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Supporting Information

Bichromophoric Compounds with Orthogonally and Parallelly Arranged Chromophores Separated by Rigid Spacers

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1 General Information

1.1 Solvents and Reagents

The used solvents had the purity *pro analysi*. Anhydrous solvents were dried over molecular sieves. Commercially available substances were used without further purification. 2,6-adamantanedione was purchased from *Ambinter* (a trademark of *Greenpharma S.A.S*), Orléans, France.

1.2 Preparative Methods

If not stated otherwise, reactions were carried out with magnetic stirring under an argon atmosphere. For reactions at low temperatures, an acetone/dry ice bath was used. Reactions at 0 °C were carried out using an ice-bath. Microwave-assisted organic synthesis were performed on a *CEM Discover* closed vessel microwave

1.3 Thin Layer Chromatography (TLC)

Analytical TLC was performed on ready-to-use plates. For TLC on silica gel *ALUGRAM SIL G/UV$_{254}$ silica gel 60* (*MACHEREY-NAGEL GmbH & Co. KG*) was used. For TLC on reversed phase (RP) *silica gel 60 RP-18 F$_{254\,s}$* (*MERCK KGaA*) was used.

1.4 Column Chromatography

Silica gel 60 with different particle sizes was used: 0.015-0.040 mm, 0.040-0.063 mm, and 0.05-0.2 mm (*MACHEREY-NAGEL GmbH & Co. KG*). RP column chromatography was carried out on *POLYGREP 60-50 C$_{18}$* (*MACHEREY-NAGEL GmbH & Co. KG*).

1.5 Nuclear Magnetic Resonance (NMR)

Routine NMR spectra were recorded with an *Agilent 400MR* spectrometer. Some NMR spectra were recorded on *Mercury-300, Unity-300* and *Varian Inova-600* spectrometers. All spectra are referenced to tetramethylsilane as an internal standard (δ = 0 ppm) using the signals of the residual protons of $CHCl_3$ (7.26 ppm) in $CDCl_3$, CHD_2OD (3.31 ppm) in CD_3OD or DMSO-d_5 (2.50 ppm) in DMSO-d_6. Multiplicities of signals are described as follows: s = singlet, s_{br} = broad singlet, d = doublet, d_{br} = broad doublet, t = triplet, q = quartet, m = multiplet. In case of diastereotopic protons, $_a$ marks the high-field shifted proton and $_b$ the low-field shifted signal. Coupling constants $^nJ_{x,y}$ are given in Hz, where *n* is the number of bonds between the two coupling nuclei x and y. Proton and carbon resonances were assigned with the aid of COSY, HSQC, and HMBC ^1H–^1H and ^1H–^{13}C 2D correlations.

1.6 Mass Spectrometry (MS)

Low resolution mass spectra (ESI) were obtained with a *Varian 500-MS.* High resolution mass spectra (ESI-HRMS) were obtained on a *Bruker APEX IV* spectrometer.

1.7 High-Performance Liquid Chromatography (HPLC)

Analytical and preparative HPLC were performed on a *Knauer* HPLC system: *Smartline pump 1000* (2×), *UV detector 2500*, *column thermostat 4000*, mixing chamber, injection valve with 20 µL loop for the analytical column and 200 µl loop for the preparative column; 6-port-3-channel switching valve; analytical column: *Eurospher-100 C_{18}*, 5 µm, 250 × 4 mm; preparative column: *Eurospher-100 C_{18}*, 5 µm, 8 × 250 mm, 200 µl loop; flow rate: 1.2 ml/min (or 5 ml/min in the preparative mode); solvent A: water + 0.1 % v/v TFA, solvent B: MeCN + 0.1 % v/v TFA; gradient A/B: 70:30 → 0:100 in 25 min (unless stated otherwise).

1.8 Fluorescence quantum yield determination

Fluorescence quantum yields were determined by comparative method.[1] The fluorescence quantum yield of the blue chromophore in **B⊥B**, **B∥B**, and **B** was determined using Coumarin 120 in methanol as fluorescence quantum yield standard (Φ_f = 0.51)[2]. The fluorescence quantum yield of **R** was determined using Rhodamine 6G in ethanol as fluorescence quantum yield standard (Φ_f = 0.95)[3].

2 Anisotropy measurements

2.1 Time resolved anisotropy

TCSPC measurements were performed in a custom-made setup consisting of a LDH-P-C-375 (blue chromophores excitation) or a LDH-P-C-510 (red chromophores excitation) picosecond pulsed laser (*PicoQuant*, Berlin, Germany), running on its internal clock at a frequency of 40 MHz, an ID100-50 (ID *Quantique SA*, Geneva, Switzerland) SPAD detector, and a *PicoHarp 300* stand-alone TCSPC module. The sync signal used to compute the photon arrival times was provided by the laser driver. Count rates on the detector where adjusted to values below 10^4 MHz in all cases (typically ~ 10^3 MHz). An "L-shape" geometry was used with two Glan-Thompson polarizers (*B. Halle Nachfl. GmbH*, Berlin, Germany), a 440/40 nm or a 620/60 nm bandpass filter (*AHF Analysentechnik*, Tübingen, Germany) placed in front of the detector, and diverse lenses to collimate the excitation light and to collect and focus the emission onto the detector. The temperature of the sample was controlled with a single Peltier cell holder (*Varian Inc.*, Australia). The internal response function (IRF) was collected with a dispersant in identical conditions than sample's measurements except for the bandpass filter which was removed. Fluorescence decays were deconvoluted and fitted using custom made routines.

2.1.1 Anisotropy decays for **B⊥B**, **B∥B**, **B**

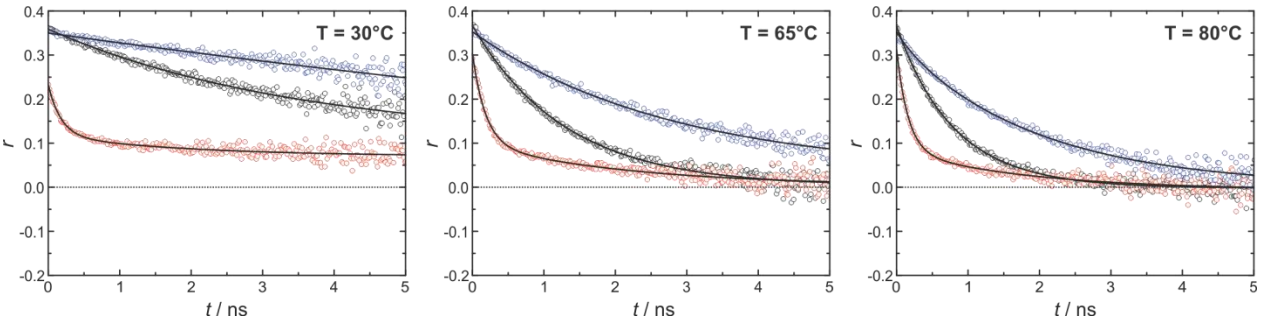


Figure S1. Anisotropy decays of compound **B⊥B** (red symbols), **B∥B** (blue symbols) and **B** (black symbols) in bis(2-ethylhexyl)phthalate (DEHP) at different temperatures. Black lines correspond to the best biexponential fits.

2.1.2 Anisotropy Decays for **B⊥R**, **B∥R**, **R**

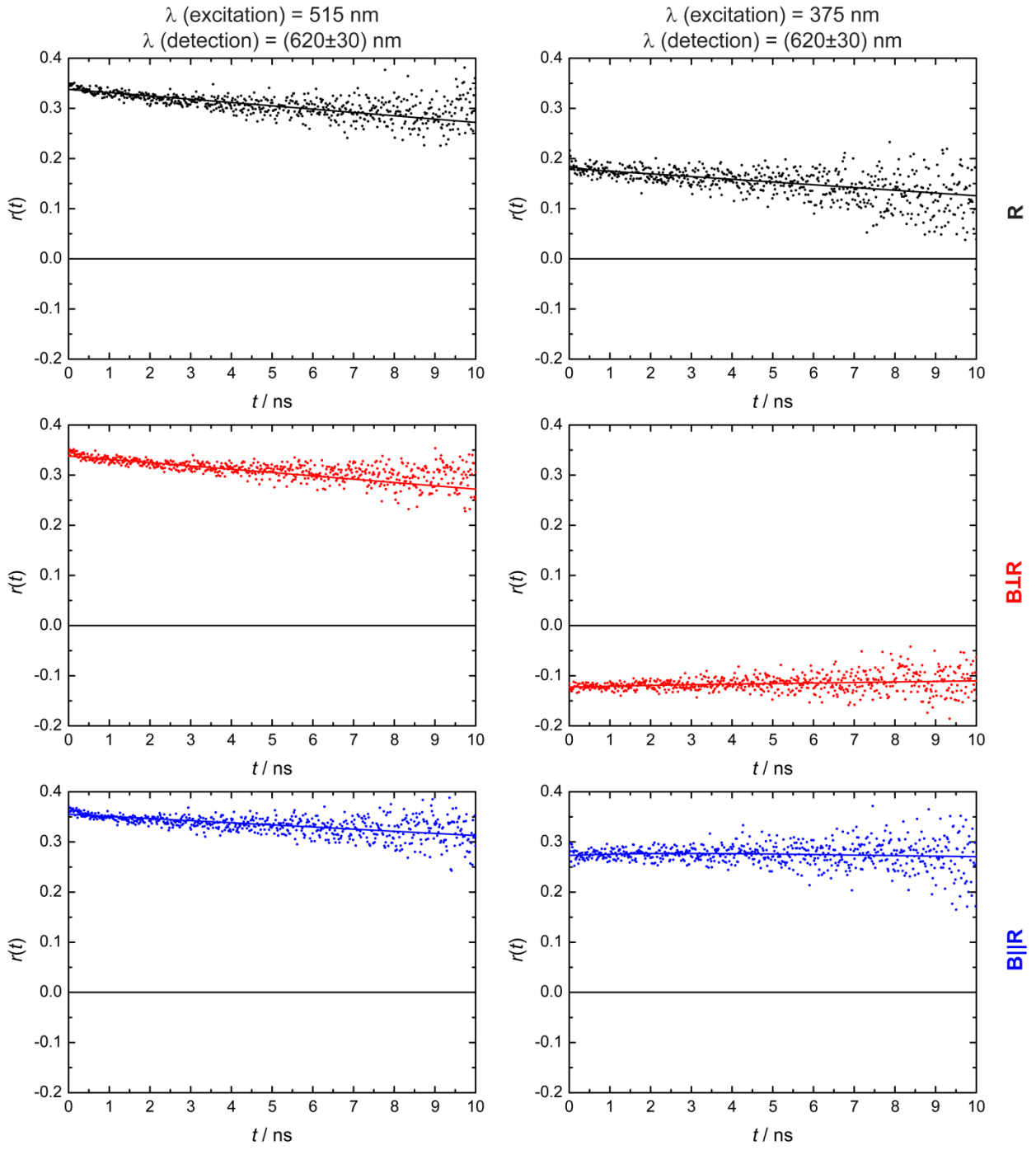


Figure S2. Anisotropy decays (time-resolved anisotropy for compounds **R**, **B⊥R** and **B∥R** in DEHP at 4 °C with excitation at 515 nm (left plots) and 375 nm (right plots). Detection was performed at 620 nm (±30 nm) in all cases, near the emission maxima of the red chromophore. Dots represent values directly calculated from experimental measurements, and the lines are values calculated from the best fits to the corresponding decays with deconvolution of the IRF.

2.2 Steady State Anisotropy

Steady state anisotropy measurements were performed in a *Cary Eclipse* fluorescence spectrophotometer (*Varian Inc.*, Australia), equipped with a film polarizer in the detection arm, and a Glan-Thompson polarizers (B. Halle Nachfl. GmbH, Berlin, Germany) in the excitation one. The temperature of the sample was controlled with a single Peltier cell holder (*Varian Inc.*, Australia).

The sample was excited with vertically polarized light. The vertically and horizontally polarized fluorescence intensities I_{VV} and I_{VH} (V = vertical, H = horizontal, first subscription: orientation of the excitation polarizer, second subscription: orientation of the emission polarizer) were measured. The *G* factor, which is the instrument sensitivity factor for vertically and horizontally polarized light, was determined according to $G = \int I_{\mathrm{HV}}\,\mathrm{d}t \,/ \int I_{\mathrm{HH}}\,\mathrm{d}t$. Then the total fluorescence intensity was calculated according to $I_{\mathrm{TOT}} = I_{\mathrm{VV}} + 2GI_{\mathrm{VH}}$.

2.2.1 Steady State Anisotropy for **B⊥B**, **B∥B**, **B**

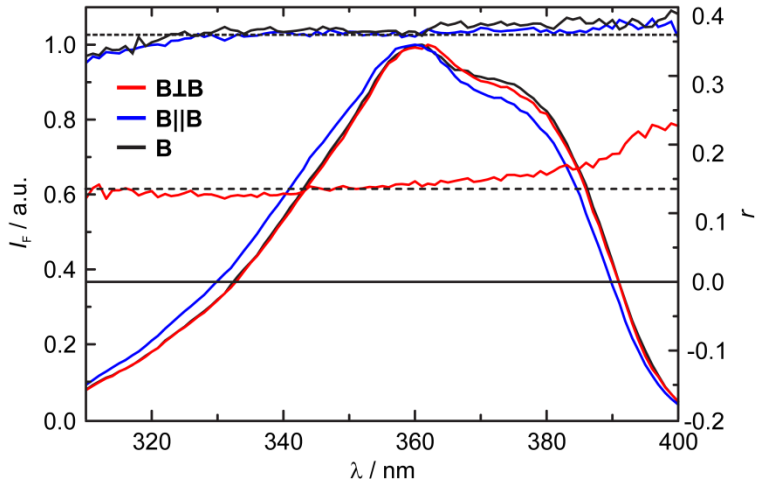


Figure S3. Excitation spectrum (I_{TOT} = I_{VV} + 2 *G* I_{VH}; black lines) and measured steady state anisotropy of compounds **B⊥B** (red lines), **B∥B** (blue lines) and **B** (black lines) in DEHP at 4 °C. The average anisotropy calculated from time-resolved anisotropy measurements is plotted with dashed lines for each chromophore.

2.2.2 Steady State Anisotropy for **B⊥R**, **B∥R**, **R**

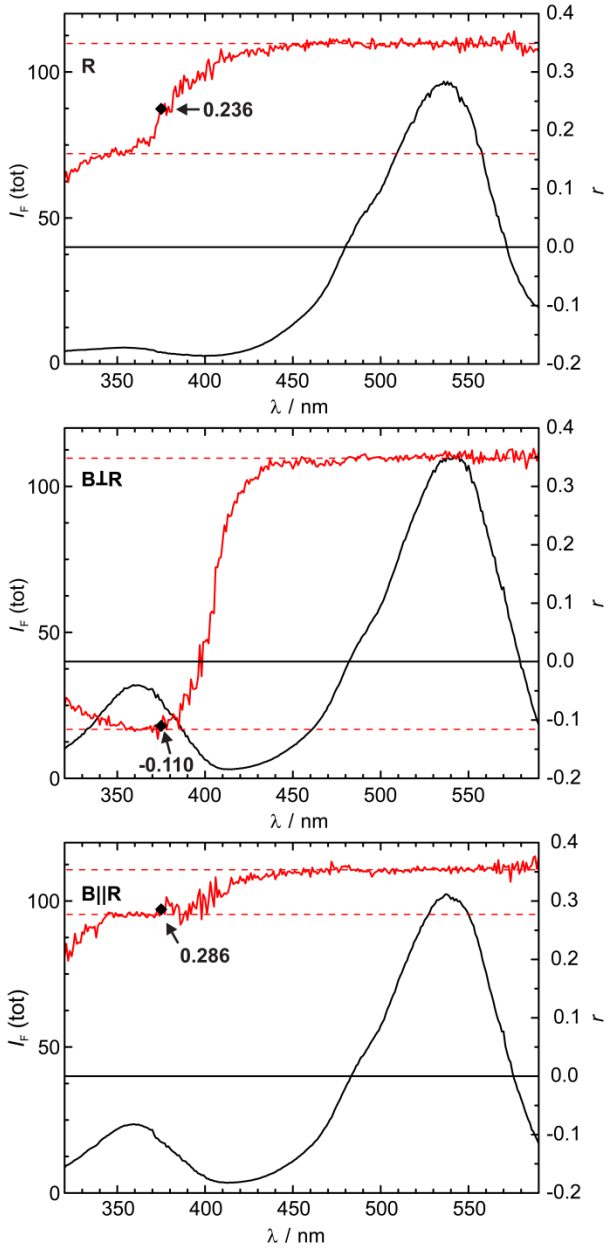


Figure S4. Excitation spectrum ($I_{TOT} = I_{VV} + 2\,G\,I_{VH}$; black lines) and measured steady state anisotropy (red lines) of compounds **R**, **B⊥R** and **B∥R** in DEHP at 4 °C. The anisotropy value at 375 nm excitation (used for TCSPC experiments) is highlighted. The average anisotropy of the first UV excitation band and the red absorption band is shown with dashed lines, for each chromophore.

2.3 Effective hydrodynamic volumes and DFT structures

The longest characteristic time of rotational anisotropy decays (or rotational correlation time) τ_{rot} for compounds **B⊥B**, **B∥B** and **B** was determined at different temperatures in order to determine the effective hydrodynamic volume V_{h} for each compound. Therefore, the rotational correlation time τ_{rot} was plotted against the viscosity η of the solvent (DEHP)[4] at the corresponding temperature (Figure S5).

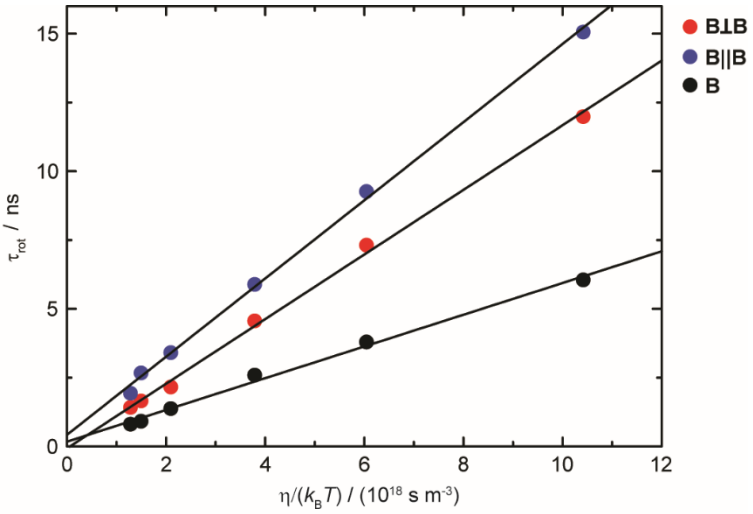


Figure S5. Rotational (longest) characteristic time of anisotropy decays τ_{rot} of compounds **B⊥B**, **B∥B** and **B** in DEHP as a function of solvent viscosity. The lines correspond to the best linear fits.

The effective hydrodynamic volume V_{h} was calculated from the slope of the plot according to

$$\tau_{\mathrm{rot}} = \frac{\eta}{k_{\mathrm{B}}T} V_{\mathrm{h}} \,. \tag{1}$$

The resulting effective hydrodynamic volumes V_{h} and radii of spheres r_{sphere} with these volumes are listed in Table S1.

Table S1. Calculated hydrodynamic volumes V_{h} and corresponding sphere radii.

compound	V_{h}/Å³	r_{sphere}/Å
B	$6.86 \cdot 10^3$	11.8
B⊥B	$1.20 \cdot 10^4$	14.2
B∥B	$1.36 \cdot 10^4$	14.8

Figure S6 shows ground state energy minimized DFT structures of compounds **B⊥B**, **B∥B** and **B** drawn inside spheres which correspond to the hydrodynamic volume listed in Table S1 (see section 4 for computational details).

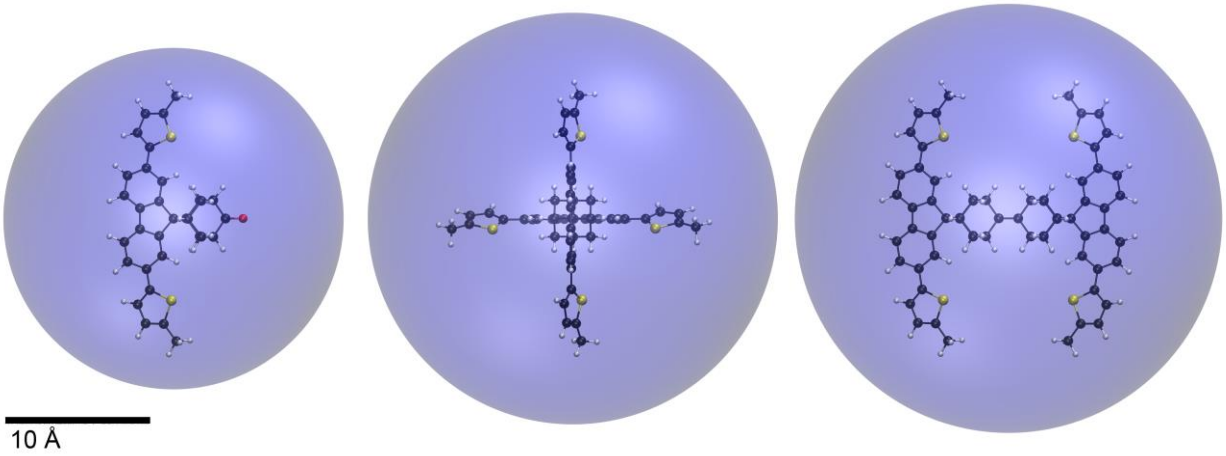


Figure S6. Orthographic projections of ground state geometries optimized by density functional calculations, drawn inside spheres with volumes corresponding to the effective hydrodynamic volume.

3 Photon Antibunching Experiments

3.1 Experimental Setup

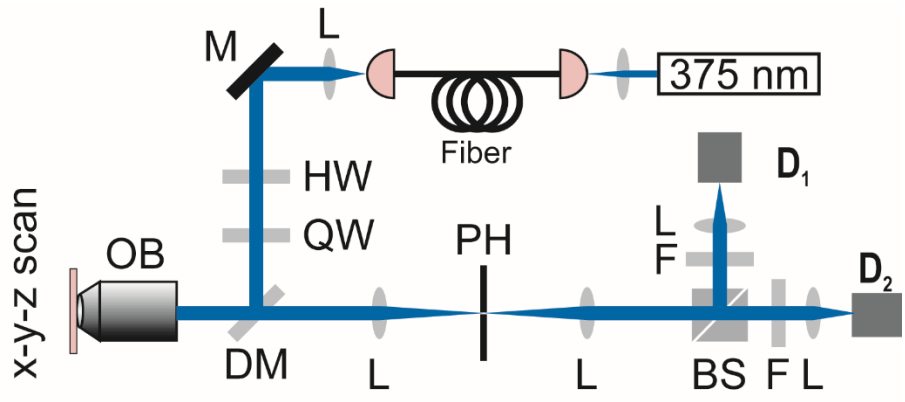


Figure S7. Confocal microscope combined with two independent detection channels. BS: beam splitter; $D_{1,2}$: avalanche photon diodes; DM: dichroic mirrors; F: fluorescence band pass filter; HW: half-wave plate; L: lens; M: Mirror; OB: objective; PH: pinhole; QW: quarter-wave plate.

A 375 nm diode laser (LDH-P-C-375; *PicoQuant*, Berlin, Germany) was fed to an optical fiber (PM-S405-XP; *Thorlabs GmbH*, Dachau/Munich, Germany) to generate a Gaussian beam. Circular polarization was generated after the excitation light passed a pair of half and quarter wave plates. Excitation light was then reflected by a hot mirror (M254H00; *Thorlabs*) into an objective (HCX-PL-APO 100x/1.4-0.7 OIL CS; *Leica Microsystems*, Wetzlar, Germany) and the fluorescence was collected by the same objective and transmitted through the hot mirror. After a tube lens (f = 200 mm), the fluorescence went through a 50 µm pinhole (correspond to ~1 airy disk diameter) and was collimated by another lens (f = 100 mm) before it was split into two identical detection channels. Detection filters of type 460/60 (F39-46; *AHF Analysentechnik AG*, Tübingen, Germany) were used with single photon counting modules (COUNT @blue; *Laser Components GmbH*, Olching, Germany) as detectors. The excitation repetition rate was 40 MHz and the laser power was ~21 µW. The detected signal was transferred through a time-correlated single photon counting card (DPC 230; *Becker & Hickl GmbH*, Berlin, Germany) and stored by a PC for post processing. Experimental control, data acquisition and analysis were performed with custom made *MATLAB* software.

