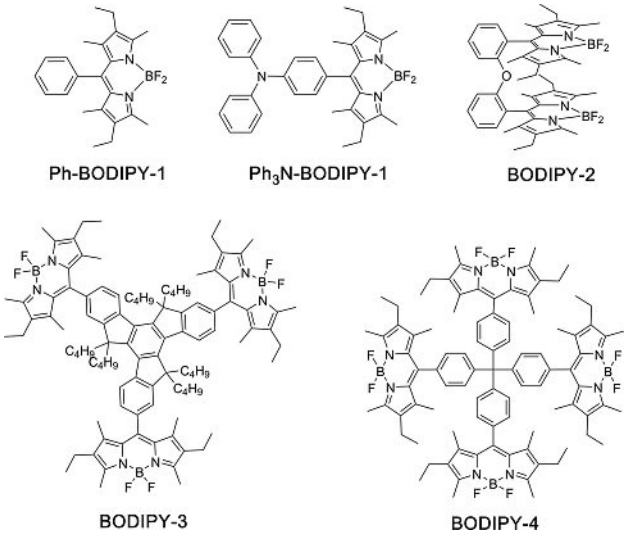
(COFs)[15] or fluorescent frameworks.[16] **BODIPY-4** has been designed to spatially isolate the BODIPY units and to avoid fluorophore stacking. This could be considered as an effective way to circumvent any aggregation and excitation quenching. The photophysical properties of the different **BODIPY 1–4** were studied. Absorption, fluorescence excitation, emission spectra and two-photon absorption spectra were recorded and the fluorescence quantum yields ($\Phi$), Stokes shifts, molar absorption coefficients (ε) and two-photon absorptions cross-sections ($\sigma_2$) were also determined.

## Results and Discussion

### Synthesis

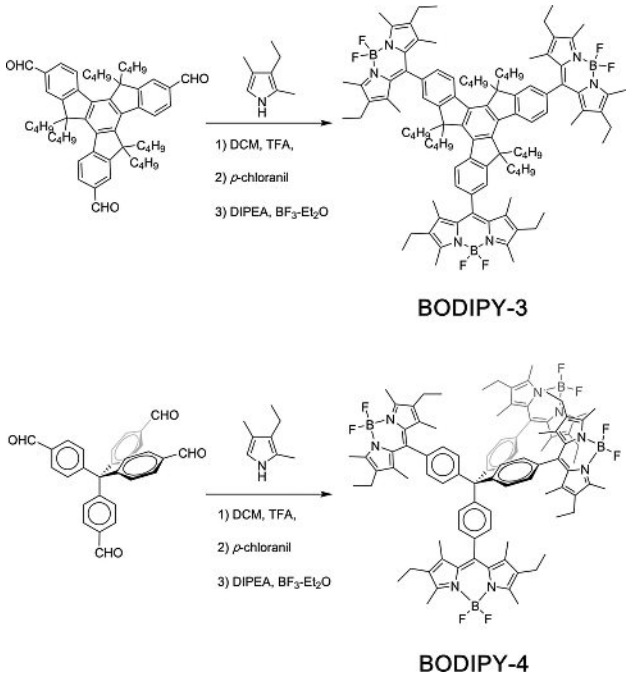
The structures of the three BODIPY derivatives (dyad, triad and tetrad) as well as the two references **Ph-BODIPY-1**, and **$Ph_3N$-BODIPY-1** are shown in Scheme 1.




**Scheme 1.** Structures of **Ph-BODIPY-1**, **$Ph_3N$-BODIPY-1**, **BODIPY-2**, **BODIPY-3** and **BODIPY-4**.

**BODIPY 1–4** (Scheme 1) were prepared *via* one-pot syntheses starting from the corresponding aldehyde precursors. In each case, the synthesis involves formation of the dipyrromethane analog. Subsequent oxidation using *p*-chloranil easily lead to form the dipyrrin then further complexation to yield the borondifluoro moiety. The synthesis of **Ph-BODIPY-1** and **$Ph_3N$-BODIPY-1** were previously described[17] and the **BODIPY-2** was prepared following a modified procedure reported in the literature.[11b] The synthesis of **BODIPY-3** and **BODIPY-4** is illustrated in Scheme 2.

