Electronic Supplementary Information (ESI)

Indoor Light Harvesting Dye-sensitized Solar Cells Surpassing 30% Efficiency without Co-sensitizers

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[b] Academy of Scientific and Innovative Research (AcSIR), Ghaziabad-201002, India.

‡ These authors contributed equally to this work.

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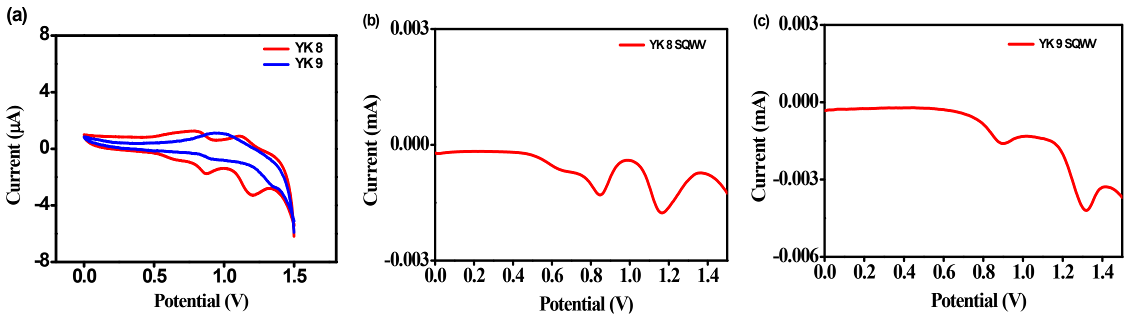


Figure S1. (a) Cyclic voltammogram of YK 8 and YK 9 and square wave voltammogram of (b) YK 8 and (c) YK 9 respectively.

The HOMO and LUMO levels of the dyes were calculated from first half wave potentials obtained from cyclic voltammogram (confirmed by square wave voltammogram) using the equations given below.

$$E_{gap} = 1240/\lambda$$

$$E_{HOMO} = -[4.8 + E_{ox/red} - E_{Fc}]$$

$$E_{LUMO} = E_{HOMO} - E_{gap}$$

Where,

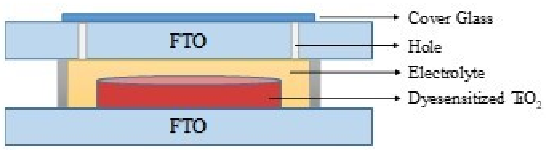
$E_{ox/red}$ - denotes the oxidation/reduction potential of the dye

E_{Fc} - denotes the oxidation potential of Ferrocene

λ - denotes the absorption onset value

All the obtained potentials were converted to NHE by considering Fc/Fc^+ as +0.765 V vs NHE in DCM

a



b

Figure S2. (a) DSC architecture employed in the present study (b) Image of fabricated DSC devices with YK 8, YK 9 and MK2 sensitizers

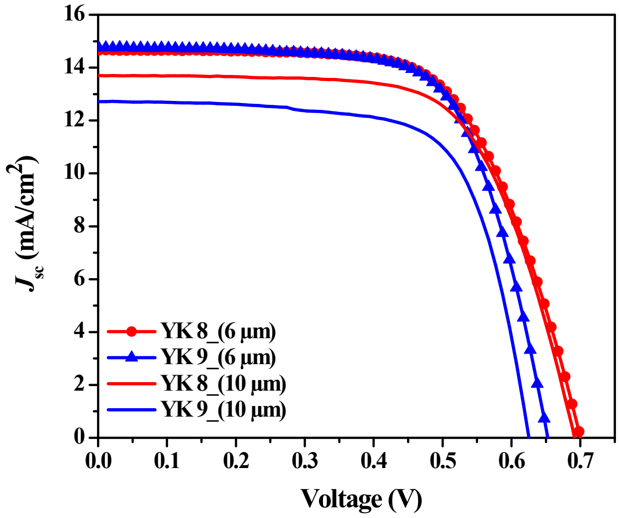
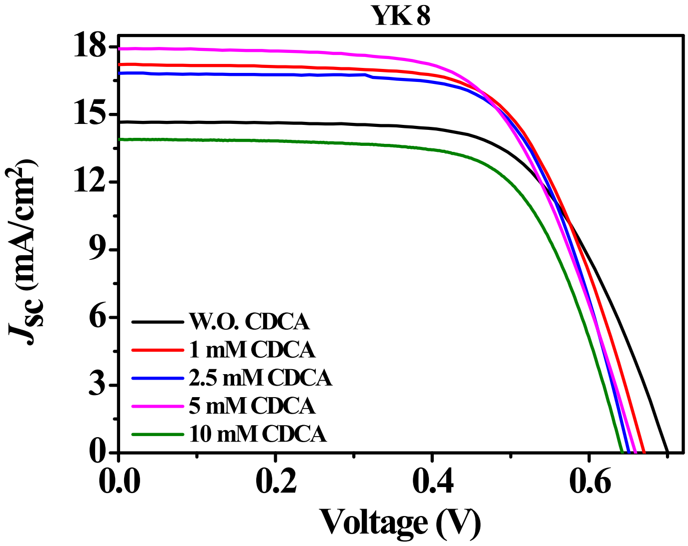


Figure S3. Current density - voltage (J-V) characteristics for the optimization of semiconductor architecture for YK 8 and YK 9 without CDCA.

a



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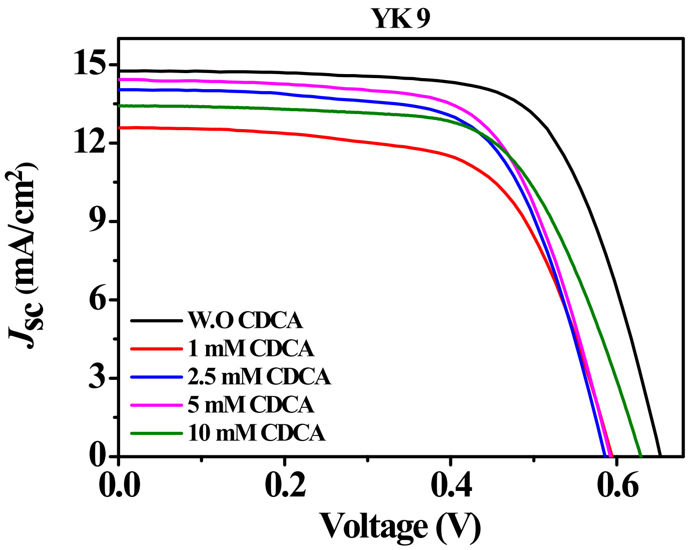


Figure S4. Current density - voltage (*J-V*) characteristics for optimization of co-adsorbent concentration for a) YK 8 and b) YK 9.

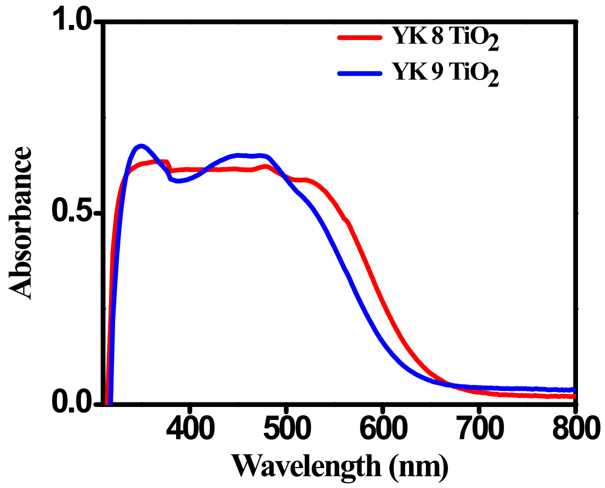


Figure S5. Absorption spectra of dyes YK 8 and YK 9 adsorbed on TiO_2.

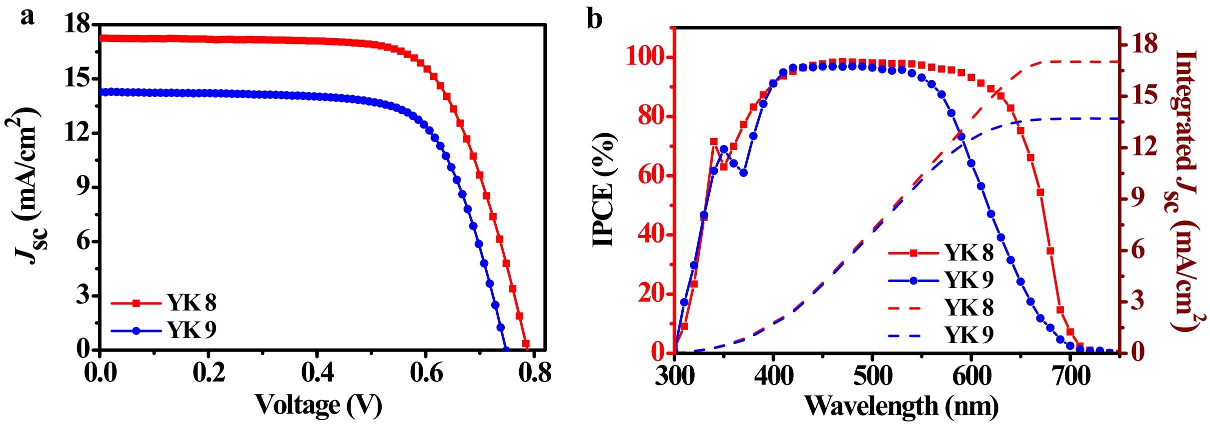
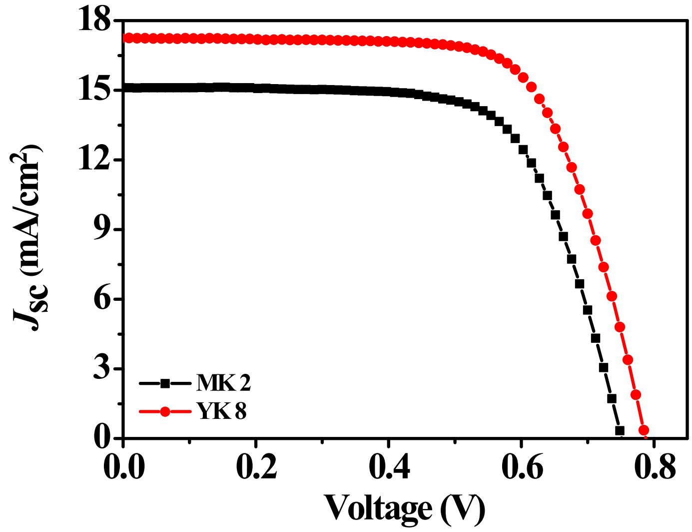


Figure S6. (a) Current density - voltage (J-V) characteristics (b) Incident photon-to-current conversion efficiency (IPCE) and integrated Jsc calculated from IPCE spectra for DSCs fabricated using YK 8 and YK 9 dyes after ageing the devices for 2700 h.

a



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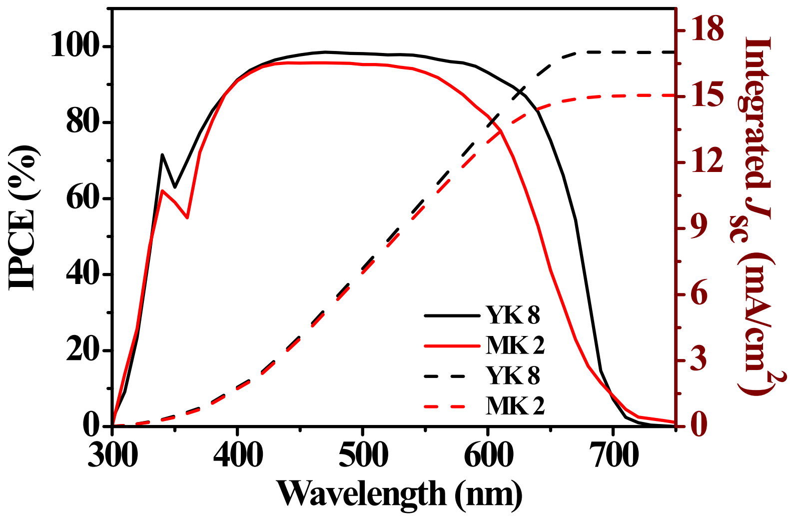


Figure S7. (a) Current density - voltage (*J*-*V*) characteristics and (b) IPCE for YK 8 and MK 2.

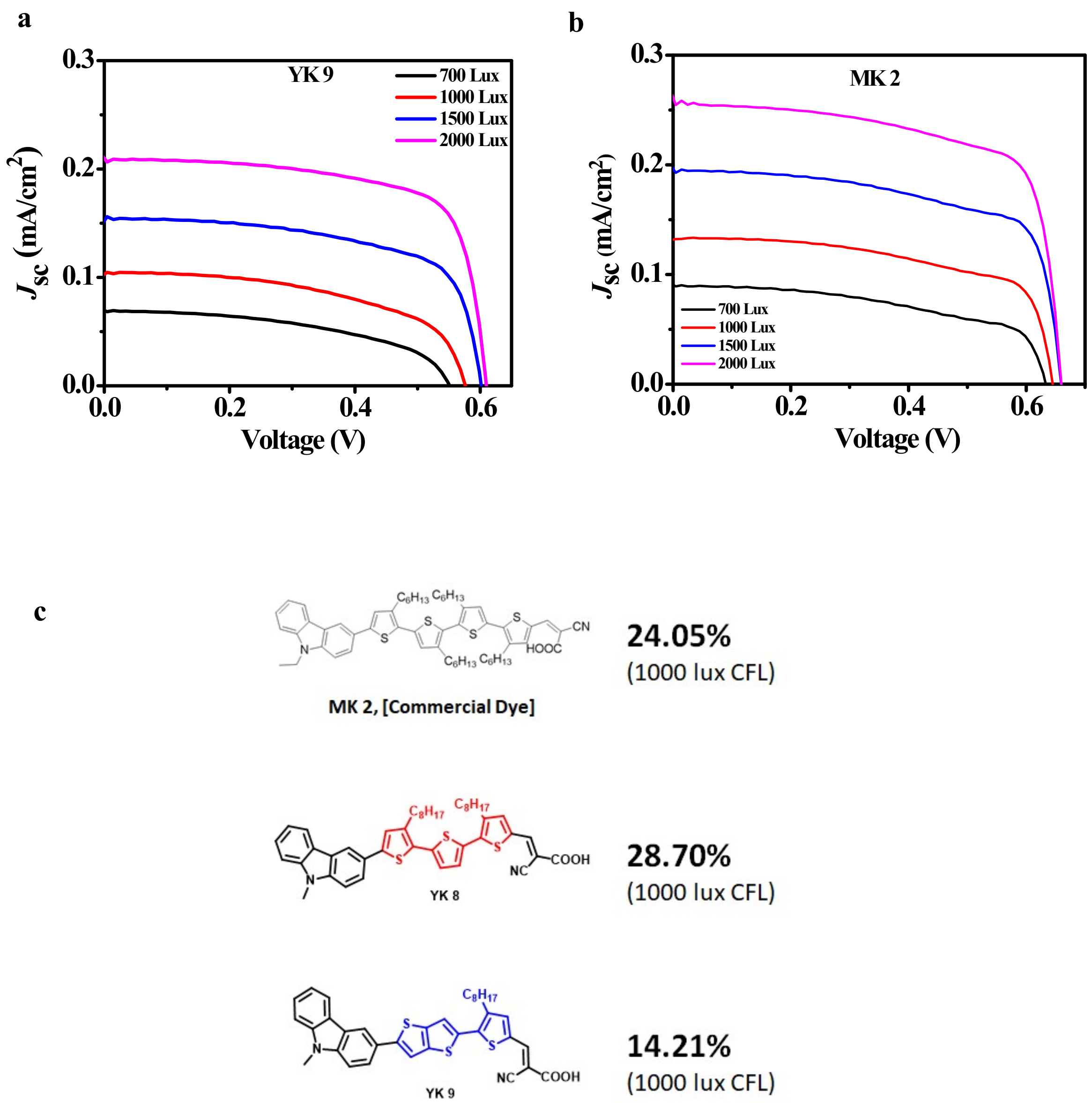


Figure S8. Current density - voltage (*J-V*) characteristics of DSCs under indoor light for (a) YK 9 ans (b) MK 2 sensitizer (Osram 14 W T2 cool day light fluorescent tube illumination) at 700 lux, 1000 lux, 1500 lux and 2000 lux intensities (c) Variation of π-spacer and its influence on indoor PV performance of organic D-π-A dyes at standard 1000 lux.