3.2 Determination of emitters per molecule

The antibunching experiments with compounds **B⊥B**, **B∥B** and **B** were carried in chloroform at concentrations of 13, 11 and 15 nmol/l, respectively. The measurement time was 300 s for each. The data was analysed according to the method reported by Enderlein and co-workers.[5] The correlation function was fitted by the model functions

$$A + B\sum_{j=0}^{\infty}\exp\left(-\frac{\left|t - jT_{\mathrm{rep}}\right|}{\tau}\right) - C\exp\left(-\frac{t}{\tau}\right) \tag{2}$$

for lag time t close to zero and

$$A' + B'\sum_{j=0}^{\infty}\exp\left(-\frac{\left|t - jT_{\mathrm{rep}}\right|}{\tau}\right) \tag{3}$$

for infinite lag time t (Figure S8, left). T_{rep} is the time between subsequent laser pulses, whereas A, B, C, A', B' and τ are fitting parameters. Although τ is the fluorescence lifetime it was not fixed during the fitting procedure. The number of independent emitters/chromophores per molecule was calculated by

$$n = \frac{B - B'}{C}. \tag{4}$$

The fluorescence correlation spectroscopy curves were fitted to model function

$$D + \frac{E + F\exp\left(-\frac{t}{t_1}\right) + G\exp\left(-\frac{t}{t_2}\right)}{(1 + t/a)\sqrt{1 + t/b}}, \tag{5}$$

with D, E, F, G, t_1, t_2, a, and b as fitting parameters (Figure S8, right). While t_1 and t_2 correspond to the temporal decay of the ACF on a microsecond time scale, the parameters a and b are related to the diffusion of the fluorophores out of the detection volume. In the end, the corrected number independent emitters/chromophores per molecules is calculated by

$$n = \frac{B - B'}{C}\frac{D + E + F + G}{D + E}. \tag{6}$$

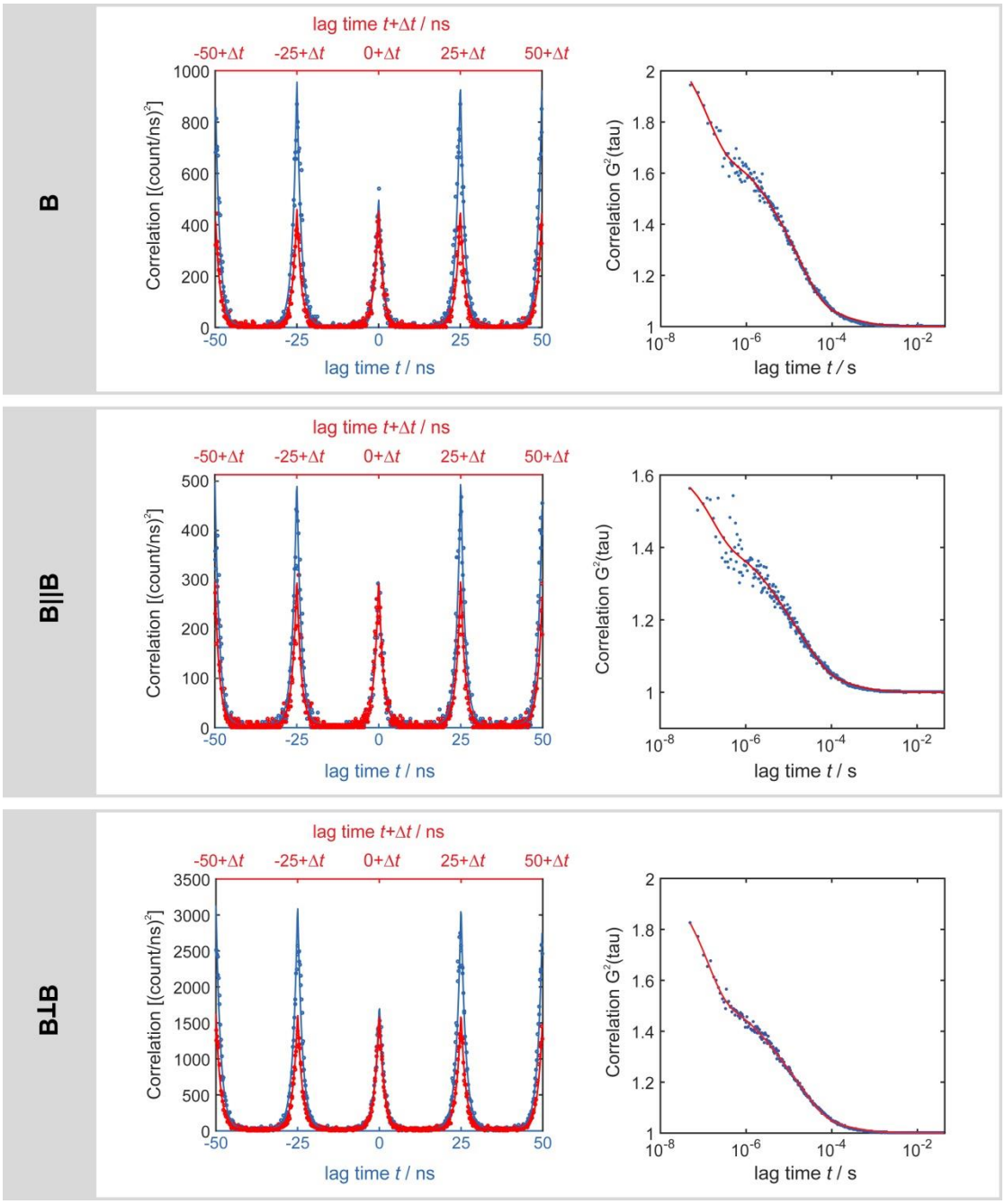


Figure S8. Measured cross correlation functions. (left) Magnification at zero lag time $t \approx 0$ (plotted in blue) and at large lag time $t + \Delta t$ where Δt was chosen to be 1 s (plotted in red); (right) normalized cross correlation function by its value at $t = \infty$. Dots: measured cross correlation function; solid lines: fitting to the experimental data (model function equation 2 and 3).

4 Estimation of FRET efficiency

Although not valid at short donor-acceptor separations in the order of the fluorophore size, the energy transfer efficiency was estimated applying the FRET point-dipole approximation. For this purpose the photophysical properties of model compounds **B** and **R** were used. The geometrical arrangement of the transition dipole moments was determined by density functional theory (DFT) and time-dependent density functional theory (TD-DFT) calculations.[6]

4.1 Optimized geometries and transition dipole moments

All DFT and TD-DFT calculations were carried out using the Gaussian 09 program[7] at the B3LYP/6-31G** level of theory in gas phase. Ground state geometries of compounds **B**, **R**, **B⊥B**, **B⊥R, B∥B** and **B∥R** were optimized using DFT calculations (Figures S9-S14). The S_1 state geometry of model compound **B** was optimized using TD-DFT (Figure S9).

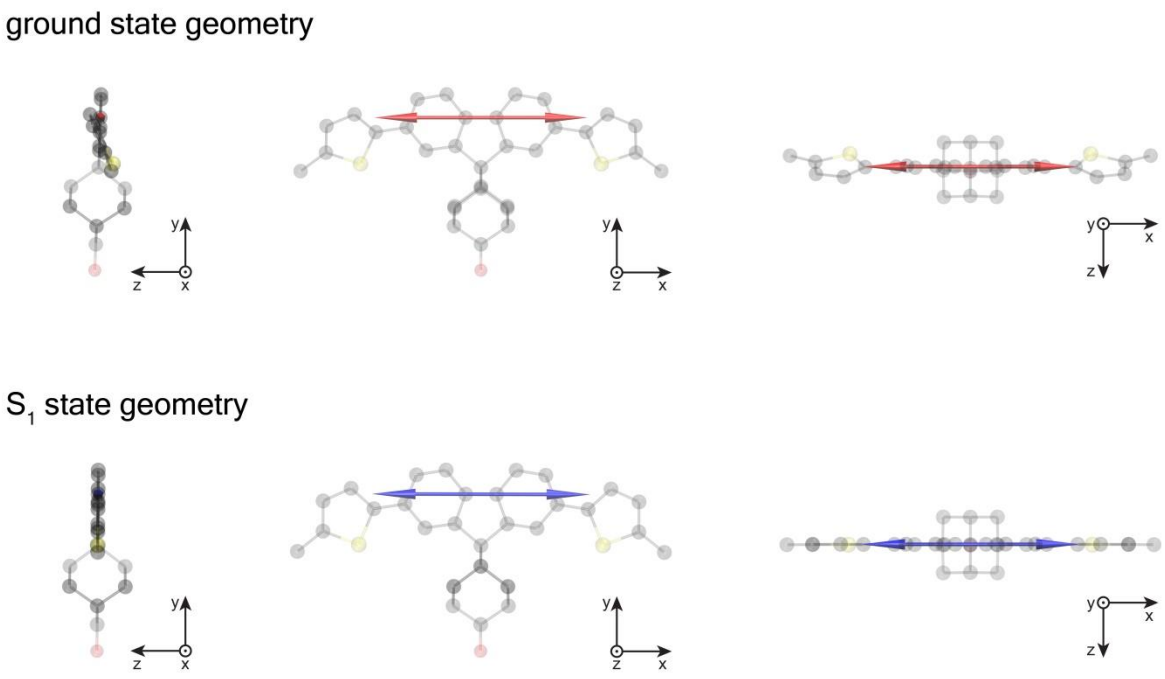


Figure S9. DFT and TD-DFT optimized geometries of model compound **B** and corresponding transition dipole moments shown as double-headed arrows. Top: Ground state geometry with absorption ($S_0 \rightarrow S_1$) transition dipole moment (red arrow); bottom: S_1 state geometry and emission ($S_1 \rightarrow S_0$) transition dipole moment (blue arrow). H atoms are omitted for sake of clarity.

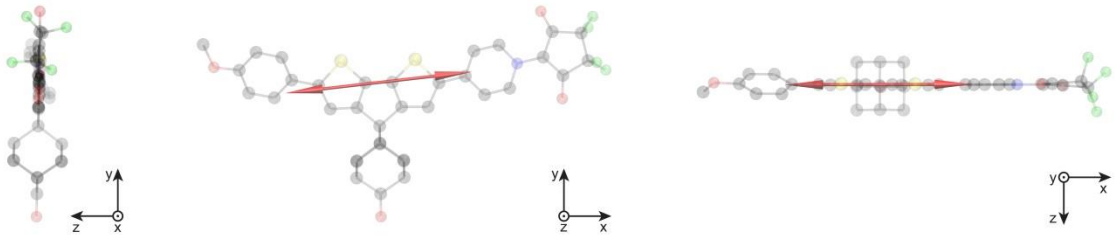


Figure S10. DFT optimized geometry of model compound **R** and absorption ($S_0 \rightarrow S_1$) transition dipole moment shown as red double-headed arrow. H atoms are omitted for sake of clarity.

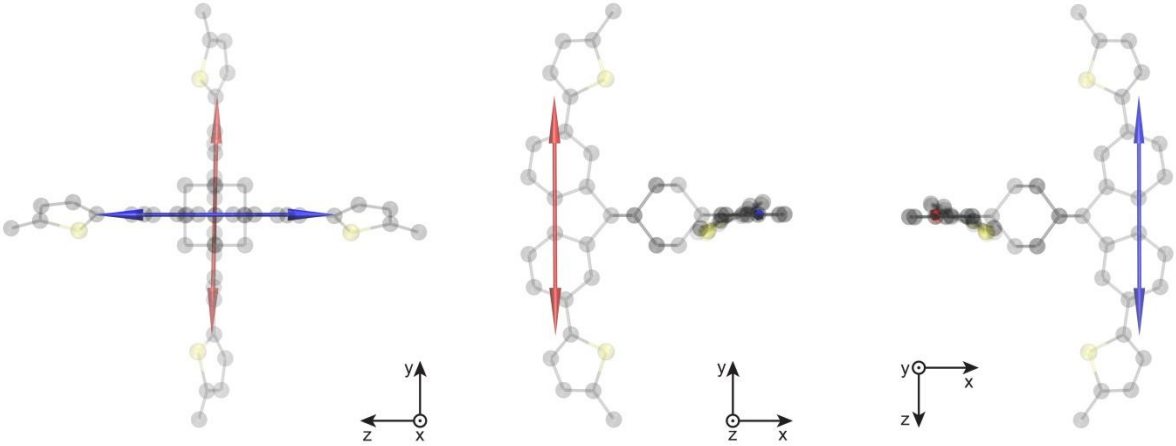


Figure S11. DFT optimized ground state geometry of bichromophore **B⊥B**. The absorption ($S_0 \rightarrow S_1$) and emission ($S_1 \rightarrow S_0$) transition dipole moments are shown as red and blue double-headed arrows, respectively. H atoms are omitted for sake of clarity.

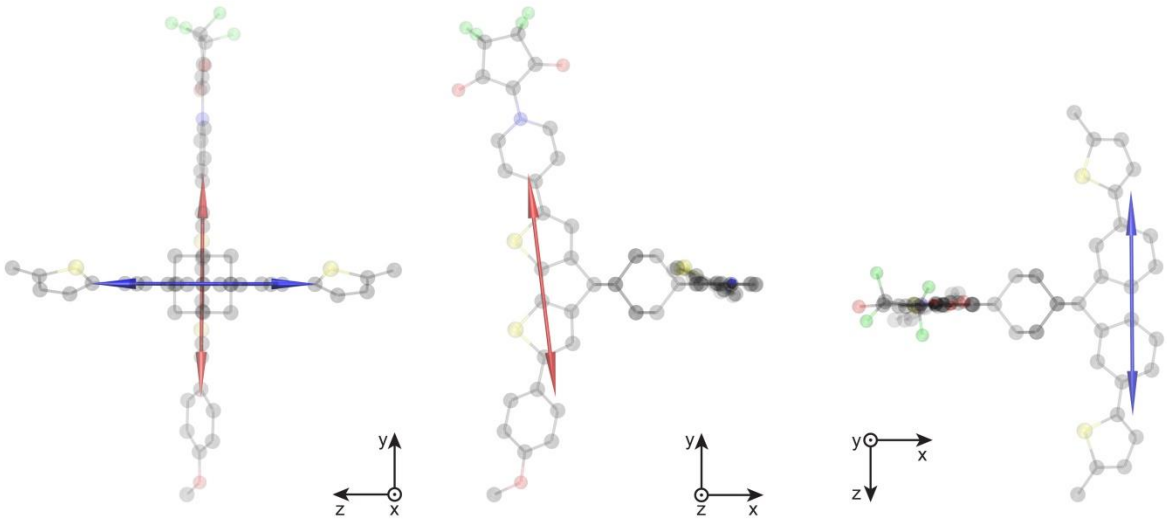


Figure S12. DFT optimized ground state geometry of bichromophore **B⊥R**. The absorption ($S_0 \rightarrow S_1$) and emission ($S_1 \rightarrow S_0$) transition dipole moments are shown as red and blue double-headed arrows, respectively. H atoms are omitted for sake of clarity.

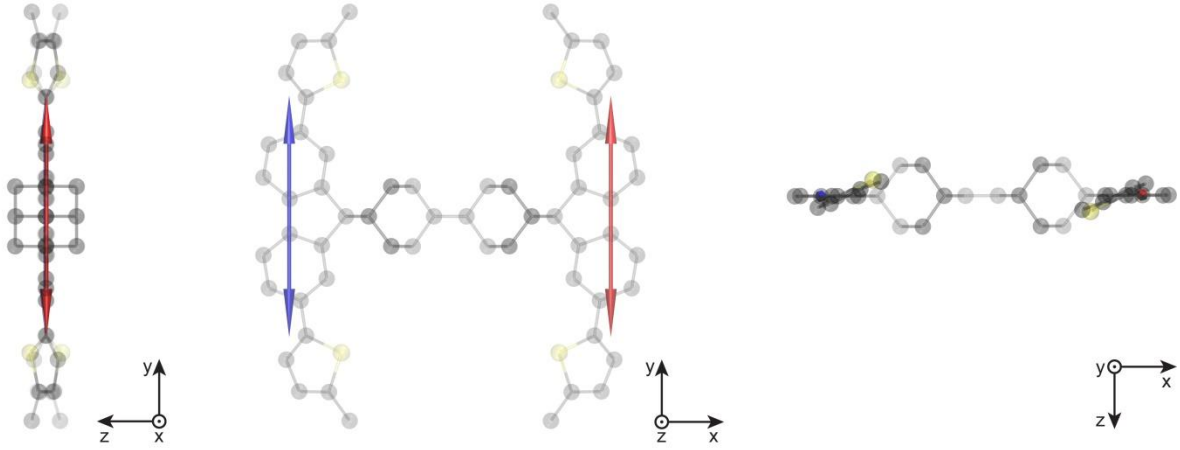


Figure S13. DFT optimized ground state geometry of bichromophore **B‖B**. The absorption ($S_0 \rightarrow S_1$) and emission ($S_1 \rightarrow S_0$) transition dipole moments are shown as red and blue double-headed arrows, respectively. H atoms are omitted for sake of clarity.

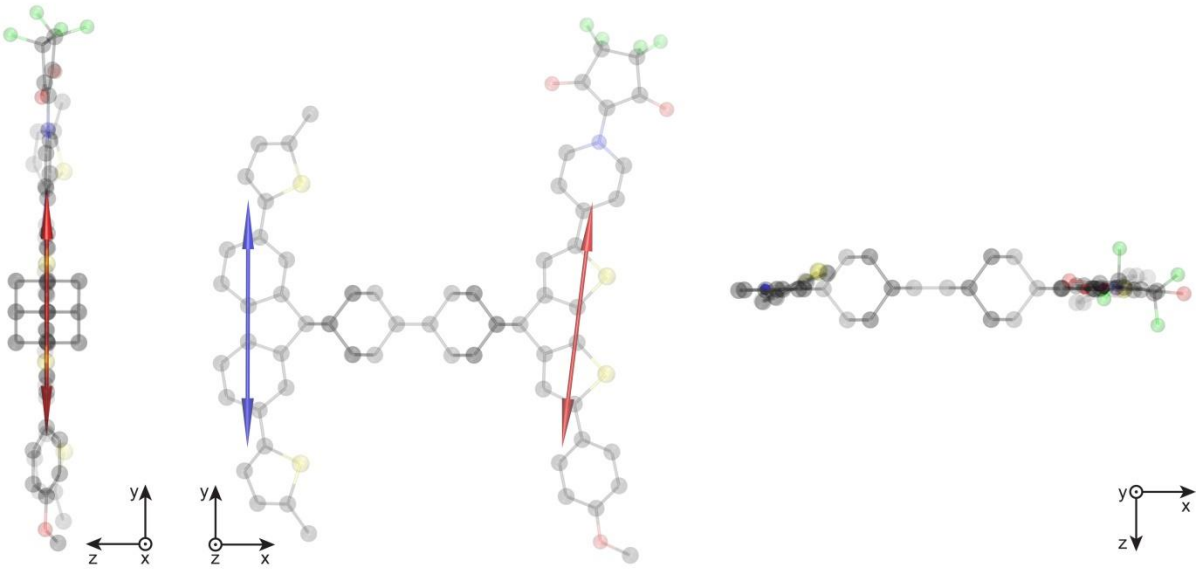


Figure S14. DFT optimized ground state geometry of bichromophore **B∥R**. The absorption ($S_0 \rightarrow S_1$) and emission ($S_1 \rightarrow S_0$) transition dipole moments are shown as red and blue double-headed arrows, respectively. H atoms are omitted for sake of clarity.

Absorption and emission transition dipole moments were calculated using TD-DFT (Figures S9-S14). According to the Franck-Condon principle, the absorption ($S_0 \rightarrow S_1$) transition dipole moments were calculated at the optimized S_0 state geometries, whereas the emission ($S_1 \rightarrow S_0$) transition dipole moments were calculated at the optimized S_1 state geometry. Absorption transition dipole moments were calculated for model compound **R**, the red fluorophores of **B⊥R** and **B∥R**, and for one fluorophore in **B∥B** and **B⊥B**. In order to reduce the computational load, the emission transition dipole moment of the blue fluorophore (energy donor) was calculated exclusively for model compound **B**. The position and orientation was transferred to the blue fluorophores of the individual bichromophores in their ground state optimized geometry using the adamantane scaffold as reference system.

The transition dipole moments are shown as double-headed arrows with arbitrary length of 10 Å (Figures S9-S14). The center of the double-headed arrow was positioned at the middle of the connecting bond between the phenyl (or thienyl) groups of the blue (or red) fluorophore (Figure S15).

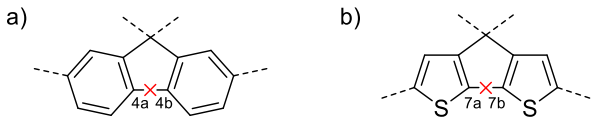


Figure S15. Position of the transition dipole moment (marked as ×) used in the context of the point dipole approximation; a) the center between atoms 4a and 4b was used for the blue fluorophore; b) the center between atoms 7a and 7b was used for the red fluorophore.

4.2 Calculation of orientation factor

From the angles between the transition dipole moments of the donor $\boldsymbol{\mu}_{\mathrm{D}}$ and acceptor $\boldsymbol{\mu}_{\mathrm{A}}$ and interconnecting vector $\boldsymbol{R}_{\mathrm{DA}}$ as defined in Figure S16, the orientation factor κ^2 was calculated according to $\kappa^2 = [\cos(\theta_{\mathrm{DA}}) - 3\cos(\theta_{\mathrm{D}})\cos(\theta_{\mathrm{A}})]^2$ (Table S2).

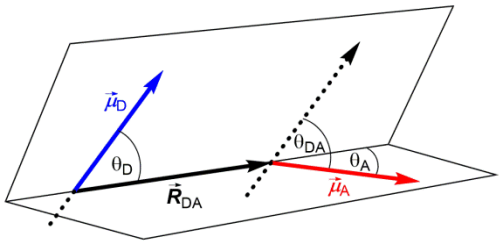


Figure S16. Angles between transition dipole moments of the donor $\boldsymbol{\mu}_{\mathrm{D}}$ and acceptor $\boldsymbol{\mu}_{\mathrm{A}}$ and interconnecting vector $\boldsymbol{R}_{\mathrm{DA}}$ relevant to the orientation factor κ^2.

4.3 Determination of spectral overlap integral

The spectral overlap integral J_{DA} was calculated for the combinations of blue/blue and blue/red chromophores Based on the absorption and emission spectra of model compounds **B** and **R** (Table S2) according to[8]

$$J_{\mathrm{DA}} = \int F_\lambda(\lambda)\, \varepsilon(\lambda)\, \lambda^4\, \mathrm{d}\lambda\,, \tag{7}$$

where $F_\lambda(\lambda)$ is the emission spectrum of the donor (model compound **B**) normalized according to $\int F_\lambda(\lambda)\, \mathrm{d}\lambda = 1$ and $\varepsilon(\lambda)$ is the absorption spectrum of the acceptor (model compound **B** or **R**).

4.4 Förster radius

The Förster radius R_0 was calculated using the photophysical data of model compounds **B** and **R** with the refractive index of the solvent $n(\mathrm{CHCl_3}, 20\ ^\circ\mathrm{C}) = 1.4459$,[9] according to

$$R_0 = \sqrt[6]{\frac{9\ln(10)}{128\,\pi^5 N_\mathrm{A}} \cdot \frac{\kappa^2 \Phi_\mathrm{D} J_\mathrm{DA}}{n^4}}, \tag{8}$$

where Φ_D is the quantum yield of the donor (model compound **B**) in absence of the acceptor, J_DA is the spectral overlap between the donor (model compound **B**) emission and acceptor (model compound **B** or **R**) absorption, and N_A is the Avogadro constant (Table S2).

4.5 Calculation of FRET efficiency

The FRET efficiency was calculated according to

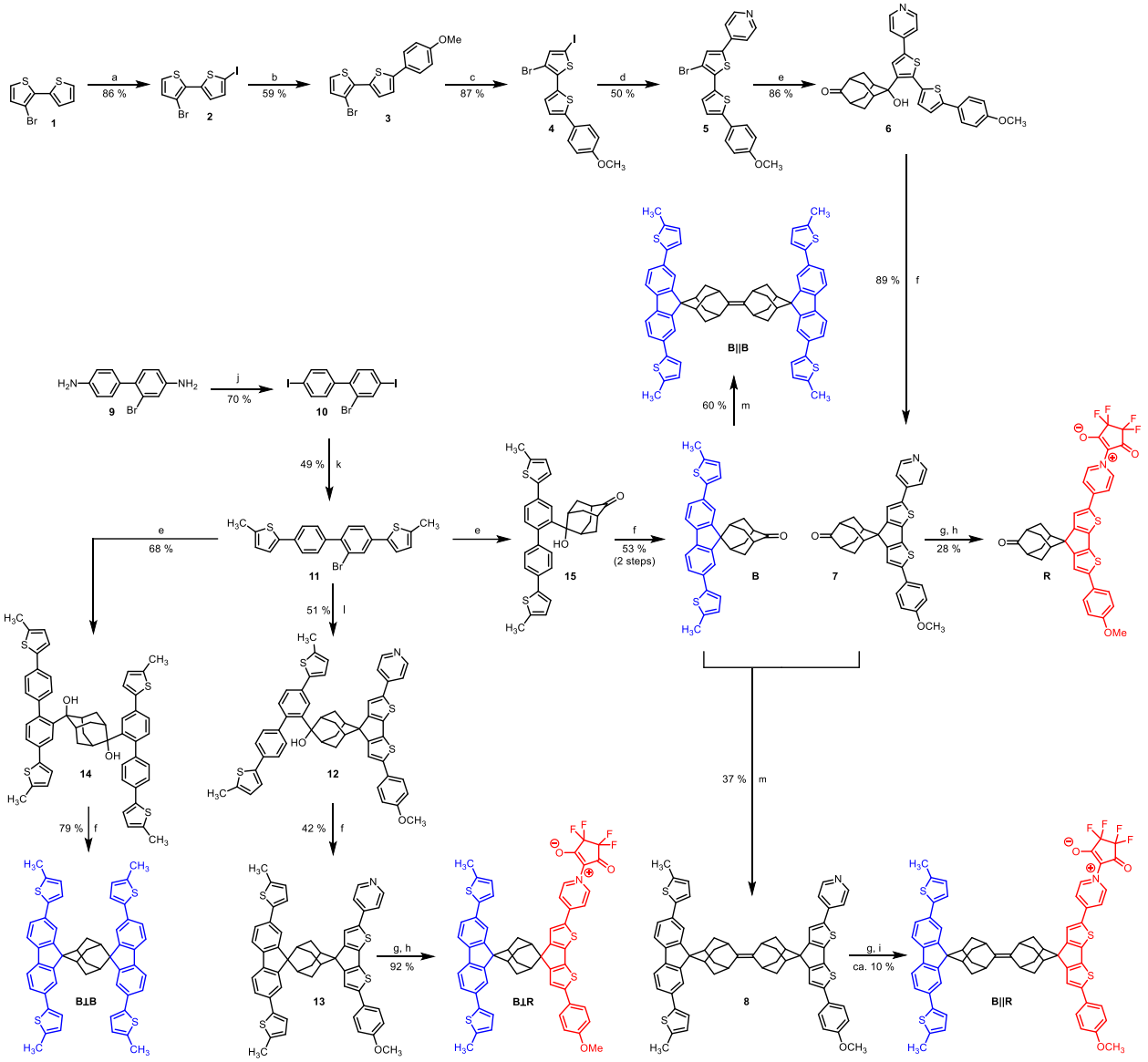
$$E_\mathrm{FRET} = \frac{1}{1+\left(\frac{|\boldsymbol{R}_\mathrm{DA}|}{R_0}\right)^6},$$

where $|\boldsymbol{R}_\mathrm{DA}|$ is the magnitude of the interconnecting vector between the positions of the transition dipole moments (determined as described above), i.e. the distance between donor and acceptor.