**BODIPY-3** and **4** were purified by chromatography on silica gel yielding 15 and 33% of pure products (for details see experimental section). High-resolution mass spectrometry (HRMS) was used to characterize the different BODIPY architectures. In all cases, a perfect match between experimental and




**Scheme 2.** Synthetic route for the preparation of **BODIPY-3** and **BODIPY-4**.

simulated ionic patterns from HR-MS measurements (ESI/Orbitrap) was observed, thus confirming the structures of **BODIPY 1–4** and **4** (see Figures S3, S6, S9 and S12 for the HRMS spectra). For example, the calculated mass for **BODIPY-4** is equal to 1528.8628 Da (chemical formula $C_{93}H_{104}B_4F_8N_8$), agreeing well with the experimental value found at 1528.8615 Da.

The $^1$H NMR spectra of the $C_3$ and $T_d$ symmetric derivatives exhibit the characteristic pattern of three and four BODIPY units linked either by a truxene or a tetrakis(4-phenyl)methane linker (See Experimental Section). Peak assignments were made on the basis of chemical shifts, multiplicity, integrations, and spectral inter-comparisons by using mono-BODIPY derivatives as reference compounds.

### X-ray Structures of BODIPY 1–4

The X-ray structure shows that **$Ph_3N$-BODIPY-1** (Figure 2) is substituted by methyl groups on the C2, C6, C11 and C16 carbons while the C3 and C13 carbons are substituted by ethyl groups oriented on either side of the dipyrrolic skeleton, this arrangement is imposed by the crystal packing. The aromatic group attached to the C9 carbon and carrying the phenylaniline group is almost perpendicular to the skeleton of **$Ph_3N$-BODIPY-1** with a dihedral angle of 76.181(3)°.

**BODIPY-2** (Figure 2), which presents two BODIPY units linked together by a diphenylether group, crystallizes with a hexagonal symmetry in the non-centrosymmetric space group $P6_522$.

The asymmetric unit is composed of half of the molecule which therefore has a crystallographic two-fold axis passing through oxygen O1 and a three-fold axis passing close to the

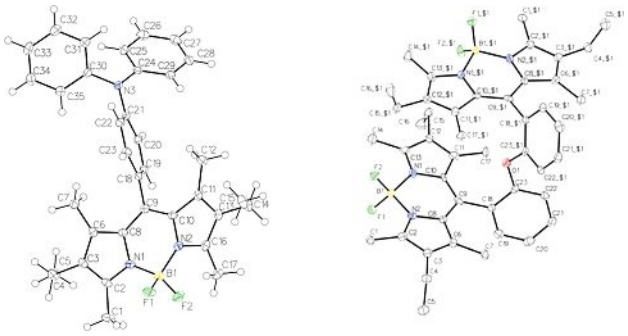


**Figure 2.** X-ray structures of **$Ph_3N$-BODIPY-1** (left) and **BODIPY-2** (right). Thermal ellipsoids are drawn at the 50% probability level. H-atoms are omitted for clarity. $1 marks atoms generated that are the symmetry equivalent ($1: *x*,1 + *x*-*y*,5/6-*z*).

benzene center composed of carbon atoms C18 to C23. Consequently, the two planes of the BODIPY molecules are parallel to each other, and the dihedral angle between these two BODIPY is exactly 120°. Unlike **$Ph_3N$-BODIPY-1**, the crystallographic structure of **BODIPY-2** shows that the ethyl groups are oriented on the same side of the dipyrrolic skeleton.

Single crystals of **BODIPY-3** (Figure 3) could be obtained in a mixture of ethanol/chloroform and the crystallographic structure could be determined by X-ray diffraction. The compound crystallized in a triclinic symmetry with the *P*-1 space group. The structure is arranged around tris-formyltruxene with three BODIPY hung on this structure. The three BODIPY units are not completely perpendicular to the plane of the truxene central platform with dihedral angles which are 102.567(4)°, 113.273(4)° and 77.071(3)° for the BODIPY containing the B1, B2 and B3 boron atom respectively. The three BODIPY units are well plane (RMSD 0.047 Å, 0.083 Å and 0.053 Å for the BODIPY containing the B1, B2 and B3 boron atom respectively) while the truxene is found slightly deformed with a RMSD of 0.143 Å.