Figure S9. Image of self-powered temperature sensor with LCD display at 500 lux (Osram 14 W T2 cool day light fluorescent tube illumination) integrated with four serially connected DSCs fabricated with YK 8 sensitizer.

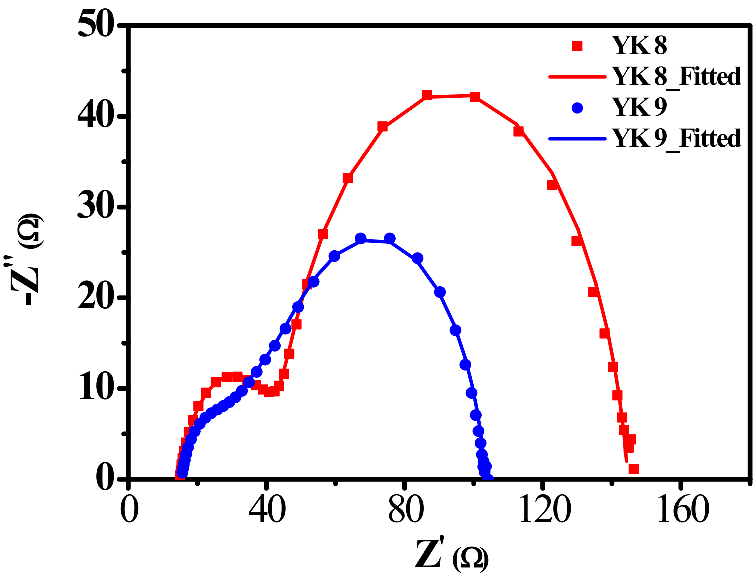


Figure S10. Nyquist plot obtained for YK 8 and YK 9 dyes.

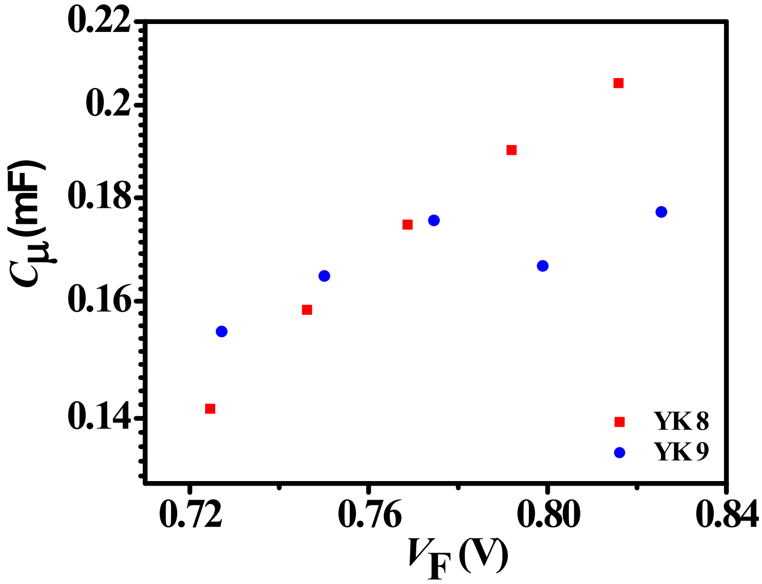


Figure S11. Chemical capacitance (C_μ) as a function of corrected voltage (V_F) for YK 8 and YK 9 dyes.

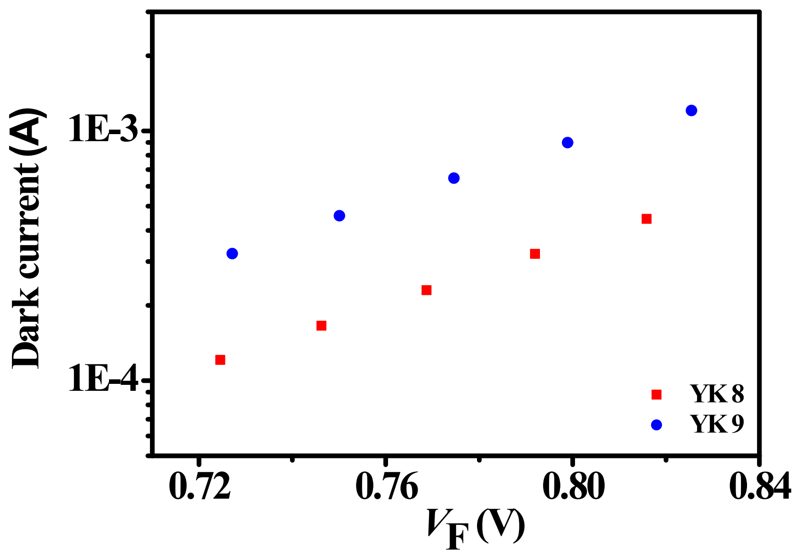


Figure S12. Dark current as function of corrected voltage (V_F) calculated from EIS for YK 8 and YK 9 dyes.

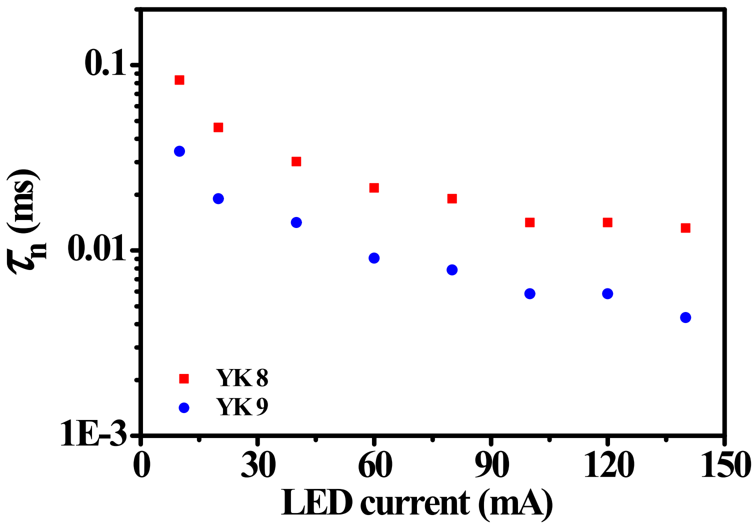


Figure S13. Lifetime (τ_n) as a function of LED current measured using IMVS technique for YK 8 and YK 9 dyes.

Indoor light measurements

The indoor light measurements were performed in a home-made indoor light measurement setup (Black Chamber) using Osram 14 W T2 cool day light fluorescent tube as the source of illumination. The spectrum of the lamp was recorded using a portable spectroradiometer (PR-655) from Photo Research Inc. The light intensity was calibrated and measured using high sensitivity certified irradiance measuring unit from Dyenamo AB (DN-AE06). The measurement system consists of a high-sensitivity thermal (thermopile) sensor (Thorlabs, Model: S401C and S/N: 01414) and USB power meter (Thorlabs, Model: PM100USB and S/N: P2010346), which are connected through the software provided by Dyenamo AB. This was cross verified by integrating the spectra also obtained using spectroradiometer. The *J-V* measurements under lower intensities were measured using a certified low power measuring unit from Dyenamo AB which was custom made for carrying out low-light (indoor ambient light) measurements with maximum accuracy (Model: DN-AE05, S/N: 0015). For Indoor Light Measurements, we have taken all preventive measures and used certified characterization tools to prevent any sort of error and issues commonly resulting from the over estimation of PV performance. We not only cover the edge of the solar cell with a black mask but also kept the devices on black surface. In addition, during the measurements we made the room absolutely dark in order to avoid any stray light. The home-made indoor/artificial light measurement setup is given below.

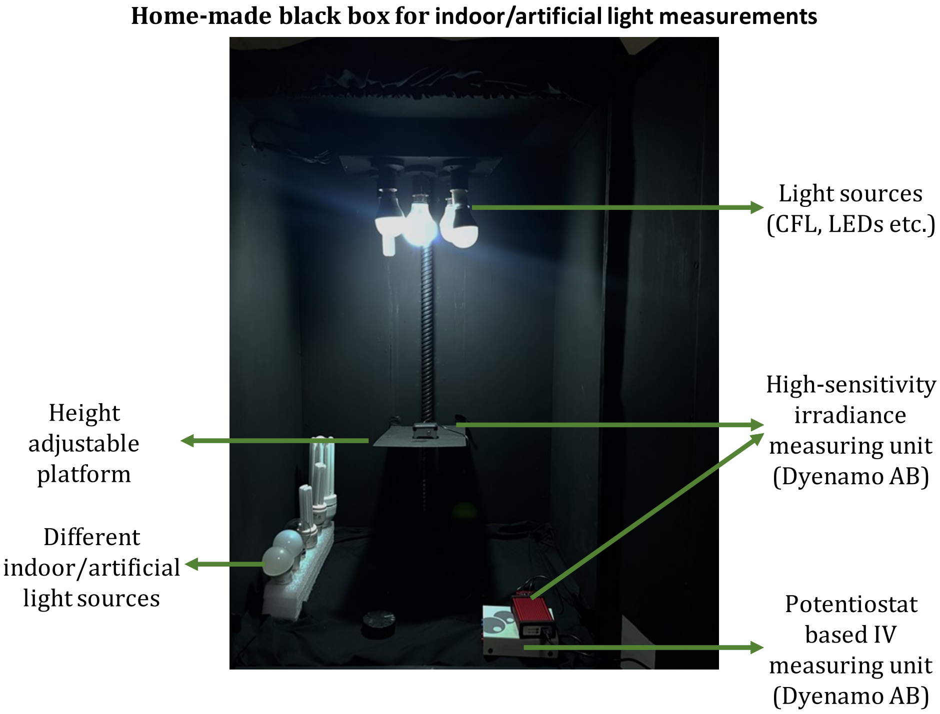


Figure S14. Home-made indoor/artificial light measurement setup integrated with Dyenamo potentiostat measuring unit, irradiance measuring unit, light source and height adjustable platform.

Figure S15 (i-xxxiii). Structural characterization of YK 8 and YK 9 dyes (^{1}H NMR, ^{13}C NMR and HRMS)

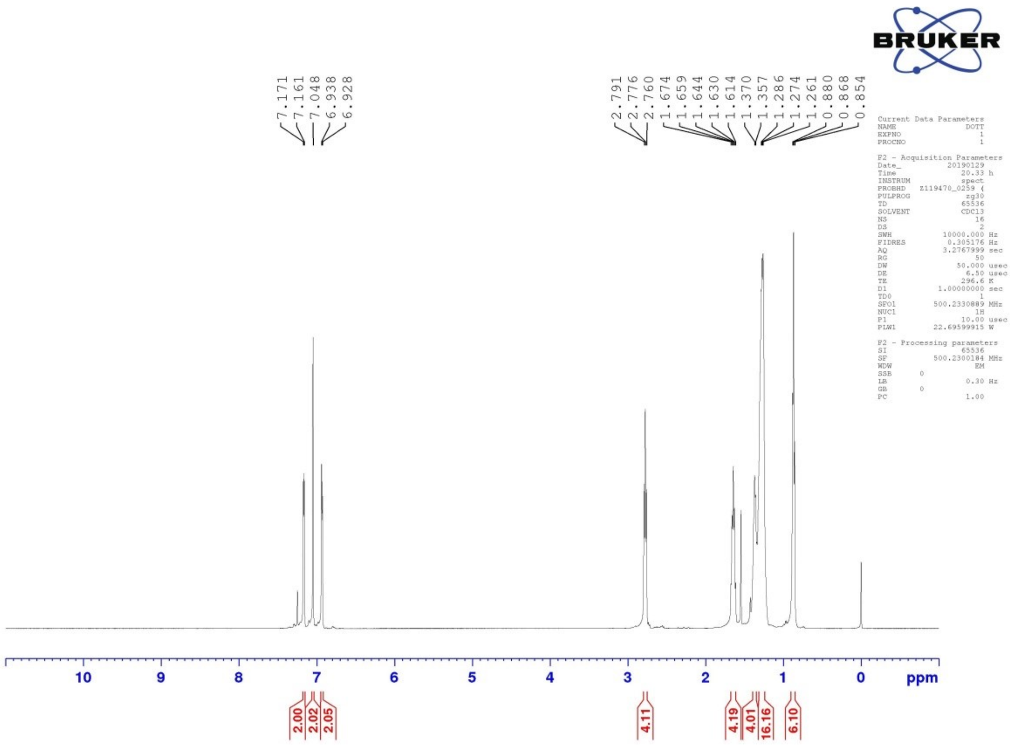


Figure S15 (i). ^{1}H NMR spectrum of compound 1.

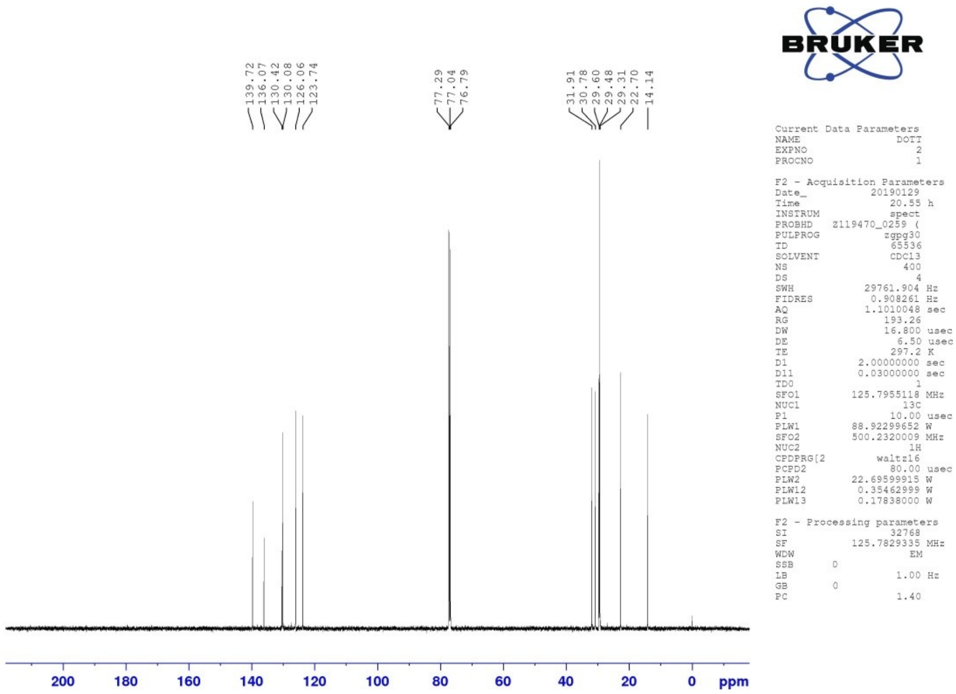


Figure S15 (ii). ^{13}C NMR spectrum of compound 1.

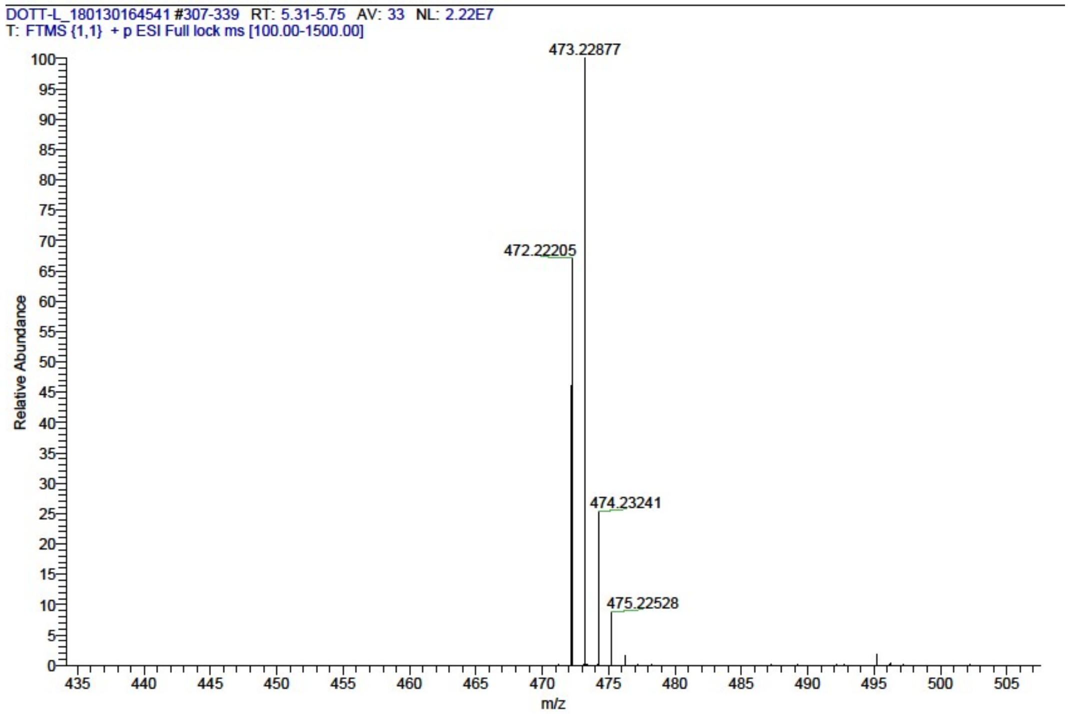


Figure S15 (iii). HRMS spectrum of compound 1.