Table S2. Angles θ_D, θ_A and θ_DA between transition dipole moments and interconnecting vector $\boldsymbol{R}_\mathrm{DA}$, orientation factor κ^2, distance between the donor and acceptor $|\boldsymbol{R}_\mathrm{DA}|$, spectral overlap J_DA, calculated Förster radius R_0, and calculated FRET efficiency E_FRET.

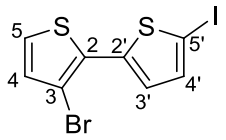
Compound	θ_D	θ_A	θ_DA	κ^2	$\lvert\boldsymbol{R}_\mathrm{DA}\rvert$/Å	J_DA/(M^{-1} cm^{-1} nm^4)	R_0/Å	E_FRET
B∥B	90.0°	90.0°	0.0°	1.00	13.3	$6.6 \cdot 10^{13}$	29.3	0.99
B∥R	90.0°	83.2°	6.9°	0.99	13.3	$2.4 \cdot 10^{14}$	36.1	1.00
B⊥B	90.1°	90.1°	91.4°	$6 \cdot 10^{-4}$	8.4	$6.6 \cdot 10^{13}$	8.5	0.51
B⊥R	89.9°	83.4°	90.5°	$1 \cdot 10^{-4}$	8.4	$2.4 \cdot 10^{14}$	7.7	0.38

5 Syntheses



Scheme S1. Synthesis strategy. Reagents and conditions: a) *N*-iodosuccinimide (NIS), HOAc, MeOH, 60 °C, 1 h; b) 4-methoxyphenylboronic acid, $Pd(PPh_3)_4$, aq. $NaHCO_3$, 1,2-dimethoxyethane, 90 °C, 16 h; c) NIS, THF, HOAc, r.t., 24 h; d) 4-pyridinylboronic acid, $Pd(PPh_3)_2Cl_2$, aq. K_3PO_4, 1,4-dioxane, 70 °C, 22 h; e) i. *n*-BuLi, THF, -78 °C, 10 min, ii. 2,6-adamantanedione, THF, -78 °C to r.t., 1-19 h; f) 60-75 % aq. H_2SO_4, *n*-octane, r.t., 30-60 min; g) perfluorocyclopentene, H_2O, HOAc; h) 1,2-dichloroethane, microwave, 130 °C, 10 min; i) THF, 40 °C, 30 min; j) 2 M HCl, MeCN, $NaNO_2$, -5 to -10 °C, 35 min, then KI, -10 °C to r.t., 16 h; k) 5-methyl-2-(tributylstannyl)thiophene, $Pd(PPh_3)_4$, PhMe, 110 °C, 16 h; l) i. *n*-BuLi, THF, -78 °C, 10 min, ii. **7**, THF, -78 °C to r.t., 5 h; m) $TiCl_4$, Zn, pyridine, THF, 80 °C, 16 h.

5.1 3-Bromo-5'-iodo-2,2'-bithienyl (**2**)



Regioselective iodination of bithiophene derivative **1** was carried out under conditions given in ref. [10].

To a solution of 3-bromo-2,2'-bithiophene (2.15 g, 8.77 mmol, 1.00 eq) in dry MeOH (194 ml), *N*-iodosuccinimide (8.29 g, 36.8 mmol, 4.20 eq) was added at r.t.. To the clear yellow solution HOAc (2.2 ml, 2.3 g, 38 mmol, 1.0 eq) was added. The solution was heated at 60 °C for 60 min. TLC of the clear brown reaction mixture on RP SiO_2-C_{18} with MeCN as eluent displayed almost full consumption of the starting compound. Then 1.0 M aq. $Na_2S_2O_3$ solution (200 ml) was added. The mixture was extracted with CH_2Cl_2 (3 × 100 ml); combined organic solutions were dried over Na_2SO_4 and concentrated *in vacuo* to give 4.16 g of brown solids suspended in a yellow oil. Column chromatography on silica gel (150 g SiO_2, cyclohexane) gave 2.81 g (7.57 mmol, 86 %) of the title compound as yellow oil.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 7.00 (d, $^3J_{H,H}$ = 5.4 Hz, 1 H, 4-H), 7.05 (d, $^3J_{H,H}$ = 3.8 Hz, 1 H, 3'-H), 7.19 (d, $^3J_{H,H}$ = 5.4 Hz, 1 H, 5-H), 7.22 (d, $^3J_{H,H}$ = 3.8 Hz, 1 H, 4'-H) ppm.

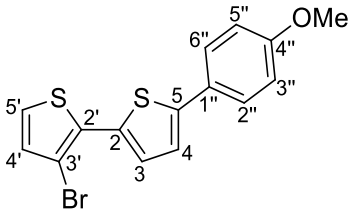
^{13}C NMR ($CDCl_3$, 101 MHz): δ = 74.7 (C-5'), 108.5 (C-3), 124.9 (C-5), 128.1 (C-3'), 131.6 (C-2'), 132.0 (C-4), 137.1 (C-4'), 140.4 (C-2) ppm.

GC-MS (EI): *m/z* (%) = 370/372 (100) $M^{+\cdot}$.

HRMS (EI): *m/z* calc. for $C_8H_4BrIS_2$ $[M]^+$ 369.7982; found 369.7978.

TLC: R_f = 0.34 (SiO_2, cyclohexane),
R_f = 0.42 (RP SiO_2-C_{18}, MeCN).

5.2 3-Bromo-5'-(*p*-methoxyphenyl)-2,2'-bithienyl (**3**)



3'-Bromo-5-iodo-2,2'-bithiophene (3.01 g, 7.57 mmol, 1.00 eq), 4-methoxyphenylboronic acid (1.38 g, 9.08 mmol, 1.20 eq), 1,2-dimethoxyethane (21.0 ml), and sat. aq. $NaHCO_3$ (21.0 ml) were mixed under argon. [$Pd(PPh_3)_4$] (0.44 g, 0.38 mmol, 0.05 eq) was added, and the yellow suspension was stirred at 90 °C for 16 h. The reaction mixture was diluted with water (100 ml) and extracted with dichloromethane (3 × 50 ml). The combined organic solutions were dried over Na_2SO_4 and concentrated *in vacuo* to give 3.35 g of a yellow oil which solidified upon standing at room temperature. The crude product was isolated by crystallization from a mixture of $CHCl_3$ and MeOH. Column chromatography on silica gel (100 g SiO_2, cyclohexane/EtOAc = 10:1) gave 1.56 g (4.46 mmol, 59 %) of a yellow solid (NOTE: The product is poorly soluble in non-chlorinated solvents, high dilution during chromatography is recommended in order to avoid precipitation).

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 3.84 (s, 3 H, OCH_3), 6.90 – 6.95 (m, 2 H, 3''-H, 5''-H), 7.02 (d, $^3J_{H,H}$ = 5.4 Hz, 1 H, 4'-H), 7.16 (d, $^3J_{H,H}$ = 3.8 Hz, 1 H, 4-H), 7.18 (d, $^3J_{H,H}$ = 5.4 Hz, 1 H, 5'-H), 7.37 (d, $^3J_{H,H}$ = 3.8 Hz, 1 H, 3-H), 7.54 – 7.58 (m, 2 H, 2''-H, 6''-H) ppm.

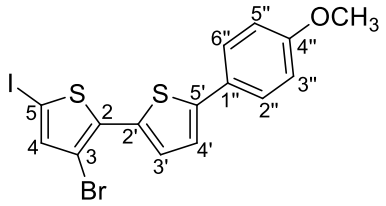
^{13}C NMR ($CDCl_3$, 101 MHz): δ = 55.5 (OCH_3), 107.6 (C-3'), 114.5 (C-3'', C-5''), 122.3 (C-4), 124.2 (C-5'), 126.9 (C-1''), 127.2 (C-2'', C-6''), 127.7 (C-3), 132.1 (C-4'), 132.6, 132.7 (C-2, C-2'), 145.0 (C-5), 159.6 (C-4'') ppm.

GC-MS (EI): *m/z* (%) = 350/352 (100) $M^{+\cdot}$.

HRMS (EI): *m/z* calc. for $C_{15}H_{11}BrOS_2$ $[M]^+$ 349.9435; found 349.9435.

TLC: R_f = 0.26 (SiO_2, cyclohexane/EtOAc = 9:1),
R_f = 0.47 (RP SiO_2-C_{18}, MeCN).

5.3 3-Bromo-5-iodo-5'-(*p*-methoxyphenyl)-2,2'-bithienyl (**4**)



Regioselective iodination of bithiophene derivative **3** was carried out under mild iodination conditions.[11]

To a solution of compound **3** (1.00 g, 2.85 mmol, 1.00 eq) in dry THF (8.0 ml) *N*-iodosuccinimide (769 mg, 3.42 mmol, 1.20 eq) was added at room temperature. To the clear yellow solution HOAc (6.0 ml) was added. The reacton mixture was stirred at room temperature for 24 h giving a yellowish suspension. TLC of the reaction mixture on RP SiO_2-C_{18} with MeCN as eluent showed almost full consumption of the starting material. Then 1.0 M aq. $Na_2S_2O_3$ solution (80 ml) was added and the mixture was extracted with CH_2Cl_2 (3 × 80 ml). The combined organic solutions were dried over Na_2SO_4 and concentrated *in vacuo* to give 1.76 g of a light brown solid. Column chromatography on silica gel (200 g SiO_2, cyclohexane/$CHCl_3$ = 5:1 → 3:1) gave 1.19 g (2.49 mmol, 87 %) of the title compound as yellowish solid.

^{1}H NMR (CDCl$_3$, 400 MHz): δ = 3.84 (s, 3 H, OCH_3), 6.90 – 6.95 (m, 2 H, 3''-H, 5''-H), 7.14 (d, $^3J_{H,H}$ = 3.9 Hz, 1 H, 4'-H), 7.14 (s, 1 H, 4-H), 7.29 (d, $^3J_{H,H}$ = 3.9 Hz, 1 H, 3'-H), 7.52 – 7.57 (m, 2 H, 2''-H, 6''-H) ppm.

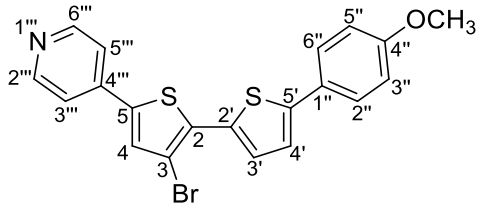
^{13}C NMR (CDCl$_3$, 101 MHz): δ = 55.5 (OCH_3), 71.5 (C-5), 107.3 (C-3), 114.5 (C-3'', C-5''), 122.3 (C-4'), 126.7 (C-1''), 127.3 (C-2'', C-6''), 128.1 (C-3'), 131.6 (C-2), 138.7 (C-2'), 140.6 (C-5), 145.6 (C-5'), 159.7 (C-4'') ppm.

MS (ESI, pos.): *m/z* (%) = 476/478 (100) $[M]^+$.

HRMS (EI): *m/z* calc. for $C_{15}H_{10}BrIOS_2$ $[M]^+$ 475.8401; found 475.8413.

TLC: R_f = 0.47 (SiO_2, cyclohexane/$CHCl_3$ = 5:1),
R_f = 0.31 (RP SiO_2-C_{18}, MeCN).

5.4 3-Bromo-5'-(*p*-methoxyphenyl)-5-(4-pyridyl)-2,2'-bithienyl (**5**)



Compound **4** (618 mg, 1.30 mmol, 1.00 eq), 4-pyridinylboronic acid (159 mg, 1.30 mmol, 1.00 eq), 1,4-dioxane (8.4 ml), and 2.0 M K_3PO_4 (2.4 ml) were mixed in a screw-capped tube, and argon was bubbled through the mixture for 10 min. $Pd(PPh_3)_2Cl_2$ (91 mg, 0.13 mmol, 0.10 eq) was added, and the resulting yellow suspension was stirred at 70 °C for 22 h. The reaction mixture was diluted with EtOAc (30 ml) and filtered through CELITE (∅ = 4 cm, *h* = 0.6 cm). The filter cake was washed with EtOAc (100 ml) followed by CH_2Cl_2 (120 ml). The combined filtrates were concentrated *in vacuo* to give 625 mg of an orange solid. Separation by column chromatography on silica gel (40 g SiO_2, CH_2Cl_2/EtOAc = 4:1 + 0.1 % NEt_3) gave 280 mg (654 µmol, 50 %) of the title compound as orange-yellow solid.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 3.85 (s, 3 H, CH_3), 6.91 – 6.96 (m, 2 H, 3''-H, 5''-H), 7.18 (d, $^3J_{H,H}$ = 3.9 Hz, 1 H, 4'-H), 7.39 – 7.43 (m, 3 H, 4-H, 3'''-H, 5'''-H), 7.45 (d, $^3J_{H,H}$ = 3.9 Hz, 1 H, 3'-H), 7.54 – 7.59 (m, 2 H, 2''-H, 6''-H), 8.60 – 8.64 (m, 2 H, 2'''-H, 6'''-H) ppm.

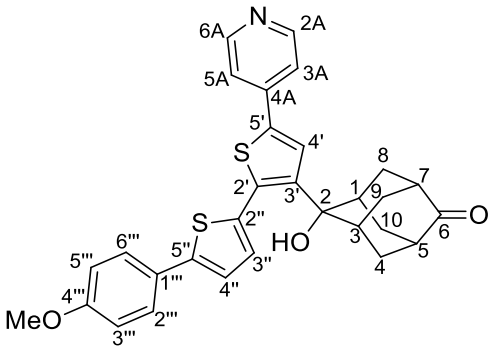
^{13}C NMR ($CDCl_3$, 101 MHz): δ = 55.5 (CH_3), 108.3 (C-3), 114.6 (C-3'', C-5''), 119.4 (C-3''', C-5'''), 122.5 (C-4'), 126.6 (C-1''), 127.3 (C-2'', C-6''), 128.3 (C-3'), 130.0 (C-4), 132.2 (C-2), 134.3 (C-5), 138.4 (C-2'), 140.0 (C-4'''), 145.9 (C-5'), 150.6 (C-2''', C-6'''), 159.8 (C-4'') ppm.

MS (ESI, pos.): *m/z* (%) = 428/430 (100) $[M+H]^+$.

HRMS (EI): *m/z* calc. for $C_{20}H_{14}BrNOS_2$ $[M]^+$ 426.9700; found 426.9703.

TLC (SiO_2): R_f = 0.24 (CH_2Cl_2/EtOAc = 1:1 + 0.1 % NEt_3).

5.5 Compound **6**



Bromide **5** (152 mg, 354 µmol, 1.00 eq) was dissolved in dry THF (7.5 mL), and the solution was cooled to -78 °C. A 1.6 M solution of *n*-BuLi in *n*-hexane (0.27 µL, 0.43 mmol, 1.2 eq) was added dropwise at -78 °C over a period of 1 min. After 15 min, the solution of lithiated **5** was transferred to a solution of 2,6-adamantanedione (175 mg, 1.06 mmol, 3.00 eq) in dry THF (5.0 mL) at -78 °C over a period of 1 min. The mixture was stirred at -78 °C for 10 min and at room temperature for additional 1.5 h. Then sat. aq. NH_4Cl (25 mL) and water (25 mL) were added. The mixture was extracted with EtOAc (3 × 25 ml), and the combined organic solutions were dried over Na_2SO_4. Concentration *in vacuo* gave 305 mg of an orange solid. Column chromatography on silica gel (45 g SiO_2, CH_2Cl_2/EtOAc = 1:1 + 0.1 % NEt_3) gave 156 mg of **6** (304 µmol, 86 %) as yellow solid.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 1.77 – 1.85 (m, 2 H, [4-H_a, 10-H_a]/[8-H_a, 9-H_a]), 1.89 – 1.98 (m, 2 H, [8-H_a, 9-H_a]/[4-H_a, 10-H_a]), 2.03 – 2.12 (m, 2 H, [4-H_b, 10-H_b]/[8-H_b, 9-H_b]), 2.36 – 2.41 (m, 1 H, 5-H/7-H), 2.45 – 2.50 (m, 1 H, 7-H/5-H), 2.59 – 2.65 (m, 2 H, 1-H, 3-H), 2.71 – 2.80 (m, 2 H, [8-H_b, 9-H_b]/ [4-H_b, 10-H_b]), 3.40 (s_{br}, 1 H, OH), 3.84 (s, 3 H, OCH_3), 6.89 – 6.98 (m, 2 H, 3'''-H, 5'''-H), 7.16 (d, $^3J_{H,H}$ = 3.7 Hz, 1 H, 4''-H), 7.30 – 7.36 (m, 3 H, 3''-H, 3A-H, 5A-H), 7.38 (s, 1 H, 4'-H), 7.52 – 7.60 (m, 2 H, 2'''-H, 6'''-H), 8.45 – 8.52 (m, 2 H, 2A-H, 6A-H) ppm.

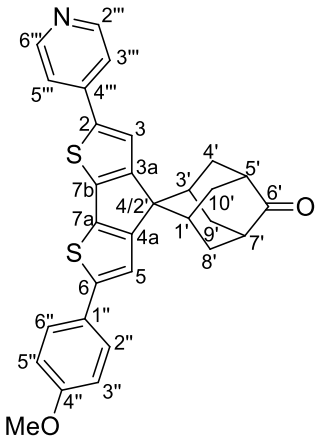
^{13}C NMR ($CDCl_3$, 101 MHz): δ = 34.1 ([C-8, C-9]/[C-4, C-10]), 35.5 (C-1, C-3), 36.5 ([C-4, C-10]/[C-8, C-9]), 45.2, 45.3 (C-5, C-7), 55.5 (OCH_3), 74.1 (C-2), 114.5 (C-3''', C-5'''), 119.5 (C-3A, C-5A), 122.4 (C-4''), 126.1 (C-4'), 126.6 (C-1'''), 127.2 (C-2''', C-6'''), 130.6 (C-3''), 133.0 (C-2''), 135.9 (C-2'), 139.4 (C-5'), 140.8 (C-4A), 143.6 (C-3'), 146.8 (C-5''), 150.3 (C-2A, C-6A), 159.8 (C-4'''), 217.2 (C-6) ppm.

MS (ESI, pos.): *m/z* (%) = 514.4 (100) $[M+H]^+$.

HRMS (ESI): calcd. for $C_{30}H_{28}NO_3S_2$ 514.1505; found 514.1515.

TLC (SiO_2): R_f = 0.27 (CH_2Cl_2/EtOAc = 1:1 + 0.1 % NEt_3).

5.6 Compound **7**



An intramolecular acid catalyzed *Friedel-Crafts* dehydration of a tertiary alcohol was carried out according to a literature method.[12]

Alcohol **6** (105 mg, 205 µmol, 1.00 eq) was suspended in *n*-octane (10 ml) using an ultrasonic bath and 70 % aq. H_2SO_4 (1.0 ml) was added. After vigorous stirring at room temperature for 15 min, the reaction was "quenched" by addition of 4.0 M aq. NaOH (70 ml) and extracted with CH_2Cl_2 (5 × 50 ml). The combined organic solutions were dried over Na_2SO_4 and concentrated *in vacuo*, to give 91 mg (0.18 mmol, 89 %) of pure compound **7** as yellow-orange solid.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 1.80 – 1.83 (m, 2 H, 1'-H, 3'-H), 2.05 – 2.16 (m, 4 H, 4-H_a, 8-H_a, 9-H_a, 10-H_a), 2.81 – 2.94 (m, 6 H, 4-H_b, 8-H_b, 9-H_b, 10-H_b, 5'-H, 7'-H), 3.86 (s, 3 H, OCH_3), 6.92 – 6.98 (m, 2 H, 3''-H, 5''-H), 7.45 – 7.52 (m, 3 H, 5-H, 3'''-H, 5'''-H), 7.53 – 7.59 (m, 2 H, 2''-H, 6''-H), 7.80 (s, 1 H, 3-H), 8.55 – 8.61 (m, 2 H, 2'''-H, 6'''-H) ppm.

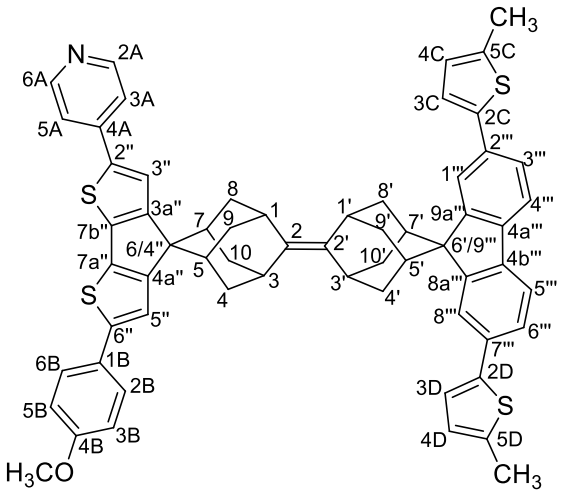
^{13}C NMR ($CDCl_3$, 101 MHz): δ = 33.5 (C-1', C-3'), 35.6, 36.0 (C-4', C-8', C-9', C-10'), 45.4 (C-5', C-7'), 55.6 (OCH_3), 57.6 (C-2'/4), 114.7 (C-3'', C-5''), 119.2 (C-3''', C-5'''), 121.8 (C-5), 124.5 (C-3), 127.1 (C-2'', C-6''), 127.5 (C-1''), 135.7 (C-7a), 139.1 (C-2), 140.2 (C-7b), 142.1 (C-4'''), 145.1 (C-6), 150.5 (C-2''', C-6'''), 156.2 (C-3a), 157.9 (C-4a), 159.6 (C-4''), 216.1 (C-6') ppm.

MS (ESI, pos.): *m/z* (%) = 469.4 (100) $[M+H]^+$.

HRMS (ESI): calcd. for $C_{30}H_{26}NO_2S_2$ 496.1399 $[M+H]^+$ found 496.1399.

TLC (SiO_2): R_f = 0.18 (EtOAc + 0.1 % NEt_3).

5.7 Compound **8**



To a freshly prepared solution of $TiCl_4$ (31 µl, 53 mg, 0.28 mmol, 4.6 eq) in dry THF (732 µl), zinc dust (<10 µm particle size, 37 mg, 0.57 mmol, 9.3 eq) was added in one portion at 0 °C. The reaction vessel was purged with Ar and sealed. The reaction mixture was heated to 80 °C (oil bath temperature) for 1 h to give a brown suspension. After cooling to room temperature, a solution of pyridine (11 mg, 11 µl, 0.14 mmol, 2.3 eq) in dry THF (0.19 ml), followed by compound **7** (30 mg, 61 µmol, 1.0 eq) and compound *B* (30 mg, 61 µmol, 1.0 eq) were added sequentially. The reaction vessel was purged with argon, sealed and heated to 80 °C (oil bath temperature) for 23 h. The reaction mixture was cooled to 0 °C and "quenched" by addition of 10 % aq. K_2CO_3 (10 ml). The mixture was diluted with water (100 ml) and brine (100 ml) and extracted with $CHCl_3$ (10 × 40 ml). The combined organic solutions were dried over Na_2SO_4 and concentrated *in vacuo* to give 61.4 mg of an orange solid. The crude product was purified by column chromatography on silica gel (15 g SiO_2, $CHCl_3$); 21 mg (22 µmol, 37 %) of the title compound was obtained as colorless solid. NOTE: Compound **8** is poorly soluble in acetone, CH_2Cl_2, benzene or THF and sensitive to acids. Dissolving in $CDCl_3$ (containing traces of phosgen and DCl) gave a black suspension; therefore $CDCl_3$ was filtered through basic Al_2O_3 before preparing NMR samples.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 1.73 – 1.98 (m, 12 H, 5-H, 7-H, 5'-H, 7'-H, 8 × C$\underline{H}_a\underline{H}_b$), 2.55 (s, 6 H, 5C-$CH_3$, 5D-$CH_3$), 2.67 – 2.81 (m, 4 H, 4 × $CH_a\underline{H}_b$), 3.08 – 3.18 (m, 4 H, 4 × $CH_a\underline{H}_b$), 3.35 – 3.46 (s, 4 H, 1-H, 3-H, 1'-H, 3'-H), 3.87 (s, 3 H, OCH_3), 6.76 – 6.80 (m, 2 H, 4C-H, 4D-H), 6.94 – 7.00 (m, 2 H, 3B-H, 5B-H), 7.16 (d, $^3J_{H,H}$ = 3.3 Hz, 2 H, 3C-H, 3D-H), 7.46 – 7.51 (m, 2 H, 3A-H, 5A-H), 7.55 – 7.63 (m, 5 H, 2B-H, 6B-H, 3'''-H, 6'''-H, 5''-H), 7.75 – 7.79 (m, 2 H, 4'''-H, 5'''-H), 7.88 (s, 1 H, 3''-H), 8.36 (s, 2 H, 1'''-H, 8'''-H), 8.56 – 8.62 (m, 2 H, 2A-H, 6A-H) ppm.