Finally, we have also obtained the crystallographic structure of **BODIPY-4** (Figure 3) which crystallizes with a monoclinic symmetry, in the space group *C*2/c. The four phenyl BODIPY units are linked together by the carbon atom C24, where the crystallographic axis symmetry *C*2 passing through it. The phenyl groups are perpendicular to the BODIPYs with dihedral

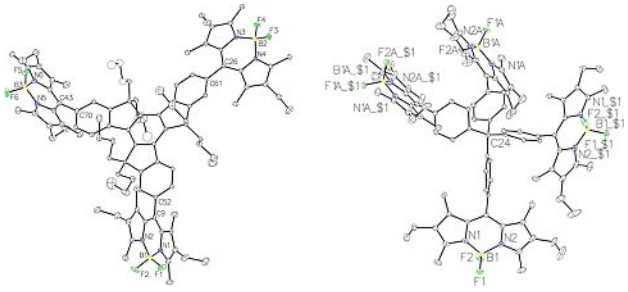


**Figure 3.** X-ray structures of **BODIPY-3** (left) and **BODIPY-4** (right). Thermal ellipsoids are drawn at the 25% probability level. H-atoms, minor disordered parts and solvent are omitted for clarity. $1 marks atoms generated that are the symmetry equivalent ($1: 1-*x*, *y*,3/2-*z*).

angles of 95.739(4)° and 82.575(4)° for the BODIPY containing the B1 and B1A boron atom respectively.

## Optical Properties

The photophysical properties of the dyes have been investigated by recording their absorption, emission and excitation spectra in THF at 298 K (Figure 4 and Figure 5). **$Ph_3N$-BODIPY-1** to **BODIPY-4** all feature characteristic $\pi \rightarrow \pi^*$ absorption bands related to the BODIPY core, composed of an intense and sharp $S_0 \rightarrow S_1$ transition centered around 525 nm and a broader and weaker band in the higher energies region (350–450 nm) corresponding to $S_0 \rightarrow S_2$ transitions. Besides that, each BODIPY displays slight changes according to their chemical functionalization. Therefore, **$Ph_3N$-BODIPY-1** features a band located at 300 nm corresponding to the triphenylamine group transitions as reported in the literature before.[17–18] **BODIPY-2** is the only dye which presents a different profile for its main absorption band, *i.e.* we notice the usual band at 527 nm and its vibronic shoulder at 500 nm, plus an additional intense transition at 539 nm. The latter has been attributed in the past to strong excitonic coupling[19] taking place between the two BODIPYs which leads to the splitting of the absorption band.[11] This

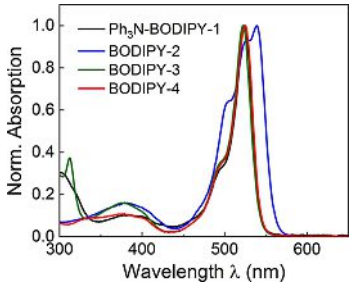



**Figure 4.** Absorption spectra (THF) of **BODIPY 1–4**.

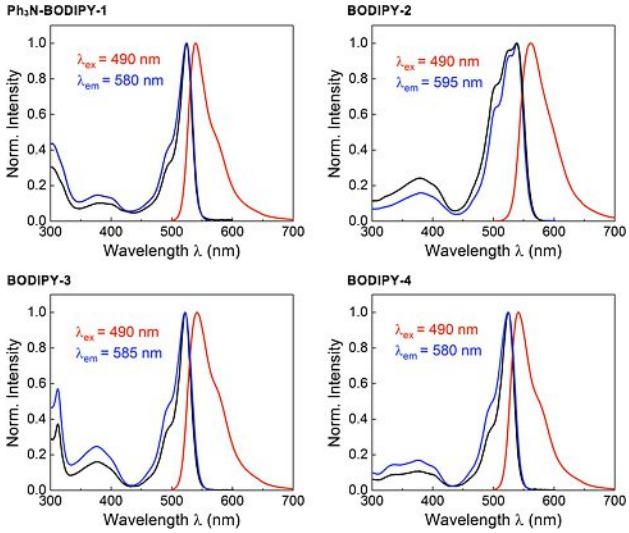



**Figure 5.** Emission (red), absorption (black) and excitation (blue) spectra of **BODIPY 1–4**.

interaction is favored by the face-to-face orientation and short distance between the two units in the **BODIPY-2** dyad structure. **BODIPY-3** is based on a BODIPY-truxene scaffold, so its absorption is ultimately the combination of the two chromophore spectra. This closely resembles to previously published results where BODIPY and truxene have been used together.[13c,g] Therefore, the spectrum is composed of the absorption band from BODIPY and a new sharp band at 312 nm unambiguously attributed to the truxene moiety ($S_0 \rightarrow S_1$ transition). Regarding **BODIPY-4**, the absorption shape of the BODIPY unit is not changed from the phenyl-BODIPY alone. The epsilon values of **Ph-BODIPY-1**, **$Ph_3N$-BODIPY-1** and **BODIPY-2** are in the same order of intensity (see Table 1). In the case of **BODIPY-3**, the epsilon value of the 523 nm band is almost 3 times the value observed in the case of **BODIPY-1**, thus depending upon the number of BODIPY units. A similar observation is made in the case of **BODIPY-4**.