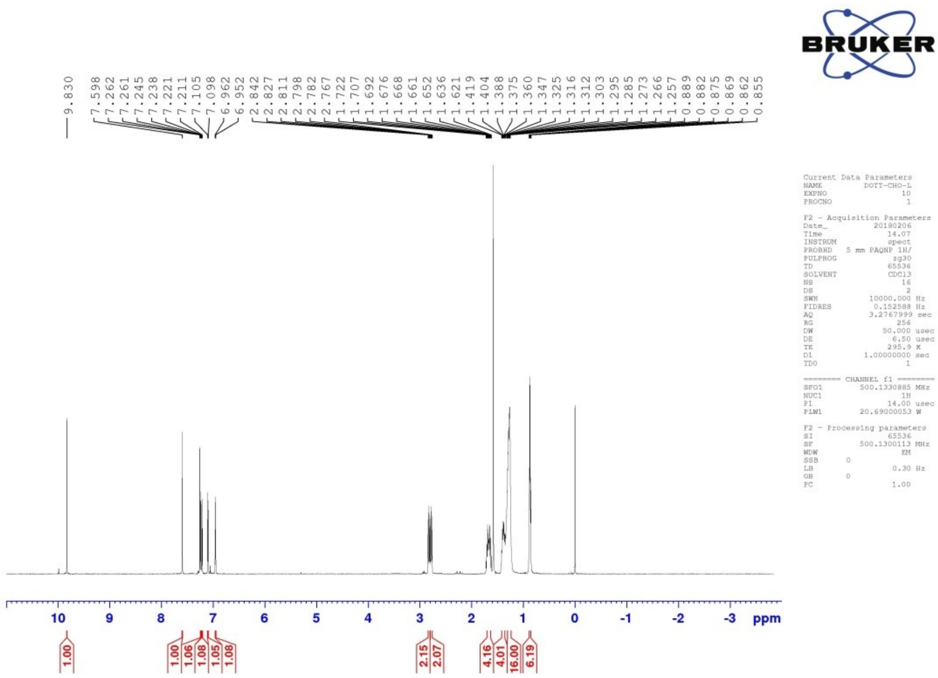


Figure S15 (iv). [1]H NMR spectrum of compound 2.

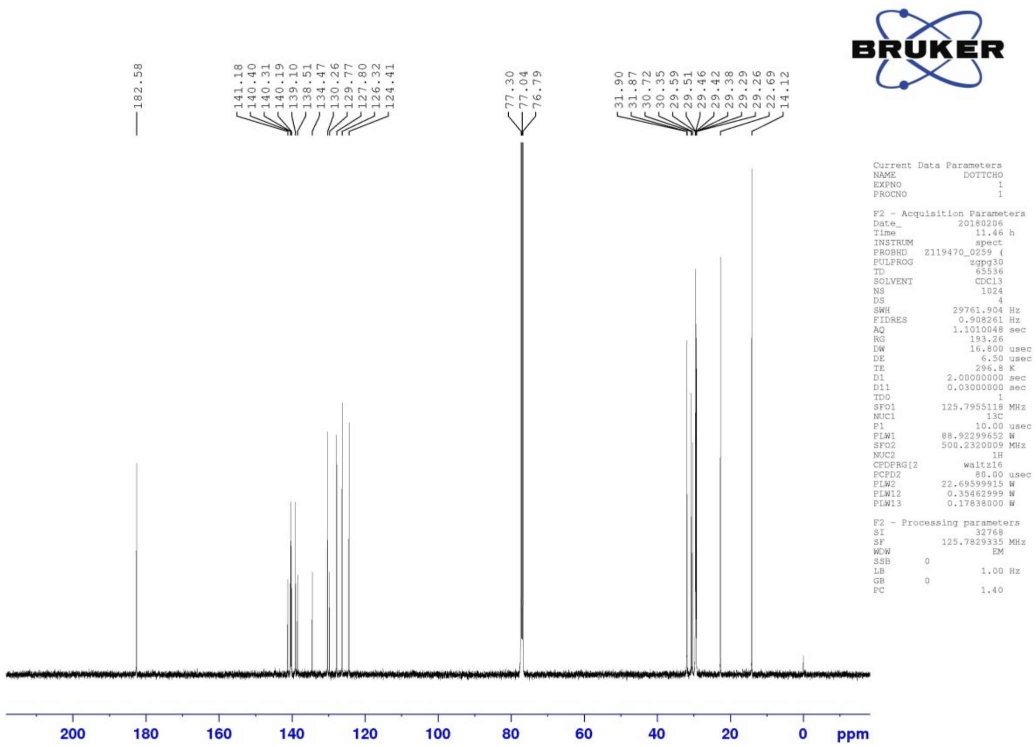


Figure S15 (v). ^{13}C NMR spectrum of compound 2.

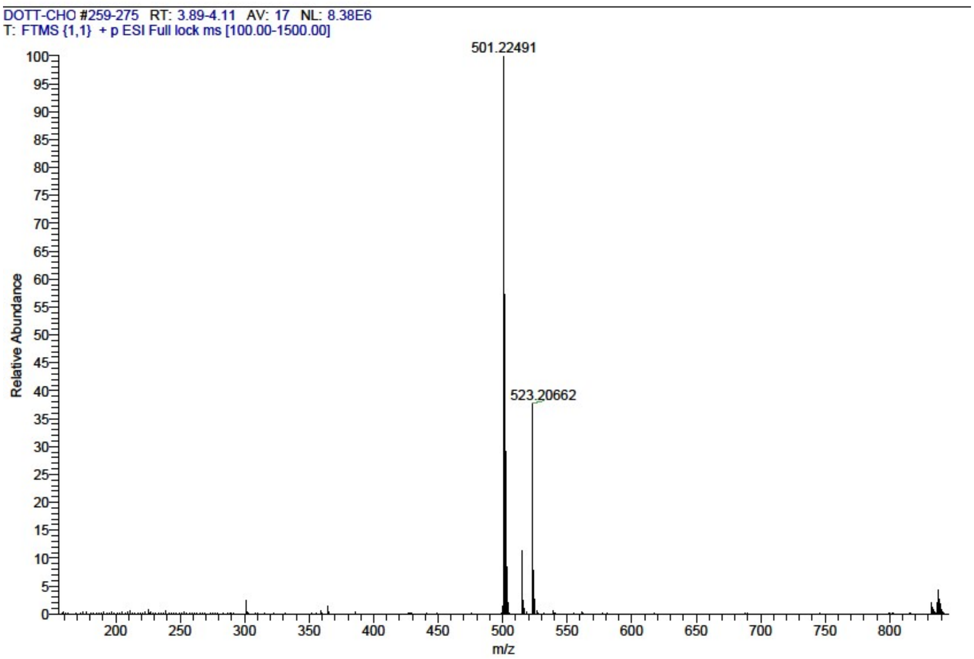


Figure S15 (vi). HRMS spectrum of compound 2.

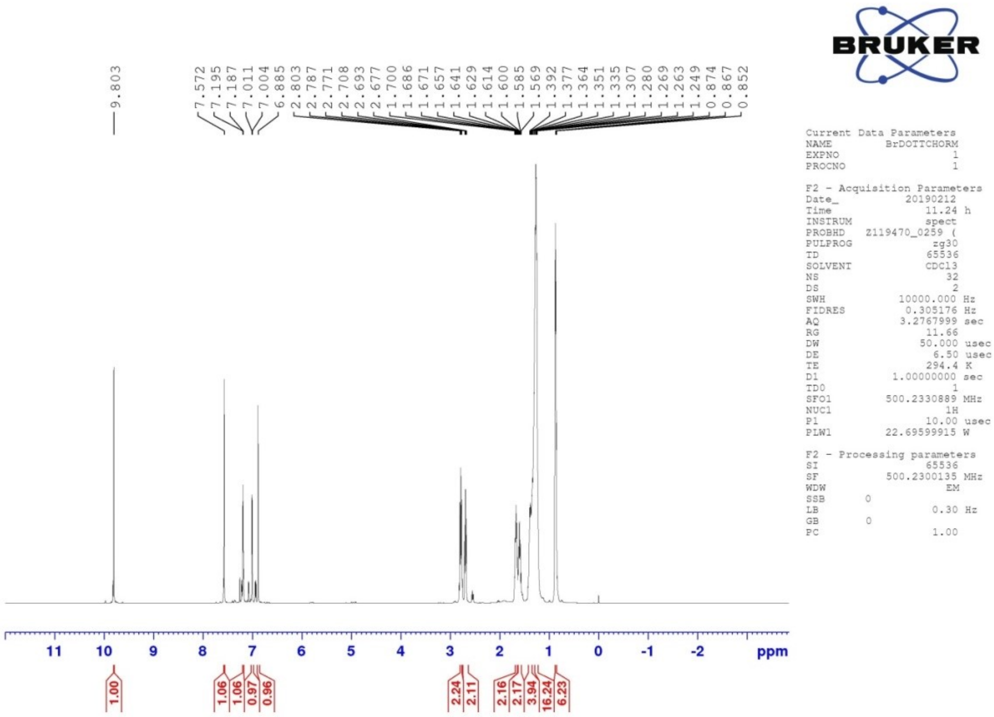


Figure S15 (vii). ^{1}H NMR spectrum of compound 3.

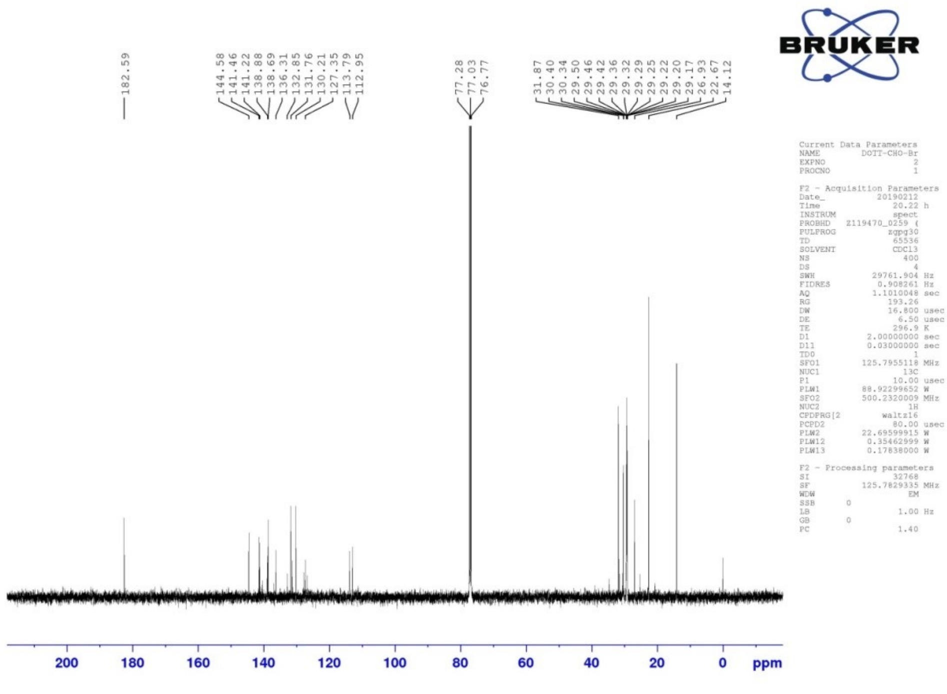


Figure S15 (viii). ^{13}C NMR spectrum of compound 3.

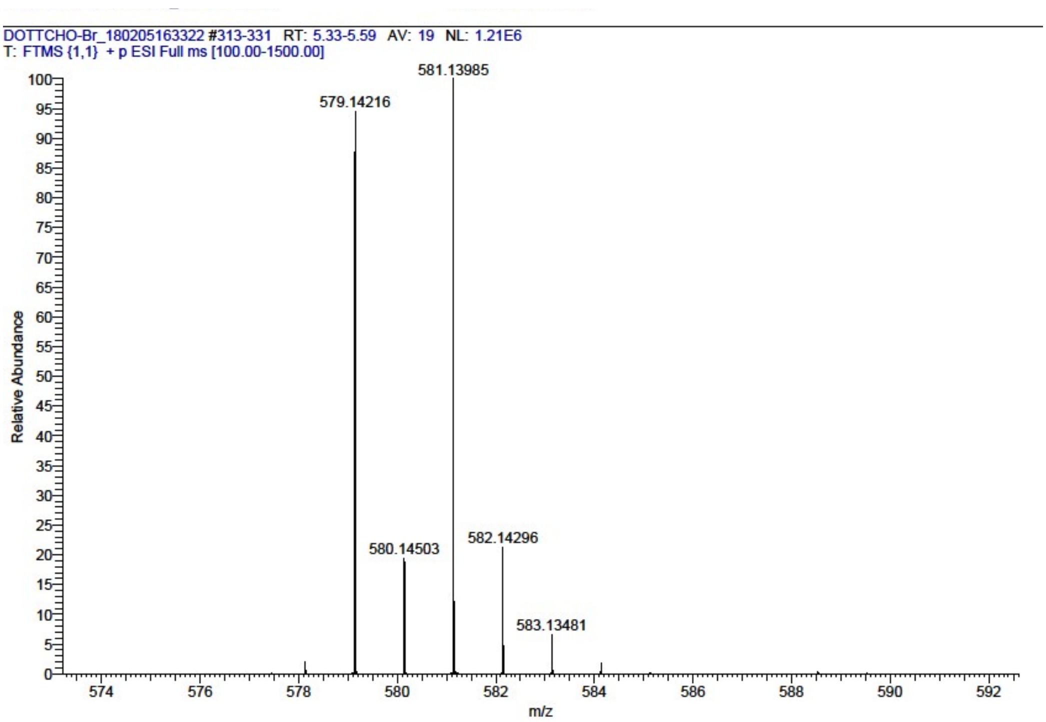


Figure S15 (ix). HRMS spectrum of compound 3.

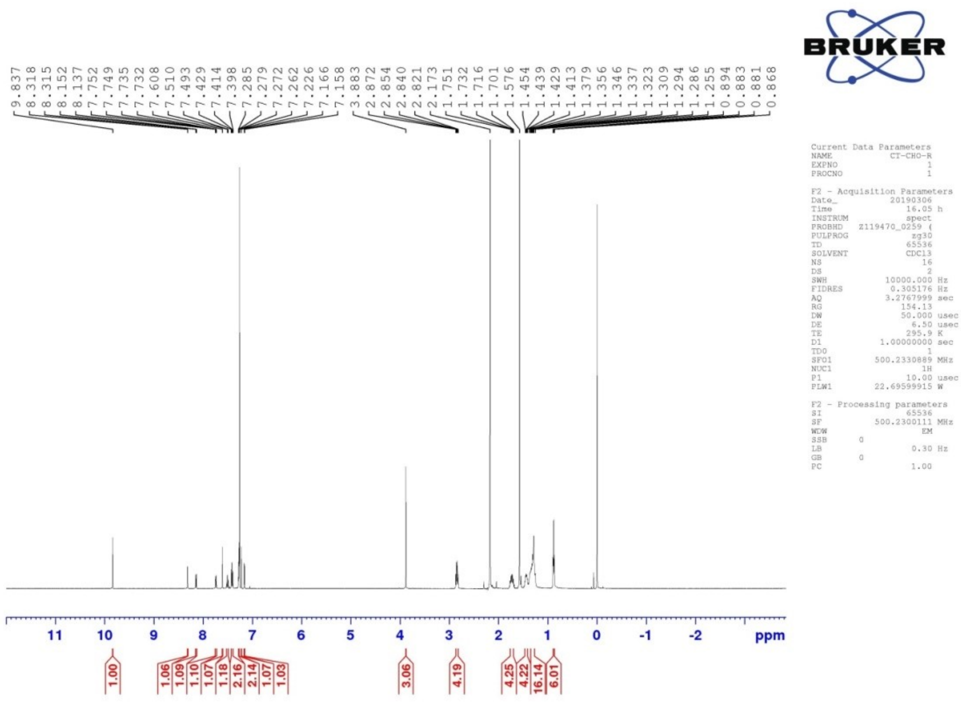


Figure S15 (x). ^{1}H NMR spectrum of compound 4.