^{13}C NMR ($CDCl_3$, 101 MHz): δ = 15.7 (5C-$\underline{C}H_3$, 5D-$\underline{C}H_3$), 30.6, 30.8 (C-1, C-3, C-1', C-3'), 34.6, 35.2 (C-5, C-7, C-5', C-7'), 35.9, 36.5, 36.9 (C-4, C-8, C-9, C-10, C-4', C-8', C-9', C-10'), 55.6 (OCH_3), 58.0, 59.0 (C-6/4'', C-6'/9'''), 114.7 (C-3B, C-5B), 119.2 (C-3A, C-5A), 119.9 (C-4''', C-5'''), 122.5 (C-5''), 122.8 (C-3A, C-3D), 124.8 (C-3''', C-6'''), 125.2 (C-3''), 126.5 (C-4C, C-4D), 127.1 (C-2B, C-6B), 127.2 (C-1''', C-8'''), 127.9 (C-1B), 132.4 (C-2/C-2'), 132.6 (C-2''', C-7'''), 135.1 (C-2'/C-2), 135.3 (C-7a''), 138.3 (C-2''), 139.4 (C-5C, C-5D), 139.9 (C-4a''', C-4b'''), 142.6 (C-4A), 143.2 (C-2C, C-2D), 144.2 (C-7b''), 150.4 (C-2A, C-6A), 151.8 (C-8a''', C-9a'''), 157.8 (C-3a''), 159.4, 159.5 (C-4a'', C-4B) ppm.

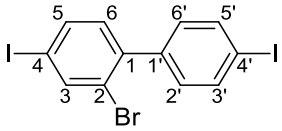
HRMS (ESI): calcd. for $C_{62}H_{54}NOS_4$ $[M+H]^+$ 956.3083; found 956.3077.

MS (ESI, pos.): *m/z* (%) = 956.6 (100) $[M+H]^+$.

MS (MALDI-TOF): *m/z* (%) = 955.3 (100) M^+.

TLC (SiO_2): R_f = 0.49 (EtOAc + 0.1% NEt_3).

5.8 2-Bromo-4,4'-diiodobiphenyl (**10**)



Compound **10** was prepared by *Sandmeyer*-type reaction[13] from 2-bromobenzidine (**9**) which was prepared according to the method of Kang *et al*.[14]

2-Bromobenzidine (1.00 g, 3.80 mmol, 1.00 eq) was dissolved in dry MeCN (61 ml) and 2.0 M HCl (61 ml, 0.12 mol, 32 eq) was added at room temperature. The colorless clear reaction mixture was cooled to -10 °C (controlled by an internal themometer). A solution of $NaNO_2$ (658 mg, 9.54 mmol, 2.51 eq) in water (20 ml) was added slowly over a period of 6 min keeping the temperature of the reaction mixture below -5 °C. The orange-brown reaction mixture was stirred at -10 °C for 30 min. Then KI (5.49 g, 33.1 mmol, 8.71 eq) was added at -10 °C in portions over a period of 5 min. The cooling-bath was removed, and the reaction mixture was stirred at room temperature for 16 h. The brown suspension was diluted with water (150 ml) and neutralized by addition of sat. aq. $NaHCO_3$ (approx. 170 ml). The mixture was extracted with Et_2O (3 × 200 ml). The dark brown combined organic solutions were washed with 1.0 M aq. $Na_2S_2O_3$ (3 × 100 ml). The combined washing solutions were extracted with Et_2O (100 ml). All organic solutions were pooled, dried over Na_2SO_4 and concentrated *in vacuo* to give a yellow solid. It was dissolved in hot cylohexane (approx. 40 ml), and loaded onto a silica gel column. Column chromatography on silica gel (150 g SiO_2, cyclohexane) gave 1.29 g (2.66 mmol, 70 %) of a colorless solid.

^{1}H NMR (CDCl$_3$, 400 MHz): δ = 7.01 (d, $^3J_{H,H}$ = 8.1 Hz, 1 H, 6-H), 7.09 – 7.14 (m, 2 H, 2'-H, 6'-), 7.68 (dd, $^3J_{H,H}$ = 8.1 Hz, $^4J_{H,H}$ = 1.8 Hz, 1 H, 3-H), 7.74 – 7.79 (m, 2 H, 3'-H, 5'-H), 8.02 (d, $^4J_{H,H}$ = 1.8 Hz, 1 H, 3-H) ppm.

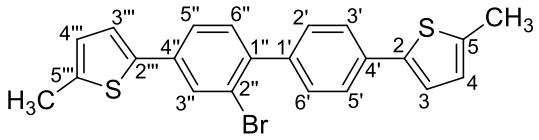
^{13}C NMR (CDCl$_3$, 101 MHz): δ = 93.4 (C-4), 94.1 (C-4'), 123.3 (C-2), 131.1 (C-2', C-6'), 132.4 (C-6), 136.8 (C-5), 137.4 (C-3', C-5'), 139.6 (C-1'), 141.1 (C-1), 141.3 (C-3) ppm.

GC-MS (EI): *m/z* (%) = 484/486 (30) $[M]^+$.

HRMS (EI): *m/z* calc. for $C_{12}H_7BrI_2$ $[M]^+$ 483.7820; found 483.7829.

TLC (SiO_2): R_f = 0.48 (cyclohexane).

5.9 2-[2'-Bromo-4'-(5-methyl-2-thienyl)-4-biphenylyl]-5-methylthiophene (**11**)



5-Methyl-2-(tributylstannyl)thiophene (7.00 g, 18.1 mmol, 2.20 eq) was added to a solution of compound **10** (3.98 g, 8.22 mmol, 1.00 eq) in dry toluene (60 ml) in a pressure tube, and a slow stream of argon was bubbled through the solution for 5 min. Then $[Pd(PPh_3)_4]$ (0.95 g, 0.82 mmol, 0.10 eq) was added. The sealed reaction vessel was heated to 110 °C for 20 h. The reaction mixture was cooled to r.t. and diluted with $CHCl_3$ (240 ml) followed by washing with 1.0 M KF (3 × 200 ml). The combined organic solutions were dried over Na_2SO_4 and concentrated *in vacuo* to give 9.81 g of a greenish solid. The crude compound was recrystallized from MeOH (500 ml) to give 2.63 g of a yellow solid. It was adsorbed on silica (~20 g) and loaded onto a silica gel column. Column chromatography on silica gel (150 g SiO_2, cyclohexane/CH_2Cl_2 = 2:1) gave 1.72 mg (4.04 mmol, 49 %) of a colorless solid.

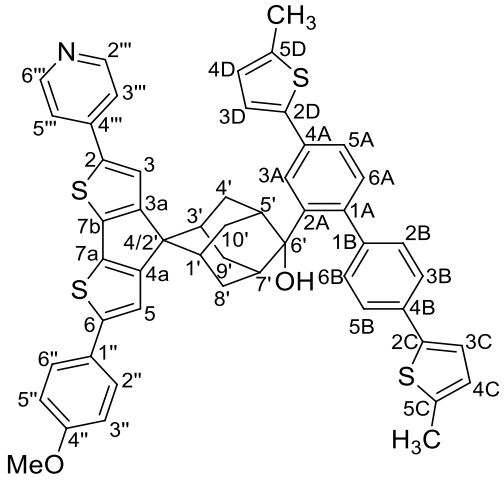
^{1}H NMR ($CDCl_3$, 400 MHz): δ = 2.53 (s, 6 H, 2 × CH_3), 6.73 - 6.77 (m, 2 H, 4-H, 4'''-H), 7.15 (d, $^3J_{H,H}$ = 3.5 Hz, 1 H, 3'''-H), 7.17 (d, $^3J_{H,H}$ = 3.5 Hz, 1 H, 3-H), 7.32 (d, $^3J_{H,H}$ = 8.0 Hz, 1 H, 6''-H), 7.41 – 7.46 (m, 2 H, 2'-H, 6'-H), 7.52 (dd, $^3J_{H,H}$ = 8.0 Hz, $^4J_{H,H}$ = 1.9 Hz, 1 H, 5''-H), 7.59 – 7.63 (m, 2 H, 3'-H, 5'-H), 7.86 (d, $^4J_{H,H}$ = 1.9 Hz, 1 H, 3''-H) ppm.

^{13}C NMR ($CDCl_3$, 101 MHz): δ = 15.7 (2 × CH_3), 123.0 (C-2''), 123.3 (C-3), 123.9 (C-3'''), 124.6 (C-5''), 125.1 (C-3', C-5'), 126.4, 126.6 (C-4, C-4'''), 130.0 (C-3''), 130.0 (C-2', C-6'), 131.6 (C-6''), 134.2 (C-4'), 135.6 (C-4''), 139.3 (C-1'), 139.9, 139.9, 140.4, 140.7 (C-5, C-1'', C-2''', C-5'''), 141.6 (C-2) ppm.

HRMS (EI): *m/z* calc. for $C_{22}H_{17}BrS_2$ $[M]^+$ 423.9955; found 423.9938.

TLC (SiO_2): R_f = 0.53 (*n*-hexane/EtOAc = 4:1).

5.10 Compound **12**



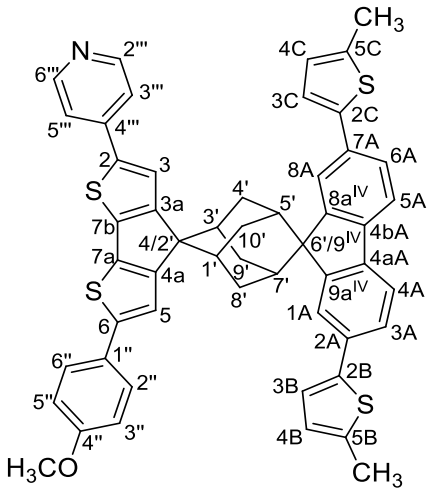
Bromide **11** (31 mg, 73 µmol, 1.2 eq) was dissolved in dry THF (3.0 mL) and cooled to -78 °C. A 1.6 M solution of *n*-BuLi in *n*-hexane (45 µL, 73 µmol, 1.2 eq) was added dropwise at -78 °C over a period of 1 min. After 10 min, the solution of lithiated **7** was transferred using a syringe to a solution of ketone **7** (30 mg, 61 µmol, 1.0 eq) in dry THF (7.0 mL) at -78 °C over a period of 1 min. The mixture was stirred at -78 °C for 10 min and then 5 h at room temperature. Then water (3 mL) was added followed by sat. aq. NH_4Cl (3 mL). The reaction mixture was extracted with CH_2Cl_2 (5 × 8 ml). The combined organic solutions were dried over Na_2SO_4 and concentration *in vacuo* to give 60 mg of an orange solid. Separation by flash column chromatography on silica gel (16 g SiO_2, CH_2Cl_2/EtOAc = 1:1 + 0.1 % NEt_3) gave 26 mg (31 µmol, 51 %) of the title compound as orange solid.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 1.34 – 1.41 (m, 1 H, 1'-H / 3'-H), 1.51 – 1.57 (m, 1 H, 3'-H / 1'-H), 1.64 – 1.89 (m, 2 H, 2 x C$\underline{H}_a$H$_b$), 2.11 – 2.77 (m, 14 H, 2 x CH$_a\underline{H}_b$, 2 x CH_2, 5'-H, 7'-H, 5C-CH_3, 5D-CH_3), 3.85 (s, 3 H, 4''-OCH_3), 6.73 – 6.76 (m, 1 H, 4C-H / 4D-H), 6.78 – 6.81 (m, 1 H, 4D-H / 4C-H), 6.92 – 6.97 (m, 2 H, 3''-H, 5''-H), 7.12 (d, $^3J_{H,H}$ = 3.4 Hz, 1 H, 3C-H / 3D-H), 7.11 (d, $^3J_{H,H}$ = 7.9 Hz, 1 H, 6A-H), 7.21 (d, $^3J_{H,H}$ = 3.4 Hz, 1 H, 3D-H / 3C-H), 7.38 – 7.48 (m, 4 H, 5-H, 5A-H, 2B-H, 6B-H), 7.48 – 7.51 (m, 2 H, 3'''-H, 5'''-H), 7.53 – 7.57 (m, 2 H, 2''-H, 6''-H), 7.58 – 7.62 (m, 2 H, 3B-H, 5B-H), 7.73 – 7.78 (m, 1 H, 3-H), 7.87 (d, $^4J_{H,H}$ = 1.8 Hz, 1 H, 3A-H), 8.50 – 8.55 (m, 2 H, 2'''-H, 6'''-H) ppm.

MS (ESI, pos.): *m/z* (%) = 842.3 (11) $[M+H]^+$.

HRMS (ESI): calcd. for $C_{52}H_{44}NO_2S_4$ $[M+H]^+$ 842.2249; found 842.2213.

5.11 Compound **13**



An intramolecular acid catalyzed *Friedel-Crafts* dehydration of a tertiary alcohol were carried out according to a literature method.[12]

Alcohol **12** (15 mg, 17 µmol, 1.0 eq) was suspended in *n*-octane (1.0 ml) using an ultrasonic bath, and 60 % aq. H_2SO_4 (0.20 ml) was added. After vigorous stirring at room temperature for 120 min, the reaction was quenched by addition of 2.0 M aq. NaOH (10 ml) and extracted with CH_2Cl_2 (3 × 10 ml). The combined organic solution were dried over Na_2SO_4 and concentrated *in vacuo*, to give 14 mg of a yellow solid. Column chromatography on silica gel (6 g SiO_2, CH_2Cl_2/EtOAc = 5:1 + 0.1 % NEt_3) gave 6.0 mg (7.3 µmol, 42 %) of the title compound as an orange solid.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 1.98 - 2.06 (m, 2 H, 5'-H, 7'-H), 2.08 - 2.12 (m, 2 H, 1'-H, 3'-H), 2.48 (s, 6 H, 5B-CH_3, 5C-CH_3), 2.56 - 2.78 (m, 4 H, 4-H_a, 8-H_a, 9-H_a, 10-H_a), 3.09 – 3.23 (m, 4 H, 4-H_b, 8-H_b, 9-H_b, 10-H_b), 3.85 (s, 3 H, OCH_3), 6.72 – 6.74 (m, 2 H, 4B-H, 4C-H), 6.93 – 6.98 (m, 2 H, 3''-H, 5''-H), 7.10 (d, $^3J_{H,H}$ = 3.6 Hz, 2 H, 3B-H, 3C-H), 7.55 – 7.59 (m, 2 H, 2''-H, 6''-H), 7.63 (d, $^3J_{H,H}$ = 7.8 Hz, 2 H, 3A-H, 6A-H), 7.65 (s, 1 H, 5-H), 7.69 – 7.73 (m, 2 H, 3'''-H, 5'''-H), 7.80 (d, $^3J_{H,H}$ = 7.8 Hz, 2 H, 4A-H, 5A-H), 8.12 (s, 1 H, 3-H), 8.35 (s, 2 H, 1A-H, 8A-H), 8.46 – 8.49 (m, 2 H, 2'''-H, 6'''-H) ppm.

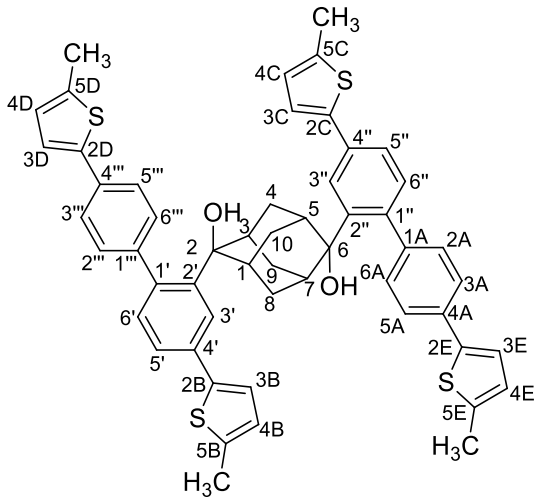
^{13}C NMR ($CDCl_3$, 101 MHz, some signals detected by gHMBCAD): δ = 15.6 (5B-$\underline{C}H_3$, 5C-$\underline{C}H_3$), 30.1, 31.1 (C-4', C-8', C-9', C-10'), 33.6, 34.2 (C-1', C-3', C-5', C-7'), 55.6 (OCH_3), 58.7, 61.4 (C-4/2', C-6'/9A), 114.8 (C-3'', C-5''), 119.5 (C-3''', C-5'''), 120.1 (C-4A, C-5A), 122.8 (C-5), 122.9 (C-3B, C-3C), 125.2 (C-3A, C-6A), 126.5 (C-4B, C-4C), 127.0 (C-1A, C-8A), 127.3 (C-1''), 127.3 (C-2'', C-6''), 132.8 (C-2A, C-7A), 134.9 (C-7a), 135.0 (C-2), 139.7 (C-5B, C-5C), 140.0 (C-4Aa, C-4Ab), 142.9 (C-2B, C-2C), 143.2 (C-2''', C-6'''), 145.5 (C-7b), 150.8 (C-8Aa, C-9Aa), 157.5 (C-3a), 159.9 (C-4''), 160.7 (C-4a) ppm.

MS (ESI, pos.): *m/z* (%) = 824.4 (100) $[M+H]^+$.

HRMS (ESI): calcd. for $C_{52}H_{42}NOS_4$ $[M+H]^+$ 824.2144; found 824.2134.

TLC (SiO_2): R_f = 0.37 (CH_2Cl_2/EtOAc) = 5:1 + 0.1% NEt_3.

5.12 Compound *rac*-**14**



Bromide **11** (50 mg, 0.12 mmol, 2.0 eq) was dissolved in dry THF (3.0 mL) and cooled to -78 °C. A 1.6 M solution of *n*-BuLi in *n*-hexane (81 µL, 0.13 mmol, 2.2 eq) was added dropwise at -78 °C over a period of 1 min. After 10 min, a solution of 2,6-adamantanedione (9.6 mg, 59 µmol, 1.0 eq) in dry THF (1.0 mL) was added at -78 °C over a period of 10 min. The mixture was stirred at -78 °C for 15 min and at room temperature for additional 2 h. Then sat. aq. NH_4Cl (5 mL) was added followed by water (5 mL). The mixture was extracted with CH_2Cl_2 (3 × 5 ml) and the combined organic solutions were dried over Na_2SO_4. Concentration *in vacuo* gave 86.4 mg of a yellowish solid. The crude product was dissolved in $CHCl_3$ (2 mL) and loaded onto a silica gel column. Column chromatography on silica gel (two columns, 2 × 15 g SiO_2, $CHCl_3$) gave 34 mg (40 µmol, 68 %) of the title compound *rac*-**14** as colorless solid.

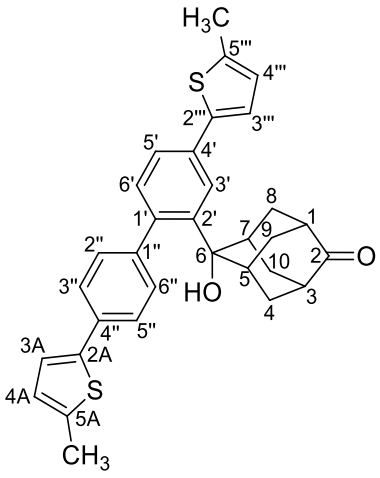
^{1}H NMR ($CDCl_3$, 400 MHz): δ = 1.36 – 1.55 (m, 4 H, CH_2, 2 × CH_aH_b), 1.79 (s, 2 H, 2 × OH), 1.97 – 2.31 (m, 8 H, CH_2, 2 × CH_aH_b, 1-H, 3-H, 5-H, 7-H), 2.50 – 2.52 (m, 12 H, 5B-CH_3, 5C-CH_3, 5D-CH_3, 5E-CH_3), 6.70 – 6.75 (m, 4 H, 4B-H, 4C-H, 4D-H, 4E-H), 7.09 (d, $^3J_{H,H}$ = 3.6 Hz, 2 H, [3B-H, 3C-H]/[3D-H, 3E-H]), 7.09 (d, $^3J_{H,H}$ = 7.9 Hz, 2 H, 6'-H, 6''-H), 7.12 (d, $^3J_{H,H}$ = 3.6 Hz, 2 H, [3D-H, 3E-H] or [3B-H, 3C-H]) , 7.28 – 7.35 (m, 4 H, 2'''-H, 6'''-H, 2A-H, 6A-H), 7.43 (dd, $^3J_{H,H}$ = 7.9 Hz, $^4J_{H,H}$ = 1.8 Hz, 2 H, 5'-H, 5''-H), 7.47 (m, 4 H, 3'''-H, 5'''-H, 3A-H, 5A-H), 7.73 (d, $^4J_{H,H}$ = 1.8 Hz, 2 H, 3'-H, 3''-H) ppm.

^{13}C NMR ($CDCl_3$, 101 MHz): δ = 15.6 (4 × CH_3), 28.2 (CH_2), 30.0 (2 × CH_2), 31.6 (CH_2), 33.9, 34.1 (C-1, C-3, C-5, C-7), 76.9 (C-2, C-6), 123.0, 123.1 (C-3B, C-3C, C-3D, C-3E), 123.7 (C-5', C-5''), 124.5 (C-3', C-3''), 124.8 (C-3''', C-5''', C-3A, C-5A, 126.3, 126.4 (C-4B, C-4C, C-4D, C-4E), 129.6 (C-2''', C-6''', C-2A, C-6A), 133.3 (C-2D, C-2E), 133.7 (C-2B, C-2C), 134.2 (C-6', C-6''), 139.6, 139.7, 141.7, 141.8, 141.9, 143.1 (C-1', C-4', C-1'', C-4'', C-1''', C-4''', C-1A, C-4A, C-5B, C-5C, C-5D, C-5E) ppm.

HRMS (ESI): calcd. for $C_{54}H_{48}NaO_2S_4$ $[M+Na]^+$ 879.2429; found 879.2378.

TLC (SiO_2): R_f = 0.41 (CH_2Cl_2).

5.13 Compound **15**



Bromide **11** (306 mg, 719 µmol, 1.00 eq) was dissolved in dry THF (23.0 mL) and cooled to -78 °C. A 1.6 M solution of *n*-BuLi in *n*-hexane (0.49 mL, 0.79 mmol, 1.1 eq) was added dropwise at -78 °C over a period of 1 min. After 10 min, the solution of lithiated **11** was transferred using a syringe to a solution of 2,6-adamantanedione (236 mg, 1.44 mmol, 2.00 eq) in dry THF (12 mL) at -78 °C over a period of 10 min. The mixture was stirred at -78 °C for 10 min and at room temperature for additional 4 h. The reaction was quenched by addition of sat. aq. NH_4Cl (40 mL) and water (40 mL). The mixture was extracted with $CHCl_3$ (4 × 50 ml) and the combined organic solutions were dried over Na_2SO_4. Concentration *in vacuo* gave 479 mg of a brownish solid. Column chromatography on silica gel (40 g SiO_2, $CHCl_3$) gave 411 mg of the title compound (with residual 2,6-adamantanedione) as yellowish solid. The product was used without further purification.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 1.68 – 1.76 (m, 2 H, [4-H_a, 10-H_a]/[8-H_a, 9-H_a]), 1.79 – 1.87 (m, 2 H, [4-H_a, 10-H_a]/[8-H_a, 9-H_a]), 1.98 – 2.07 (m, 2 H, [8-H_b, 9-H_b]/[4-H_b, 10-H_b]), 2.31 – 2.41 (m, 2 H, 1-H, 3-H), 2.48 – 2.60 (m, 10 H, [8-H_b, 9-H_b]/[4-H_b, 10-H_b], 5-H, 7-H, 2 × CH_3), 6.72 – 6.77 (m, 2 H, 4'''-H, 4A-H), 7.12 (d, $^3J_{H,H}$ = 3.5 Hz, 1 H, 3'''-H/3A-H), 7.16 (d, $^3J_{H,H}$ = 3.5 Hz, 1 H, 3A-H/3'''-H), 7.17 (d, $^3J_{H,H}$ = 7.8 Hz, 1 H, 6'-H), 7.35 – 7.40 (m, 2 H, 2''-H, 6''-H), 7.49 (dd, $^3J_{H,H}$ = 7.8 Hz, $^4J_{H,H}$ = 1.8 Hz, 1 H, 5'-H), 7.58 – 7.54 (m, 2 H, 3''-H, 5''-H), 7.82 (d, $^4J_{H,H}$ = 1.8 Hz, 1 H, 3'-H) ppm.