Emission spectra of **$Ph_3N$-BODIPY-1**, **BODIPY-3** and **BODIPY-4** feature a strong fluorescence band ($S_1 \rightarrow S_0$ transition) at ~540 nm with a shoulder around 580 nm resulting in small Stoke shifts of 531 $cm^{-1}$, 707 $cm^{-1}$ and 600 $cm^{-1}$, respectively, which are typical for BODIPY. The emission spectra of **BODIPY-2** is shifted toward lower energies ($\lambda_{em} = 556$ nm), as its absorption spectrum was, with a Stoke shift of 728 $cm^{-1}$. In this case, the communication between the BODIPY units leads to slightly broader fluorescence band. The quantum yields of **BODIPY 1–4** are in the range 62–84%, the highest value being observed in the case of **BODIPY-2** ($\Phi = 84\%$).

For all compounds, excitation spectra match absorption very well, displaying particularities of each BODIPY assembly. Noteworthy, in the case of **BODIPY-3** triad, the band at 312 nm attributed to the truxene central unit is observed when recording fluorescence of the BODIPY fluorophore at $\lambda_{em} = 585$ nm. The proper relative intensity of this band compared to the BODIPY ones is denoting a good communication between truxene and BODIPYs, probably by an efficient energy transfer mechanism from singlet excited state of the truxene to the singlet excited state of the BODIPY.

The two-photon absorption (TPA) properties of **BODIPY 1–4** and **$Ph_3N$-BODIPY-1** were investigated by the up converted fluorescence method. Two-photon excitation spectra are shown in Figure 6. As expected, **Ph-BODIPY-1** and **$Ph_3N$-BODIPY-1** show moderate TPA cross section in the 700–900 nm range, about 30 GM at 740 nm and 32 GM at 810 nm. This last one is in the same range as described for other simple BODIPY's substituted with an electron donating moiety at the *meso* position.[6a] For the dimer **BODIPY-2**, the $s_2$ is slightly red shifted to 760 nm, with a value of 64 GM. This value is double than the one of the monomer, indicating an additivity of the TPA cross-sections, without any cooperative effect. Interestingly, the excitonic coupling pointed out for this dimer with the one-photon photophysical properties didn't led to an increase of the two-photon absorption cross-section. This result shows the extreme importance of the geometry induced by linking groups, as for a biphenyl system, a cooperative effect has been shown using a rigid conjugated bridge (biphenyl system) with a linear geometry.[9]

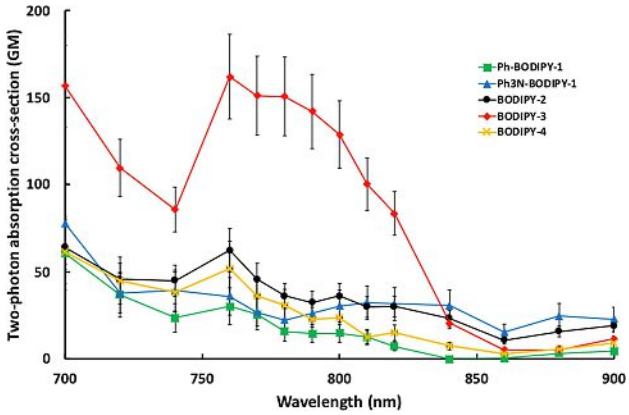



**Figure 6.** Two-photon absorption cross-sections of **BODIPY 1–4**.

Concerning the trimeric system, the TPA cross section is about 160 GM at 770 nm. This represents an enhancement of 4.8 times compared to the monomeric system, for the three same BODIPY units. This increase could be due to the modification of the spatial distribution of the charges, passing from a dipolar architecture to octupolar one.[20] The difference between one and two-photon processes can here be clearly seen, as the one photon properties of **$Ph_3N$-BODIPY-1** and **BODIPY-3** show similar absorption and emission characteristics, with an epsilon ratio of about 3. On another hand, the tetramer's TPA properties of **BODIPY-4** are very close to the monomeric one. While one-photon photophysical properties suggests limited interaction between the BODIPY units (both wavelength and epsilon), the two-photon absorption cross-section is not increased indicating a deleterious effect of this tetrahedral assembly in this case.

