Supporting Information

for

Dual-Guest Functionalised Zeolitic Imidazolate Framework-8 for 3D Printing White Light-Emitting Composites

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1 Statistics on luminescent MOF research

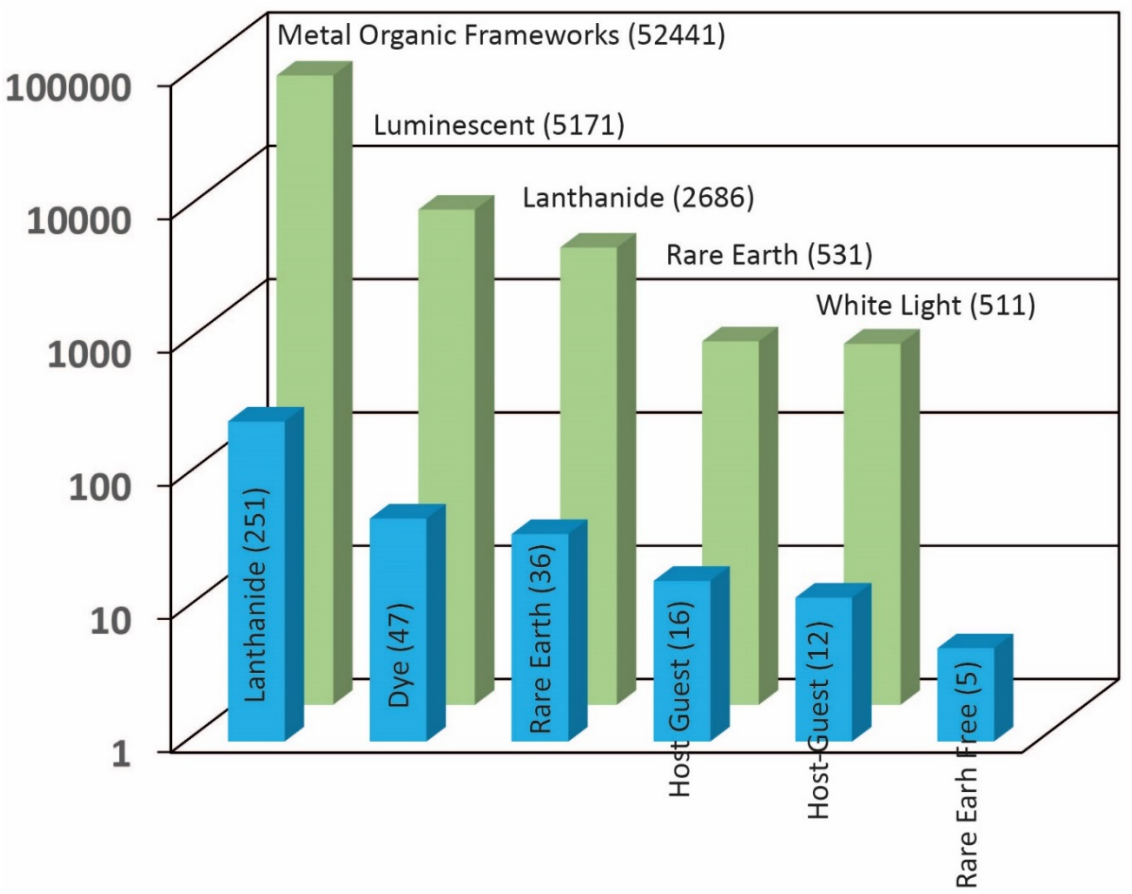

Figure S1. Statistical data indicating number of publications related to luminescent properties of MOF and MOF-derived materials under the main topic of metal organic frameworks. The statistics above are direct search results on the Web of Science (25/06/2019) using the keywords specified on the bars. Blue bars represent MOF-based white-light emitters.

2 Synthesis of yellow light-emitting solution

Yellow light-emitting solution was made by combining 0.1 mM solution of Rhodamine B and 0.1 mM solution of Fluorescein in methanol solvent. Initially 25 mL of Fluorescein was taken, into which Rhodamine B solution was slowly added to yield the yellow emission. The final combined solution has a volumetric ratio of 25:1.25 mL for Fluorescein to Rhodamine B, respectively. The ratio was determined by stepwise addition of 300 μL of solution B into a 25 mL of solution A. At each increment point, the change in emission was monitored under 365 nm UV lamp employing the UPRTek handheld photospectrometer. In this work, the final volume of B for addition into A to yield a warm white light emission was determined by examining the variation of the colour chromaticity using the CIE diagram in Figure S2.

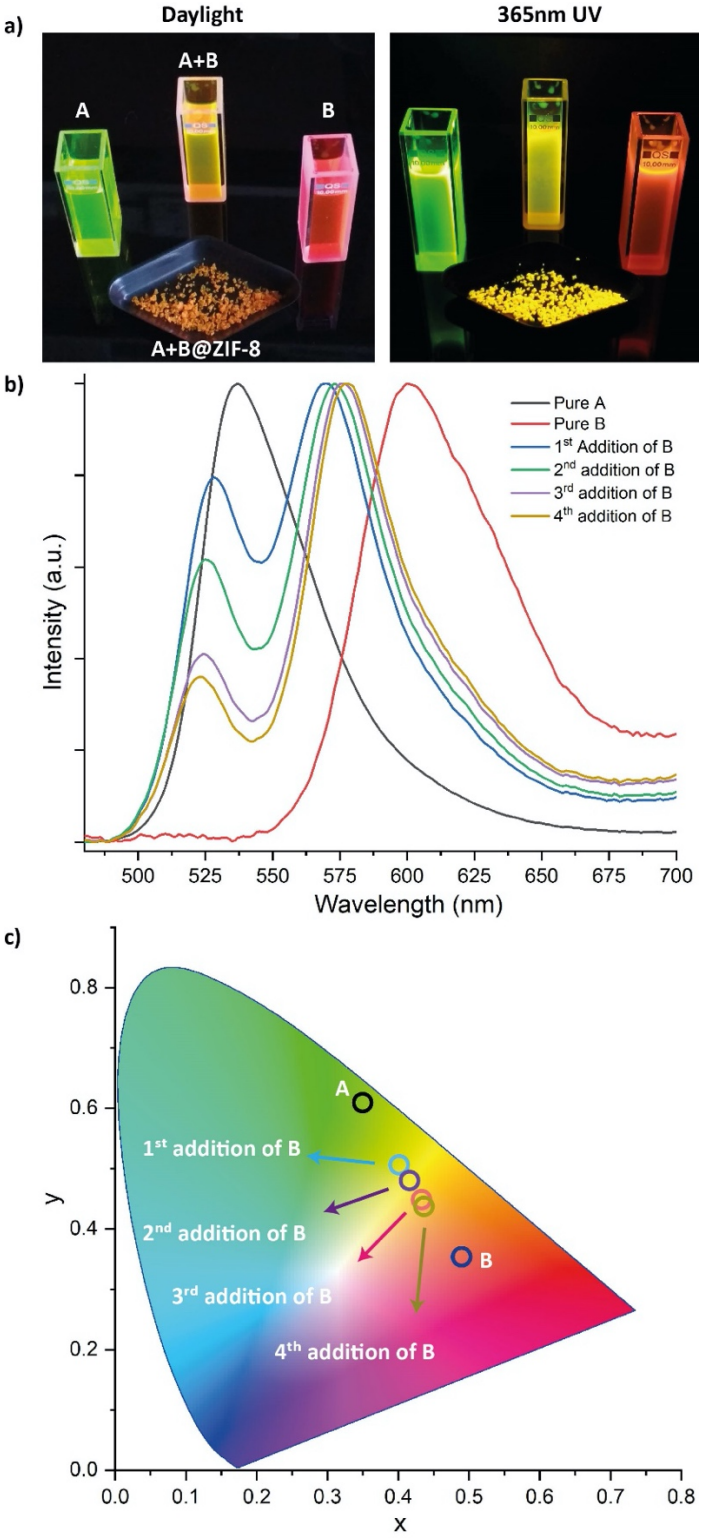

Figure S2. (a) Photograph taken under the 365 nm UV lamp, showing the emission of solutions A = Fluorescein, B = Rhodamine B, A+B mixture, and the solid-state emission of A+B@ZIF-8 powder (after drying). (b) Changes in the emission spectra of the combined solutions of A+B upon addition of 300 µL of B into A at each incremental point, (c) CIE 1931 diagram showing changes in colour chromaticity corresponding to the spectra in (b).

3 Synthesis of yellow light-emitting A+B@ZIF-8 powder

Yellow light-emitting solid powder was made by using the yellow solution of A+B described in §2 above, $Zn(NO_3)_2$ and 2-methylimidazole (mIm). Two separate solutions were prepared: (i) 3 mmol of $Zn(NO_3)_2$ in 3 mL methanol to yield a Zn^{2+} solution, and (ii) 9 mmol of mIm (deprotonated using 9 mmol of trimethylamine) in 3 mL methanol.

In the encapsulation reaction, first, the A+B yellow solution was mixed with Zn^{2+} solution (i). Then, a deprotonated solution of mIm (ii) was quickly added to (i), which immediately formed a thick precipitated product. The precipitate was then thoroughly washed 3 times with methanol, and the product isolated by centrifuge and dried. During each washing cycle, the material was subjected to 50 mL of methanol and 10 minutes of sonication to separate the aggregates. After sonication, the solid product of A+B@ZIF-8 was separated by centrifugation for 10 minutes at 8000 rpm, and then dried at 70 °C for 4 hr.

In contrast to the approach implemented above, we have also attempted to yield white light emission using the separate scheme of A@ZIF-8 and B@ZIF-8 *via* two separate synthesis and subsequent combination in resin to tune the emission. However, this approach failed due to inhomogeneity problem and non-uniformity in emission of the 3D printed (bulk) sample. Therefore the dual-guest approach has the advantage compared to the (conventional) individually encapsulated MOF approach.