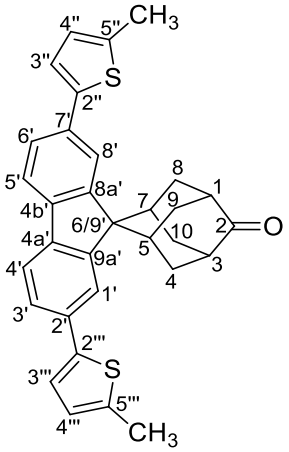
^{13}C NMR ($CDCl_3$, 101 MHz): δ = 15.6 (5'''-$\underline{C}H_3$, 5A-$\underline{C}H_3$), 34.3 ([C-4, C-10]/[C-8, C-9]), 34.8 (C-5, C-7), 36.2 ([C-8, C-9]/[C-4, C-10]), 45.0, 45.4 (C-1, C-3), 76.4 (C-6), 123.1, 123.3 (C-3''', C-3A), 124.2, 124.3 (C-3', C-5'), 125.0 (C-3'', C-6''), 126.4, 126.5 (C-4''', C-4A), 129.7 (C-2'', C-6''), 133.6 (C-4''), 134.0 (C-4'), 134.7 (C-6'), 139.9, 140.1 (C-5''', C-5A), 140.9 (C-1'), 141.1 (C-1''), 141.5, 141.6 (C-2''', C-2A), 142.7 (C-1''), 217.5 (C-2) ppm.

MS (ESI, pos.): *m/z* (%) = 533.2 (100) $[M+Na]^+$.

HRMS (ESI): *m/z* calc. for $C_{32}H_{30}NaO_2S_2$ $[M+Na]^+$ 533.1579; found 533.1566.

TLC (SiO_2): R_f = 0.24 ($CHCl_3$).

5.14 Compound **B**



Intramolecular acid catalyzed *Friedel-Crafts* dehydrations of tertiary alcohols were carried out according to literature methods.[12]

Alcohol **15** (363 mg with residual 2,6-adamantanedione) was suspended in *n*-octane (10.0 ml) using an ultrasonic bath and 75 % aq. H_2SO_4 (5.0 ml) was added. After vigorous stirring at room temperature for 30 min, the reaction was quenched by addition of 3.0 M aq. NaOH (100 ml) and extracted with CH_2Cl_2 (5 × 200 ml). The combined organic solutions were dried over Na_2SO_4 and concentrated *in vacuo*, to give 320 mg of a colorless solid. Column chromatography on regular silica gel (50 g SiO_2, cyclohexane/CH_2Cl_2 = 1:1) gave 186 mg (0.378 µmol, 53 %, over two steps) of compound *B* as a colorless solid.

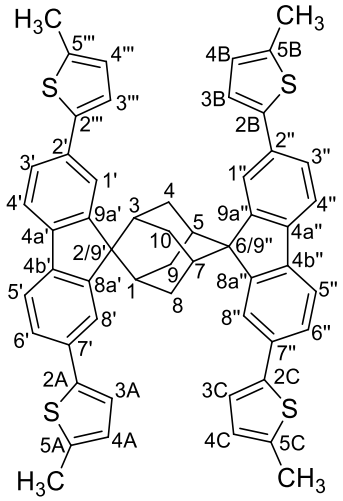
^{1}H NMR ($CDCl_3$, 400 MHz): δ = 1.81 - 1.86 (m, 2 H, 5-H, 7-H), 1.97 - 2.05 (m, 4 H, 4-H_a, 8-H_a, 9-H_a, 10-H_a), 2.54 (s, 6 H, 2 × CH_3), 2.90 - 2.95 (m, 2 H, 1-H, 3-H), 3.19 – 3.29 (m, 4 H, 4-H_b, 8-H_b, 9-H_b, 10-H_b), 6.76 – 6.79 (m, 2 H, 4''-H, 4'''-H), 7.13 (d, $^3J_{H,H}$ = 3.5 Hz, 2 H, 3''-H, 3'''-H), 7.61 (d, $^3J_{H,H}$ = 7.9 Hz, 2 H, 3'-H, 6'-H), 7.77 (d, $^3J_{H,H}$ = 7.9 Hz, 2 H, 4'-H, 5'-H), 8.24 (s, 2 H, 1'-H, 8'-H) ppm.

^{13}C NMR ($CDCl_3$, 101 MHz): δ = 15.6 (5''-$\underline{C}H_3$, 5'''-$\underline{C}H_3$), 34.2 (C-5, C-7), 34.6 (C-4, C-8, C-9, C-10), 45.4 (C-1, C-3), 56.9 (C-6/9'), 120.2 (C-4', C-5'), 123.0 (C-3'', C-3'''), 125.4 (C-3', C-6'), 126.5 (C-4'', C-4'''), 126.7 (C-1', C-8'), 133.0 (C-2', C-7'), 139.8 (C-4a', C-4b', C-5'', C-5'''), 142.6 (C-2'', C-2'''), 150.5 (C-8a, C-9a), 216.1 (C-2) ppm.

HRMS (EI): *m/z* calc. for $C_{32}H_{28}OS_2$ $[M]^+$ 492.1582; found 492.1575.

TLC (SiO_2): R_f = 0.65 ($CHCl_3$).

5.15 Compound **B⊥B**



Intramolecular acid catalyzed *Friedel-Crafts* dehydrations of tertiary alcohols were carried out according to literature methods.[12]

Alcohol **14** (34 mg, 40 µmol, 1.0 eq) was suspended in *n*-octane (2.0 ml) using an ultrasonic bath and aq. H_2SO_4 (75 %, 1.0 ml) was added. After vigorous stirring at room temperature for 60 min, the reaction was quenched by addition of 3.0 M aq. NaOH (10 ml) and extracted with CH_2Cl_2 (5 × 15 ml). The combined organic solutions were dried over Na_2SO_4 and concentrated *in vacuo*, to give 27.2 mg of a yellowish solid. The crude product was purified by column chromatography on silica gel (15 g SiO_2, cyclohexane/$CHCl_3$ = 5:1 → 4:1). 26 mg (31 µmol, 79 %) of the desired product was obtained as colorless solid.

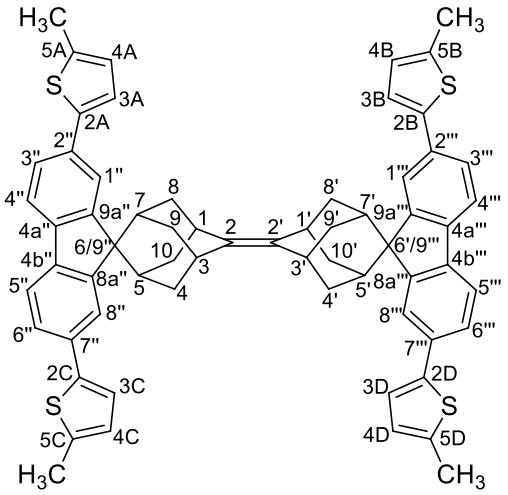
^{1}H NMR ($CDCl_3$, 400 MHz): δ = 2.09 – 2.16 (m, 4 H, 1-H, 3-H, 5-H, 7-H), 2.48 (d, $^4J_{H,H}$ = 1.1 Hz, 12 H, 4 × CH_3), 3.07 – 3.17 (m, 8 H, 4-H_2, 8-H_2, 9-H_2, 10-H_2), 6.69 – 6.74 (m, 4 H, 4‘’’-H, 4A-H, 4B-H, 4C-H), 7.08 (d, $^3J_{H,H}$ = 3.6 Hz, 4 H, 3’’’-H, 3A-H, 3B-H, 3C-H), 7.60 (dd, $^3J_{H,H}$ = 7.9 Hz, $^4J_{H,H}$ = 1.2 Hz, 4 H, 3’-H, 6’-H, 3’’-H, 6’’-H), 7.78 (d, $^3J_{H,H}$ = 8.0 Hz, 4 H, 4’-H, 6’-H, 4’’-H, 6’’-H), 8.46 (d, $^4J_{H,H}$ = 1.2 Hz, 4 H, 1’-H, 8’-H, 1’’-H, 8’’-H) ppm.

^{13}C NMR ($CDCl_3$, 101 MHz): δ = 15.6 (5’’’-$\underline{C}H_3$, 5A-$\underline{C}H_3$, 5B-$\underline{C}H_3$, 5C-$\underline{C}H_3$), 28.9 (C-4, C-8, C-9, C-10), 34.6 (C-1, C-3, C-5, C-7), 59.7 (C-2/9’, C-6/9’’), 119.9 (C-4’, C-6’, C-4’’, C-6’’), 122.8 (C-3’’’, C-3A, C-3B, C-3C), 125.1 (C-3’, C-6’, C-3’’, C-6’’), 126.4 (C-4’’’, C-4A, C-4B, C-4C), 127.4 (C-1’, C-8’, C-1’’, C-8’’), 132.7 (C-2’, C-7’, C-2’’, C-7’’), 139.4 (C-5’’’, C-5A, C-5B, C-5C), 140.1 (C-4a’, C-4b’, C-4a’’, C-4b’’), 143.1 (C-2’’’, C-2A, C-2B, C-2C), 151.1 (C-8a’, C-9a’, C-8a’’, C-9a’’) ppm.

HRMS (MALDI-TOF): calcd. for $C_{54}H_{44}S_4$ M^+ 820.2320; found 820.2331.

TLC (SiO_2): R_f = 0.21 (cyclohexane/$CHCl_3$ = 5:1).

5.16 Compound **B‖B**



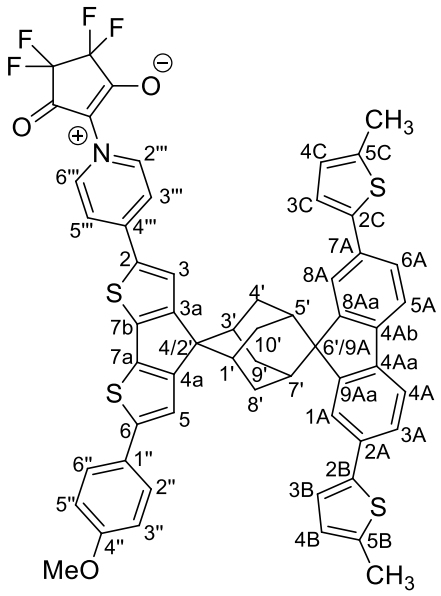
To freshly prepared solution of $TiCl_4$ (18 µl, 31 mg, 0.16 mmol, 4.6 eq) in dry THF (0.43 ml) was added zinc dust (<10 µm particle size, 22 mg, 0.33 mmol, 9.3 eq) at 0 °C in one portion. The reaction vessel was purged with Ar and sealed. The stirred reaction mixture was heated to 80 °C (oil bath temperature) for 1 h to give a brown suspension. After cooling to room temperature, a solution of pyridine (6.6 µl, 6.5 mg, 82 µmol, 2.3 eq) in dry THF (93.4 µl), followed by solid compound *B* (35 mg, 71 µmol, 2.0 eq) were added. The reaction vessel was purged with argon, sealed and heated to 80 °C (oil bath temperature) for 16 h. The reaction mixture was cooled to 0 °C and quenched with 10 % aq. K_2CO_3 (5 ml). The mixture was stirred at room temperature for 15 min and filtered through a pad of CELITE (∅ = 4 cm, *h* = 0.5 cm). Some product remained as yellow solid on the pad of the CELITE. The CELITE cake was refluxed with hot $CHCl_3$ (100 ml) for 3 min, filtered hot and washed with hot $CHCl_3$ (2 × 30 ml). The combined filtrates were dried over Na_2SO_4 and concentrated *in vacuo* to give 33 mg of a yellowish solid with low solubility in common organic solvents including EtOAc, CH_2Cl_2 and *n*-hexane. The crude product was recrystallized from EtOAc (approx. 100 ml) to give 20 mg (21 µmol, 60 %) of the desired product as yellowish solid.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 1.77 – 1.91 (m, 12 H, 4-$\underline{H}_aH_b$, 8-$\underline{H}_aH_b$, 9-$\underline{H}_aH_b$, 10-$\underline{H}_aH_b$, 4'-$\underline{H}_aH_b$, 8'-$\underline{H}_aH_b$, 9'-$\underline{H}_aH_b$, 10'-$\underline{H}_aH_b$, [1-H, 3-H, 1'-H, 3'-H]/[5-H, 7-H, 5'-H, 7'-H]), 2.56 (d, $^4J_{H,H}$ = 1.2 Hz, 12 H, 4 × CH_3), 3.08 – 3.19 (m, 8 H, 4-$H_a\underline{H}_b$, 8-$H_a\underline{H}_b$, 9-$H_a\underline{H}_b$, 10-$H_a\underline{H}_b$, 4'-$H_a\underline{H}_b$, 8'-H_aH_b, 9'-$H_a\underline{H}_b$, 10'-$H_a\underline{H}_b$), 3.43 – 3.51 (m, 4 H, [5-H, 7-H, 5'-H, 7'-H]/[1-H, 3-H, 1'-H, 3'-H]), 6.78 (dd, $^3J_{H,H}$ = 3.6 Hz, $^4J_{H,H}$ = 1.2 Hz, 4 H, 4A-H, 4B-H, 4C-H, 4D-H) , 7.17 (d, $^3J_{H,H}$ = 3.5 Hz, 4 H, 3A-H, 3B-H, 3C-H, 3D-H), 7.61 (dd, $^3J_{H,H}$ = 7.9 Hz, $^4J_{H,H}$ =1.3 Hz, 4 H, 3''-H, 6''-H, 3'''-H, 6'''-H), 7.76 (d, $^3J_{H,H}$ = 7.9 Hz, 4 H, 4''-H, 5''-H, 4'''-H, 5'''-H), 8.38 (d, $^4J_{H,H}$ = 1.3 Hz, 4 H, 1''-H, 8''-H, 1'''-H, 8'''-H) ppm.

HRMS (MALDI-TOF): calcd. for $C_{64}H_{56}S_4$ M^+ 952.3259; found 952.3260.

TLC (SiO_2): R_f = 0.80 (CH_2Cl_2).

5.17 Compound **B⊥R**



To a solution of compound **13** (9.8 mg, 10 µmol, 1.0 eq) in 1,2-dichloroethane (4.0 ml) water was added (44 µl) and HOAc (45 µl). The mixture was cooled to 0 °C, and octafluorocyclopentene (0.44 ml, 0.70 g, 3.3 mmol, ~320 eq) was added using a pre-cooled syringe. The sealed reaction vessel was placed into a microwave cavity, and the reaction mixture was irradiated (150 W max. power) with controlled reaction temperature at 130 °C for 10 min. The dark purple reaction mixture was cooled to r.t. and diluted with CH_2Cl_2 (25 ml) and sat. aq. Na_2CO_3 (25 ml). The organic phase was extracted with CH_2Cl_2 (25 ml), dried over Na_2SO_4 and concentrated *in vacuo* to give 11 mg (9.3 µmol, 92 %) of a purple black solid. An analytically pure sample was obtained by normal phase HPLC (ProntoSIL 120-5 Amino E, 5 µm, 16 mm inner diameter, 25 cm length; *iso*-octane/$CHCl_3$ = 55:45; 11 ml/min flow; 6.9 min retention time).

^{1}H NMR (DMSO-d$_6$, 400 MHz): δ = 1.76 - 1.95 (m, 4 H, 1'-H, 3'-H, 5'-H, 7'-H), 2.32 (s, 6 H, 5B-CH_3, 5C-CH_3) 2.63 - 2.75 (m, 2 H, 4-H_a, 8-H_a, 9-H_a, 10-H_a), 2.86 – 3.04 (m, 4 H, 4-H_b, 8-H_b, 9-H_b, 10-H_b), 3.71 (s, 3 H, 4''-OCH_3), 6.69 – 6.72 (m, 2 H, 4B-H, 4C-H), 6.87 – 6.93 (m, 2 H, 3''-H, 5''-H), 7.20 – 7.24 (m, 2 H, 3B-H, 3C-H), 7.56 – 7.63 (m, 4 H, 2''-H, 6''-H, 3A-H, 6A-H), 7.86 – 7.92 (m, 2 H, 4A-H, 5A-H), 7.95 (s, 1 H, 5-H), 8.17 – 8.24 (m, 2 H, 3'''-H, 5'''-H), 8.27 (s, 2 H, 1A-H, 8A-H), 8.71 (s, 1 H, 3-H), 8.84 – 8.90 (m, 2 H, 2'''-H, 6'''-H) ppm.

^{13}C NMR (DMSO-d$_6$, 101 MHz, some quaternary carbon atoms not detected): δ = 14.9 (C-5B, C-5C), 29.1, 30.0 (C-4', C-8', C-9', C-10'), 32.9, 33.9 (C-1', C-3', C-5', C-7'), 55.1 (4''-OCH_3), 58.3, 60.5 (C-4/2', C-6'/9A), 114.5 (C-3'', C-5''), 119.8 (C-3''', C-5'''), 120.4 (C-4A, C-5A), 122.7 (C-5), 123.2 (C-3B, C-3C), 124.6 ([C-3A, C-6A]/[C-2'', C-6'']), 125.7 (C-1A, C-8A), 126.4, 126.8 (C-4B, C-4C), 126.9 ([C-2'', C-6'']/[C-3A, C-6A]), 131.2

(C-3), 131.9, 133.8, 134.7, 138.8, 139.2, 140.8 (C-2‘’’, C-6‘’’), 141.6, 146.6, 147.0, 147.5, 150.5, 157.7, 159.3, 161.4 ppm.

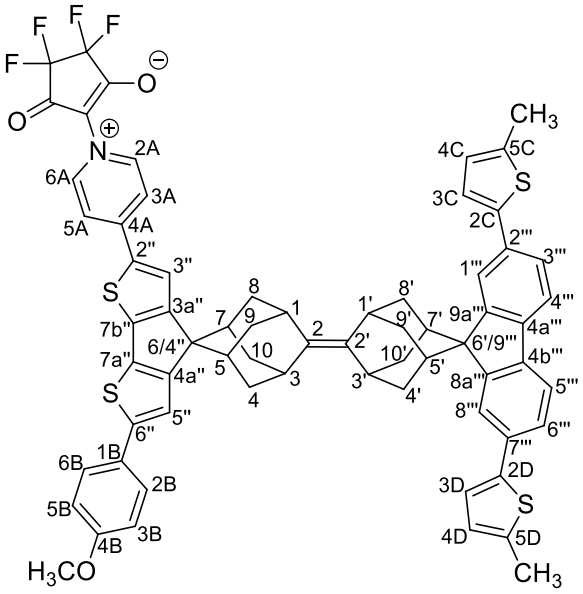
^{19}F NMR (DMSO-d_6, 376.4 MHz): δ = -125.9 ppm.

MS (ESI, pos.): *m/z* (%) = 992.4 (100) $[M+H]^+$.

HRMS (ESI): calcd. for $C_{57}H_{42}F_4NO_3S_4$ $[M+H]^+$ 992.1978; found 992.1978.

TLC (SiO_2): R_f = 0.76 (CH_2Cl_2/MeOH = 50:1).

5.18 Compound **B‖R**



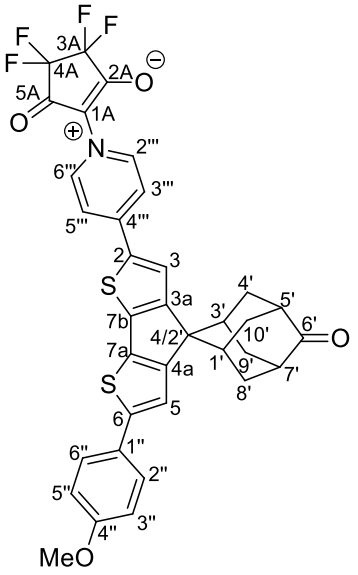
To a suspension of compound **8** (~1 mg, ~1 µmol, 1 eq) in HOAc (450 µl) water was added (10 µl). The mixture was cooled to 0 °C and octafluorocyclopentene (50 µl, 79 mg, 0.37 mmol, ~370 eq) was added using a pre-cooled syringe. The sealed reaction vessel was stirred at r.t. for 22 h. TLC (SiO_2, EtOAc as eluent) showed unreacted starting material. After addition of THF (0.46 ml) and octafluorocyclopentene (50 µl, 79 mg, 0.37 mmol, ~370 eq) and stirring the reaction mixture at r.t. for 18 h and at 56 °C for 8 h, more octafluorocyclopentene (50 µl, 79 mg, 0.37 mmol, ~370 eq) was added, and the reaction mixture was stirred at 56 °C for 14 h. The dark purple reaction mixture was cooled to r.t.; TLC showed almost full conversion and a complex mixture of products. The desired product was isolated by preparative normal phase HPLC (Knauer Nucleosil 100 OH, 7 µm, 10 mm inner diameter, 25 cm length; *iso*-octane/$CHCl_3$ = 60:40 to 0:100 gradient over 15 min; 5 ml/min flow; 6.3 min retention time) as a dark purple solid (0.1 mg, ~10 %).

HRMS (MALDI-TOF): calcd. for $C_{67}H_{53}F_4NO_3S_4$ M^+ 1123.2844; found 1123.2861.

MS (ESI, pos.): *m/z* (%) = 1124.4 (100) $[M+H]^+$.

TLC (SiO_2): R_f = 0.62 (CH_2Cl_2/MeOH = 100:1).

5.19 Compound **R**



To a solution of compound **7** (12 mg, 25 µmol, 1.0 eq) in 1,2-dichloroethane (4.0 ml) water was added (44 µl) followed by HOAc (45 µl). The mixture was cooled to 0 °C and octafluorocyclopentene (0.44 ml, 0.70 g, 3.3 mmol, ~130 eq) was added using a pre-cooled syringe. The sealed reaction vessel was placed into a microwave cavity and the reaction mixture was irradiated (150 W max. power) with controlled reaction temperature at 130 °C for 10 min. The dark purple reaction mixture was cooled to r.t. and diluted with CH_2Cl_2 (25 ml) and sat. aq. Na_2CO_3 (25 ml). The organic phase was extracted with CH_2Cl_2 (25 ml), dried over Na_2SO_4 and concentrated *in vacuo* to give 12 mg of a purple black solid. Column chromatography on silica gel (10 g SiO_2, CH_2CH_2/MeOH = 25:1) gave 4.6 mg (6.9 µmol, 28 %) of compound *R* as a black solid.

^{1}H NMR ($CDCl_3$, 400 MHz): δ = 1.66 – 1.72 (m, 2 H, 1'-H, 3'-H), 1.92 – 2.05 (m, 4 H, 4'-H_a, 8'-H_a, 9'-H_a, 10'-H_a), 2.65 – 2.72 (m, 2 H, 5'-H, 7'-H), 2.82 – 2.94 (m, 4 H, 4'-H_b, 8'-H_b, 9'-H_b, 10'-H_b), 3.82 (s, 3 H, OCH_3), 7.01 - 7.07 (m, 2 H, 3''-H, 5''-H), 7.75 – 7.82 (m, 2 H, 2''-H, 6''-H), 8.09 (s, 1 H, 5-H), 8.36 – 8.42 (m, 2 H, 3'''-H, 5'''-H), 8.82 (s, 1 H, 3-H), 8.95 – 9.01 (m, 2 H, 2'''-H, 6'''-H) ppm.

MS (ESI, neg.): *m/z* (%) = 698.6 (100) $[M+Cl]^-$.

HRMS (ESI): calcd. for $C_{35}H_{25}F_4NO_4S_2$ $[M+H]^+$ 664.1234; found 664.1221.

TLC (SiO_2): R_f = 0.59 (EtOAc + 0.1 % NEt_3).