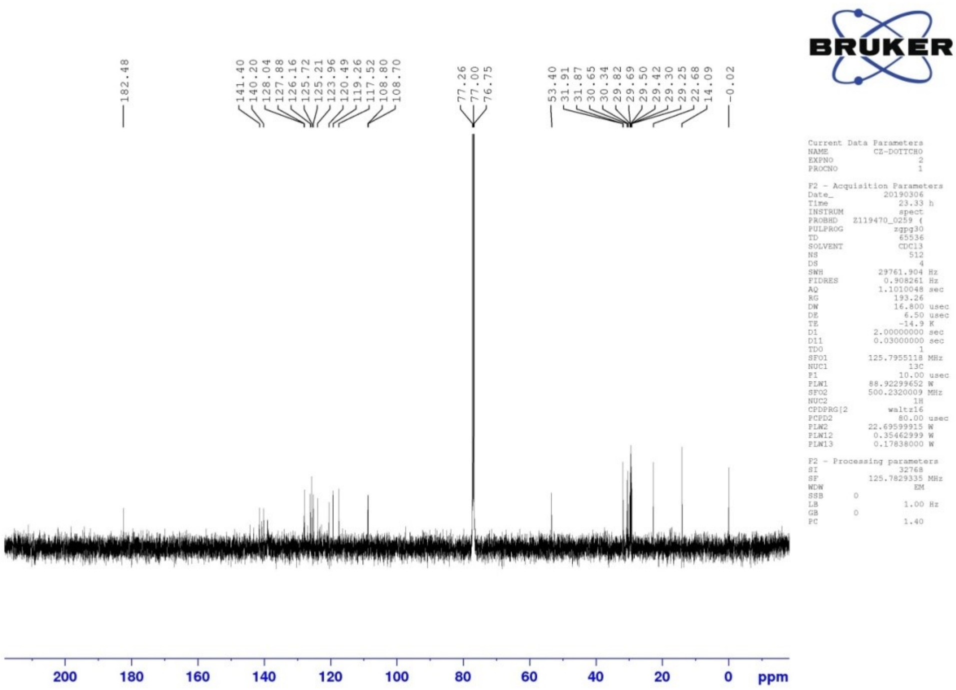


Figure S15 (xi). ^{13}C NMR spectrum of compound 4.

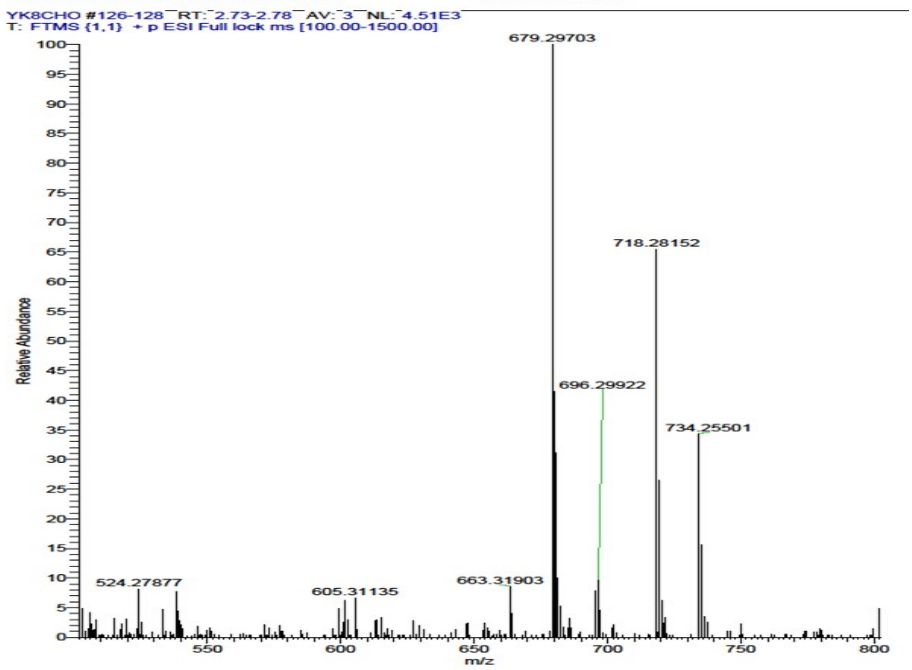


Figure S15 (xii). HRMS spectrum of compound 4.

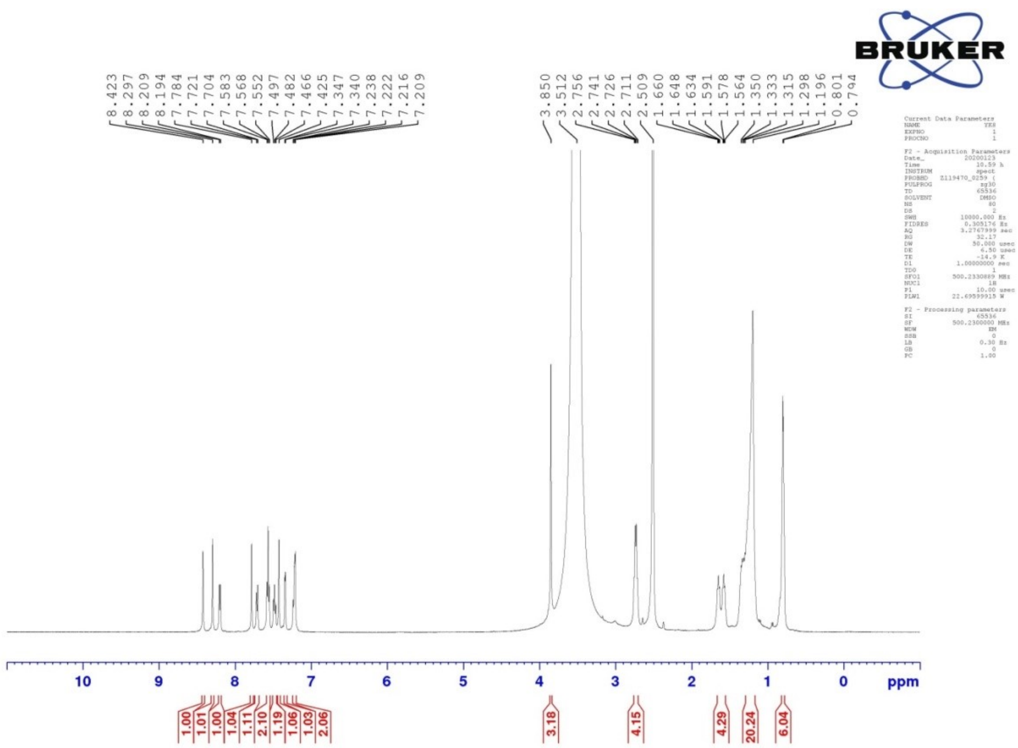


Figure S15 (xiii). ^{1}H NMR spectrum of YK 8 dye.

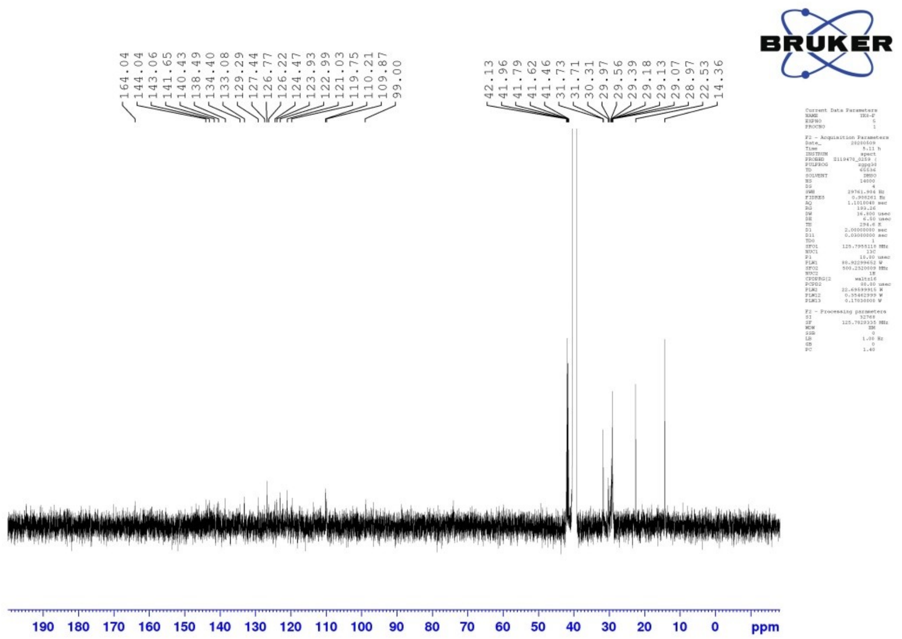


Figure S15 (xiv). ^{13}C NMR spectrum of YK 8 dye.

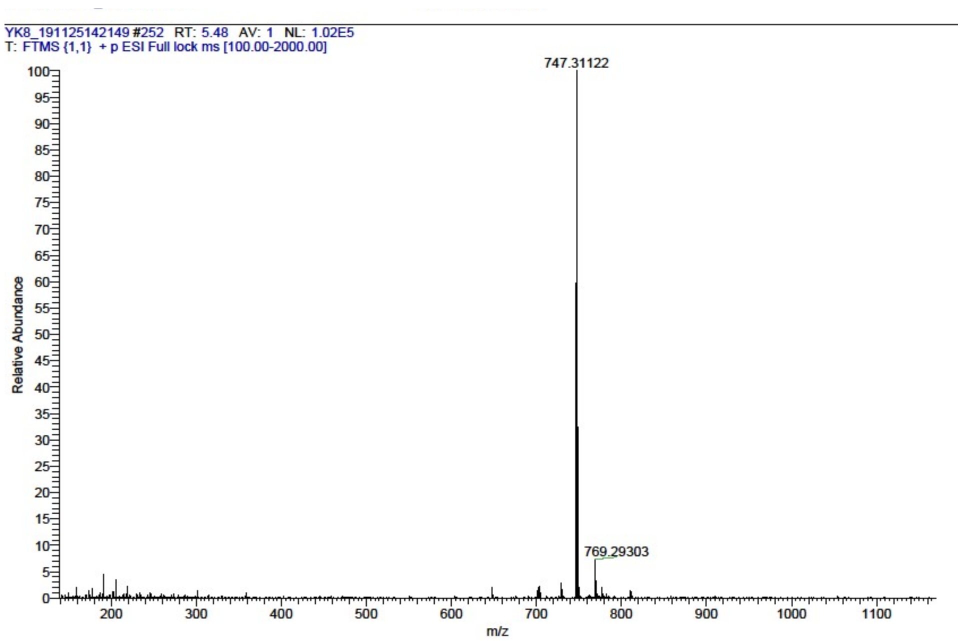


Figure S15 (xv). HRMS spectrum of YK 8 dye.

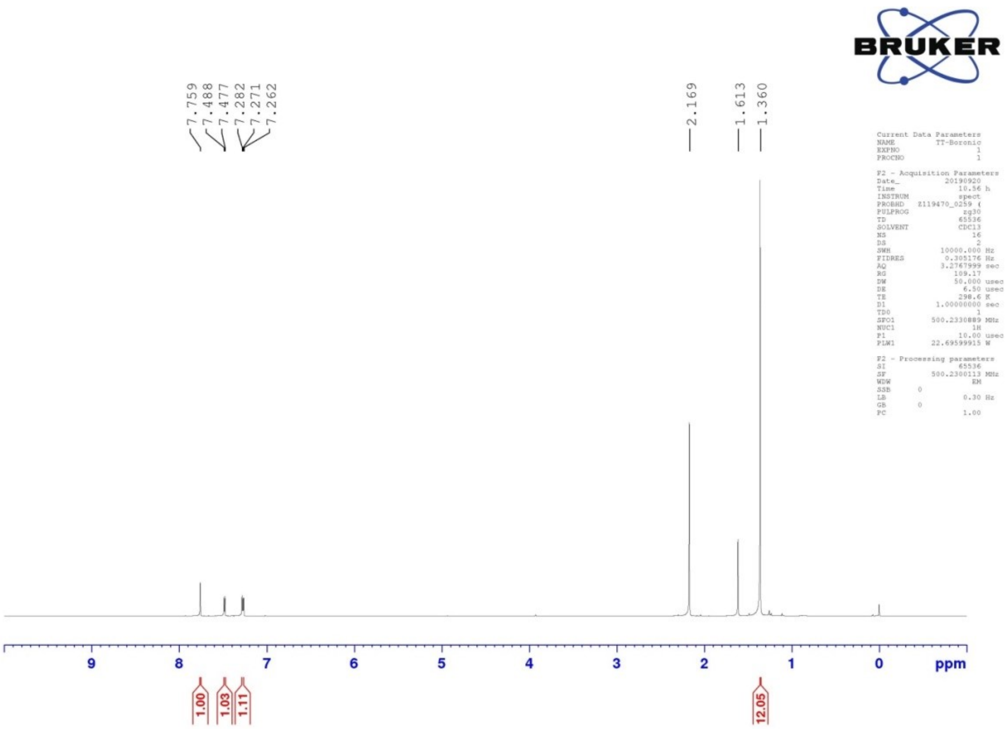


Figure S15 (xvi). ^{1}H NMR spectrum of compound 5.

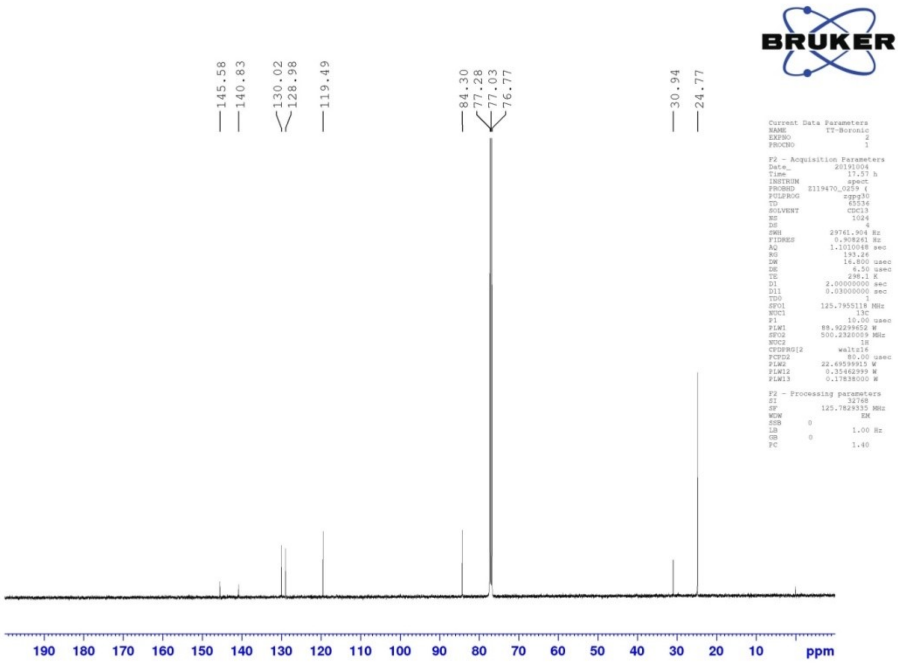


Figure S15 (xvii). ^{13}C NMR spectrum of compound 5.