**Table 1.** Photophysical properties of **BODIPY 1–4** (solvent: THF).

| Compound | $\lambda_{em}$ [nm] | $\lambda_{abs}$ [nm] | $\Phi$ [%] | ε [$L\,mol^{-1}\,cm^{-1}$] | Stokes shift [nm] |
|---|---|---|---|---|---|
| **Ph-BODIPY-1** | 537 | 525 | 74 | $5.78\times10^4$ | 12 |
| **$Ph_3N$-BODIPY-1** | 537 | 525 | 62 | $7.43\times10^4$ | 12 |
| **BODIPY-2** | 556 | 539 | 84 | $7.89\times10^4$ | 17 |
| **BODIPY-3** | 539 | 523 | 77 | $20.0\times10^4$ | 16 |
| **BODIPY-4** | 538 | 526 | 76 | $23.8\times10^4$ | 12 |

## Conclusion

In conclusion, we have prepared and characterized a series of dyad, triad and tetrad containing two, three and four BODIPY units in good yields. Four different geometries, linear for the monomer, cofacial for the dimer, trigonal for the trimer and tetrahedral for the tetramer were obtained. These special arrangements were all confirmed by spectroscopic characterization and single crystal X-ray diffraction. The one photon photophysical properties were studied in THF and showed good emission properties. Concerning the TPA properties, interestingly, the behavior of **$Ph_3N$-BODIPY-1** and **BODIPY-2** are

not surprising but two behaviors have been pointed out. For the triad, the TPA properties has shown a cooperative effect, while one-photon photophysical properties didn't show particular behavior. This could be explained by the geometrical structure of this compound, which can be seen as a bidimensional planar simplification of an octupolar system. On another hand, the tetrameric arrangement show deleterious effect on the TPA properties and calculation would have to be performed to rationalize this result.

## Experimental Section

**X-ray data and experiment**: All details about equipment and refinement are given in the Supporting Information. CCDC-1830057, 1830058, 1830059 and 1830060 contain the supplementary crystallographic data for this paper for **$Ph_3N$-BODIPY-1**, **BODIPY-2, BODIPY-3** and **BODIPY-4** respectively. These data can be obtained free of charge from The Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/data_request/cif.

**Physicochemical characterization**: $^1$H NMR spectra were recorded on a Bruker Avance II 500 (500 MHz) spectrometer; chemical shifts are expressed in ppm relative to chloroform (7.26 ppm). UV-Vis spectra were recorded on a Varian Cary 1 spectrophotometer in quartz cell (1 cm). Mass spectra and accurate mass measurements (HRMS) were obtained on a Bruker Daltonics Ultraflex II spectrometer in the MALDI/TOF reflectron mode using dithranol as a matrix or on a LTQ Orbitrap XL (THERMO) and Amazon SL (Bruker) instruments in ESI mode. Infrared spectra were recorded on an IR FT Bruker Vertex 70v. Measurements were carried out by using the PEG-ion series (PEG 900 or PEG 1500) as an internal calibrant. All measurements were made at the "*Welience, Pôle Chimie Moléculaire de l'Université de Bourgogne (WPCM)*".