6 ^{1}H and ^{13}C NMR spectra and HPLC chromatograms

6.1 3-Bromo-5'-iodo-2,2'-bithienyl (**2**)

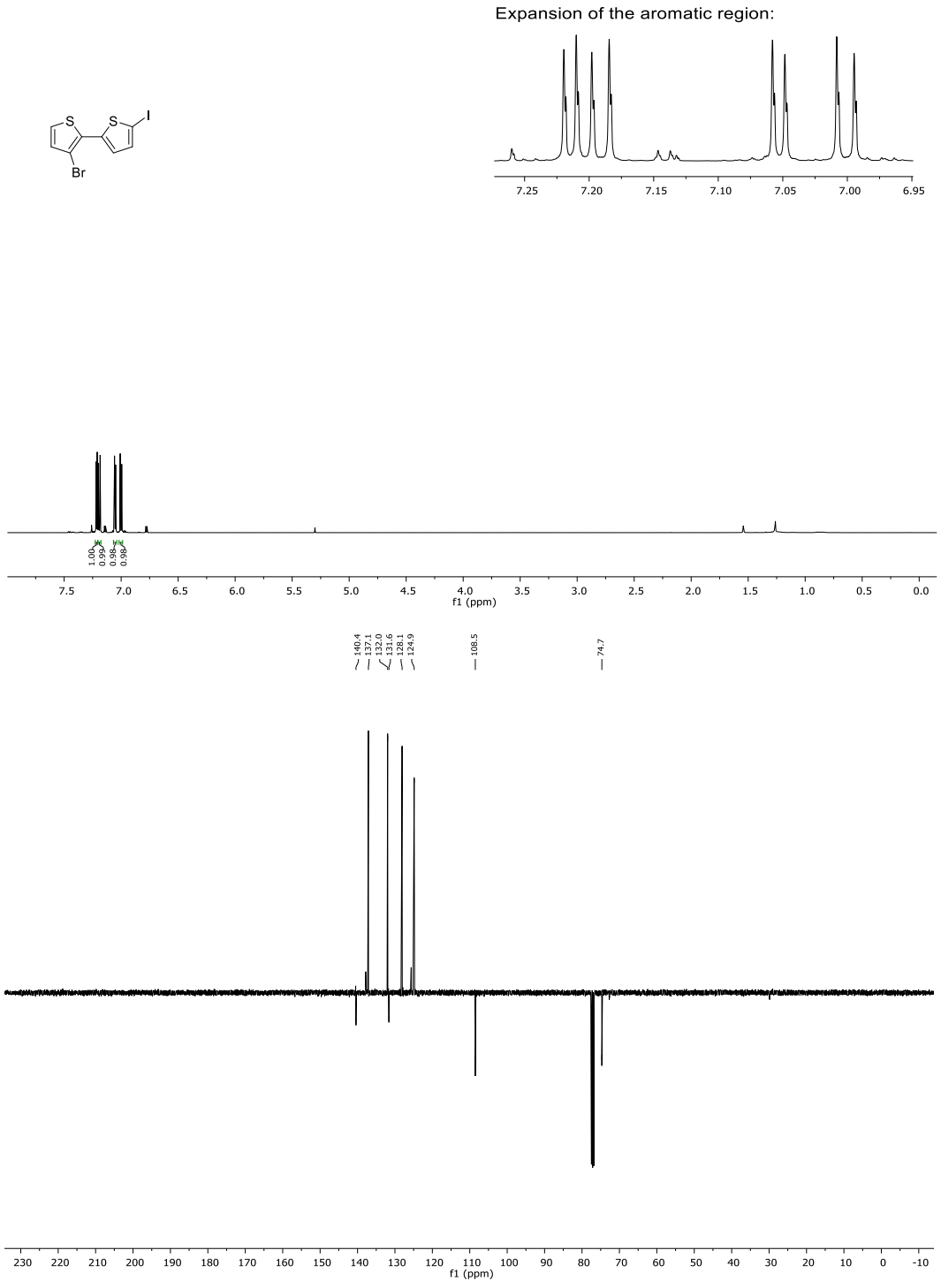


Figure S17. NMR spectra of compound **2** in $CDCl_3$. Top: ^{1}H NMR spectrum (400 MHz); bottom: ^{13}C APT NMR spectrum (101 MHz).

6.2 3-Bromo-5'-(*p*-methoxyphenyl)-2,2'-bithienyl (**3**)

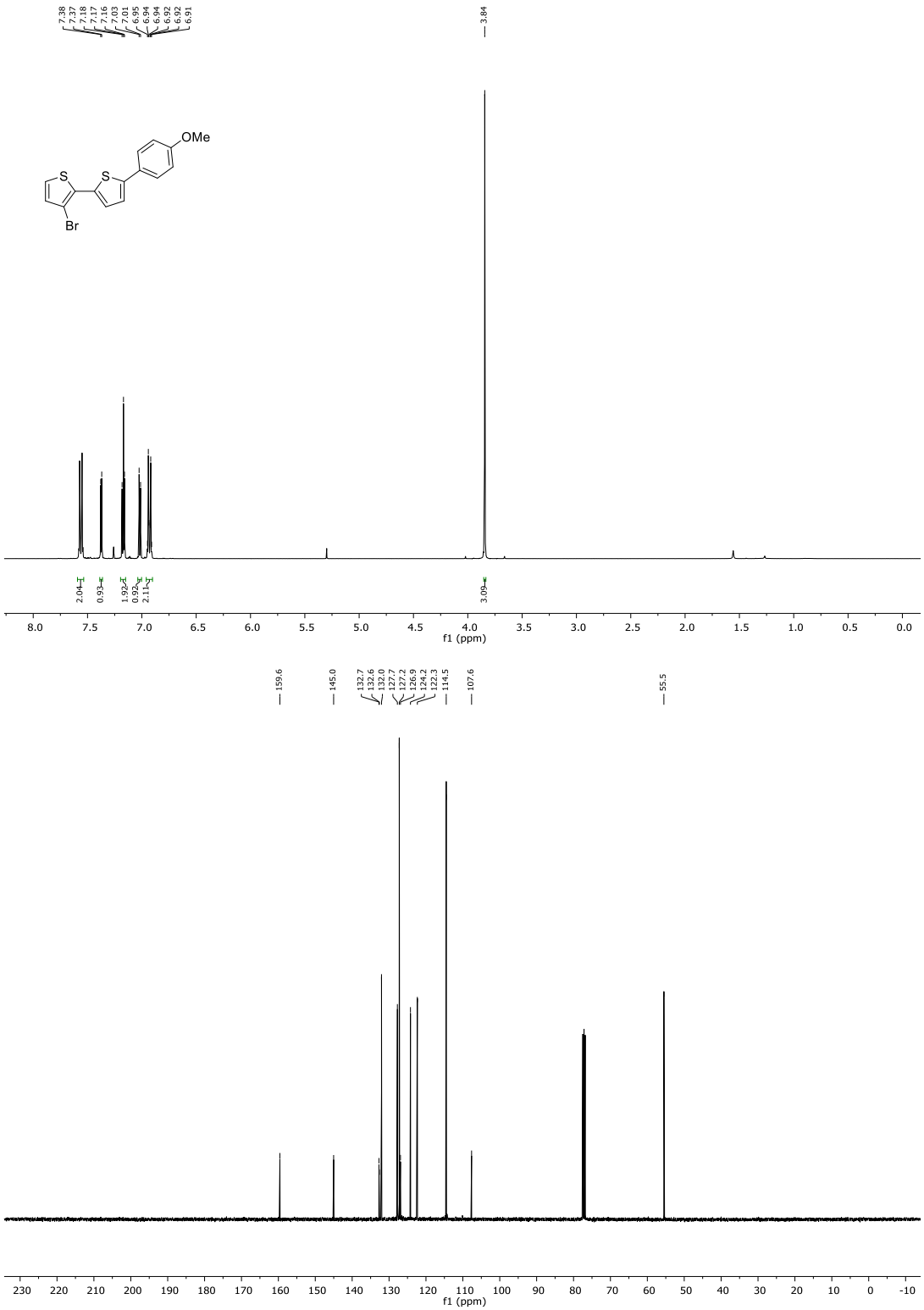


Figure S18. NMR spectra of compound **3** in $CDCl_3$. Top: ^{1}H NMR spectrum (400 MHz); bottom: ^{13}C NMR spectrum (101 MHz).

6.3 3-Bromo-5-iodo-5'-(p-methoxyphenyl)-2,2'-bithienyl (**4**)

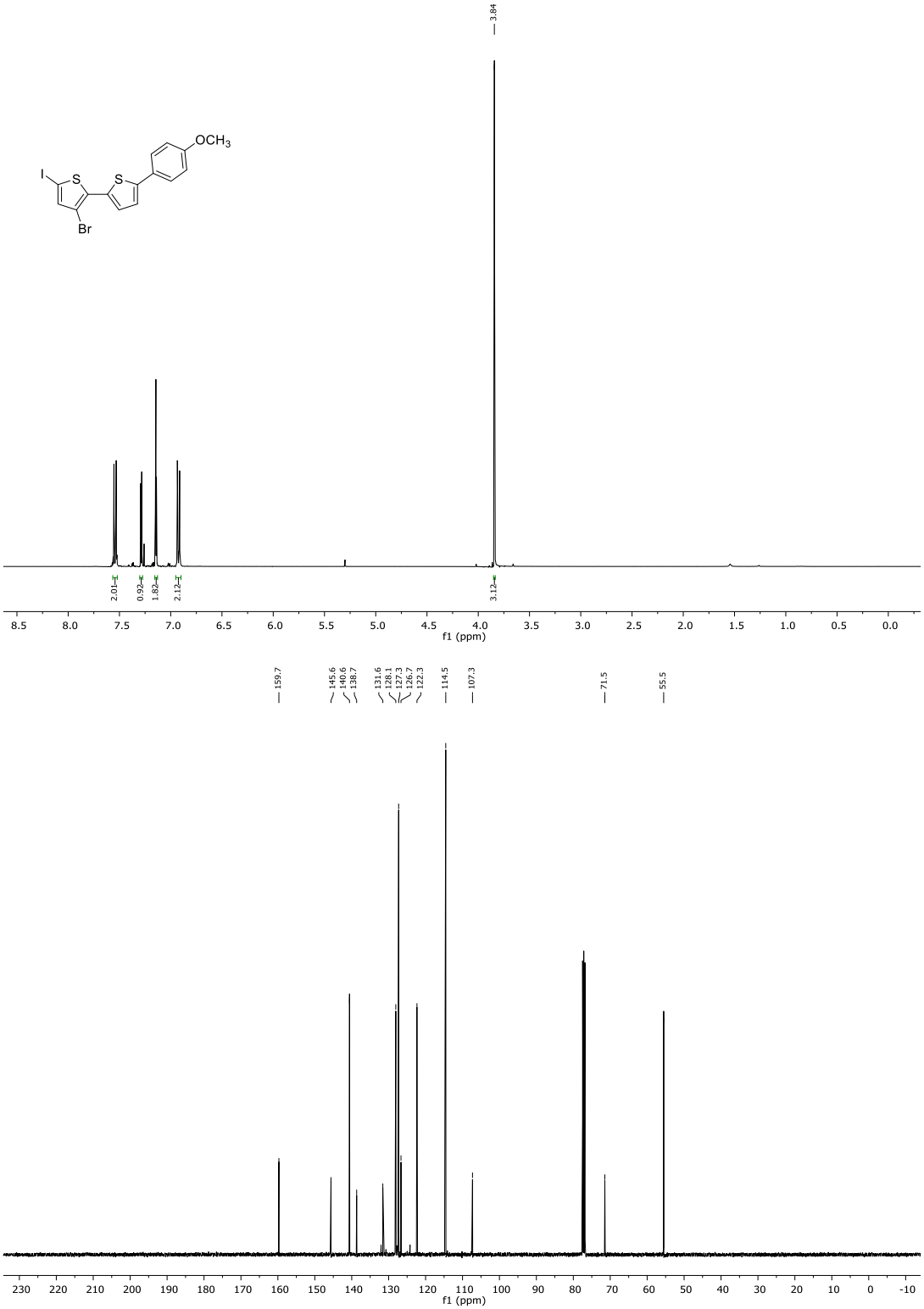


Figure S19. NMR spectra of compound **4** in $CDCl_3$. Top: ^{1}H NMR spectrum (400 MHz); bottom: ^{13}C NMR spectrum (101 MHz).

6.4 3-Bromo-5'-(*p*-methoxyphenyl)-5-(4-pyridyl)-2,2'-bithienyl (**5**)

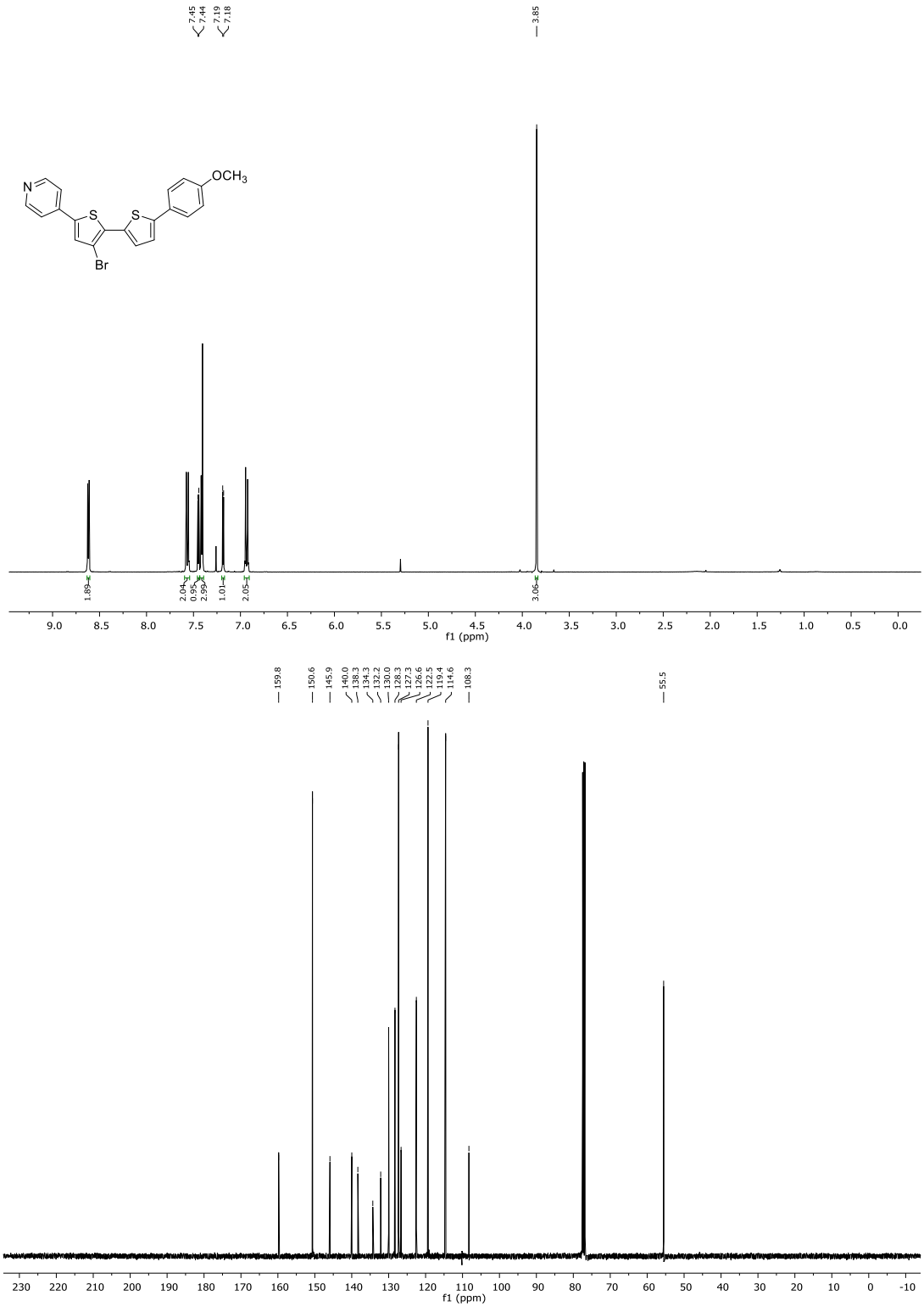


Figure S20. NMR spectra of compound **5** in $CDCl_3$. Top: ^{1}H NMR spectrum (400 MHz); bottom: ^{13}C NMR spectrum (100 MHz).

6.5 Compound **6**

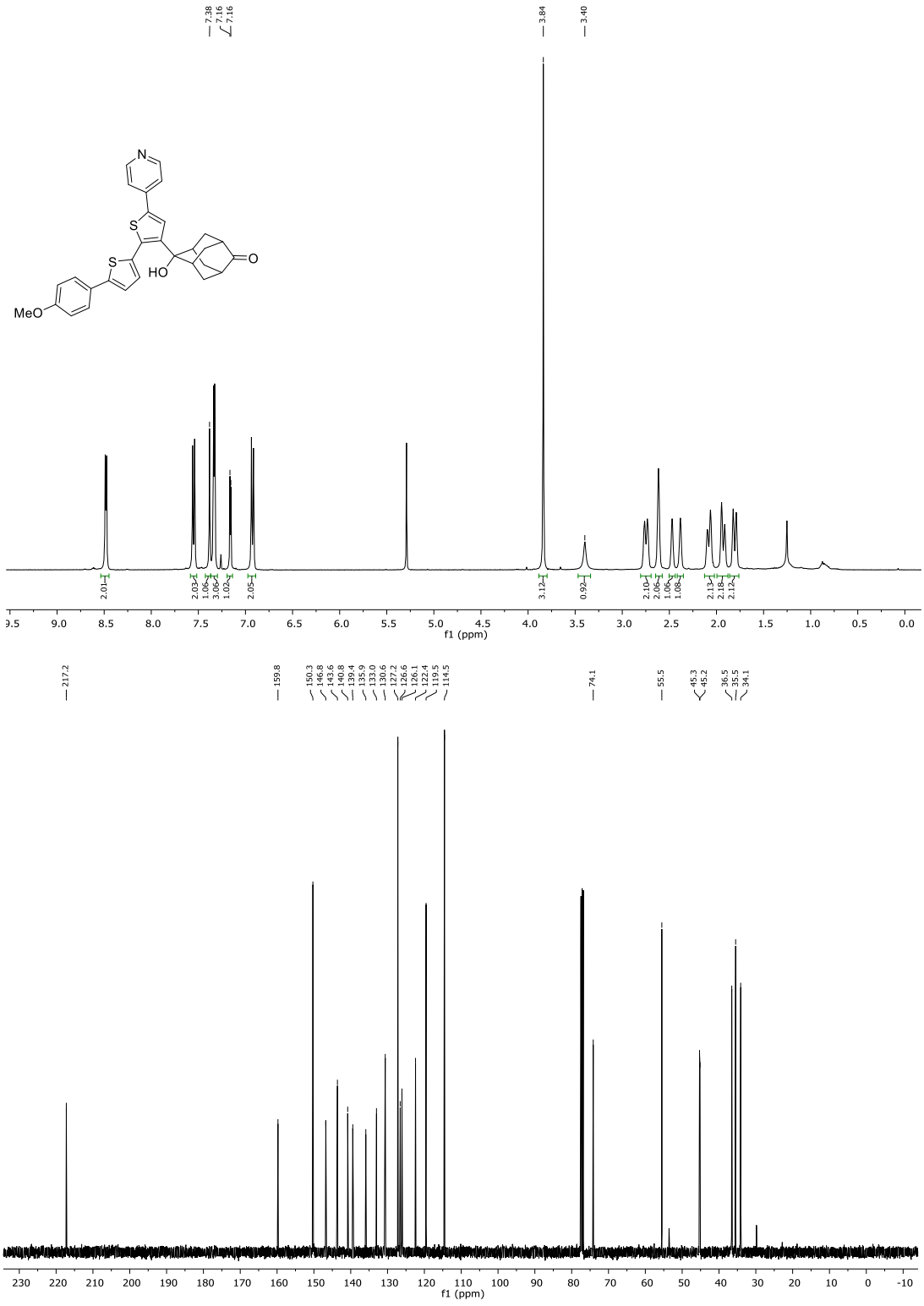


Figure S21. NMR spectra of compound **6** in $CDCl_3$. Top: ^{1}H NMR spectrum (400 MHz); bottom: ^{13}C NMR spectrum (101 MHz).

6.6 Compound **7**

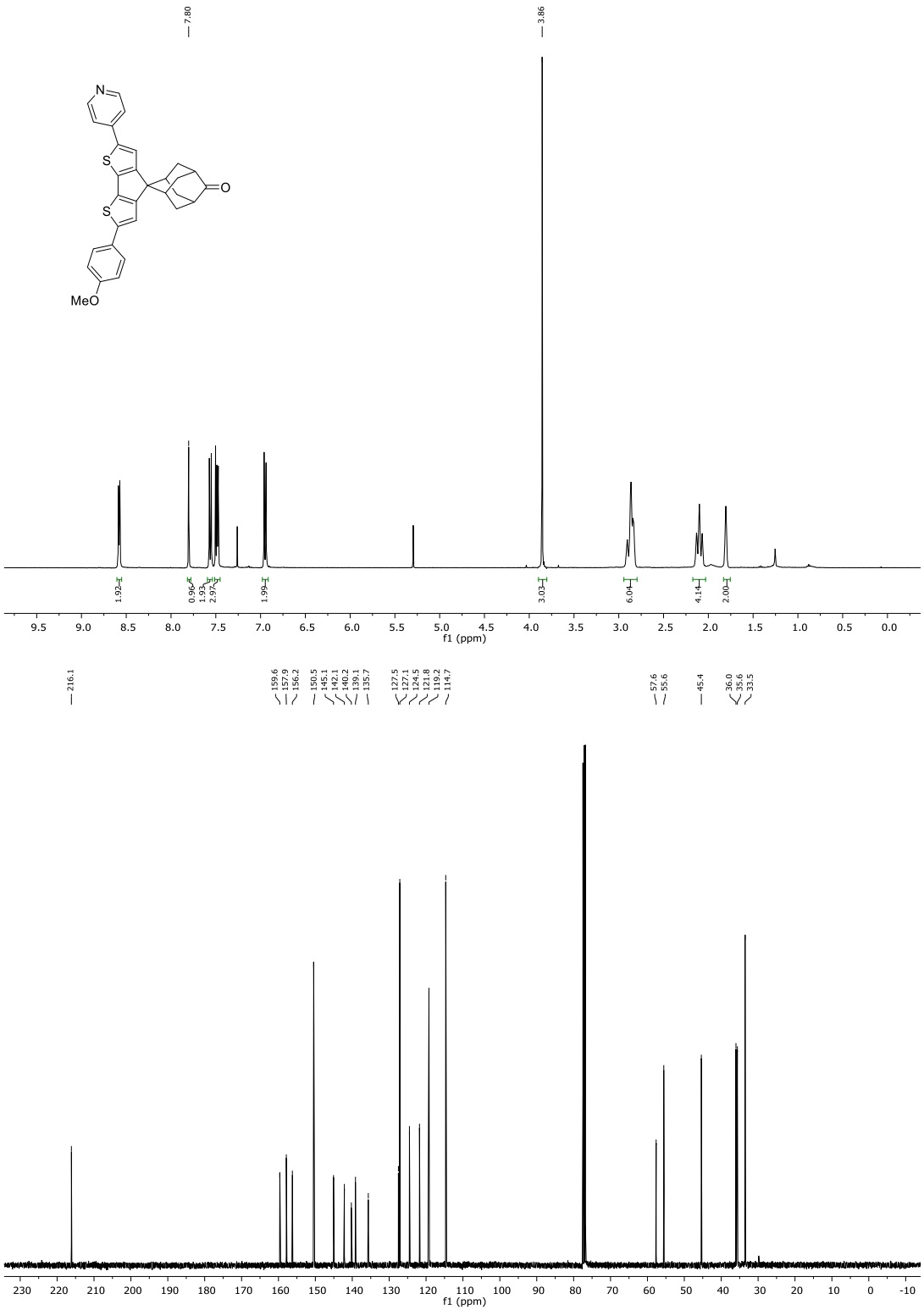


Figure S22. NMR spectra of compound **7** in $CDCl_3$. Top: ^{1}H NMR spectrum (400 MHz); bottom: ^{13}C NMR spectrum (101 MHz).

6.7 Compound **8**

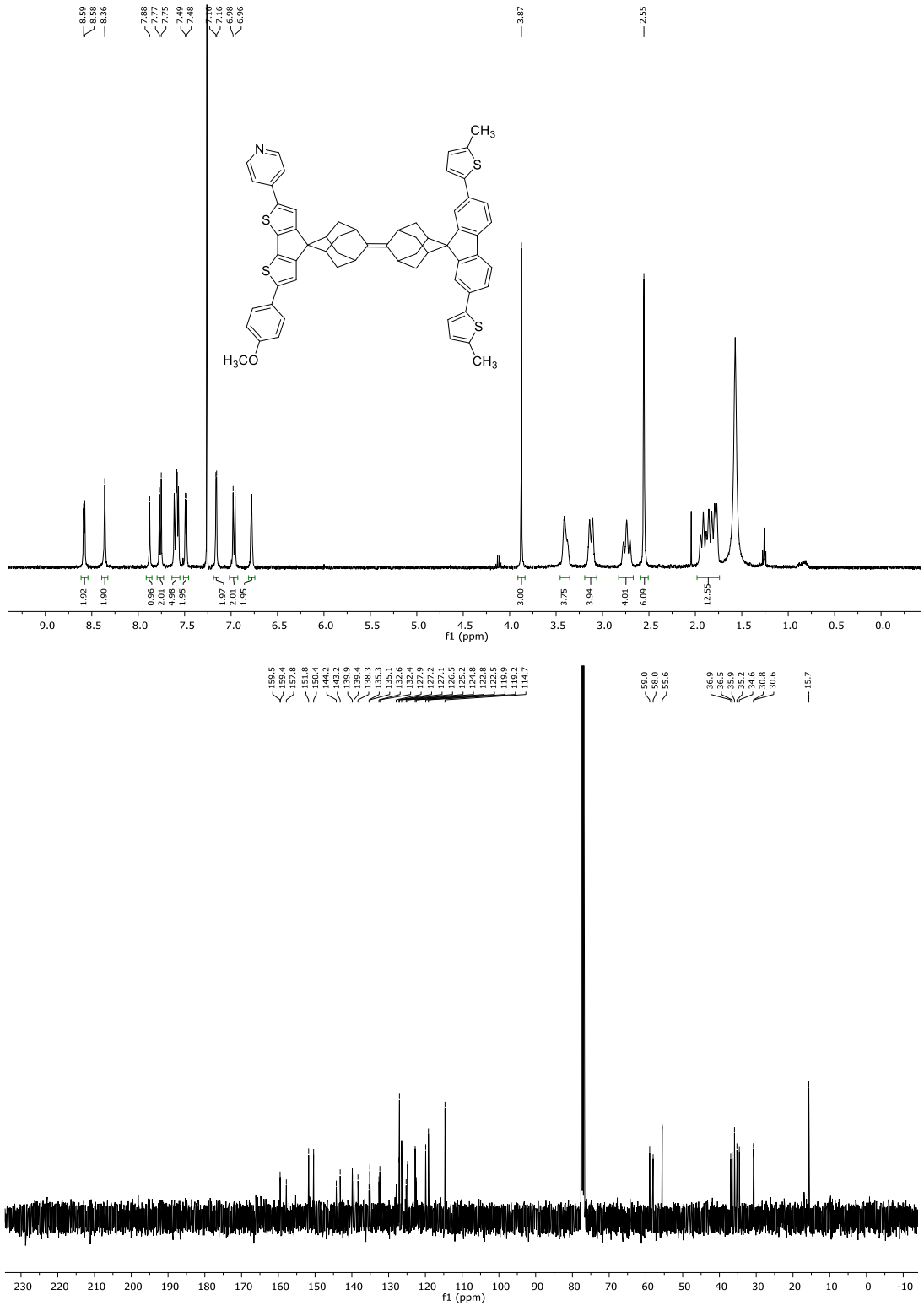


Figure S23. NMR spectra of compound **8** in $CDCl_3$. Top: ^{1}H NMR spectrum (400 MHz); bottom: ^{13}C NMR spectrum (101 MHz).