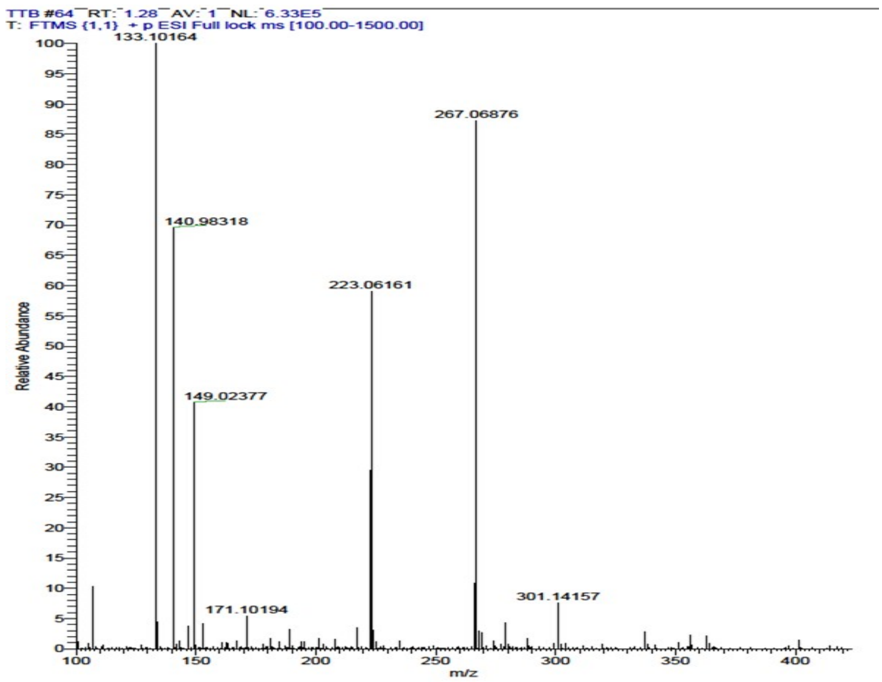


Figure S15 (xviii). HRMS spectrum of compound 5.

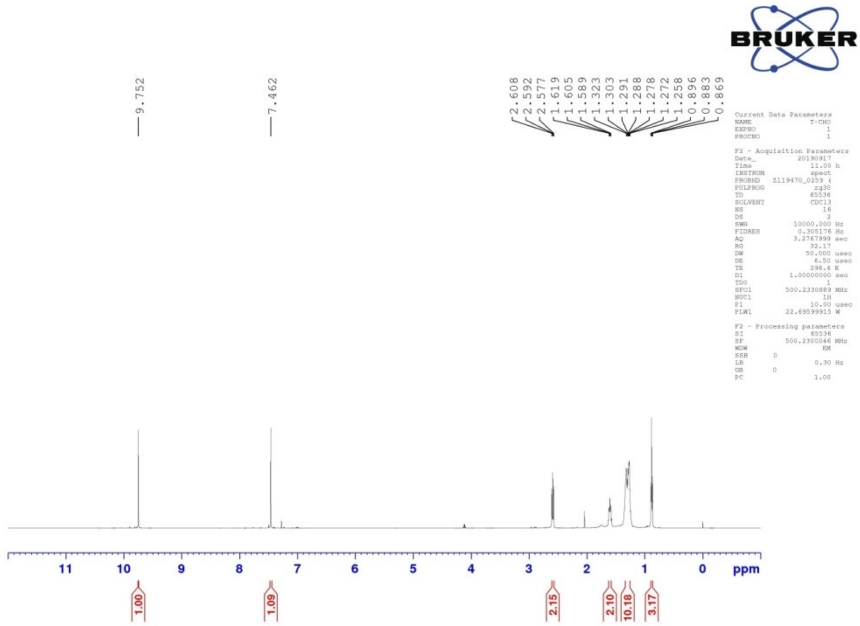


Figure S15 (xix). ^{1}H NMR spectrum of compound 6.

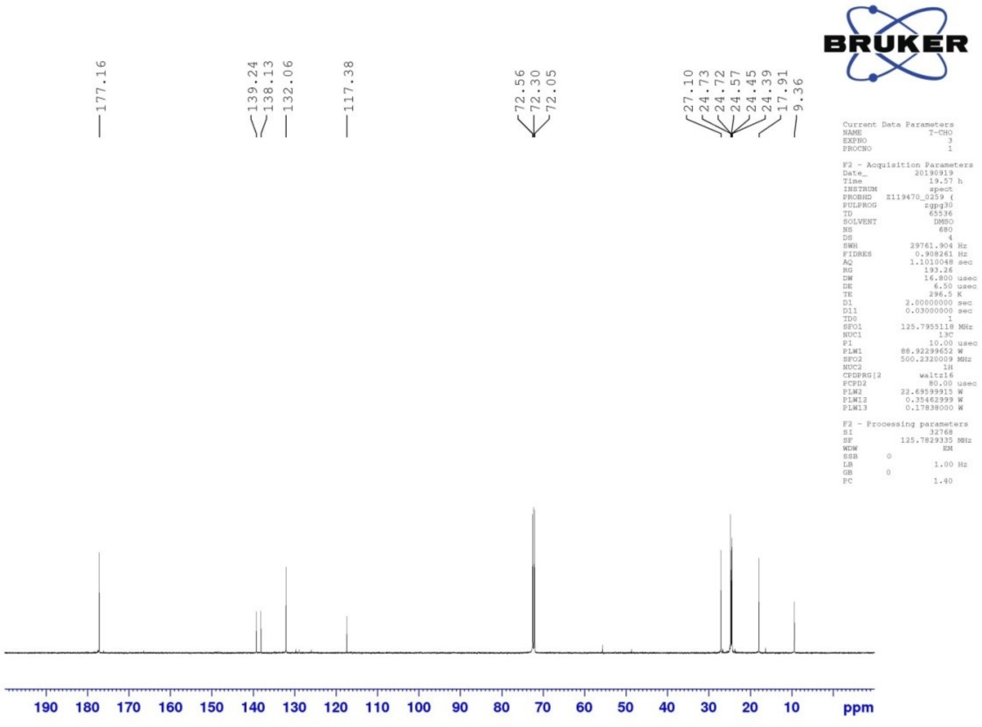


Figure S15 (xx). ^{13}C NMR spectrum of compound 6.

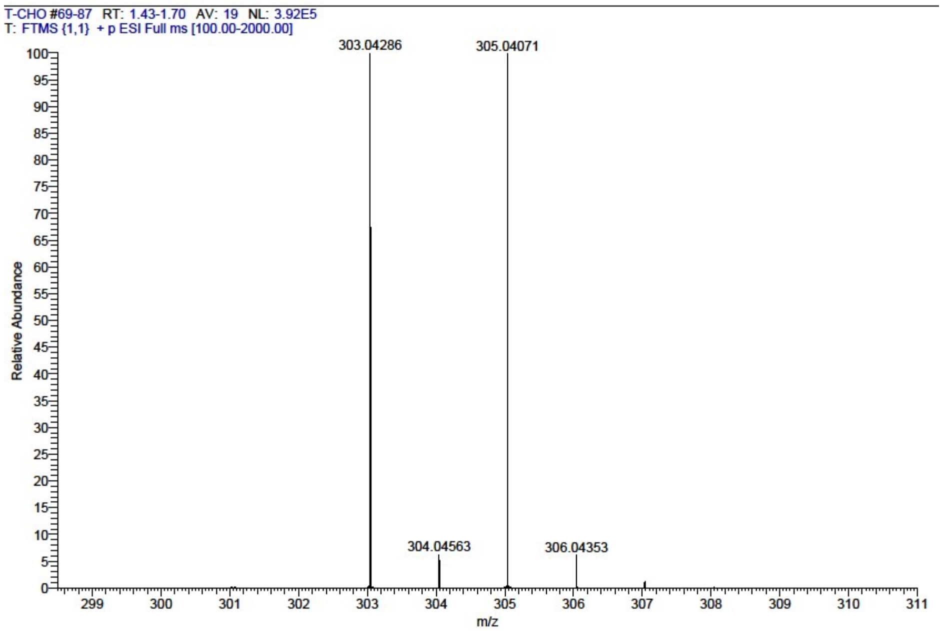


Figure S15 (xxi). HRMS spectrum of compound 6.

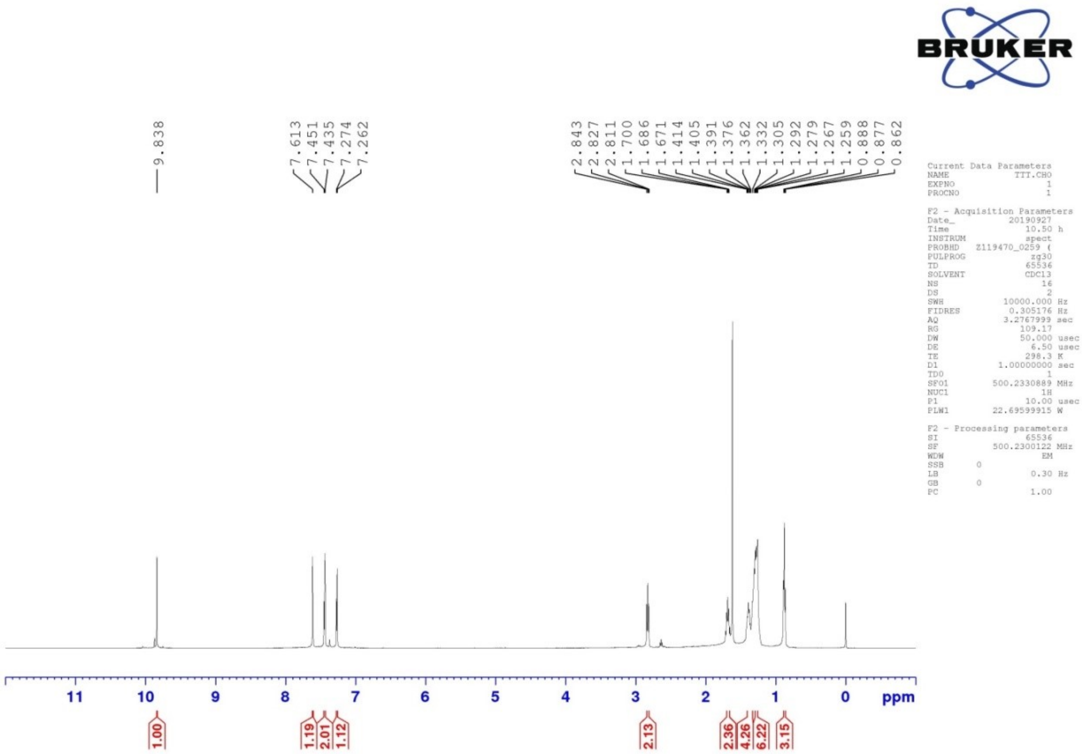


Figure S15 (xxii). ^{1}H NMR spectrum of compound 7.

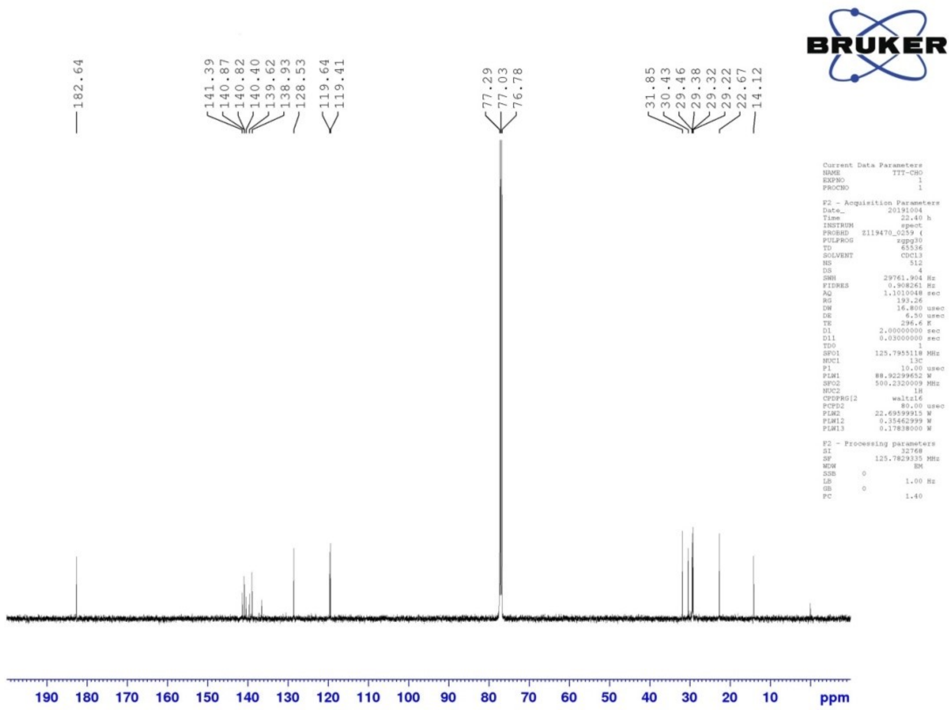


Figure S15 (xxiii). ^{13}C NMR spectrum of compound 7.

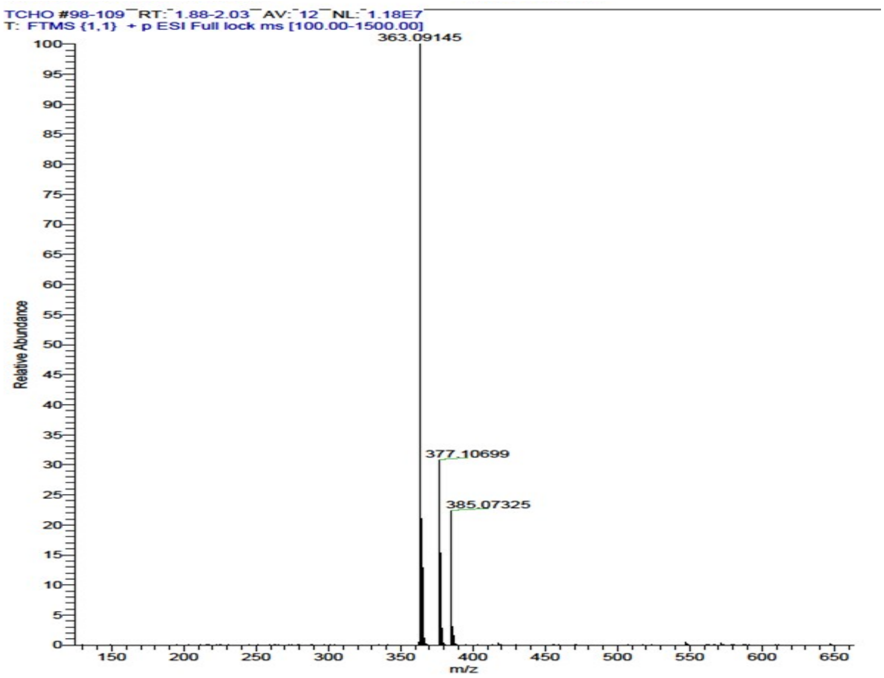


Figure S15 (xxiv). HRMS spectrum of compound 7.

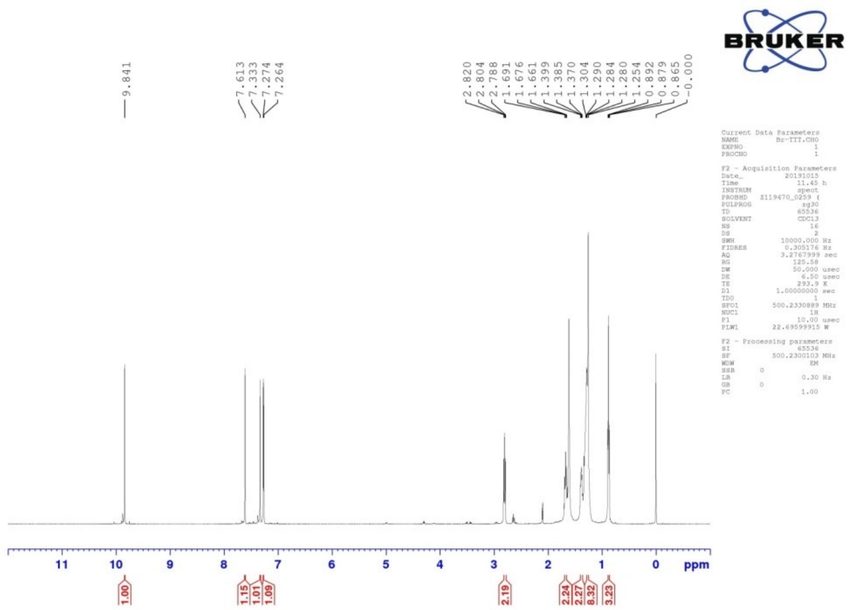


Figure S15 (xxv). ^{1}H NMR spectrum of compound 8.