4 3D printing of A+B@ZIF-8 dispersed in a clear photopolymer resin

3D printing was conducted using the Form 2 stereolithography printer made by Formlabs. For printing the 'blank' pellets, we used the clear resin commercially available from Formlabs, without further alteration. This clear resin is a photopolymer mixture of methacrylic acid esters and photoinitiator, designed for curing using the 405 nm laser of the Form 2 printer. However, the 'composite' pellets were 3D printed from the homogenous mixture of 10 g of A+B@ZIF-8 combined with 50 mL of clear resin. To obtain a homogenous composite mixture of resin and MOF powder, we used wet powder sample (i.e. after washing and centrifugation, but before drying) to mix with clear resin to minimise aggregation. To improve MOF dispersion in the clear resin, the mixture was stirred in the dark for ~12 hours using a mechanical stirrer, see Figure S3 (for protection against any visible light that might partially cure the resin). Subsequently, the 3D printing process was carried in automatic mode where the composite resin was dispensed from a 1-L cartridge into a standard resin tank (~130 mL), equipped with temperature control (31.5 °C) and automatic wiper.

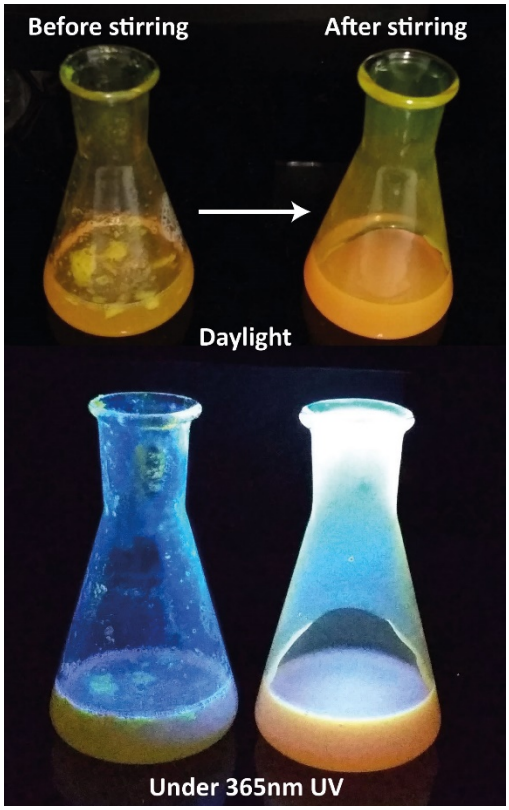

Figure S3. Photograph showing the effect of overnight stirring of (wet powder) A+B@ZIF-8 into the clear photopolymer resin, it was found that the non-homogenous mixture turned into a uniform homogenous suspension after overnight stirring.

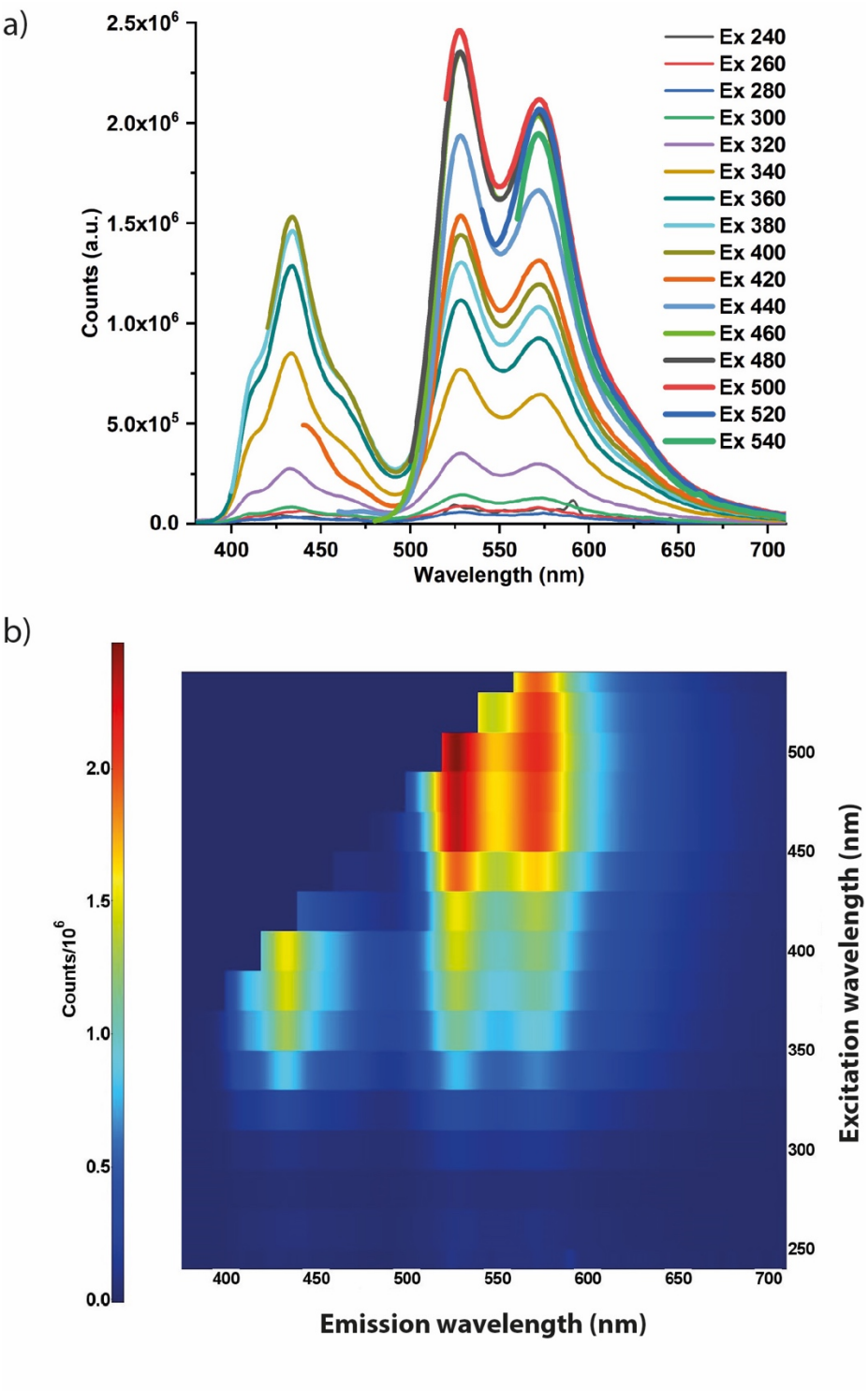

Figure S4. (a) Emission spectra of the 3D printed pellet (3 mm thickness) showing the unchanging emission wavelengths subject to different excitation wavelengths, ranging from 240–540 nm. (b) Excitation-emission map corresponding to the series of spectral data in (a). The measurements were performed using the FS5 spectrofluorometer.

5 Materials Characterisation

Powder X-ray diffraction (PXRD) of the solid-state powder sample was performed using the Rigaku Miniflex diffractometer. Diffraction data were collected using $2\theta = 5 – 30°$ at a scan rate of 1.0°/min and a step size of 0.01.

Solid-state diffuse reflectance spectra were collected on the Shimadzu UV 2600 equipped with an integration sphere. The sample was prepared by drop coating the powder dispersed in methanol onto a strip of Whatman filter paper. Blank Whatman paper was used to measure the baseline correction and background.

Atomic force microscopy (AFM) imaging on a sample drop-casted onto a 1 cm^2 silicon wafer substrate was performed using the neaspec neaSNOM instrument, operating under the tapping mode. Height topography images were collected using the Scout350 probe (NuNano), which has a nominal tip radius of 5 nm, a spring constant of 42 N/m and resonant frequency of 350 kHz.

Thermogravimetric analysis (TGA) was performed on the TA Instrument Q50 instrument, employing at a heating rate of 20 °C/min from 50-650 °C under constant nitrogen flow.

Emission and excitation spectra were measured on the FS5 spectrofluorometer (Edinburgh Instruments) equipped with Xenon lamp light source and a standard detector. Excitation and emission bandwidths were adjusted to maximise the signal for each sample. Fluorescence lifetime decay was studied using the time-correlated single photon counting (TCSPC) technique employing the 363.5nm EPLED picosecond pulsed laser source (Edinburgh Instruments). The quantum yield (QY) measurements of the solid-state and solution samples were performed using the SC-30 integrating sphere module. Lifetime and QY data were analysed using the Fluoracle software. The parameters used in the FS5 spectrofluorometric measurements are listed below.

Excitation: A=Fluorescein Solution

Excitation Scan Parameters:

Ex Wavelength (nm)	: 250.00 to 570.00 step 1.00
Dwell Time (s)	: 0.200 per repeat
Repeats	: 2

Ex Arm Parameters (Scan Arm):

Bandwidth (nm) : 1.00

Em Arm Parameters (Fixed Arm):

Wavelength (nm) : 520.00

Bandwidth (nm) : 1.00

Emission: A=Fluorescein Solution

Emission Scan Parameters:

Em Wavelength (nm) : 460.00 to 750.00 step 1.00

Dwell Time (s) : 0.200 per repeat

Repeats : 1

Ex Arm Parameters (Fixed Arm):

Wavelength (nm) : 450.00

Bandwidth (nm) : 1.00

Em Arm Parameters (Scan Arm):

Bandwidth (nm) : 1.00

Excitation: B=Rhodamine B Solution

Excitation Scan Parameters:

Ex Wavelength (nm) : 250.00 to 650.00 step 0.50

Dwell Time (s) : 0.200 per repeat

Repeats : 2

Ex Arm Parameters (Scan Arm):

Bandwidth (nm) : 1.00

Em Arm Parameters (Fixed Arm):

Grating : Vis

Wavelength (nm) : 600.00

Bandwidth (nm) : 0.50

Emission: B=Rhodamine B Solution

Emission Scan Parameters:

Em Wavelength (nm) : 480.00 to 750.00 step 1.00

Dwell Time (s) : 0.200 per repeat

Repeats : 1

Ex Arm Parameters (Fixed Arm):

Wavelength (nm) : 470.00

Bandwidth (nm) : 1.00

Em Arm Parameters (Scan Arm):

Bandwidth (nm) : 1.00

Excitation: A+B Solution

Excitation Scan Parameters:

Ex Wavelength (nm) : 250.00 to 650.00 step 1.00

Dwell Time (s) : 0.200 per repeat

Repeats : 2

Ex Arm Parameters (Scan Arm):