**$Ph_3N$-BODIPY-1**:[17] The 4-formyltriphenylamine (100 mg, 0.366 mmol, 1 eq.) and 2,4-dimethyl-3-ethylpyrrole (100 μL, 0.768 mmol, 2.05 eq.) were dissolved in dichloromethane (50 mL), bubbled by argon for 10 min. One drop of trifluoroacetic acid (TFA) was added and the mixture was stirred under argon overnight. Then *p*-chloranil (90.0 mg, 0.366 mmol, 1 eq.) was added and the mixture was stirred under argon for 30 min. Then *N,N*-diisopropylethylamine (500 μL, 2.87 mmol 7.8 eq.) was added and stirred under argon for 1 hour and boron trifluoride etherate (500 μL, 4.05 mmol 11 eq.) was added and the mixture was stirred under argon for 2 hours. The mixture was checked by MALDI/TOF. After the evaporation of the solvent, the residue was filtered through a small silica gel column (dichloromethane). The main product was collected and **$Ph_3N$-BODIPY-1** (87.2 mg, 0.159 mmol, 44%) was obtained after a second column chromatography purification step (Silica, 1:1 dichloromethane:heptane v/v). UV-Vis (DCM): $\lambda_{max}$ (nm) ($7.43\times10^4$ L mol$^{-1}$ cm$^{-1}$) 525. $^1$H NMR ($CDCl_3$, 300 K, 500 MHz): δ 7.31-7.27 (m, 4H), 7.19-7.16 (m, 2H), 7.13–7.11 (m, 6H), 7.08–7.04 (m, 2H), 2.53 (s, 6H), 2.33 (q, $J$=7.5 Hz, 4H), 1.50 (s, 6H), 1.01 (t, $J$=7.5 Hz, 6H) ppm. $^{13}$C NMR ($CDCl_3$, 300 K, 500 MHz): δ 153.51, 148.38, 147.45, 140.34, 138.28, 132.70, 131.06, 129.43, 129.26, 129.21, 124.59, 123.57, 123.33, 17.13, 14.67, 12.50, 11.89 ppm. $^{11}$B NMR ($CDCl_3$, 300 K, 160 MHz, $BF_3$.$OEt_2$ external standard): δ 0.83 (t, $J$=33 Hz) ppm. MS (MALDI/TOF): *m/z* 546.799 $[M]^+$, 547.297 calcd for $C_{35}H_{36}BF_2N_3$. HRMS (ESI): *m/z* 547.2939 $[M]^+$, 547.2970 calcd for $C_{35}H_{36}BF_2N_3$.

**BODIPY-2**:[11b] A similar procedure to that described above was followed, using bis(2-formylphenyl)ether (113 mg, 0.5 mmol,1 equiv), 2,4-dimethyl-3-ethylpyrrole (238 μL, 2.1 mmol, 4.2 equiv), DCM (50 mL), the mixture was stirred overnight. Then *p*-chloranil (246 mg, 1 mmol) was added and the mixture was stirred under argon for 30 minutes. Then *N,N*-diisopropylethylamine (1.0 mL, 5.7 mmol) was added and stirred under argon for 1 hour and boron trifluoride etherate (1.01 mL, 8.0 mmol) was added and the mixture was stirred under argon for 2 days. After the evaporation of the solvent, the residue was filtered through a small silica gel column (dichloromethane). The main product was collected and **BODIPY-2** (70.9 mg, 0.092 mmol, 18%) was obtained after a second column chromatography purification step (Silica, 7:3 dichloromethane:heptane v/v). UV-Vis (DCM): $\lambda_{max}$ (nm) ($7.89\times10^4$ L mol$^{-1}$ cm$^{-1}$) 539. $^1$H NMR ($CDCl_3$, 300 K, 500 MHz): δ 7.38 (td, $^3J$=7.0 Hz, $^4J$=2.0 Hz, 2H), 7.23 (dd, $^3J$=7.5 Hz, $^4J$=2.0 Hz, 2H), 7.17 (td, $^3J$=7.5 Hz, $^4J$=0.5 Hz, 2H), 7.06 (d, $J$=8.0 Hz, 2H), 2.46 (s, 12H), 2.31-2.19 (m, 8H), 1.29 (s, 12H), 0.92 (t, $J$=7.5 Hz, 12H) ppm. $^{13}$C NMR ($CDCl_3$, 300 K, 500 MHz): δ 153.26, 137.43, 137.41, 134.94, 132.57, 131.11, 130.68, 130.20, 127.26, 124.03, 116.90, 16.99, 14.68, 12.48, 11.00 ppm. $^{11}$B NMR ($CDCl_3$, 300 K, 160 MHz, $BF_3$.$OEt_2$ external standard): δ 0.61 (t, $J$=33 Hz) ppm. MS (MALDI/TOF): *m/z* 774.327 $[M]^+$, 774.426 calcd for $C_{46}H_{52}B_2F_4N_4O$. HRMS (ESI): *m/z* 774.4247 $[M]^+$, 774.4263 calcd for $C_{46}H_{52}B_2F_4N_4O$.