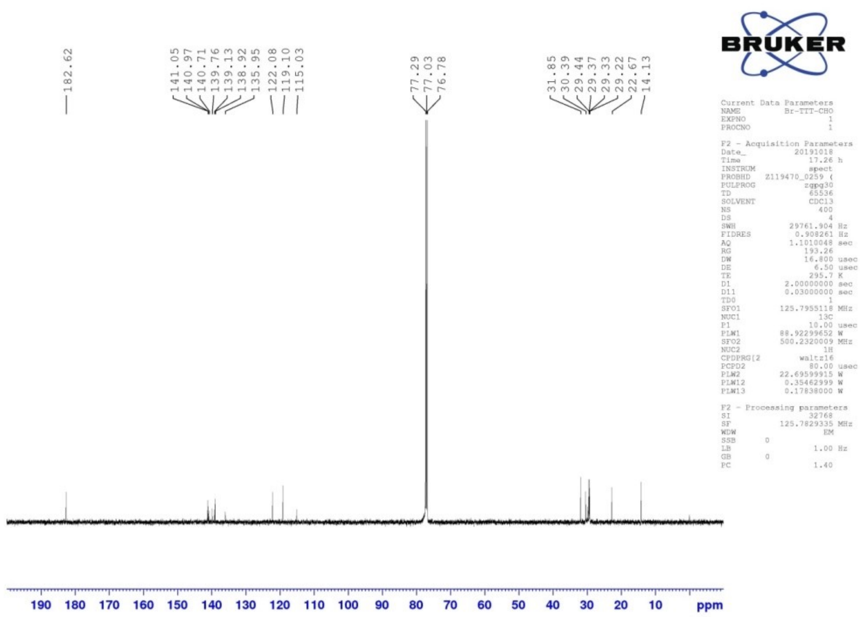


Figure S15 (xxvi). ^{13}C NMR spectrum of compound 8.

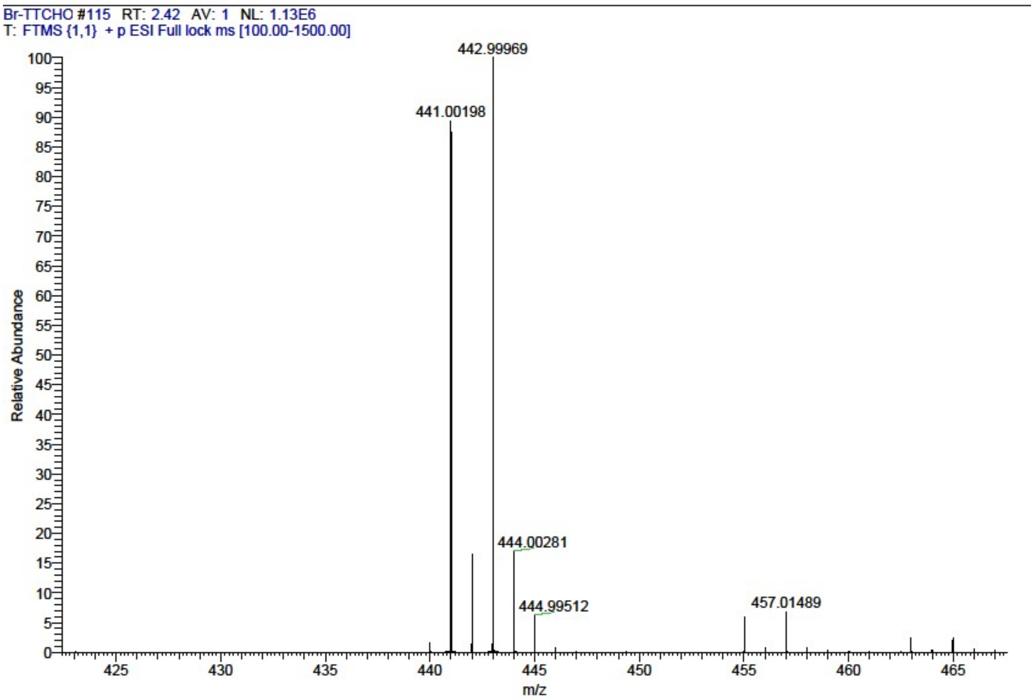


Figure S15 (xxvii). HRMS spectrum of compound 8.

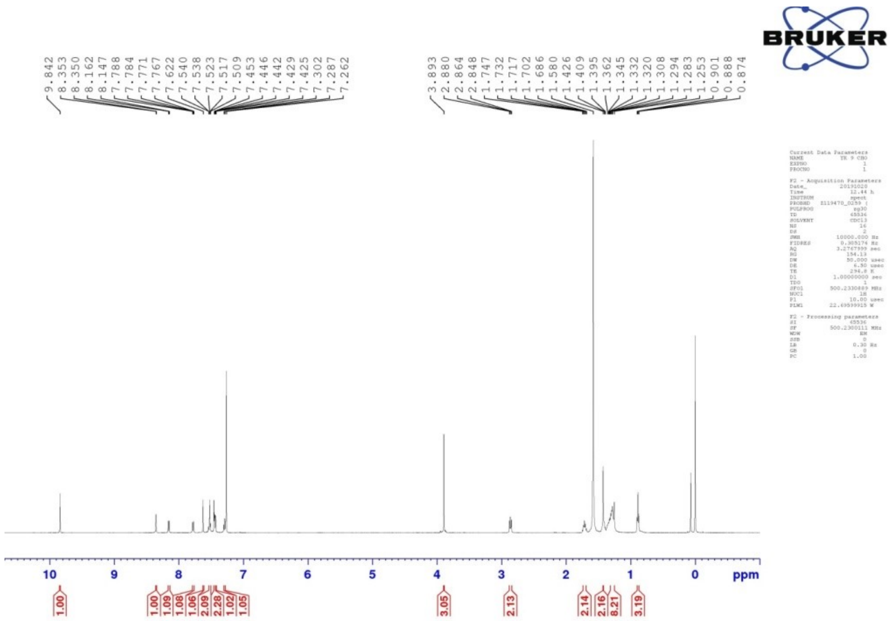


Figure S15 (xxviii). ^{1}H NMR spectrum of compound 9.

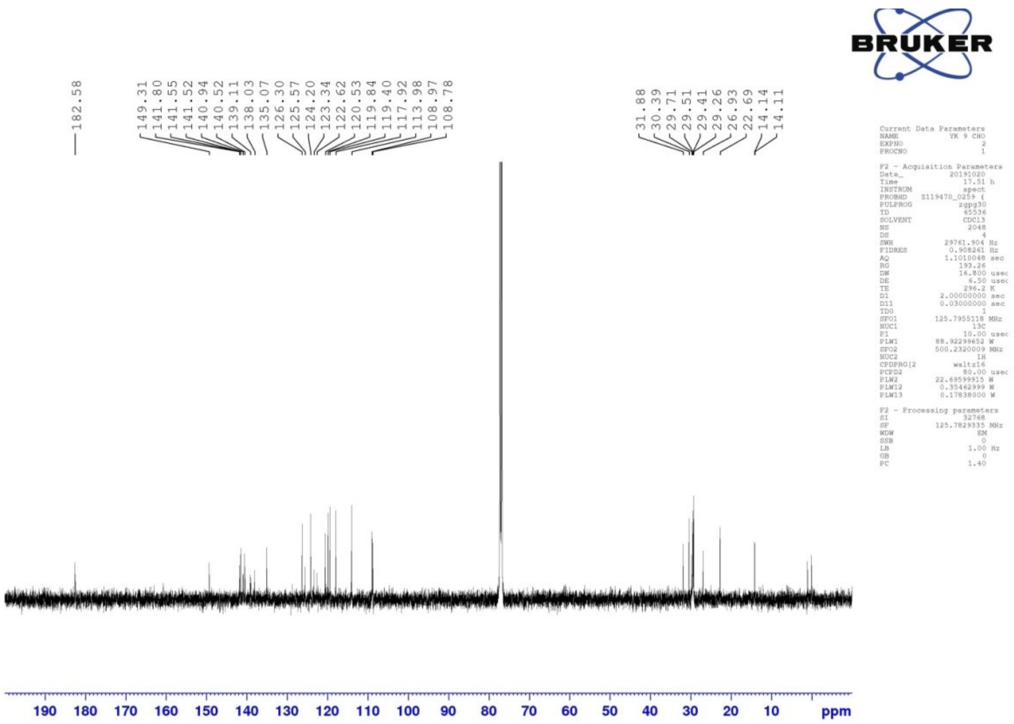


Figure S15 (xxix). ^{13}C NMR spectrum of compound 9.

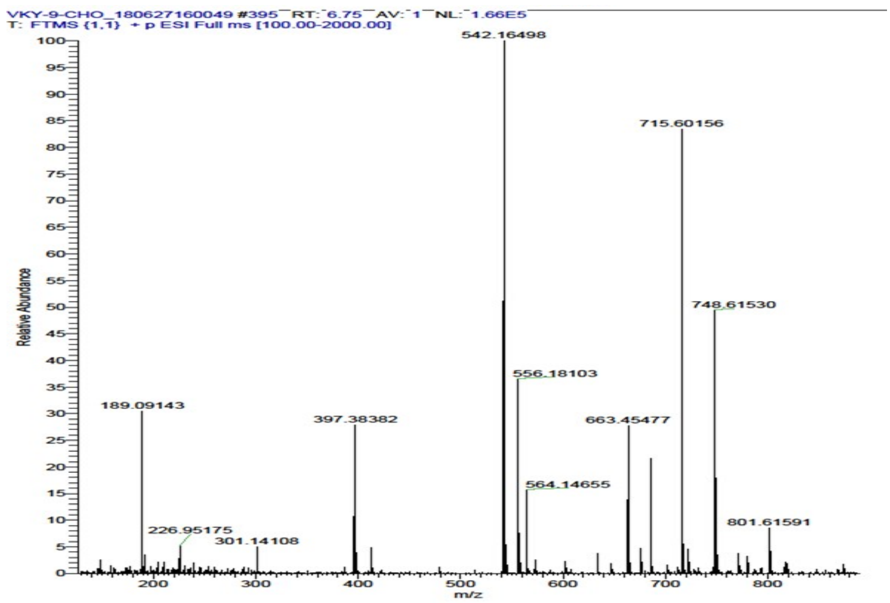


Figure S15 (xxx). HRMS spectrum of compound 9.

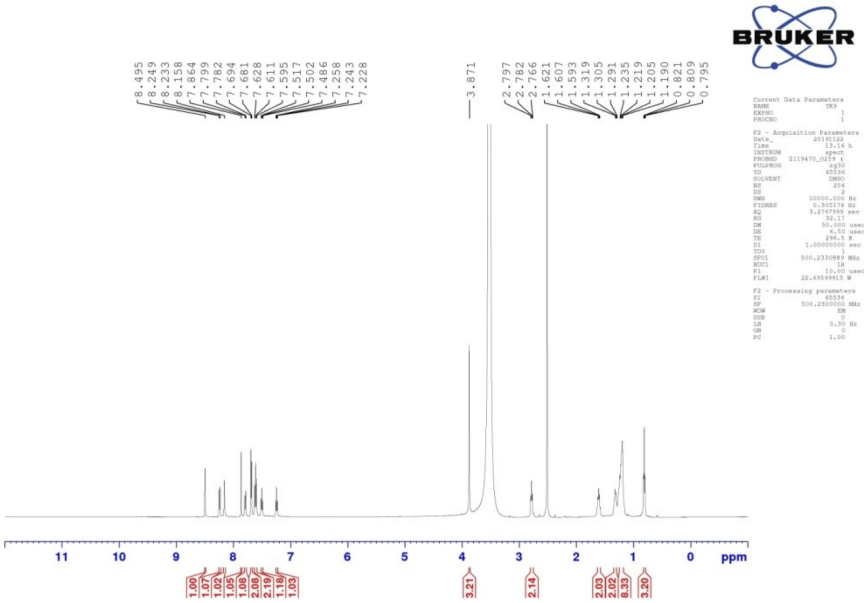


Figure S15 (xxxi). ^{1}H NMR spectrum of YK 9 dye.

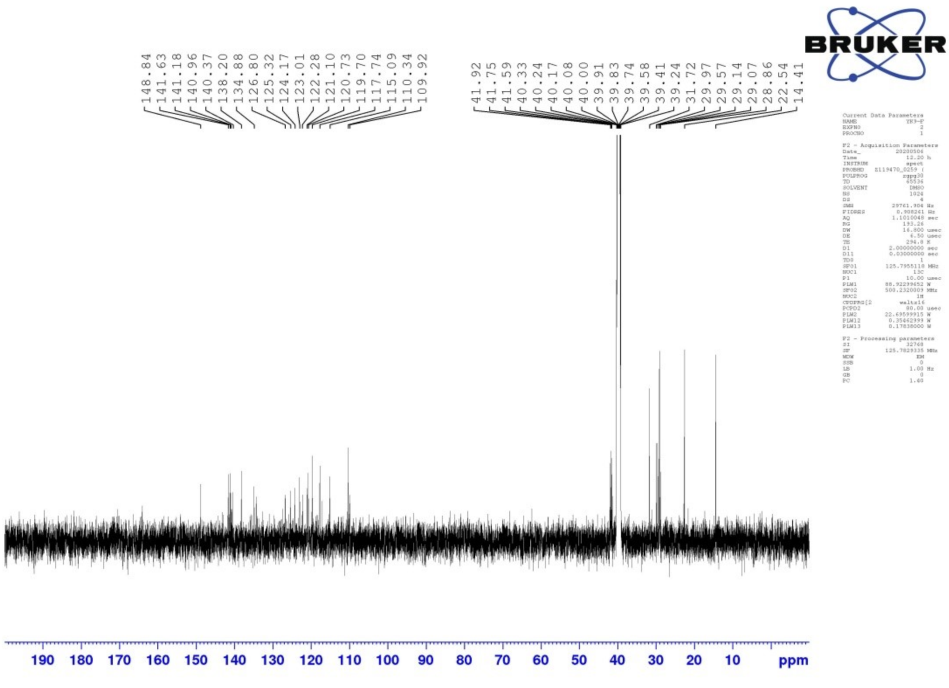


Figure S15 (xxxii). ^{13}C NMR spectrum of YK 9 dye.

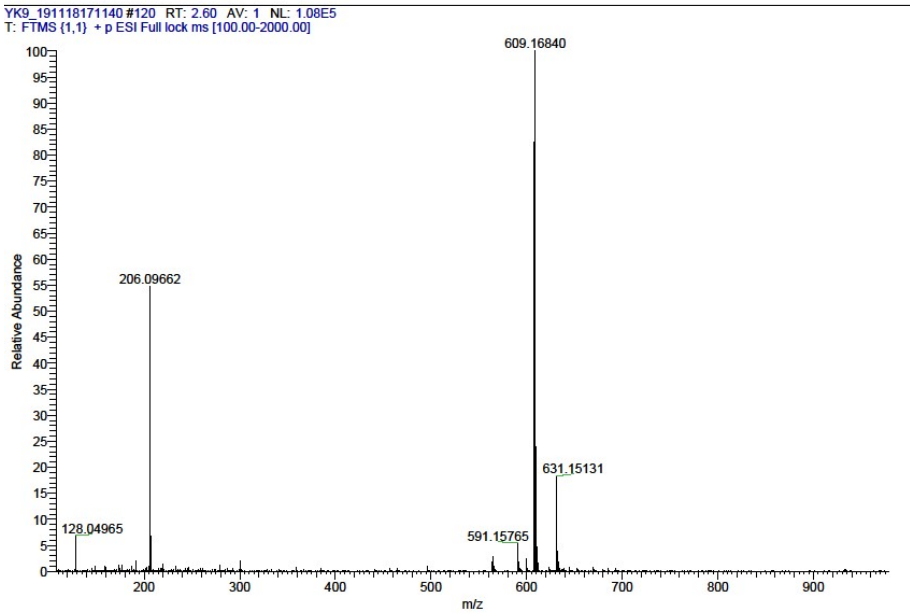
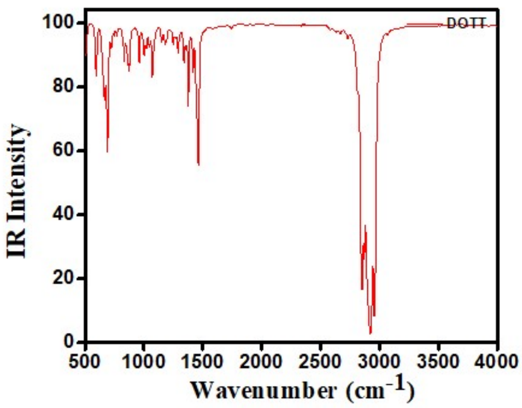


Figure S15 (xxxiii). HRMS spectrum of YK 9 dye.