Bandwidth (nm) : 1.00

Em Arm Parameters (Fixed Arm):

Wavelength (nm) : 550.00

Bandwidth (nm) : 1.00

Emission: A+B Solution

Emission Scan Parameters:

Em Wavelength (nm) : 460.00 to 750.00 step 1.00

Dwell Time (s) : 0.200 per repeat

Repeats : 1

Ex Arm Parameters (Fixed Arm):

Wavelength (nm) : 450.00

Bandwidth (nm) : 1.00

Em Arm Parameters (Scan Arm):

Bandwidth (nm) : 1.00

Excitation: A+B@ZIF-8 Powder

Excitation Scan Parameters:

Ex Wavelength (nm) : 300.00 to 400.00 step 0.50

Dwell Time (s) : 0.500 per repeat

Repeats : 1

Ex Arm Parameters (Scan Arm):

Bandwidth (nm) : 2.31

Em Arm Parameters (Fixed Arm):

Wavelength (nm) : 620.00

Bandwidth (nm) : 0.16

Emission: A+B@ZIF-8 Powder

Emission Scan Parameters:

Em Wavelength (nm) : 480.00 to 750.00 step 1.00

Dwell Time (s) : 0.100 per repeat

Repeats : 1

Ex Arm Parameters (Fixed Arm):

Wavelength (nm) : 400.00

Bandwidth (nm) : 4.05

Em Arm Parameters (Scan Arm):

Bandwidth (nm) : 0.12

Excitation: Composite Pellet

Excitation Scan Parameters:

Ex Wavelength (nm) : 240.00 to 605.00 step 0.50

Dwell Time (s) : 0.500 per repeat

Repeats : 1

Ex Arm Parameters (Scan Arm):

Bandwidth (nm) : 1.50

Em Arm Parameters (Fixed Arm):

Wavelength (nm) : 610.00

Bandwidth (nm) : 0.80

Emission: Composite Pellet

Emission Scan Parameters:

Em Wavelength (nm) : 400.00 to 710.00 step 1.00

Dwell Time (s) : 0.100 per repeat

Repeats : 1

Ex Arm Parameters (Fixed Arm):

Wavelength (nm) : 380.00

Bandwidth (nm) : 1.00

Em Arm Parameters (Scan Arm):

Bandwidth (nm) : 0.50

Excitation: Blank Pellet

Excitation Scan Parameters:

Ex Wavelength (nm) : 240.00 to 500.00 step 0.50

Dwell Time (s) : 0.500 per repeat

Repeats : 1

Ex Arm Parameters (Scan Arm):

Bandwidth (nm) : 1.00

Em Arm Parameters (Fixed Arm):

Wavelength (nm) : 520.00

Bandwidth (nm) : 0.50

Emission: Blank Pellet

Emission Scan Parameters:

Em Wavelength (nm) : 400.00 to 700.00 step 1.00

Dwell Time (s) : 0.100 per repeat

Repeats : 1

Ex Arm Parameters (Fixed Arm):

Wavelength (nm) : 380.00

Bandwidth (nm) : 1.00

Em Arm Parameters (Scan Arm):

Bandwidth (nm) : 0.20

5.1 Atomic force microscopy (AFM)

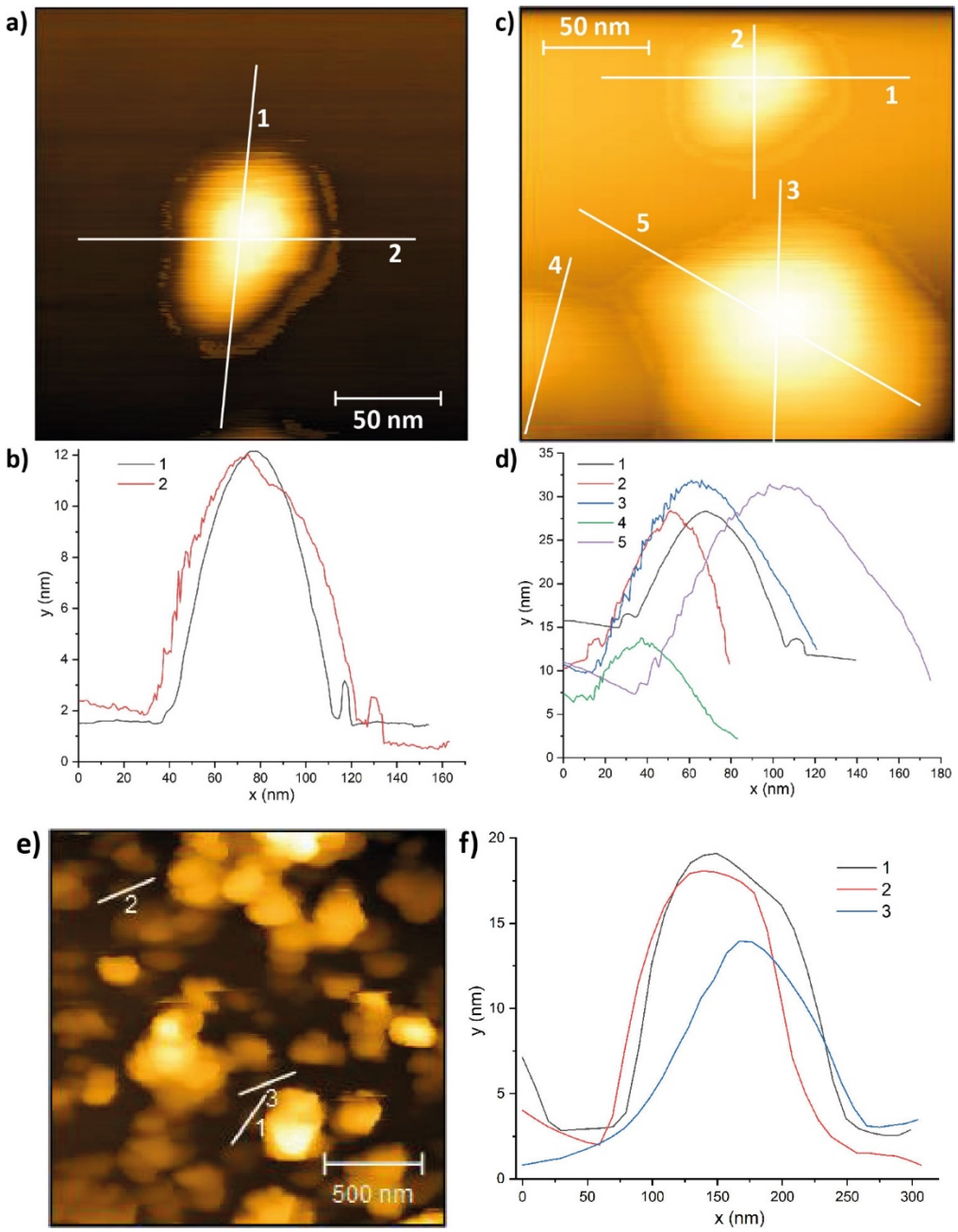

Figure S5. Representative AFM images of the nanodiscs of A+B@ZIF-8 (top, a & c), with a graph showing their height profiles (bottom b & d) extracted from the marked regions of the nanodiscs. The nanodiscs exhibit an aspect ratio (width/height) ranging from 5:1 to 10:1

5.2 Thermogravimetric analysis (TGA)

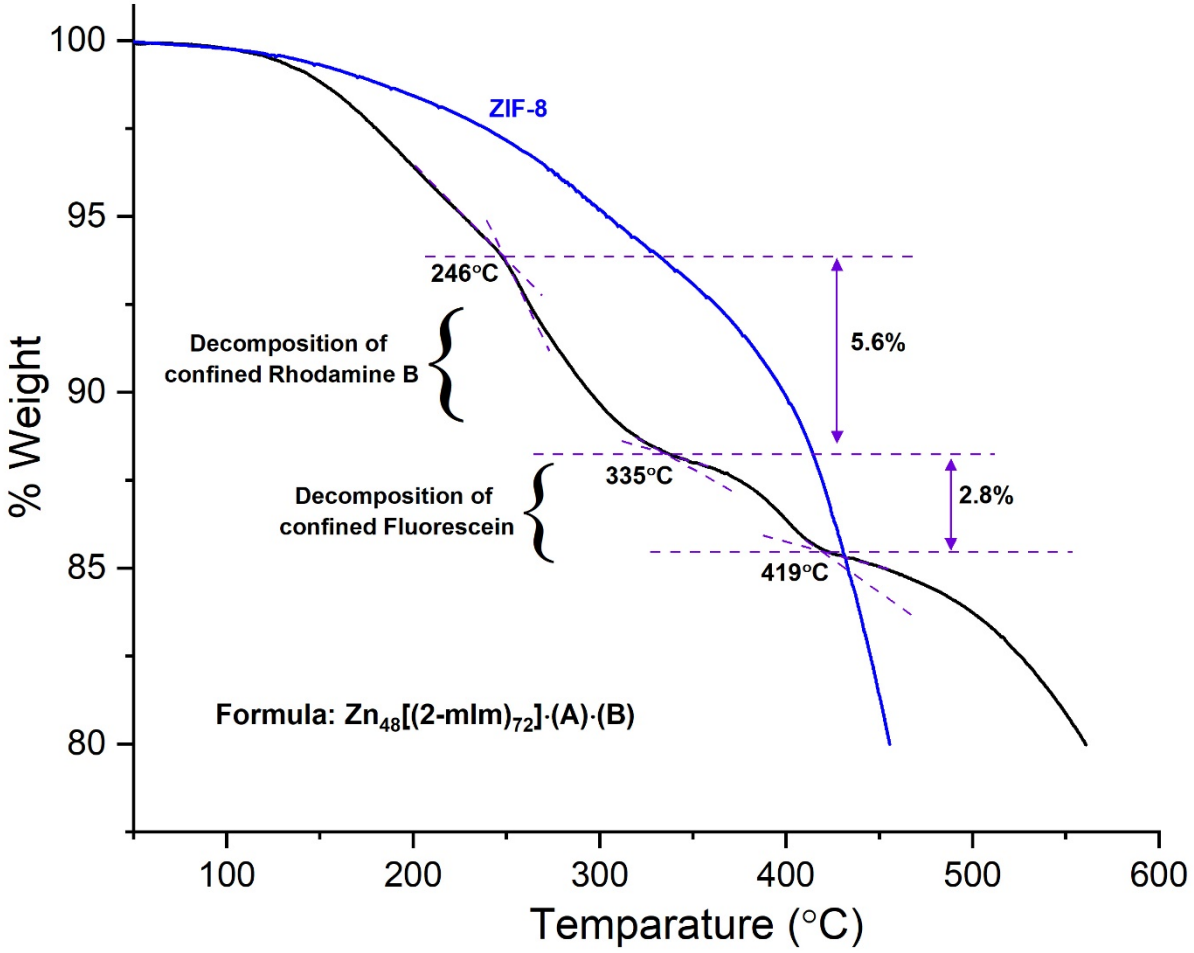

Figure S6. TGA of A+B@ZIF-8 powder indicating stepwise degradation of the two confined guest species: Rhodamine B and Fluorescein (A), which were estimated to be at 5.6 wt.% and 2.8 wt.%, respectively. TGA of pristine ZIF-8 is shown for comparison, which was synthesised using the same conditions to that of A+B@ZIF-8 (but without the addition of A+B guest solution).