6.8 2-Bromo-4,4'-diiodobiphenyl (**10**)

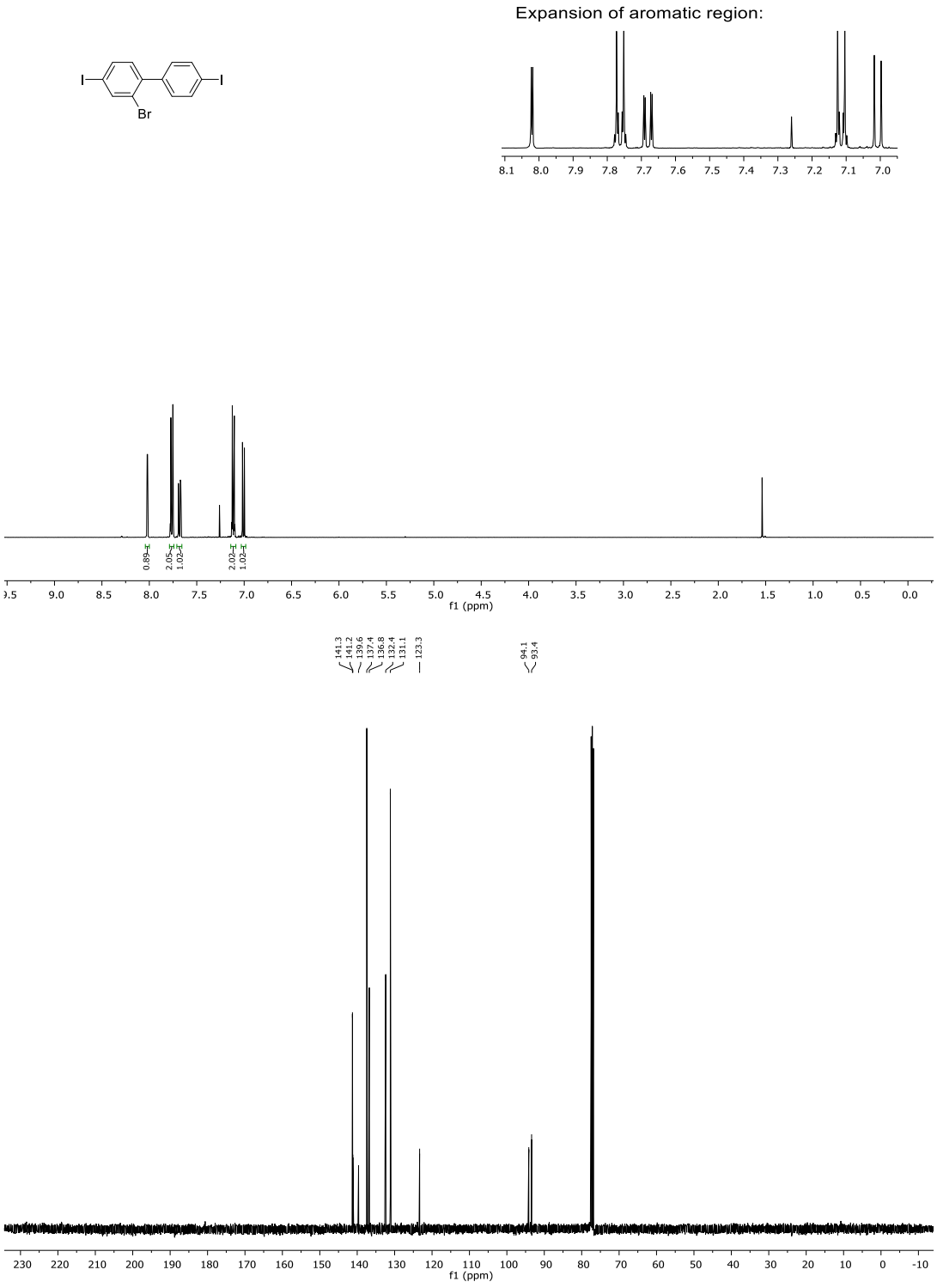


Figure S24. NMR spectra of compound **10** in $CDCl_3$. Top: ^{1}H NMR spectrum (400 MHz); bottom: ^{13}C NMR spectrum (101 MHz).

6.9 2-[2'-Bromo-4'-(5-methyl-2-thienyl)-4-biphenylyl]-5-methylthiophene (**11**)

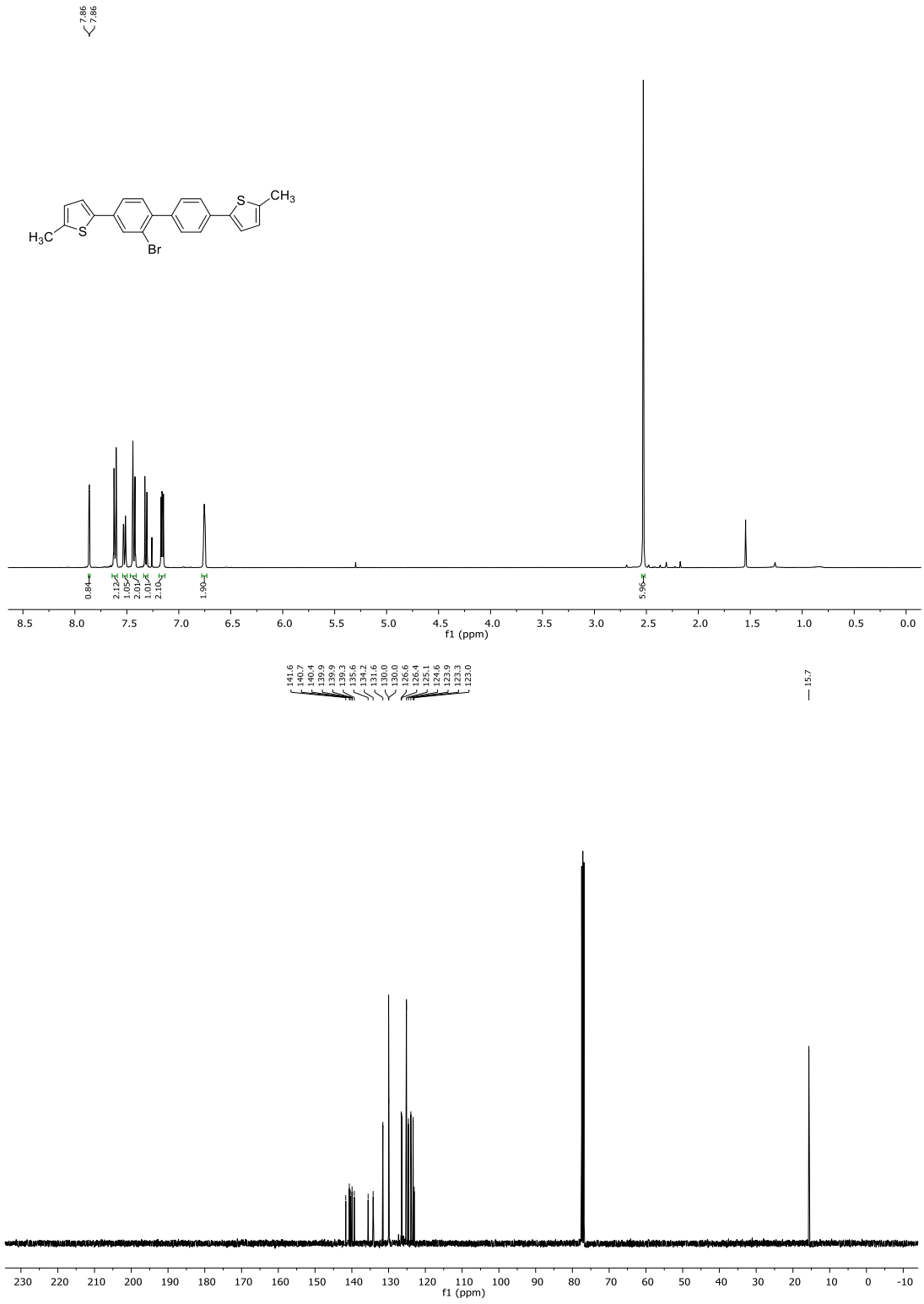


Figure S25. NMR spectra of compound **11** in $CDCl_3$. Top: ^{1}H NMR spectrum (400 MHz); bottom: ^{13}C NMR spectrum (101 MHz).

6.10 Compound **12**

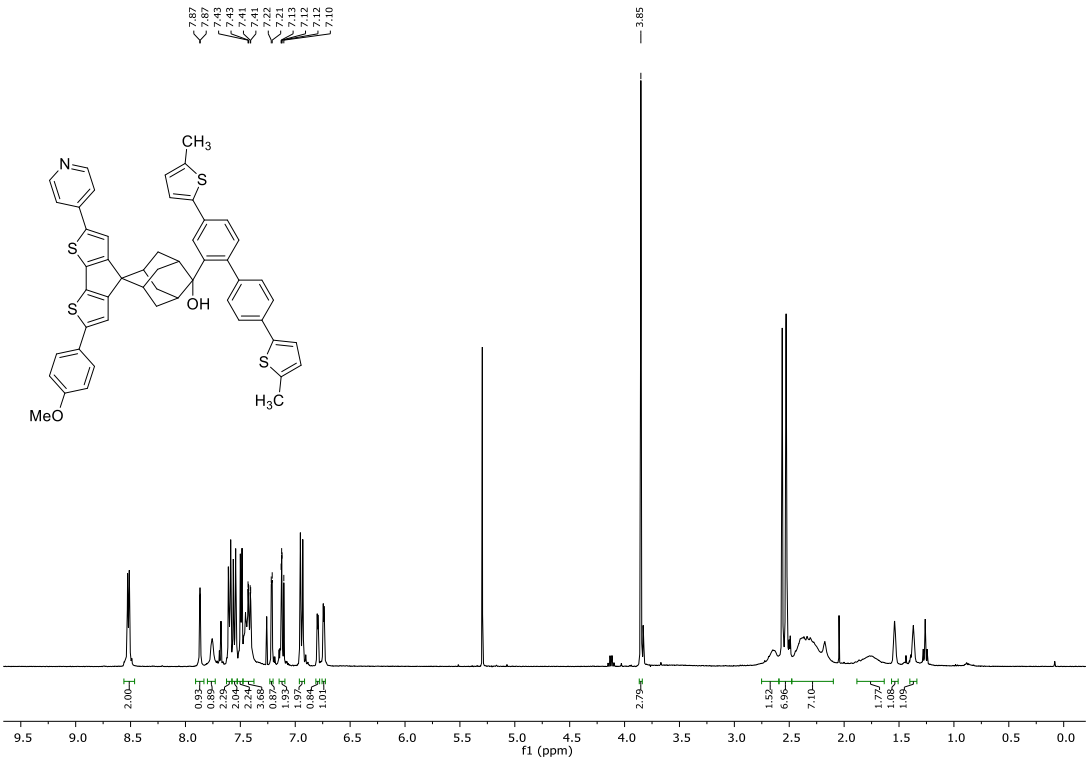


Figure S26. ^{1}H NMR spectrum (400 MHz) of compound **12** in $CDCl_3$.

6.11 Compound **13**

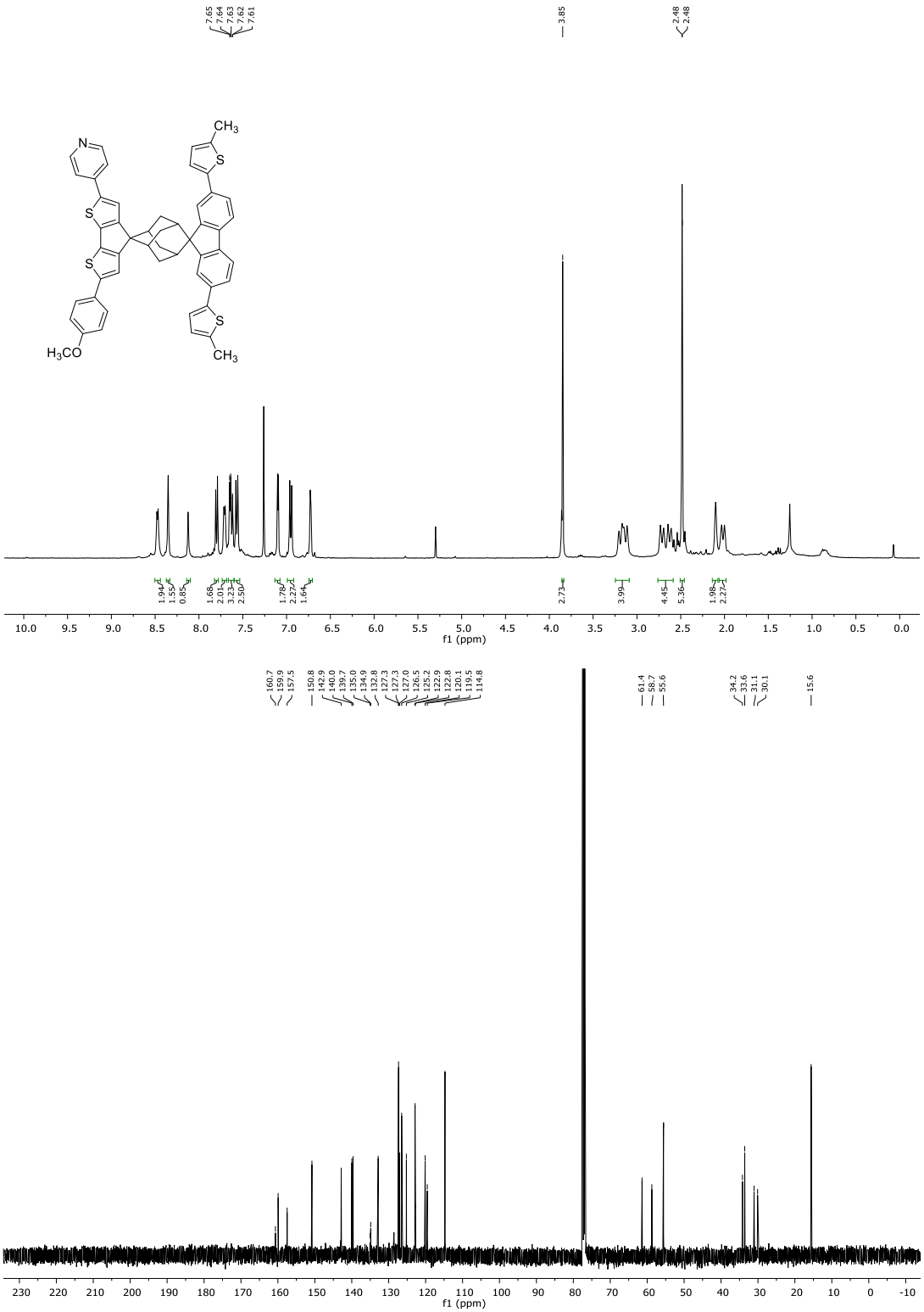


Figure S27. NMR spectra of compound **13** in $CDCl_3$. Top: ^{1}H NMR spectrum (400 MHz); bottom: ^{13}C NMR spectrum (101 MHz).

6.12 Compound **15**

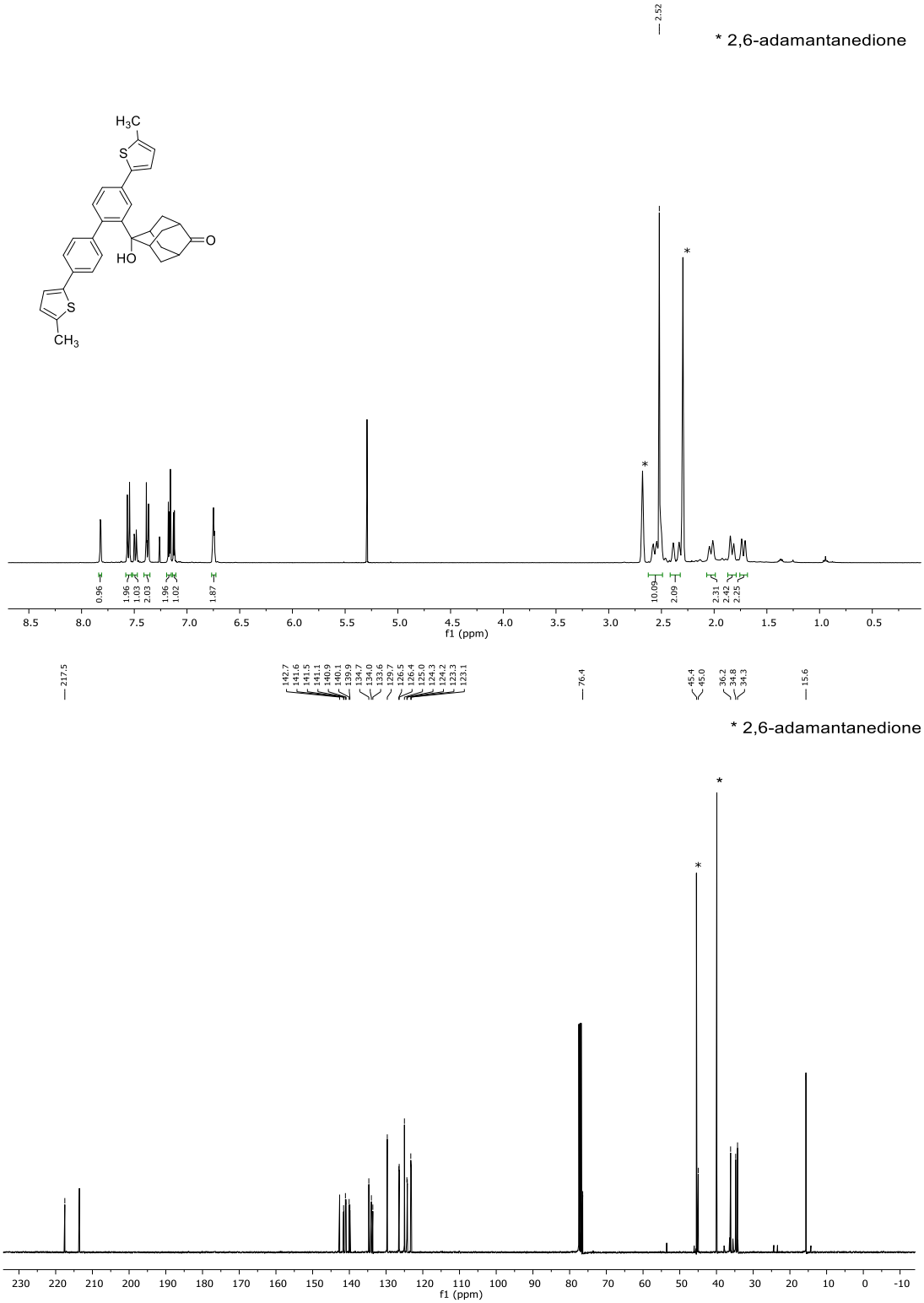


Figure S28. NMR spectra of compound **15** in $CDCl_3$. Top: ^{1}H NMR spectrum (400 MHz); bottom: ^{13}C NMR spectrum (101 MHz).

6.13 Compound *rac*-**14**

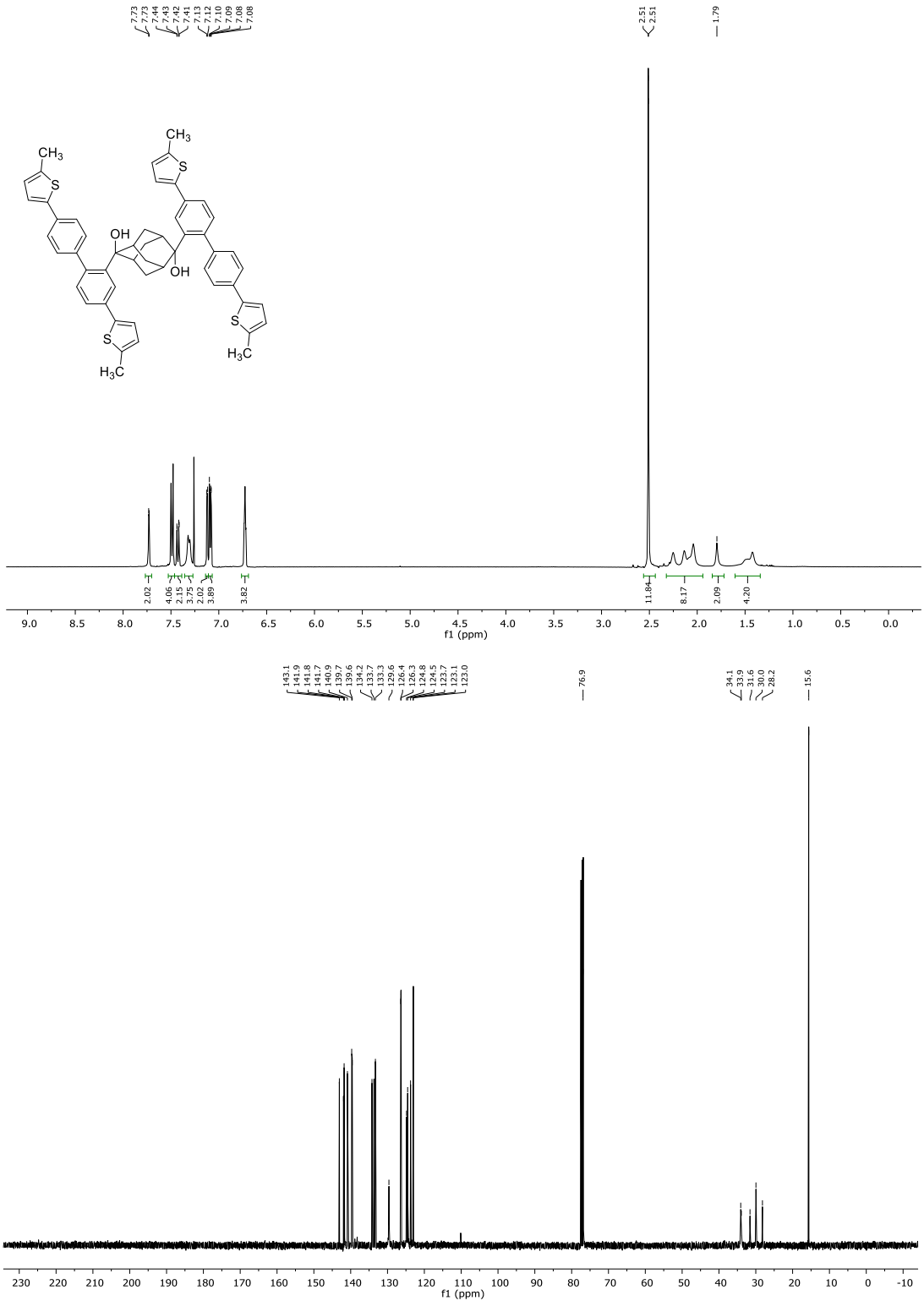


Figure S29. NMR spectra of compound **14** in $CDCl_3$. Top: ^{1}H NMR spectrum (400 MHz); bottom: ^{13}C NMR spectrum (101 MHz).