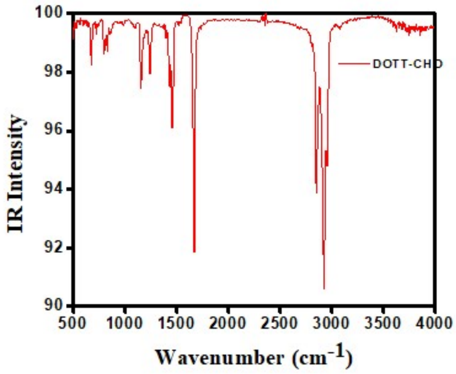
Figure S15 (xxxiv). ATR-FTIR spectra of all major intermediates and YK8 and YK 9 dyes.

Compound 1



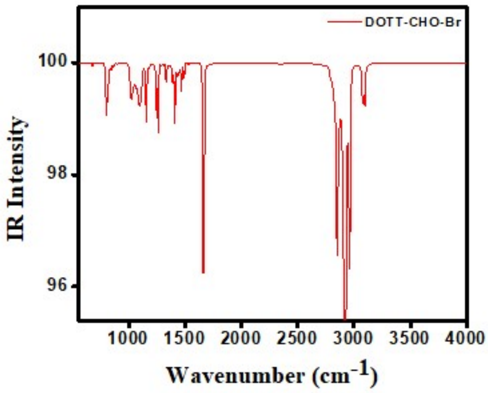
2954 - C-H stretch Alkane
2922 - C-H stretch Alkane
2852 - C-H stretch Alkane
1462 – $-CH_2$ scissor
1417 - aromatic C=C stretch
1433- thiophene ring stretch
1375 - $-CH_3$ bend
1070 – alkane C-C stretch
1290- aromatic C-H in plane bend
900-675 aromatic C-H out of plane bend
721- CH_2 rock
594 – aromatic C=C out of plane bending

Compound 2



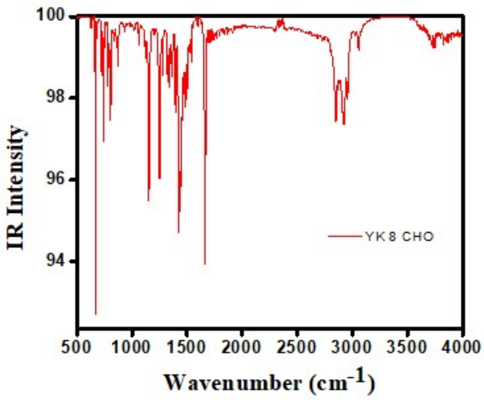
2954 - C-H stretch Alkane
2924 - C-H stretch Alkane
2850 - C-H stretch Alkane
1670 – Ar-conjugated C=O stretch - aldehyde
1456 – C-H bending methyl group
1433 – thiophene ring stretching
1393 – C-H bending aldehyde
1242 - aromatic C-H in plane bend
1155 - alkane C-C stretch
721 - CH_2 rock
900-675 aromatic C-H out of plane bend

Compound 3



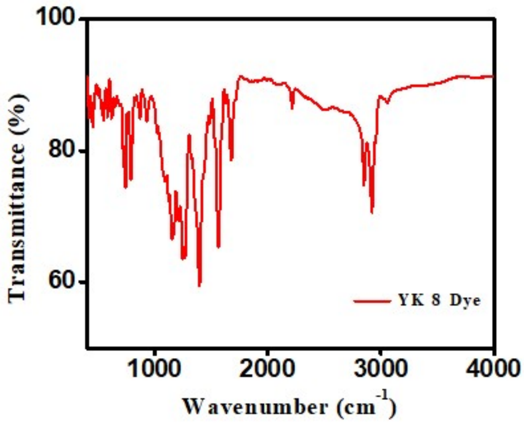
3079- Aromatic C-H stretch
2960 - C-H stretch Alkane
2920 - C-H stretch Alkane
2850 - C-H stretch Alkane
1662 - Ar-conjugated C=O stretch - aldehyde
1467 - C-H bending methyl group
1390 - C-H bending aldehyde
1245 - aromatic C-H in plane bend
1156 - alkane C-C stretch
900-690 aromatic C-H out of plane bend

Compound 4



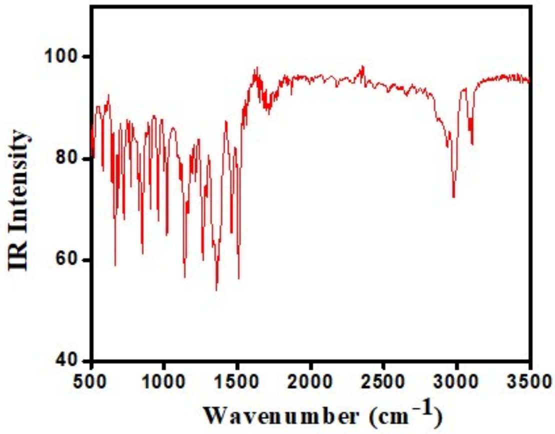
3057 - Aromatic C-H stretch
2954 - C-H stretch Alkane
2924 - C-H stretch Alkane
2848 - C-H stretch Alkane
1664 - Ar-conjugated C=O stretch - aldehyde
1427 - thiophene ring stretching
1393 – C-H bending aldehyde
1249 - aromatic C-H in plane bend
1153 - alkane C-C stretch
723 - CH_2 rock
900-690 aromatic C-H out of plane bend

YK 8



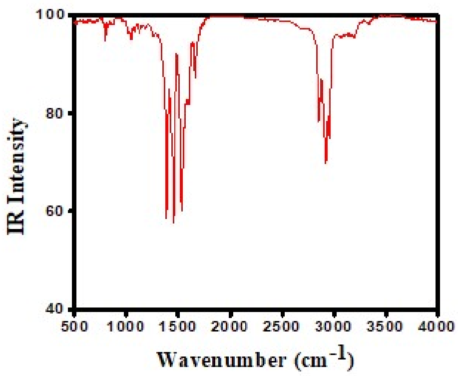
3060 – Aromatic C-H stretch
2920 – C-H stretch Alkane
2851 - C-H stretch Alkane
2216 – C-N stretch Nitrile
1678 – C=O stretch conjugated carboxylic acid
1563 – aromatic C=C stretch
1397 – aromatic C=C stretch
1267 - aromatic C-H in plane bend
900-690 aromatic C-H out of plane bend
723 – CH_2 Rocking

Compound 5



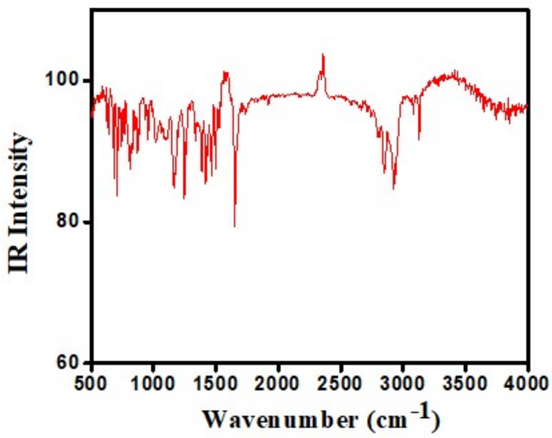
3103 - Aromatic C-H stretch
3084 - Aromatic C-H stretch
2976 - C-H stretch Alkane
2933 - C-H stretch Alkane
1460 - aromatic C=C stretch
1357 - $-CH_3$ bend
1265 - aromatic C-H in plane bend
1139 - alkane C-C stretch
900-675 aromatic C-H out of plane bend

Compound 6



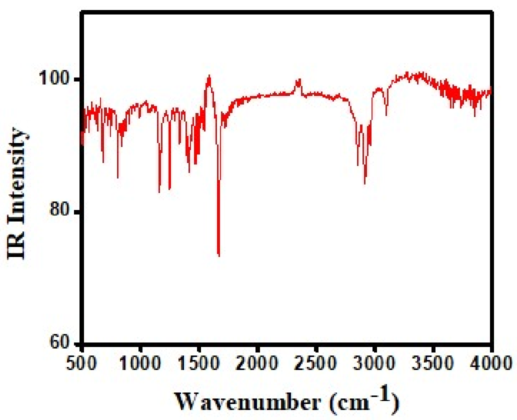
3089 - Aromatic C-H stretch
2956 - C-H stretch Alkane
2922 - C-H stretch Alkane
2870 -C-H stretch Alkane
1665 - Ar-conjugated C=O stretch - aldehyde
1531 - aromatic C=C stretch
1456 - $-CH_2$ scissor
1384- C-H bending aldehyde
1253 - aromatic C-H in plane bend
900-675 aromatic C-H out of plane bend

Compound 7



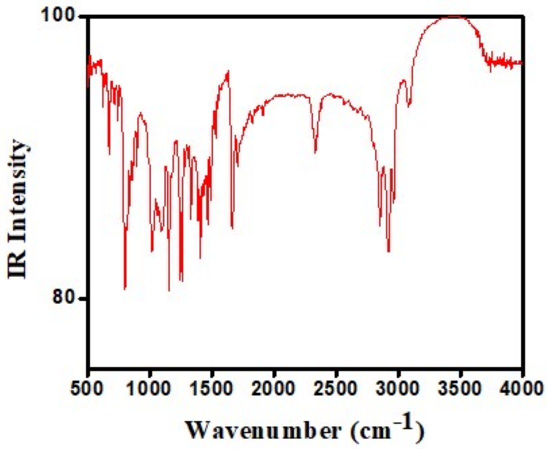
3130 - Aromatic C-H stretch
3082 - Aromatic C-H stretch
2943 - C-H stretch Alkane
2926 - C-H stretch Alkane
2848 -C-H stretch Alkane
1651- Ar-conjugated C=O stretch - aldehyde
1496 – aromatic C=C stretch
1465 - $-CH_2$ scissor
1386 - C-H bending aldehyde
1246 - aromatic C-H in plane bend
1165 - alkane C-C stretch
900-675 aromatic C-H out of plane bend

Compound 8



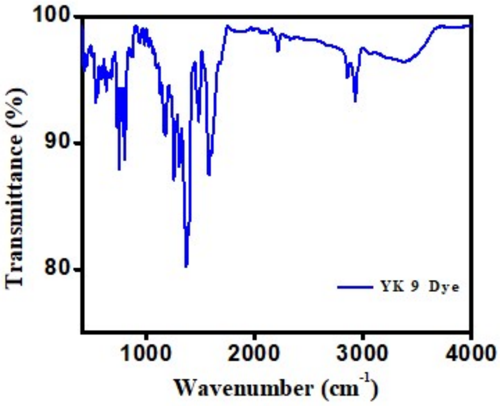
3097 - Aromatic C-H stretch
2956 - C-H stretch Alkane
2922 - C-H stretch Alkane
2852 -C-H stretch Alkane
1662- Ar-conjugated C=O stretch - aldehyde
1490 – aromatic C=C stretch
1467 - $-CH_2$ scissor
1390 - C-H bending aldehyde
1246 - aromatic C-H in plane bend
1159 - alkane C-C stretch
900-675 aromatic C-H out of plane bend

Compound 9



3097 - Aromatic C-H stretch
3080 - Aromatic C-H stretch
2961- C-H stretch Alkane
2921 - C-H stretch Alkane
2849 - C-H stretch Alkane
1663 - Ar-conjugated C=O stretch - aldehyde
1534 - aromatic C=C stretch
1491 - aromatic C=C stretch
1467 - $-CH_2$ scissor
1390 - aromatic C=C stretch
1245 - aromatic C-H in plane bend
1156 - alkane C-C stretch
900-690 aromatic C-H out of plane bend

YK 9



3070 - Aromatic C-H stretch
2924 - C-H stretch Alkane
2852 - C-H stretch Alkane
2212 - C-N stretch Nitrile
1679 - C=O stretch conjugated carboxylic acid
1574 - aromatic C=C stretch
1364 - aromatic C=C stretch
1248 - aromatic C-H in plane bend
900-690 aromatic C-H out of plane bend
727 - CH_2 Rocking

ATR-FTIR spectra of all major intermediates and YK8 and YK 9 dyes.

TABLES

	V_{oc} (mV)	J_{sc} ($mAcm^{-2}$)	*FF* (%)	Efficiency (%)
YK 8_(6μm)	699 ± 1	14.67 ± 0.12	64.52 ± 0.14	6.62 ± 0.04
YK 9_(6μm)	650 ± 4	14.88 ± 0.29	67.63 ± 0.60	6.55 ± 0.21
YK 8_(10μm)	691 ± 1	13.71 ± 0.04	66.49 ± 0.09	6.30 ± 0.02
YK 9_(10μm)	625 ± 2	12.71 ± 0.04	69.35 ± 0.18	5.51 ± 0.02

Table S1. Tabulated PV data for optimization of semiconductor architecture for YK 8 and YK 9 without CDCA.

(a) YK 8

CDCA Concentration	V_{oc} (mV)	J_{sc} ($mAcm^{-2}$)	*FF* (%)	Efficiency (%)
w.o CDCA	699 ± 1	14.67 ± 0.12	64.52 ± 0.14	6.62 ± 0.04
1 mM CDCA	670 ± 1	17.23 ± 0.22	64.86 ± 0.12	7.49 ± 0.06
2.5 mM CDCA	651 ± 1	16.83 ± 0. 02	67.39 ± 0.16	7.37 ± 0.02
5 mM CDCA	660 ± 1	17.91 ± 0.7	62.71 ± 0.09	7.40 ± 0.02
10 mM CDCA	644± 3	13.89 ± 0.76	67.26 ± 0.48	6.02 ± 0.12

(b) YK 9

CDCA Concentration	V_{oc} (mV)	J_{sc} ($mAcm^{-2}$)	*FF* (%)	Efficiency (%)
w.o. CDCA	650 ± 4	14.88 ± 0.29	67.63 ± 0.60	6.55 ± 0.21
1 mM CDCA	594 ± 1	12.58 ± 0.04	63.83 ± 0.74	4.77 ± 0.05
2.5 mM CDCA	586 ± 2	14.04 ± 0.05	64.99 ± 0.43	5.39 ± 0.03
5 mM CDCA	710 ± 2	14.10 ± 0.10	67.93 ± 0.54	6.90 ± 0.10
10 mM CDCA	630 ± 4	13.43 ± 0.14	64.31 ± 0.33	5.44 ± 0.07

Table S2. Tabulated PV data for optimization of co-adsorbent concentration (a) YK 8 and (b) YK 9.

	V_{oc} (mV)	J_{sc} (mAcm^{-2})	FF (%)	Efficiency (%)
MK 2	751 ± 1	15.11 ± 0.07	68.26 ± 0.15	7.74 ± 0.04

Table S3. Solar cell characteristics of DSCs based on MK 2 sensitizer under 1 sun AM 1.5G irradiation.

	V_{oc} (mV)	J_{sc} (mAcm^{-2})	Integrated J_{sc} (mAcm^{-2})	FF (%)	Efficiency (%)
YK 8	790 ± 6	17.24 ± 0.10	17.02	68.93 ± 0.29	9.39 ± 0.18
YK 9	750 ± 1	14.26 ± 0.02	13.71	69.91 ± 0.35	7.48 ± 0.03

Table S4. Summary of photovoltaic performance of DSCs based on YK 8 and YK 9 dyes after ageing the devices for 2700 h.