5.3 Diffuse reflectance spectra (DRS)

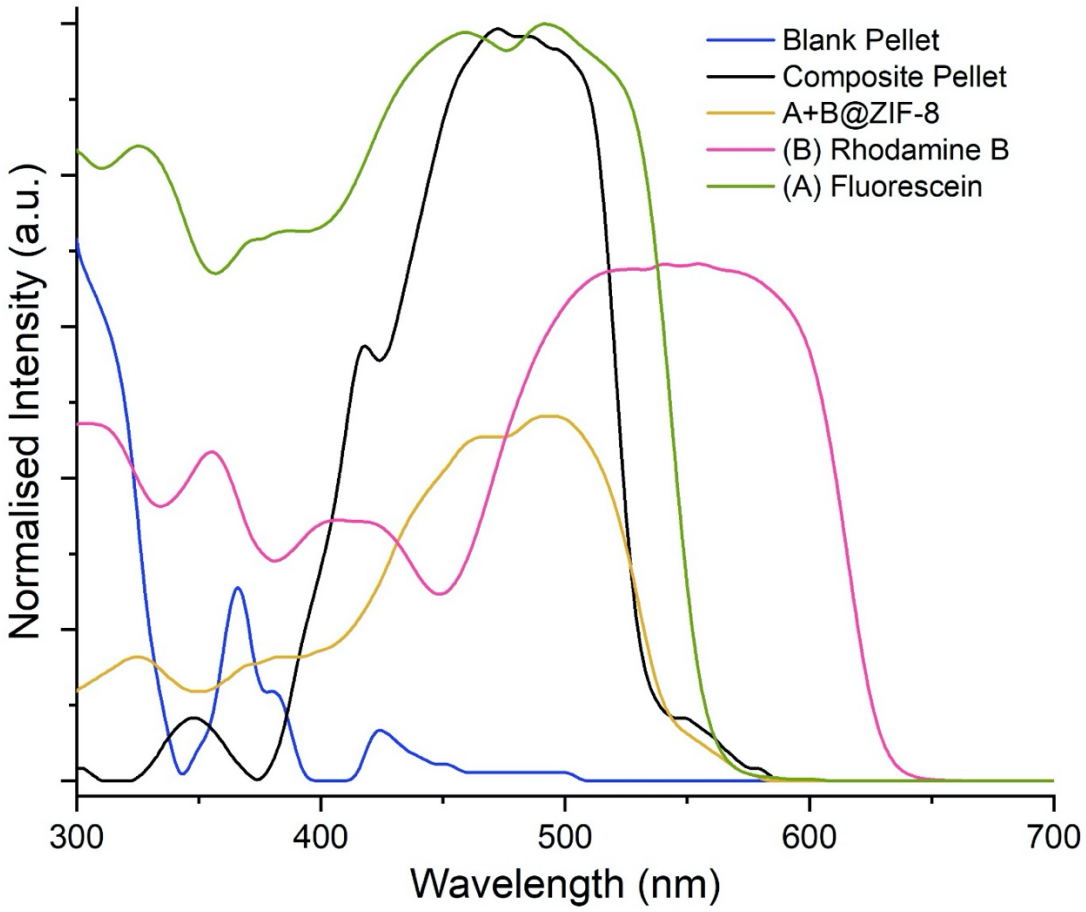

Figure S7. Solid-state diffuse reflectance spectra of the 3D printed pellets (blank and composite), powder sample of the guest emitters, and A+B@ZIF-8 powder.

5.4 Time-correlated single photon counting (TCSPC)

Table S1. Fluorescence lifetime (τ) of different individual materials used in this study. α is the normalised pre-exponential factor.

Material	λ_{em} (nm)	α	χ^2	τ (ns)	Rel. %
(A) Fluorescein Solution	515	0.193	1.331	4.0859	100
(B) Rhodamine B Solution	571	0.215	1.315	2.4137	100
A+B Solution	515	0.194	1.184	4.0236	100
	571	0.197	1.184	4.0756	100
A+B@ZIF-8 Powder	541	0.186	1.387	1.59	52.6
		0.077		3.46	47.4
	577	0.223	1.469	4.78	100
'Blank' 3D printed pellet (Formlab's clear resin)	440	0.182	1.345	15.4	100
'Composite' 3D printed pellet (A+B@ZIF-8 combined with clear resin)	433	0.303	1.319	1.2816	88.96
		0.004		11.711	11.04
	528	-0.141	1.171	1.0377	10.13
		0.288		3.8009	75.97
		0.015		13.9975	14.57
	571	-0.382	1.067	2.15	24
		0.46		4.97	66
		0.02		15.58	9.1

5.5 Quantum yield (QY)

Table S2. Quantum yield (%) of different individual materials used in this study.

Material / Species	Quantum Yield (%)
A = Fluorescein	40.28
B = Rhodamine B	35.53
A+B Solution	68.01
A+B@ZIF-8 Powder	47.31
Composite Pellet (3D printed)	43.56
Blank Pellet (3D printed)	62.32

Quantum Yield: A=Fluorescein Solution

Emission Scan Parameters:

Em Wavelength (nm) : 450.00 to 750.00 step 1.00

Dwell Time (s) : 0.200 per repeat

Repeats : 1

Ex Arm Parameters (Fixed Arm):

Wavelength (nm) : 460.00

Bandwidth (nm) : 3.50

Mono Type : FS5

Em Arm Parameters (Scan Arm):

Bandwidth (nm) : 0.35

Quantum Yield: B=Rhodamine B Solution

Emission Scan Parameters:

Em Wavelength (nm) : 460.00 to 750.00 step 1.00

Dwell Time (s) : 0.200 per repeat

Repeats : 1

Ex Arm Parameters (Fixed Arm):

Wavelength (nm) : 470.00

Bandwidth (nm) : 3.50

Em Arm Parameters (Scan Arm):

Bandwidth (nm) : 0.35

Quantum Yield: A+B Solution

Emission Scan Parameters:

Em Wavelength (nm) : 450.00 to 750.00 step 1.00

Dwell Time (s) : 0.200 per repeat

Repeats : 1

Ex Arm Parameters (Fixed Arm):

Wavelength (nm) : 460.00

Bandwidth (nm) : 3.50

Em Arm Parameters (Scan Arm):

Bandwidth (nm) : 0.35

Quantum Yield: A+B@ZIF-8 Powder

Emission Scan Parameters:

Em Wavelength (nm) : 460.00 to 750.00 step 1.00

Dwell Time (s) : 0.200 per repeat

Repeats : 1

Ex Arm Parameters (Fixed Arm):

Wavelength (nm) : 480.00

Bandwidth (nm) : 4.00

Em Arm Parameters (Scan Arm):

Bandwidth (nm) : 0.40

Quantum Yield: Composite Pellet

Emission Scan Parameters:

Em Wavelength (nm) : 350.00 to 750.00 step 1.00

Dwell Time (s) : 0.200 per repeat

Repeats : 1

Ex Arm Parameters (Fixed Arm):

Wavelength (nm) : 370.00

Bandwidth (nm) : 9.00

Em Arm Parameters (Scan Arm):

Bandwidth (nm) : 0.80

Quantum Yield: Blank Pellet

Emission Scan Parameters:

Em Wavelength (nm) : 370.00 to 650.00 step 1.00

Dwell Time (s) : 0.200 per repeat

Repeats : 1

Ex Arm Parameters (Fixed Arm):

Wavelength (nm) : 390.00

Bandwidth (nm) : 4.00

Em Arm Parameters (Scan Arm):

Bandwidth (nm) : 0.40

Table S3. Change in the quantum yield (QY) of the 3D printed disc pellet upon exposure to water, UV, and heat. Note that these are accelerated ageing conditions where more extreme test conditions were applied compared to a typical LED.

	QY (%)		
Exposure time	0 hr	1 hr	24 hr
Water Immersion	43.56	42.42	40.34
UV radiation at 400 nm	43.56	41.57	38.63
Heating at 60 °C	43.56	42.19	39.18

Table S4. Characterisation of the lighting performance of the 3D printed composite pellets when irradiated under the 400-nm UV LED, measured using the UPRtek photospectrometer. Note: LUX = spectral illuminance; CRI = colour rendering index; CCT = chromaticity colour temperature (in K).