**BODIPY-3**: The tris-formyltruxene (200 mg, 0.263 mmol, 1 eq.) and 2,4-dimethyl-3-ethylpyrrole (250 μL, 1.73 mmol, 6.6 eq.) were dissolved in dichloromethane (50 mL), bubbled by argon for 10 min. One drop of trifluoroacetic acid (TFA) was added and the mixture was stirred under argon overnight. Then *p*-chloranil (200 mg, 0.789 mmol) was added and the mixture was stirred under argon for 2 hours next morning. Then *N,N*-diisopropylethylamine (1.50 mL, 8.61 mmol) was added and stirred under argon for 1 hour and boron trifluoride etherate (1.80 mL, 14.58 mmol) was added and the mixture was stirred under argon for 2 hours. After the evaporation of the solvent, the residue was filtered through a small silica gel column (dichloromethane). The main product was collected and **BODIPY-3** (62 mg, 0.039 mmol, 15%) was obtained after a second column chromatography purification step (Silica, 2:8 ethyl acetate:heptane v/v). UV-Vis (DCM): $\lambda_{max}$ (nm) ($2.00\times10^5$ L mol$^{-1}$ cm$^{-1}$) 523. $^1$H NMR ($CDCl_3$, 300 K, 500 MHz): δ 8.50 (d, $J$=8.0 Hz, 3H), 7.47 (d, $^4J$=2.0 Hz, 3H), 7.34 (dd, $^3J$=8.0 Hz, $^4J$=1.5 Hz, 3H), 3.07-3.01 (m, 6H), 2.57 (s, 18H), 2.33 (q, $^3J$=7.5 Hz, 12H), 2.16-2.10 (m, 6H), 1.40 (s, 18H), 1.01 (t, $^3J$=7.5 Hz, 18H), 0.97–0.87 (m, 12H), 0.70–0.54 (m, 12H), 0.51 (t, $^3J$=7.5 Hz, 18H) ppm. $^{13}$C NMR ($CDCl_3$, 300 K, 500 MHz): δ 154.48, 153.83, 145.78, 140.71, 140.54, 138.2 (2C), 134.24, 132.85, 130.88, 126.58, 125.18, 122.55, 56.15, 36.50, 26.55, 22.77, 17.14, 14.61, 13.83, 12.56, 11.75 ppm. $^{11}$B NMR ($CDCl_3$, 300 K, 160 MHz, BF3.$OEt_2$ external standard): δ 0.89 (t, $J$=32 Hz) ppm. MS (MALDI/TOF): *m/z* 1584.926 $[M]^+$, 1585.046 calcd for $C_{102}H_{129}B_3F_6N_6$. HRMS (ESI): *m/z* 1585.0479 $[M]^+$, 1585.0462 calcd for $C_{102}H_{129}B_3F_6N_6$.

**BODIPY-4**: The tetrakis(4-formylphenyl)methane (50.0 mg, 0.116 mmol) and 2,4-dimethyl-3-ethylpyrrole (139 μL, 1.03 mmol, 8.8 eq.) were dissolved in toluene (25 mL) under argon. One drop of trifluoroacetic acid (TFA) was added and the mixture was stirred under argon overnight. Then *p*-chloranil (250 mg, 1.00 mmol) was added and the mixture was stirred under argon for 30 minutes next morning. Then *N,N*-diisopropylethylamine (1.00 mL, 5.70 mmol) was added and stirred under argon for 1 hour and boron trifluoride etherate (1.50 mL, 12.20 mmol) was added and the mixture was stirred under argon for 2 hours. After the evaporation of the solvent, the residue was filtered through a small silica gel column (dichloromethane). The main product was collected and **BODIPY-4** (58.2 mg, 0.038 mmol, 33%) was obtained after a second column chromatography purification step (Silica, 8:2 dichloromethane: heptane v/v). UV-Vis (DCM): $\lambda_{max}$ (nm) ($2.38\times10^5$ L mol$^{-1}$ cm$^{-1}$) 526. $^1$H NMR ($CDCl_3$, 300 K, 500 MHz): δ 7.44 (d, $^3J$=8.5 Hz, 8H), 7.30 (d, $^3J$=8.0 Hz, 8H), 2.54 (s, 24H), 2.30 (q, $^3J$=7.5 Hz, 16H), 1.37 (s, 24H), 0.97 (t, $^3J$=7.5 Hz, 24H) ppm. $^{13}$C NMR ($CDCl_3$, 300 K, 500 MHz): δ

154.02, 146.91, 139.20, 137.83, 134.33, 133.04, 131.48, 130.70, 128.20, 64.67, 17.08, 14.65, 12.54, 11.91 ppm. $^{11}$B NMR ($CDCl_3$, 300 K, 160 MHz, $BF_3.OEt_2$ external standard): δ 0.80 (t, $J$ = 31 Hz) ppm. MS (MALDI/TOF): *m/z* 1528.800 $[M]^+$, 1528.863 calcd for $C_{93}H_{104}B_4F_8N_8$. HRMS (ESI): *m/z* 1528.8615 $[M]^+$, 1528.8628 calcd for $C_{93}H_{104}B_4F_8N_8$.