6.14 Compound *B*

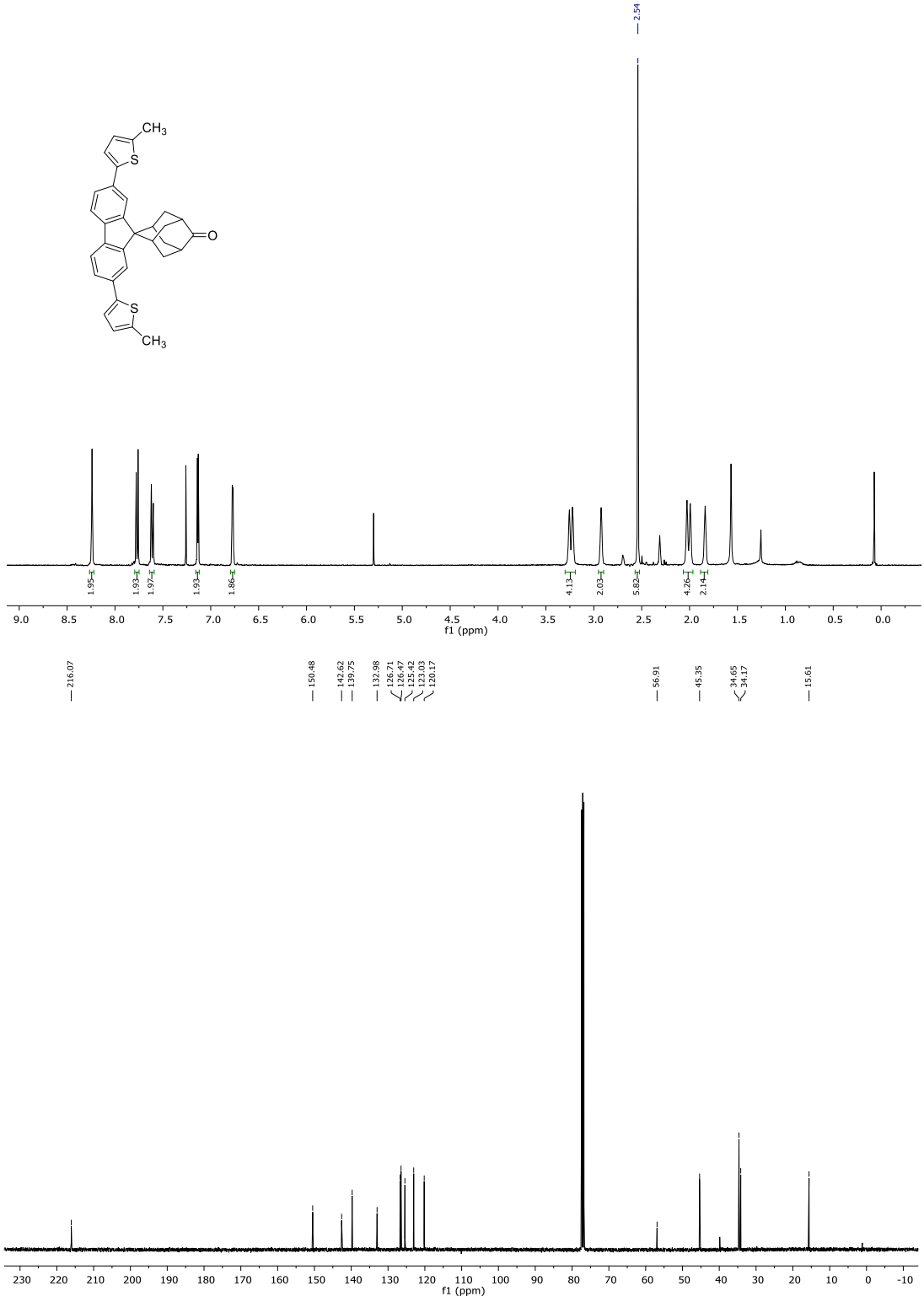


Figure S30. NMR spectra of compound *B* in $CDCl_3$. Top: ^{1}H NMR spectrum (400 MHz); bottom: ^{13}C NMR spectrum (101 MHz).

6.15 Compound **B⊥B**

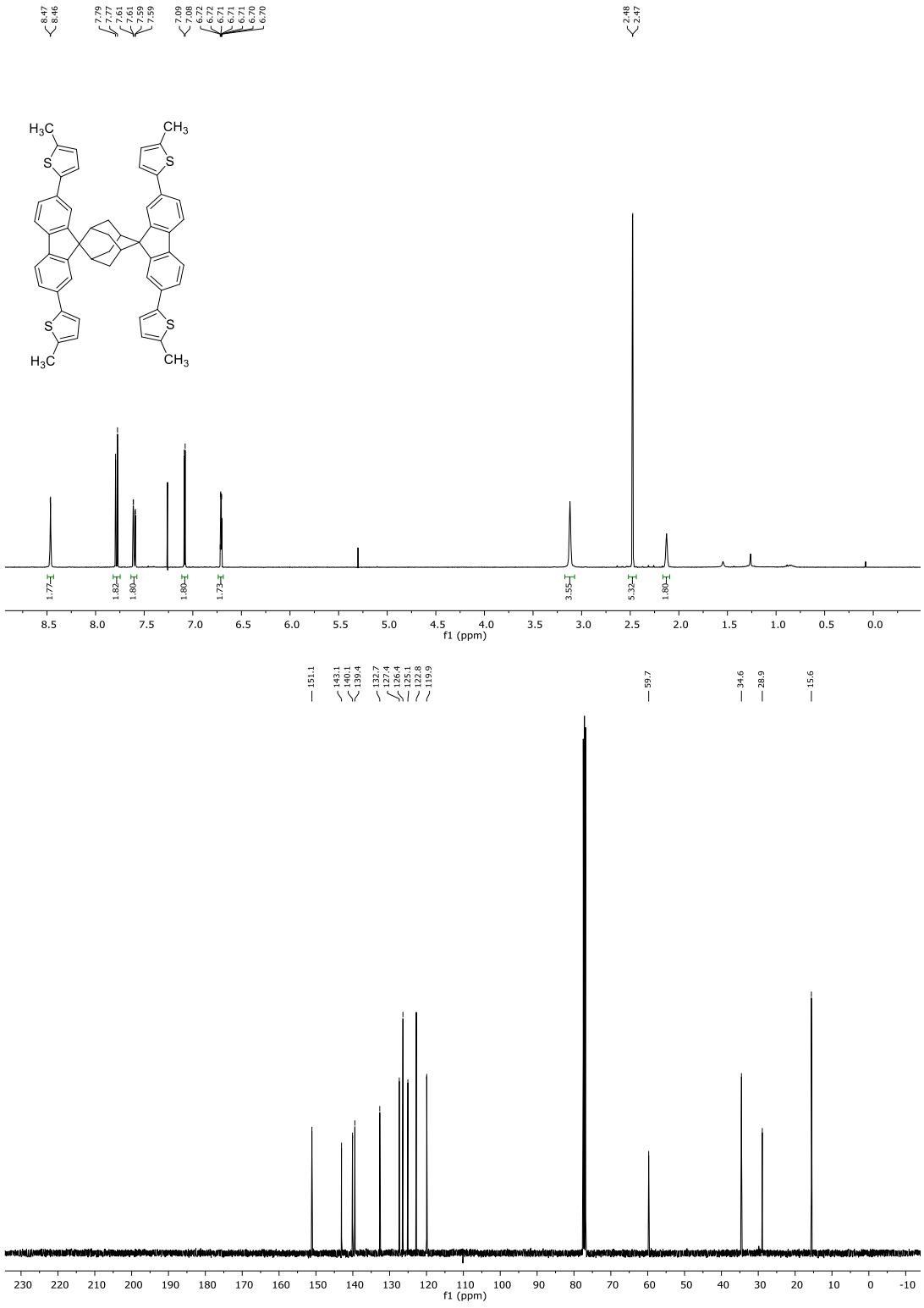


Figure S31. NMR spectra of compound **B⊥B** in $CDCl_3$. Top: ^{1}H NMR spectrum (400 MHz); bottom: ^{13}C NMR spectrum (101 MHz).

6.16 Compound **B‖B**

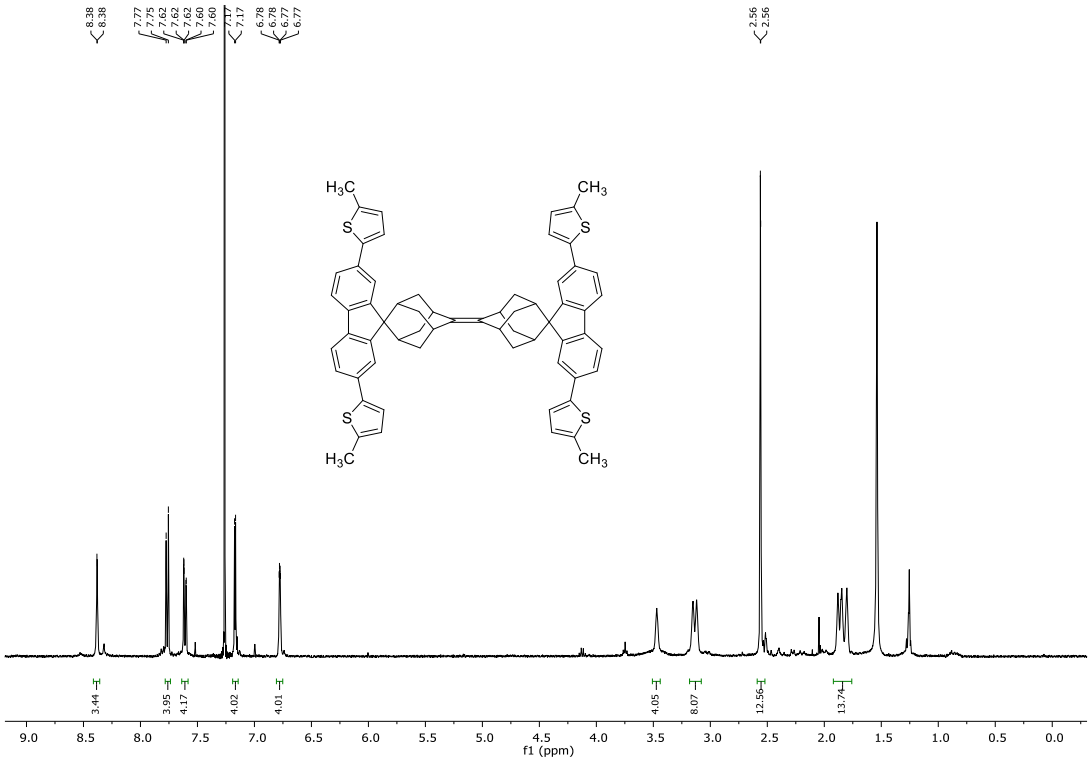


Figure S32. ^{1}H NMR spectrum (400 MHz) of compound **B‖B** in $CDCl_3$.

6.17 Compound **B⊥R**

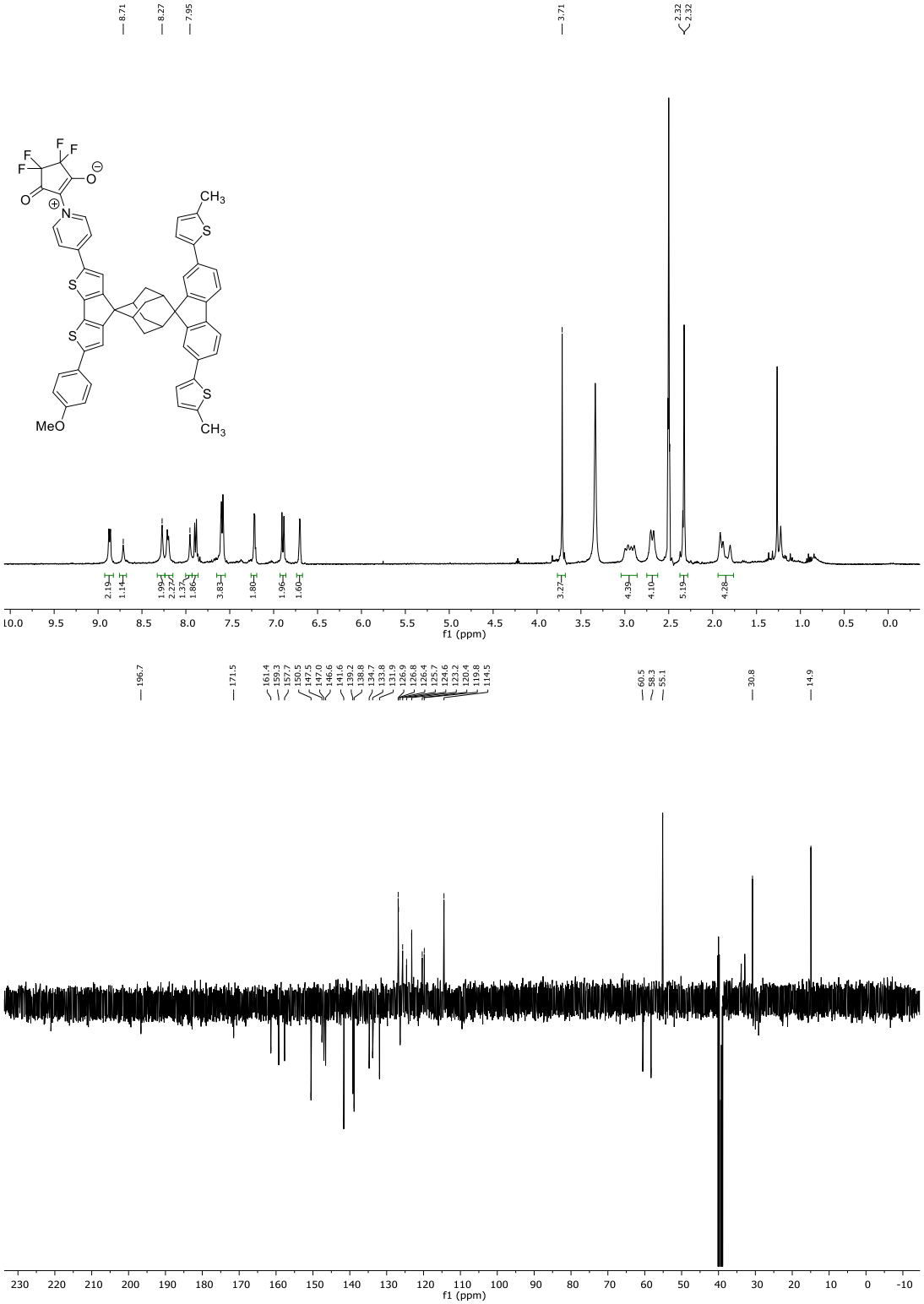


Figure S33. NMR spectra of compound **B⊥R** in DMSO-d_6. Top: ^{1}H NMR spectrum (400 MHz); bottom: ^{13}C APT NMR spectrum (101 MHz).

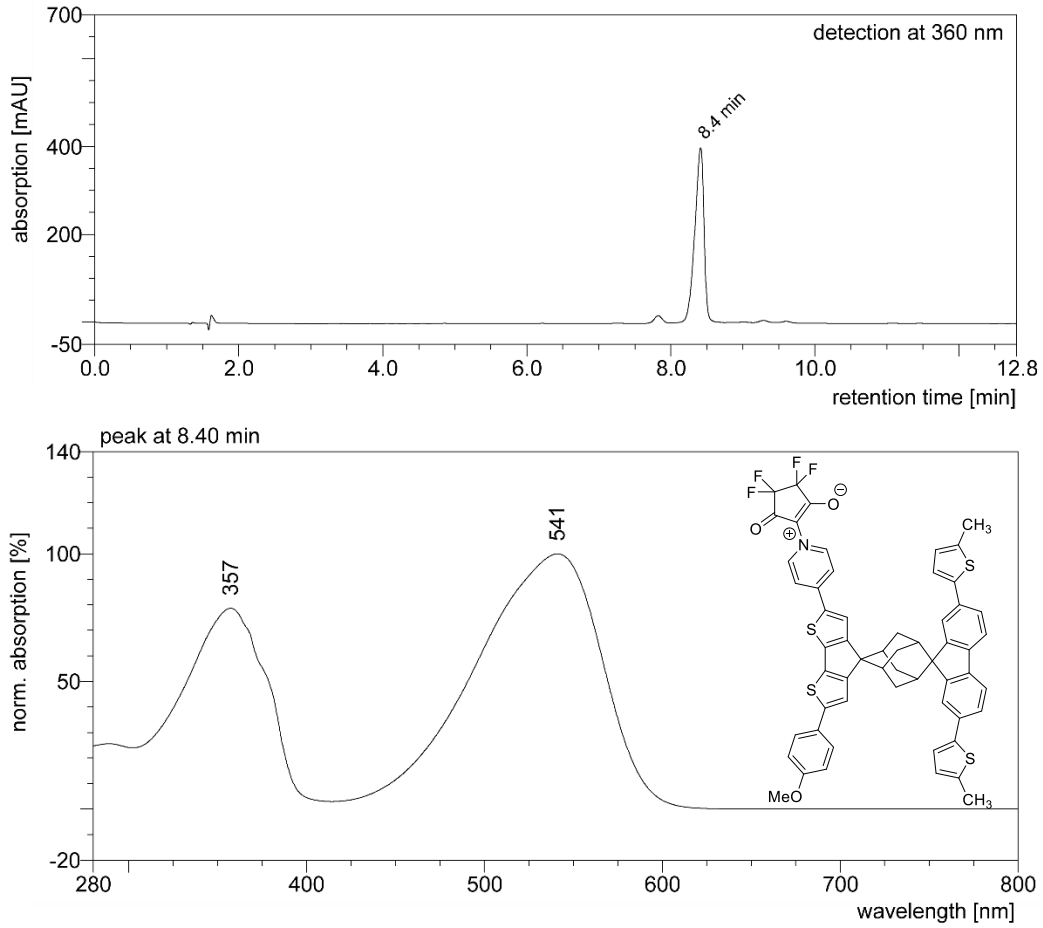


Figure S34. HPLC analysis of compound *B*⊥*R* after purification by preparative HPLC (ProntoSIL 120-5 Amino E, 5 µm, 4 × 250 mm; *iso*-octane/$CHCl_3$ = 80:20 to 0:100 in 20 min; 1.5 ml/min flow); top: HPLC trace; bottom: UV/Vis absorption spectrum of the peak with t_R = 8.4 min.

6.18 Compound **B‖R**

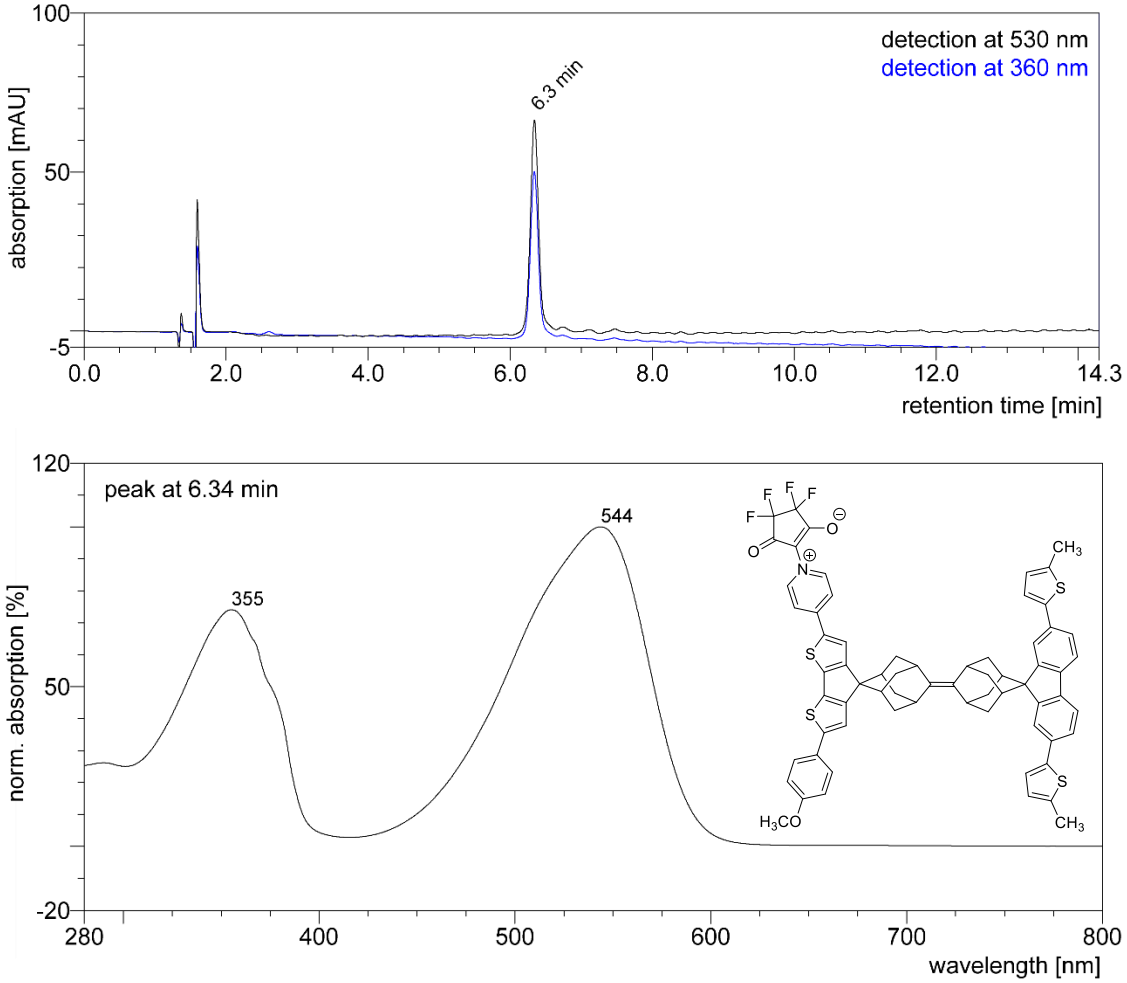


Figure S35. HPLC analysis of compound **B‖R** after purification by preparative HPLC (ProntoSIL 120-5 Amino E, 5 µm, 4 × 250 mm; *iso*-octane/$CHCl_3$ = 70:30 to 0:100 in 15 min; 1.5 ml/min flow); top: HPLC trace; bottom: UV/Vis absorption spectrum of the peak with t_R = 6.34 min.

6.19 Compound **R**

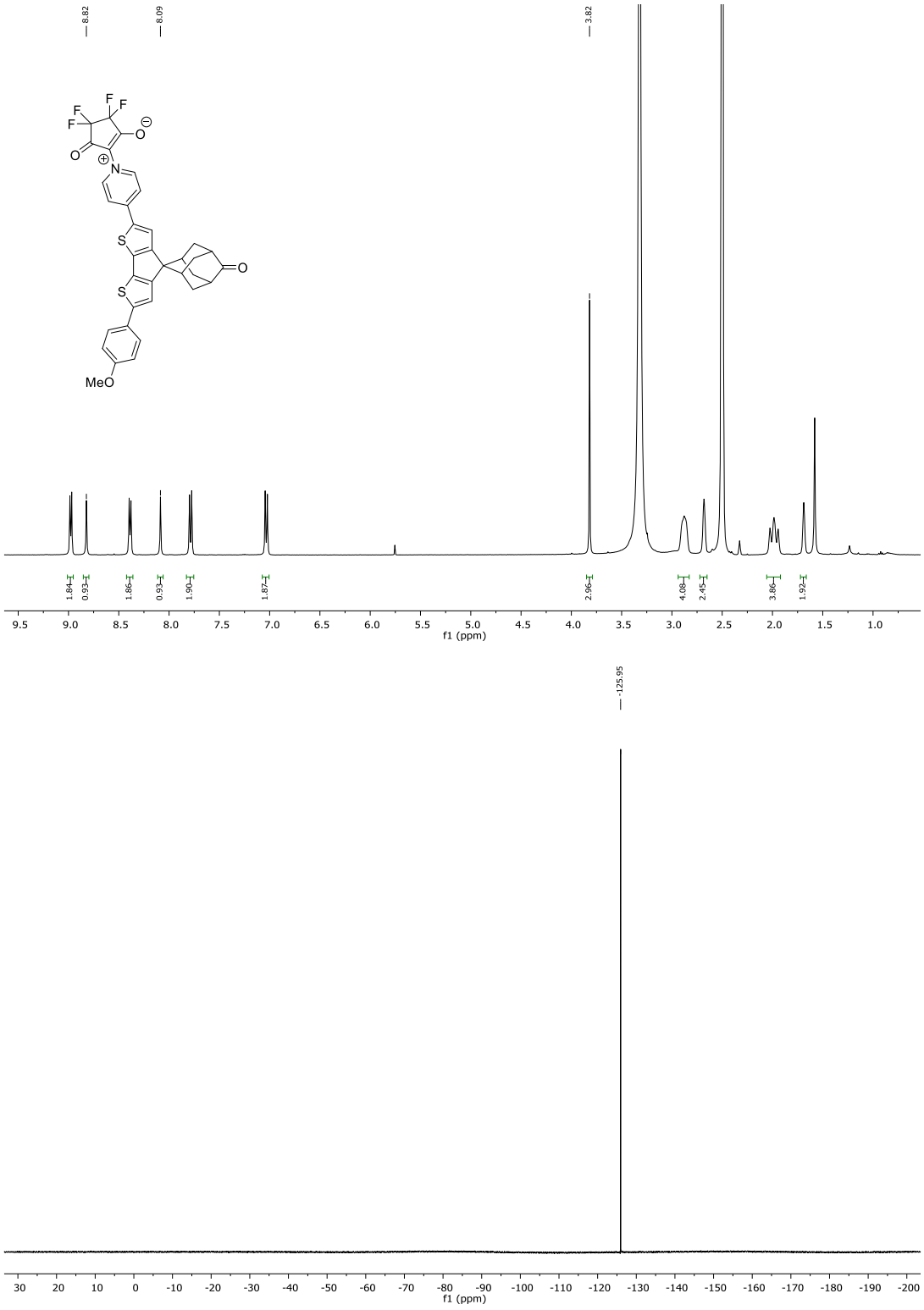


Figure S36. NMR spectra of compound **R** in DMSO-d_6. Top: ^{1}H NMR spectrum (400 MHz); bottom: ^{19}F NMR spectrum (376 MHz).

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