Thickness of 3D printed composite pellet (mm) →	**0.5**	**1.5**	**2.2**	**3.0**	**4.4**	**5.2**
LUX	1376.906	1824.283	1419.112	1332.541	922.5844	808.158
CRI	-	46.64893	43.39875	42.12814	42.53244	43.5467
CCT (K)	-	8325	6095	4701	4180	3701

5.6 Lifetime measurements using TCSPC

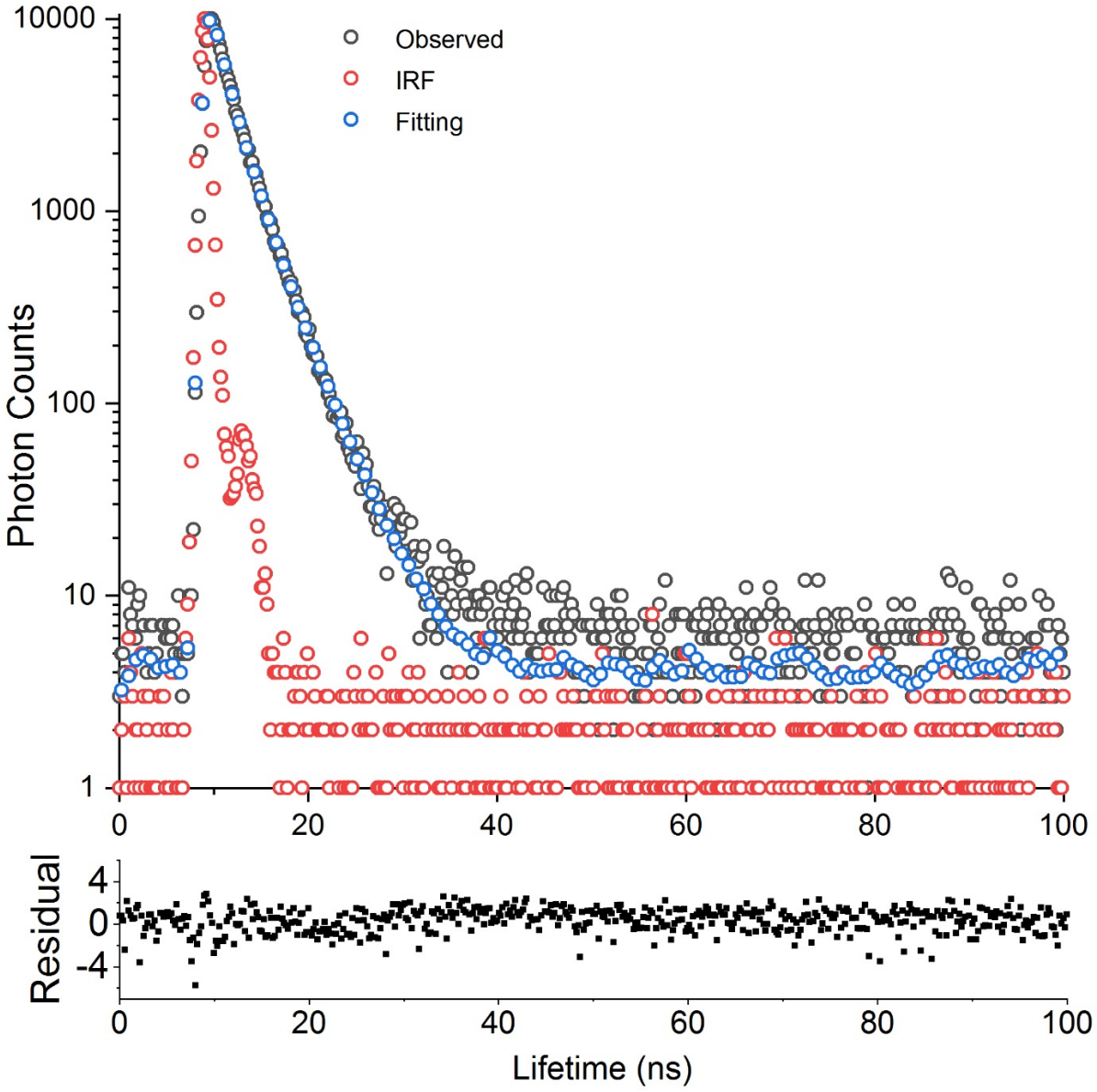

Figure S8. Lifetime decay profile of A+B@ZIF-8 powder measured for the emission maximum at 541 nm. IRF is the instrument response function.

Decay: A+B@ZIF-8 Powder@541nm emission

Lifetime Parameters:	
Time Range (ns)	: 0.00000 to 199.80469 step 0.19531
Channel Range	: 0 to 1023
Mode	: TCSPC
TAC (ns)	: 200
Delay (ns)	: 0

Time Calibration (ns)	: 0.19531
Reps	: 1
Acq Time (s)	: 20.3
Ex Arm Parameters:	
WaveLength (nm)	: 362.50
Bandwidth (nm)	: 0.01
Lightpath	: TCSPC Diode
Em Arm Parameters:	
WaveLength (nm)	: 541.00
Bandwidth (nm)	: 5.70

IRF: A+B@ZIF-8 Powder@541nm emission

Lifetime Parameters:	
Time Range (ns)	: 0.00000 to 199.80469 step 0.19531
Channel Range	: 0 to 1023
Mode	: TCSPC
TAC (ns)	: 200
Delay (ns)	: 0
Time Calibration (ns)	: 0.19531
Reps	: 1
Acq Time (s)	: 7.1
Ex Arm Parameters:	
Intensity	: 50
WaveLength (nm)	: 362.50
Bandwidth (nm)	: 0.01
Lightpath	: TCSPC Diode
Em Arm Parameters:	
WaveLength (nm)	: 362.50
Bandwidth (nm)	: 5.70

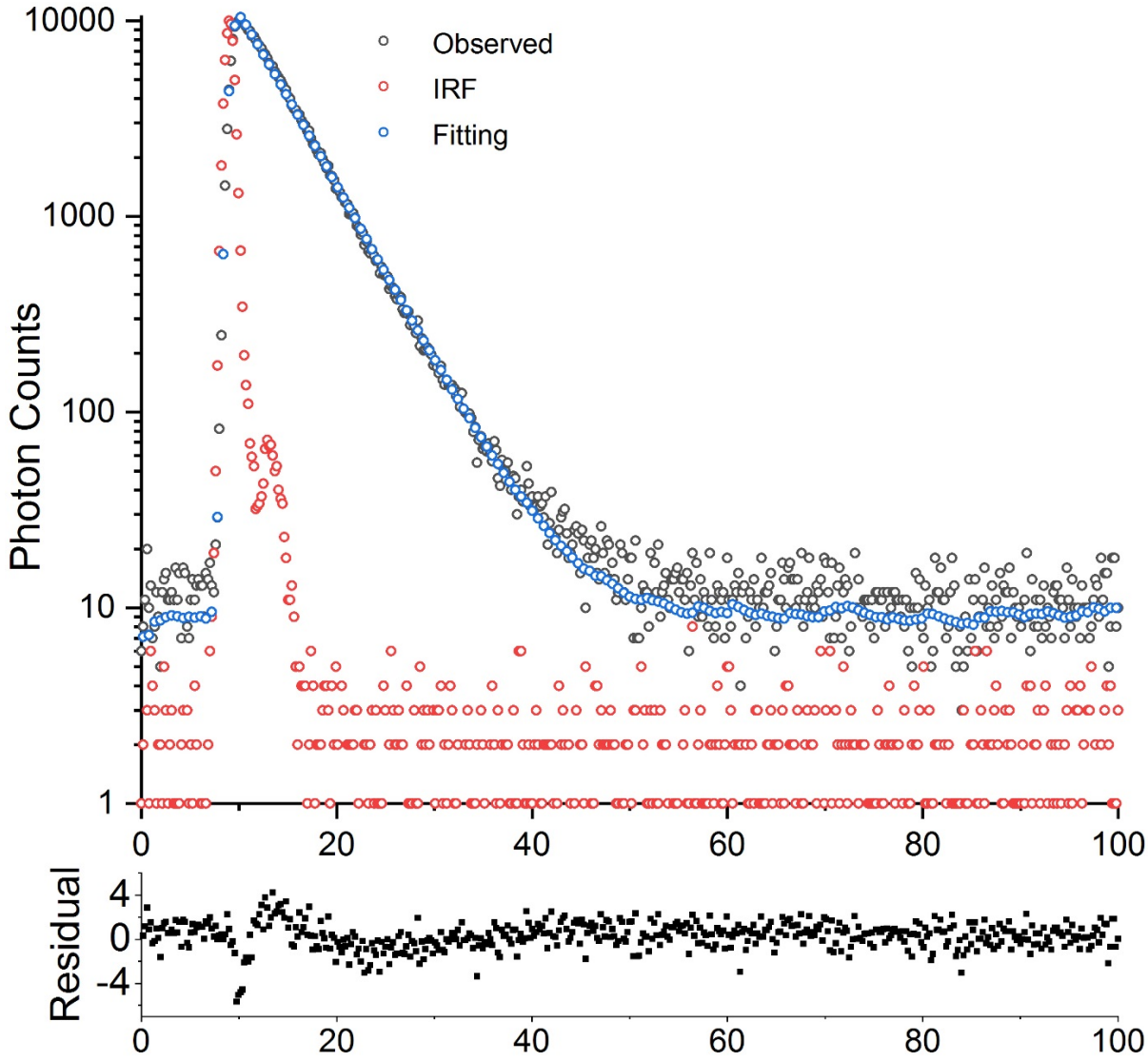

Figure S9. Lifetime decay profile of A+B@ZIF-8 powder measured for the emission maximum at 577 nm.