Intensity	Input Power (µW/cm^2)	Output Power (µW/cm^2)	V_{oc} (mV)	J_{sc} (µAcm^{-2})	FF (%)	Efficiency (%)
700 Lux	160	32.69	638 ± 7	89 ± 2	58.31 ± 1.21	20.43 ± 0.57
1000 Lux	240	57.72	649 ± 7	132 ± 4	66.26 ± 1.20	24.05 ± 0.47
1500 Lux	360	92.65	669 ± 6	195 ± 11	71.99 ± 1.69	25.74 ± 0.46
2000 Lux	480	129.41	669 ± 1	256 ± 10	76.59 ± 2.11	26.96 ± 0.49

Table S5: Tabulated photovoltaic results of DSCs under Osram 14 W T2 cool day light fluorescent tube illumination for MK 2 sensitizer at 700 lux, 1000 lux, 1500 lux and 2000 lux intensities.

Table S6. Comparison of the indoor photovoltaic performance of YK 8 and YK 9 sensitizers with other dyes reported so far which are measured under similar conditions using iodide/triiodide electrolyte.

	Intensity (lux)/ Light source	**Input power (μWcm^{-2})**	**V_{oc} (mV)**	**J_{sc} (μAcm^{-2})**	**FF (%)**	**Efficiency (%)**	**Reference**
YK 8	**1000/ T2 CFL**	**240**	**669± 7**	**141 ±3**	**72.10 ±1.28**	**28.70 ± 1.14**	**Present Work**
YK 8	1500/ T2 CFL	360	679 ± 1	200 ± 2	80.03 ± 2.30	**30.24 ± 1.23**	**Present Work**
YK 9	**1000/ T2 CFL**	**240**	**589± 7**	**103± 2**	**58.39± 1.55**	**14.21 ± 0.56**	**Present Work**
YK 9	1500/ T2 CFL	360	608 ± 6	154 ± 4	69.51 ± 2.26	**17.84 ± 1.17**	**Present Work**
TY6	1200/T5	345	671	164	77.8	24.43	[1]
GJ-P	1200/T5	352.3	532	117.49	73.4	12.14	[2]
GJ-BP	1200/T5	352.3	508	127.29	72.2	13.26	[2]
MM-6+MM-3	1000/TL84	185	598 ± 3	137 ±3.8	65± 0.25	28.7 ± 1.0	[3]
MM-6	1000/TL84	185	570 ± 4	128 ±3.7	70± 1.22	27.6 ± 1.8	[3]
MM-3	1000/TL84	185	436 ± 3	65.8 ±2.5	62± 0.55	9.6 ± 0.6	[3]
YL4	1025/T5	330	576 ± 6	224± 6	63± 1	25.0 ± 0.8	[4]
YL3	1025/T5	330	552 ± 7	143± 2	65± 1	15.6 ± 0.2	[4]
YL2	1025/T5	330	542 ± 6	133± 6	56± 1	12.4 ± 0.3	[4]
TY6	1000/CFL		769 ± 6	89.51 ±1.76	78 ± 1.64	16.5± 0.4	[5]
TY6	1000/LED		766 ± 6	84.96 ±1.74	78 ± 1.71	15.1± 0.4	[5]
AN-11	1000/CFL		972 ± 9	44.35 ±0.77	69 ± 1.24	9.2± 0.3	[5]
AN-11	1000/LED		977 ± 8	45.51 ±0.80	70 ± 1.28	9.2± 0.3	[5]
D-Dye	1200/T5		500 ± 5	81 ±71	60± 0.29	12.95± 0.29	[6]
N-719	1200/T5		550 ± 3	83.5 ± 6	65± 4	12.79± 1.6	[7]
RY3	1000/TL84	185	590 ± 3.6	85.8 ± 3	66.33± 0.53	18.15 ± 1	[8]
N719+RY3	1000/TL84	185	569 ± 3.7	120 ± 3	66.26± 1.13	24.45 ± 1.12	[8]
N-719	1000/TL84	185	550 ± 4.2	110 ± 4	64.62± 1.51	21.13 ± 1.49	[8]
Dye 1	1200/T5	--	530	124.4	63	10.73	[9]

Table S7: List of highest reported indoor performance in DSCs using copper electrolyte.

	Intensity (lux)/ Light source	Input power (μWcm^{-2})	V_{oc} (mV)	J_{sc} (μAcm^{-2})	FF (%)	Efficiency (%)	Year	Reference
D35 + XY1	1000/Osram 930	306.6	797	138.0	80	28.9	2017	[10]
XY1b + Y123	1000/Osram 930	318.2	878	149.3	77	31.8	2018	[11]
L350	1000		837	132.9	78	28.4	2018	[12]
XY1 + 5T	1000/Osram 930	303.1	860	131.2	78	29.2	2020	[13]
XY1	1000/ Osram 930	303.1	850	114.2	78	24.6	2020	[14]
XY1 + L1	1000/ Osram 930	303.1	910	147.0	77	34.0	2020	[14]
XY1b + MS5	1000/ Osram 930	318.2	980	138.2	81	34.5	2021	[15]

Table S8: YK 8 dye cost calculation

YK 8 Cost Calculation

1. Compound 1

Reagent	Market Price (₹)	Used (₹)
2,5-bis(tributylstannyl)thiophene	5g= 14510	500mg= 1451
2-bromo-3-octylthiophene	5g=11033.40	436mg=962.1
Dry toluene	500ml=700	20ml=28
$Pd_2(dba)_3$	1g=8247.39	20mg=164.948
$P(o\text{-tolyl})_3$	1g=1830	30mg= 54.9

Remarks : Product=303 mg= 2660.946₹
1g= 8782₹

2. Compound 2

Reagent	Market Price (₹)	Used (₹)
Compound 1	1g=8782	1g=8782
N,N-dimethylformamide	100ml=3696.30	1.8ml=66.53
1,2-dichloroethane	100ml=3774	20ml=754.8
$POCl_3$	500ml=670	0.3ml=0.402

Remarks : Product=800mg=9603.732 ₹
1g= 12004.665₹

3. Compound 3

Reagent	Market Price (₹)	Used (₹)
Compound 2	1g=12004.665	500mg=6002.33
N,N-dimethyl formammide	100ml=3696.30	10ml=369.63
N-bromosuccinimide	5g=2100	266mg=111.72

Remarks : Product=400mg=6483.6826₹
1g= 16209.21₹

4. Compound 4

Reagent	Market Price (₹)	Used (₹)
Compound 3	1g=16209.21	543mg=8801.59
K_2CO_3	100g=2842	276mg=7.844
9-methyl-9H-carbazole-3-boronic acid pinacol ester	1g=6327	288mg=1822.176
Toluene	500ml=700	20ml=28
$Pd(PPh_3)_4$	1g=5790	30mg=173.7

Remarks : Product=565mg= 10833.31₹
1g= 19174₹

5. YK 8 dye

Reagent	Market Price (₹)	Used (₹)
Compound 4	1g=19174	200mg=3834.8
Cyanoacetic acid	25g=2297.70	130mg=11.95
Dry chloroform	500ml=495	20ml=19.8
Piperidine	100ml=4784.10	1ml=47.841

Remarks : Product=171mg=3914.391₹
1g= 22891.18₹

6. Solvents and Materials used for extraction

Reagent	Used (₹)
Dichloromethane	200ml = 135
Na_2SO_4	10g = 115.22
Silica gel	250g = 20068.80
Hexane	200ml = 271.2
Chloroform	100ml = 60
Methanol	50ml = 2

Total Cost for making 1G YK 8 Dye = 43543.4 ₹ (Indian Rupee)
~585 USD
~492 Euro

Sigma-Aldrich (Merck) discontinued MK2 dye (Product No 728705) and other providers who are selling MK2 dye are 20 times or more to price of YK 8 dye

Solar Simulator and associated measuring set-up used for JV measurements

The current density versus voltage (J-V) curve of the fabricated DSCs were measured under AM 1.5 G irradiation (100 $mWcm^{-2}$) using Newport class AAA solar simulator (Oriel Sol3A, Model: 94023A, S/N: 438) having 450 W Xenon short arc lamp (6280NS, Newport). The intensity of illumination is measured with standard silicon reference cell (Model: 91150V, S/N: 1694) calibrated by Newport. The measurement is carried out using Keithley 2440 source measuring unit (S/N: 1235971) controlled by PVIV (Oriel Instruments) testing software provided by Newport. In order to avoid the overestimation of J_{sc} due to stray light, during all the photovoltaic characterizations, we used a black mask of aperture 0.1256 cm^2 (radius - 2 mm) over the device with a total active area of 0.31 cm^2. Also, all the photovoltaic results reported are from the data obtained from 8 devices, and the error was estimated using the standard deviation method.

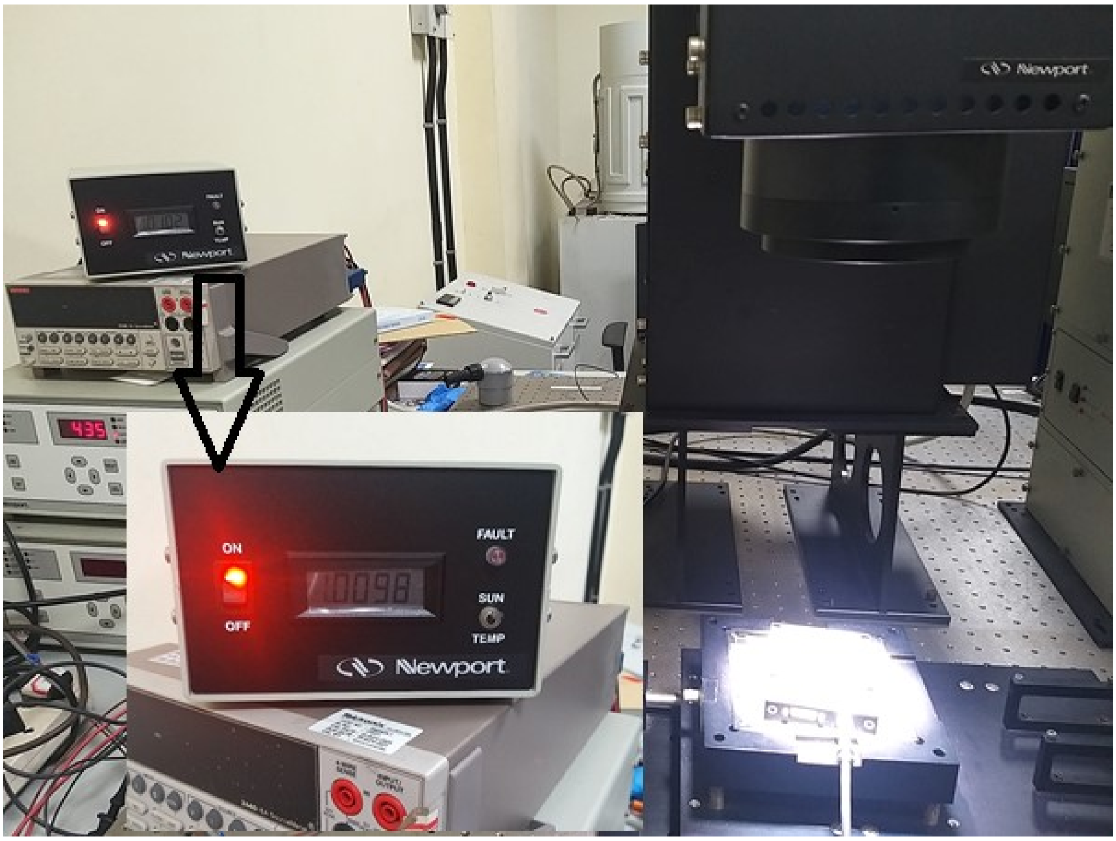


Figure S16. Newport class AAA solar simulator (Oriel Sol3A, Model: 94023A, S/N: 438).

Figure S17. Standard silicon reference cell (Model: 91150V, S/N: 1694) calibrated by Newport.

IPCE Measurement System and associated measuring set-up used for measurements

The incident photon-to-current conversion efficiency (IPCE) measurements were carried out in DC mode using the constant light source as 350 W Xenon arc lamp (6258, Newport, lamp house S/N: 876). The Cornerstone™ 260 UV-VIS Monochromator (Model: 74125, S/N: 310) is used to get the monochromatic light for the measurement, the reference is recorded using the detector (818-UV, S/N: 10878) calibrated and provided by Newport. The power meter (Model: 1918-R, S/N: 17953, Newport) is used for recording the measurement in each wavelength synchronised to the Cornerstone™ Monochromator using TracQ™ 6.5 data acquisition software provided by Newport. The measurement of reference silicon solar cell (QE Solar Cell, Newport) is being carried out to verify the measurement conditions.

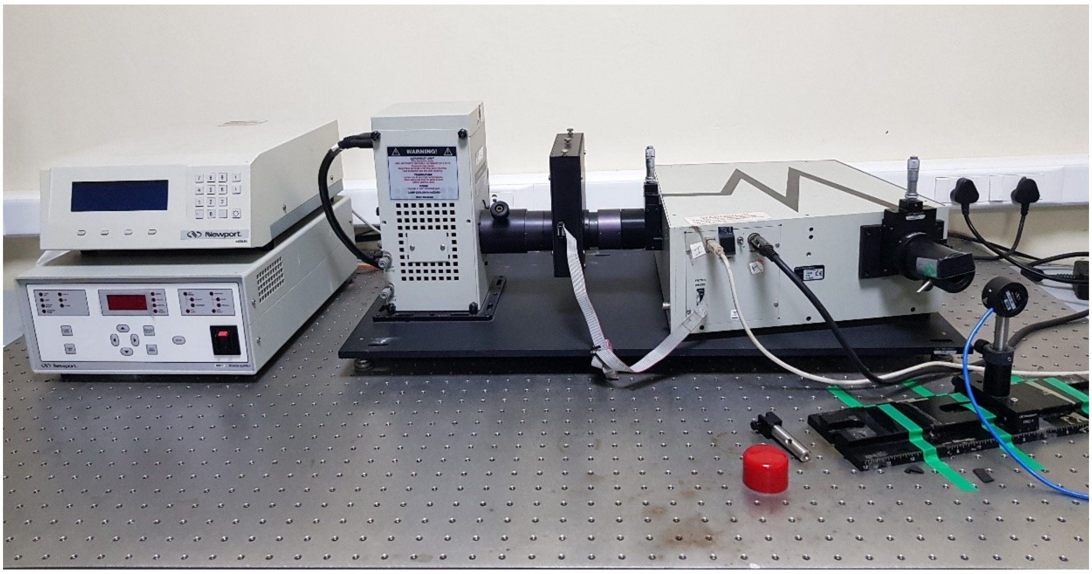


Figure S18. IPCE measurement setup.

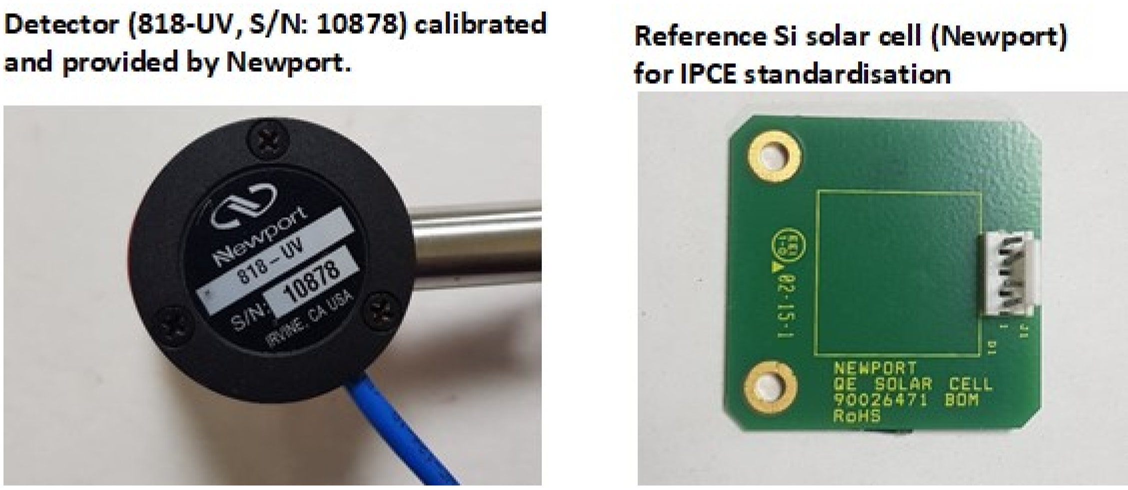


Figure S19. Detector and silicon reference cell for IPCE measurement.

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