**Synthesis of tetraphenylmethane**:[3] Chlorotriphenylmethane (25.0 g, 89.7 mmol) and aniline (22.0 mL, 232 mmol) were heated up to 190°C under vigorous stirring. After 15 min the liquid reaction mixture was converted to a solid, which was cooled down to room temperature. Then 2 M HCl (100 mL) and methanol (150 mL) were added to the pulverized solid and the suspension was heated up to 80°C for 30 min. The solid was filtered off and washed several times with water. The dry solid was suspended in DMF (250 mL) and cooled down to −15°C. Then sulfuric acid (96%, 27.5 mL) and isoamyl nitrite (19.9 mL, 148 mmol) were added dropwise and for 1 h. Hypophosphoric acid (30%, 75 mL) was added slowly and the reaction mixture was heated up to 50°C. When no gas evolution was observed anymore, the reaction mixture was cooled down. The solid was filtered off and washed subsequently with DMF, water and ethanol. After drying in *vacuo*, a beige powder was obtained. Further purification was not necessary (15.0 g, 46.78 mmol, 52%). $^1$H NMR ($CDCl_3$, 300 K, 500 MHz): δ 7.20–7.08 (m, 20H) ppm.

**Synthesis of tetrakis(4-bromophenyl)methane**:[3] Tetraphenylmethane (8.0 g, 24.96 mmol) was added into pure bromine. Keep vigorous stirring for 20 min, then the mixture was cooled to −78°C. Ethanol (150 mL) was added slowly and when it was completed the mixture was allowed to warm to room temperature. For reduction of excess bromine, the mixture was treated with an aqueous sodium bisulfate solution. After this, the precipitate was filtered and washed additionally with sodium hydrogen sulfate solution and water. The crude material was recrystallized from chloroform/ethanol (1:1) to afford a yellow solid (13.5 g, 21.5 mmol, 85%). $^1$H NMR ($CDCl_3$, 300 K, 500 MHz): δ 7.39 (d, $J$ = 10 Hz, 8H), 7.01 (d, $J$ = 10 Hz, 8H).

**Synthesis of tetrakis(4-formylphenyl)methane**:[21] A solution of tetrakis(4-bromophenyl)methane (8.0 g, 12.58 mmol) in THF (250 mL) was cooled down to −78°C. Under stirring a solution of *n*-butyllithium (2.5 M in hexane, 50 mL, 125 mmol) was added dropwise. The mixture was kept for 1 h at −78°C and then anhydrous dimethylformamide (DMF) (20.24 mL, 250 mmol) was added. The resulting green suspension was allowed to warm up to room temperature overnight. The milky solution was treated with 1 M HCl until the mixture became acidic. The clear solution was extracted with ethyl acetate; the organic phase was washed twice with water and dried over $Na_2SO_4$. After filtration, the volatiles were removed under reduced pressure. The crude yellow product was further purified by chromatography via a column using silica gel (toluene/acetone = 98/2) (1.5 g, 3.52 mmol, 28%), $^1$H NMR ($CDCl_3$, 300 K, 500 MHz): δ 10.02 (s, 4H), 7.84 (d, $J$ = 10 Hz, 8H), 7.43 (d, $J$ = 10 Hz, 8H).

**Two-photon absorption cross-sections**: The two-photon excitation spectra were obtained by upconverted fluorescence measurements using a Ti:sapphire femtosecond laser Insight DS with pulse width < 120 fs and a repetition rate of 80 MHz (Spectra-Physics) as described previously.[22] The excitation beam was collimated over the cell length (10 mm) and the fluorescence, collected at 90° of the excitation beam, was focused into an optical fiber connected to a spectrometer. The incident beam intensity was adjusted to ensure an intensity-squared dependence of the fluorescence over the whole spectral range investigated. Calibration of the spectra was performed by comparison with the published rhodamine B TPA spectrum.[23]

Supporting information ($^1$H, $^{11}$B, $^{13}$C NMR spectra, MS and HRMS spectra, crystal data and emission spectra of **BODIPY 1**–**4**) is given *via* a link at the end of the document.

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## Conflict of Interest

*The authors declare no conflict of interest.*

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