Decay: A+B@ZIF-8 Powder@577nm emission

Lifetime Parameters:	
Time Range (ns)	: 0.00000 to 199.80469 step 0.19531
Channel Range	: 0 to 1023
Mode	: TCSPC
TAC (ns)	: 200
Delay (ns)	: 0
Time Calibration (ns)	: 0.19531

Reps	: 1
Acq Time (s)	: 39.2
Ex Arm Parameters:	
WaveLength (nm)	: 362.50
Bandwidth (nm)	: 0.01
Lightpath	: TCSPC Diode
Em Arm Parameters:	
WaveLength (nm)	: 577.00
Bandwidth (nm)	: 5.70

IRF: A+B@ZIF-8 Powder@577nm emission

Lifetime Parameters:	
Time Range (ns)	: 0.00000 to 199.80469 step 0.19531
Channel Range	: 0 to 1023
Mode	: TCSPC
TAC (ns)	: 200
Delay (ns)	: 0
Time Calibration (ns)	: 0.19531
Reps	: 1
Acq Time (s)	: 7.1
Ex Arm Parameters:	
WaveLength (nm)	: 362.50
Bandwidth (nm)	: 0.01
Lightpath	: TCSPC Diode
Em Arm Parameters:	
WaveLength (nm)	: 362.50
Bandwidth (nm)	: 5.70

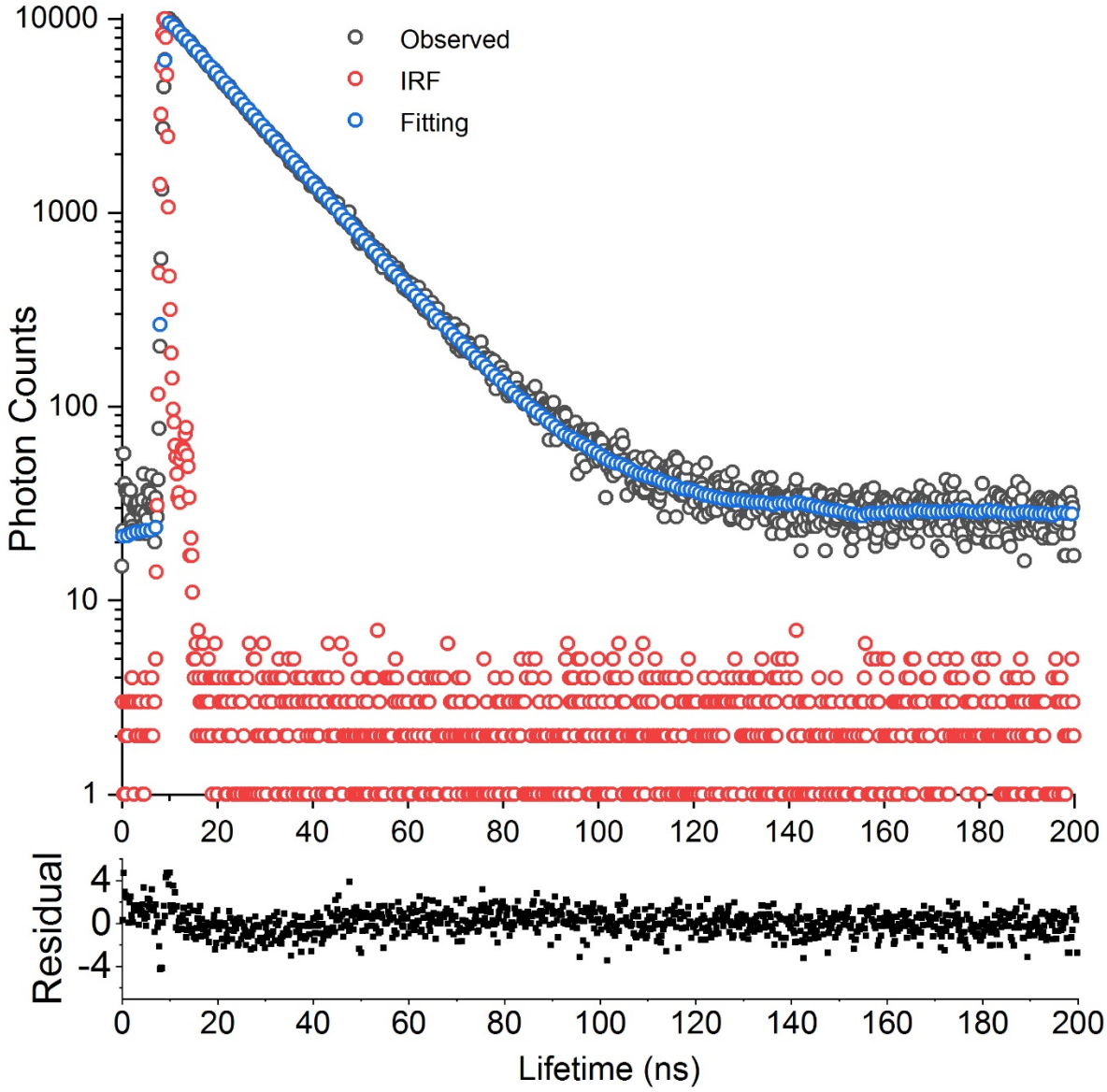

Figure S10. Lifetime decay profile of blank pellet (3D printed pure resin) measured for the emission maximum at 440 nm.

Decay: Blank Pellet@440nm emission

Lifetime Parameters:	
Time Range (ns)	: 0.00000 to 199.80469 step 0.19531
Channel Range	: 0 to 1023
Mode	: TCSPC
TAC (ns)	: 200
Delay (ns)	: 0
Time Calibration (ns)	: 0.19531

Reps	: 1
Acq Time (m:s)	: 01:38.3
Ex Arm Parameters:	
WaveLength (nm)	: 362.50
Bandwidth (nm)	: 0.01
Lightpath	: TCSPC Diode
Em Arm Parameters:	
WaveLength (nm)	: 440.00
Bandwidth (nm)	: 1.65

IRF: Blank Pellet@440nm emission

Lifetime Parameters:	
Time Range (ns)	: 0.00000 to 199.80469 step 0.19531
Channel Range	: 0 to 1023
Mode	: TCSPC
TAC (ns)	: 200
Delay (ns)	: 0
Time Calibration (ns)	: 0.19531
Reps	: 1
Acq Time (s)	: 7.7
Ex Arm Parameters:	
WaveLength (nm)	: 362.50
Bandwidth (nm)	: 0.01
Lightpath	: TCSPC Diode
Em Arm Parameters:	
WaveLength (nm)	: 362.50
Bandwidth (nm)	: 1.49

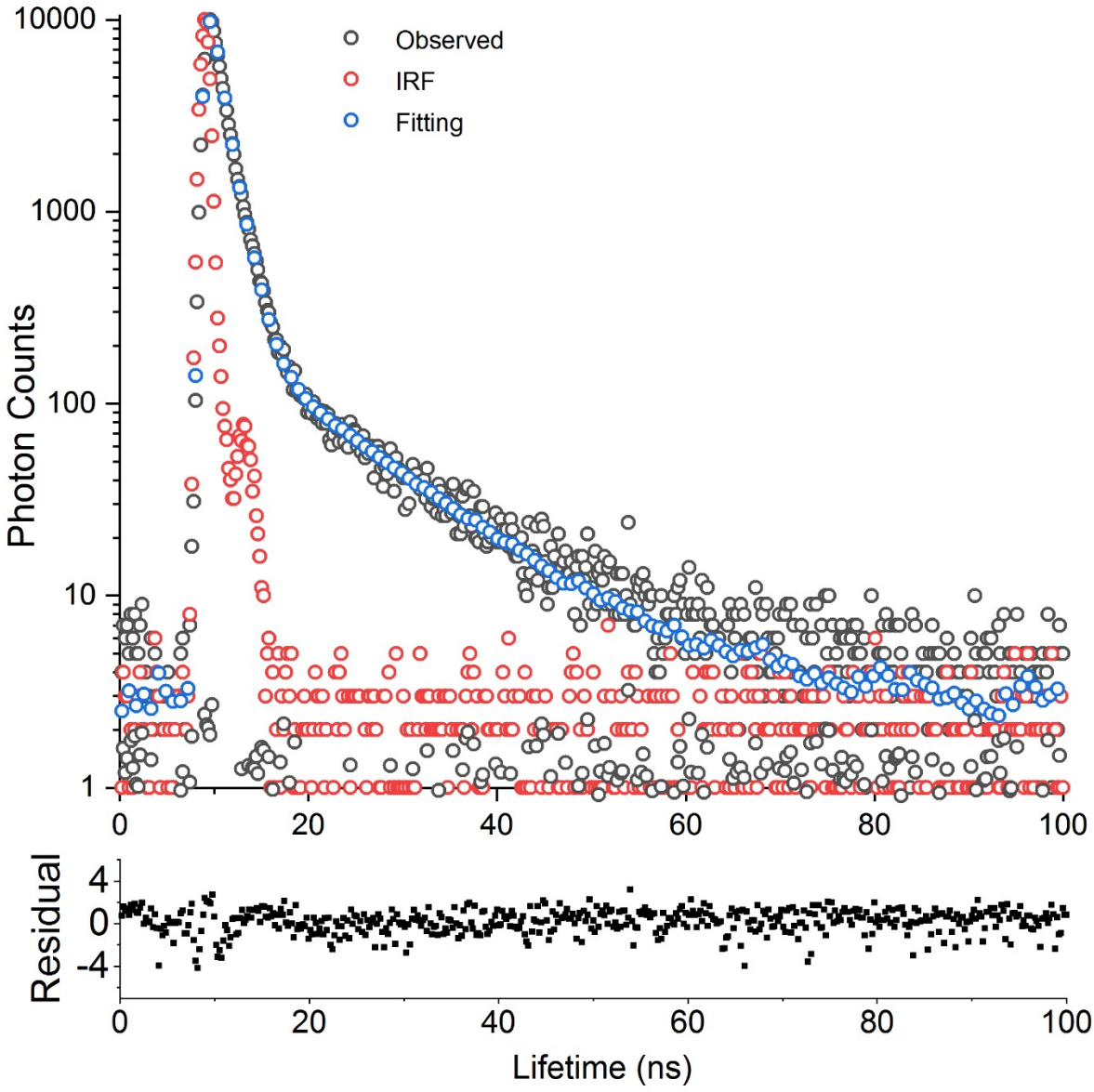

Figure S11. Lifetime decay profile of composite 3D printed pellet measured for the emission maximum at 433 nm.

Decay: Composite Pellet@433nm emission

Lifetime Parameters:	
Time Range (ns)	: 0.00000 to 199.80469 step 0.19531
Channel Range	: 0 to 1023
Mode	: TCSPC
TAC (ns)	: 200
Delay (ns)	: 0
Time Calibration (ns)	: 0.19531

Reps	: 1
Acq Time (s)	: 7.8
Ex Arm Parameters:	
WaveLength (nm)	: 362.50
Bandwidth (nm)	: 0.01
Lightpath	: TCSPC Diode
Em Arm Parameters:	
WaveLength (nm)	: 433.00
Bandwidth (nm)	: 3.33

IRF: Composite Pellet@433nm emission

Lifetime Parameters:	
Time Range (ns)	: 0.00000 to 199.80469 step 0.19531
Channel Range	: 0 to 1023
Mode	: TCSPC
TAC (ns)	: 200
Delay (ns)	: 0
Time Calibration (ns)	: 0.19531
Reps	: 1
Acq Time (s)	: 3.10
Ex Arm Parameters:	
WaveLength (nm)	: 362.50
Bandwidth (nm)	: 0.01
Lightpath	: TCSPC Diode
Em Arm Parameters:	
WaveLength (nm)	: 362.50
Bandwidth (nm)	: 3.33

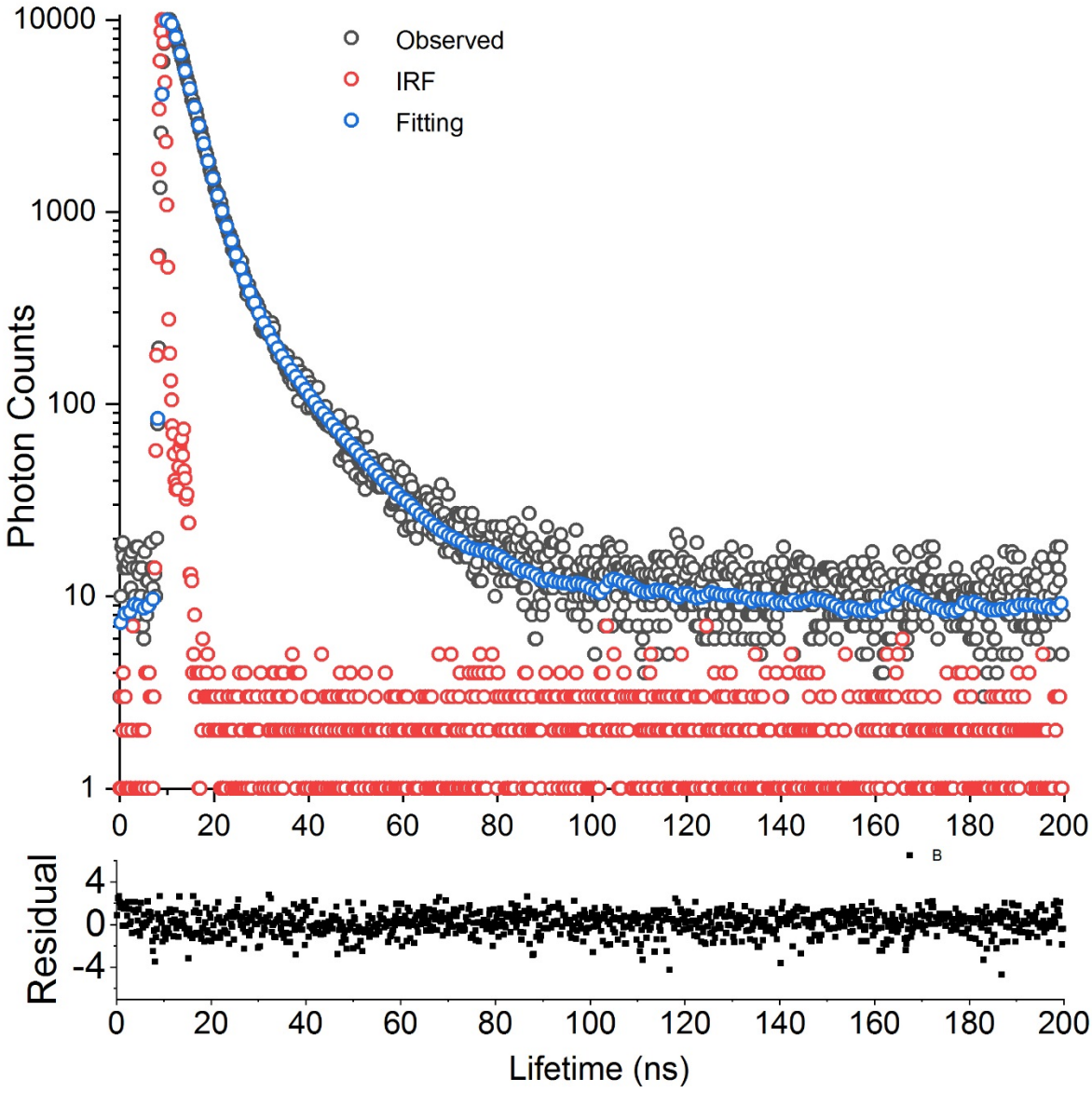

Figure S12. Lifetime decay profile of composite 3D printed pellet measured for the emission maximum at 528 nm.

Decay: Composite Pellet@528nm emission

Lifetime Parameters:	
Time Range (ns)	: 0.00000 to 199.80469 step 0.19531
Channel Range	: 0 to 1023
Mode	: TCSPC
TAC (ns)	: 200
Delay (ns)	: 0
Time Calibration (ns)	: 0.19531

Reps	: 1
Acq Time (s)	: 30.0
Ex Arm Parameters:	
WaveLength (nm)	: 362.50
Bandwidth (nm)	: 0.01
Lightpath	: TCSPC Diode
Em Arm Parameters:	
WaveLength (nm)	: 528.00
Bandwidth (nm)	: 3.33

IRF: Composite Pellet@528nm emission

Lifetime Parameters:	
Time Range (ns)	: 0.00000 to 199.80469 step 0.19531
Channel Range	: 0 to 1023
Mode	: TCSPC
TAC (ns)	: 200
Delay (ns)	: 0
Time Calibration (ns)	: 0.19531
Reps	: 1
Acq Time (s)	: 5.0
Ex Arm Parameters:	
WaveLength (nm)	: 362.50
Bandwidth (nm)	: 0.01
Lightpath	: TCSPC Diode
Em Arm Parameters:	
WaveLength (nm)	: 362.50
Bandwidth (nm)	: 3.33

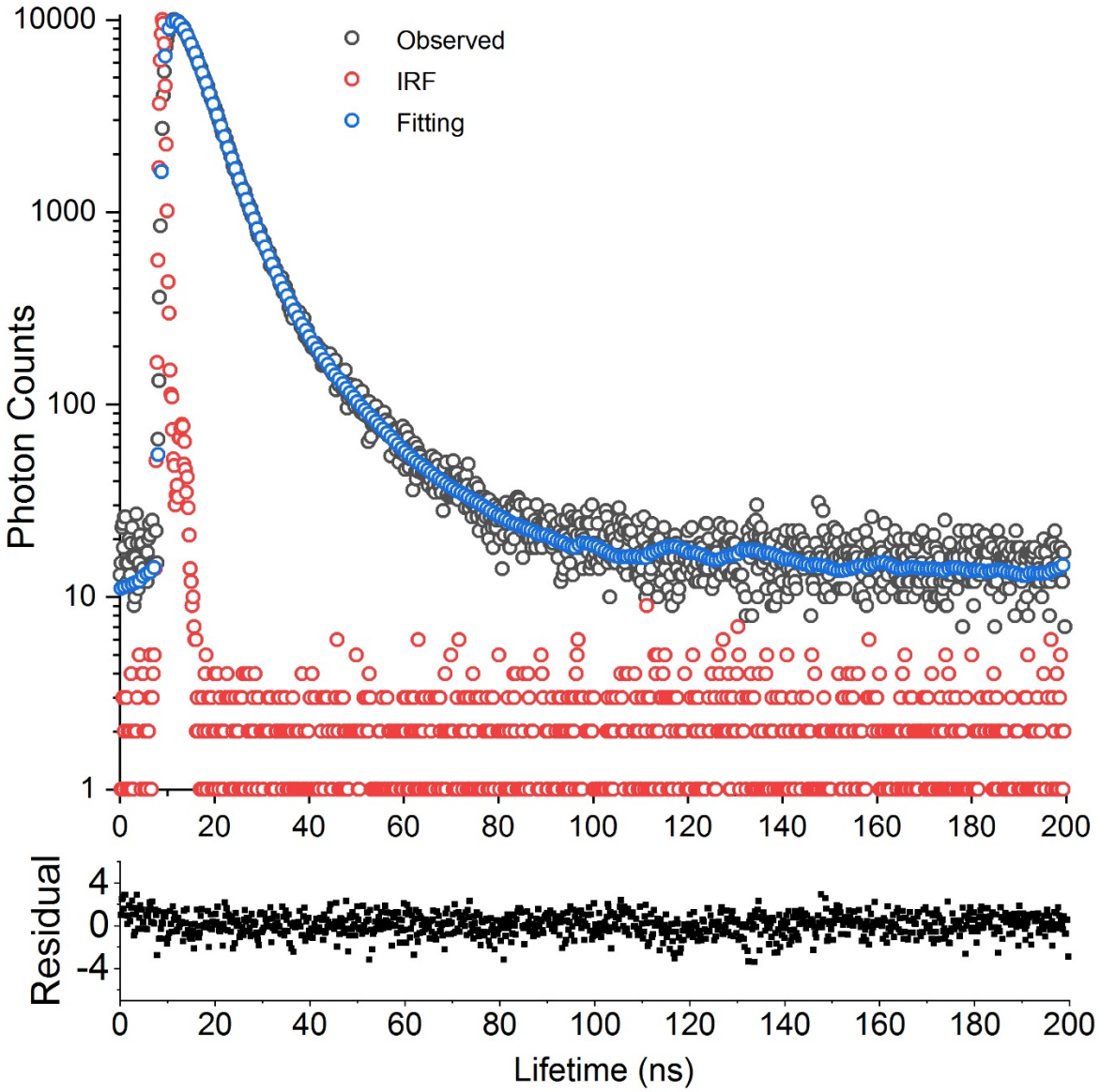

Figure S13. Lifetime decay profile of composite 3D printed pellet measured for the emission maximum at 572 nm.

Decay: Composite Pellet@572nm emission

Lifetime Parameters:	
Time Range (ns)	: 0.00000 to 199.80469 step 0.19531
Channel Range	: 0 to 1023
Mode	: TCSPC
TAC (ns)	: 200
Delay (ns)	: 0
Time Calibration (ns)	: 0.19531

Reps	: 1
Acq Time (m:s)	: 01:18.6
Ex Arm Parameters:	
WaveLength (nm)	: 362.50
Bandwidth (nm)	: 0.01
Lightpath	: TCSPC Diode
Em Arm Parameters:	
WaveLength (nm)	: 572.00
Bandwidth (nm)	: 3.33

IRF: Composite Pellet@572nm emission

Lifetime Parameters:	
Time Range (ns)	: 0.00000 to 199.80469 step 0.19531
Channel Range	: 0 to 1023
Mode	: TCSPC
TAC (ns)	: 200
Delay (ns)	: 0
Time Calibration (ns)	: 0.19531
Reps	: 1
Acq Time (s)	: 8.1
Ex Arm Parameters:	
WaveLength (nm)	: 362.50
Bandwidth (nm)	: 0.01
Mono Type	: FS5
Lightpath	: TCSPC Diode
Em Arm Parameters:	
WaveLength (nm)	: 362.50
Bandwidth (nm)	: 3.33

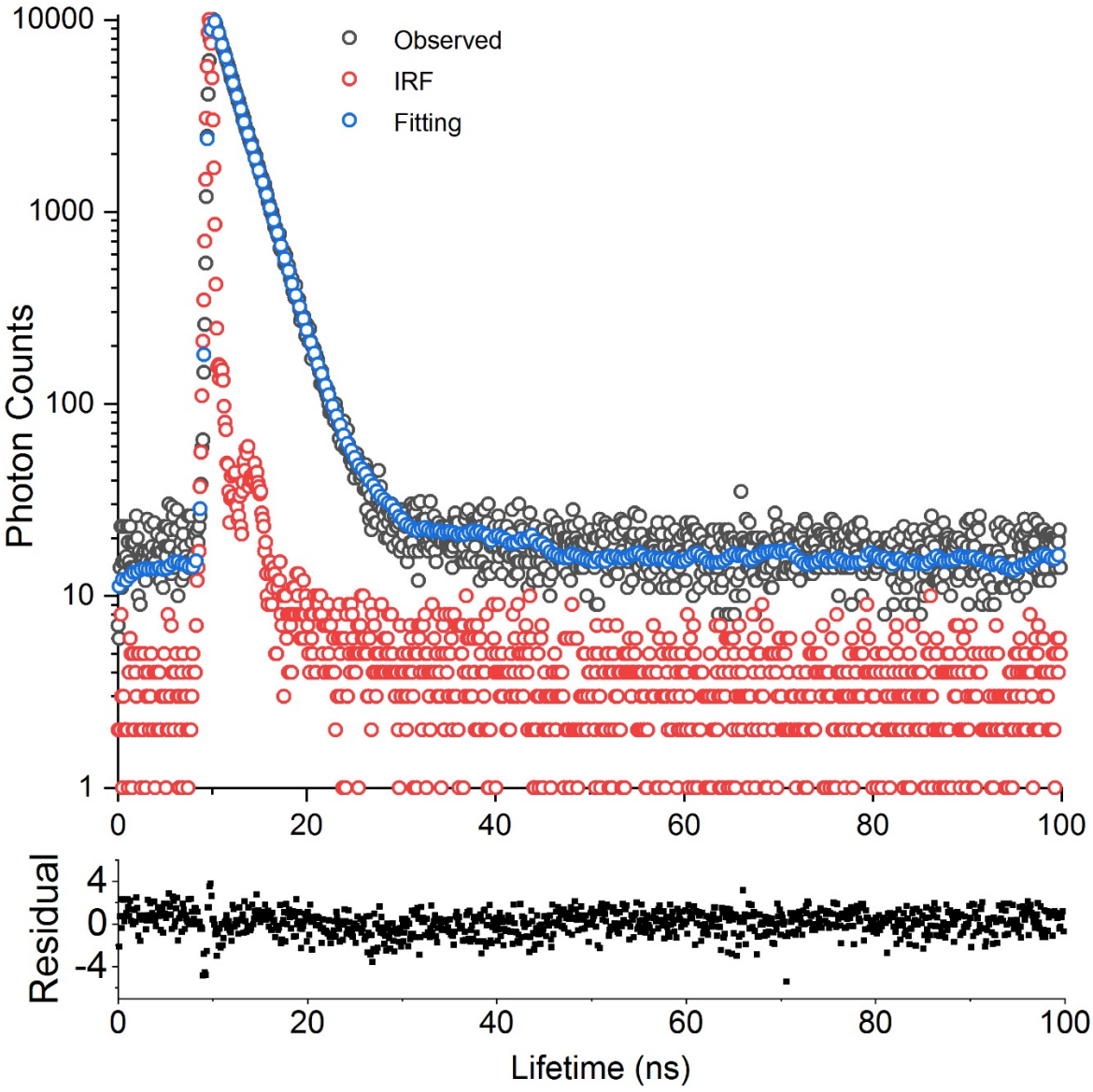

Figure S14. Lifetime decay profile of Rhodamine B solution measured for the emission maximum at 571 nm.

Decay: B=Rhodamine B Solution

Lifetime Parameters:	
Time Range (ns)	: 0.00000 to 99.90234 step 0.09766
Channel Range	: 0 to 1023
Mode	: TCSPC
TAC (ns)	: 100
Delay (ns)	: 0
Time Calibration (ns)	: 0.09766

Reps	: 1
Acq Time (m:s)	: 01:12.1
Ex Arm Parameters:	
WaveLength (nm)	: 362.50
Bandwidth (nm)	: 0.01
Lightpath	: TCSPC Diode
Em Arm Parameters:	
WaveLength (nm)	: 571.00
Bandwidth (nm)	: 1.00
Lightpath	: Standard Detector

IRF: B=Rhodamine B Solution

Lifetime Parameters:	
Time Range (ns)	: 0.00000 to 99.90234 step 0.09766
Channel Range	: 0 to 1023
Mode	: TCSPC
TAC (ns)	: 100
Delay (ns)	: 0
Time Calibration (ns)	: 0.09766
Reps	: 1
Acq Time (s)	: 15.7
Ex Arm Parameters:	
WaveLength (nm)	: 362.50
Bandwidth (nm)	: 0.01
Lightpath	: TCSPC Diode
Em Arm Parameters:	
WaveLength (nm)	: 362.50
Bandwidth (nm)	: 4.01
Lightpath	: Standard Detector

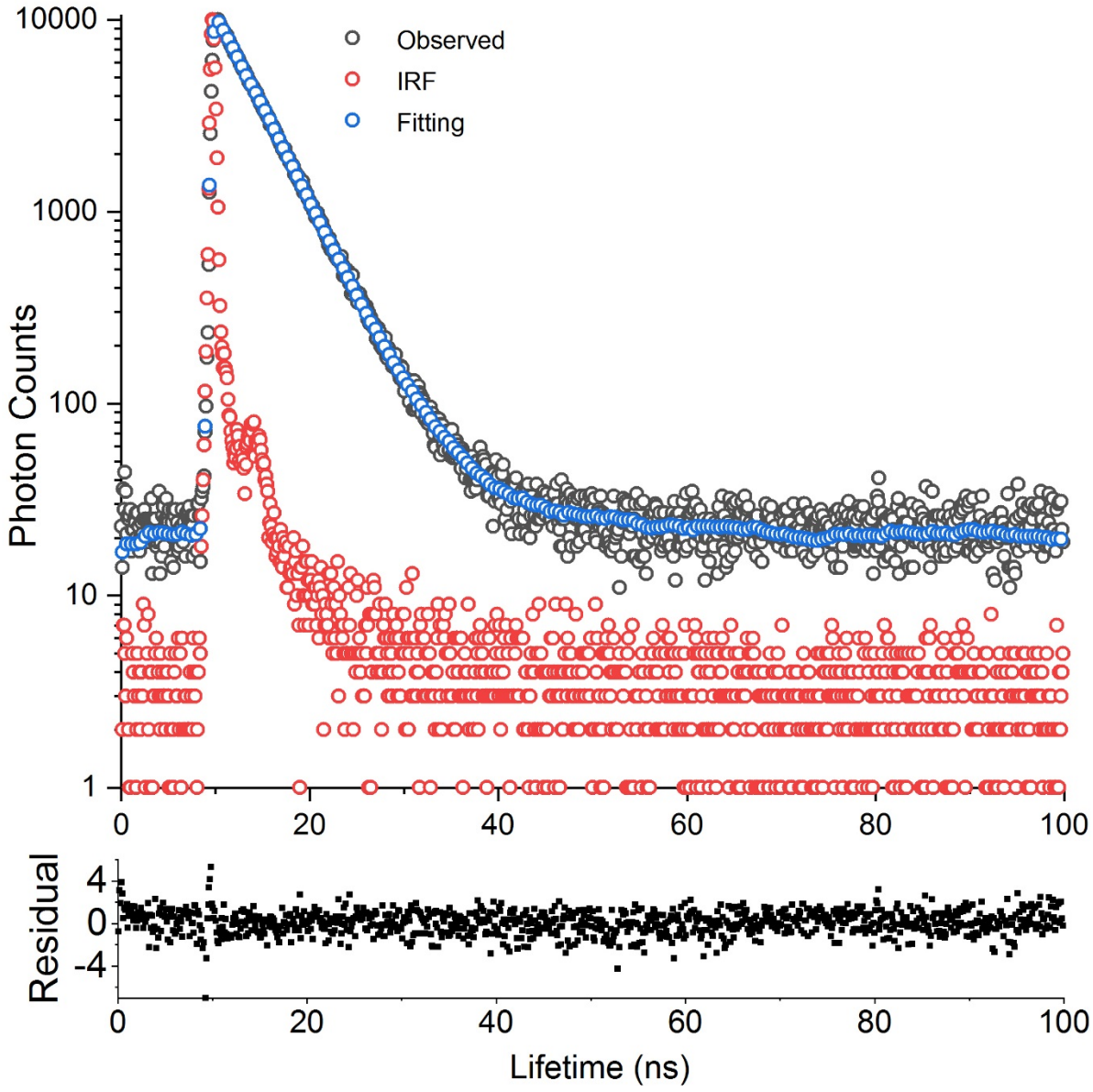

Figure S15. Lifetime decay profile of A = Fluorescein solution measured for the emission maximum at 515 nm.

Decay: A=Fluorescein Solution

Lifetime Parameters:	
Time Range (ns)	: 0.00000 to 99.90234 step 0.09766
Channel Range	: 0 to 1023
Mode	: TCSPC
TAC (ns)	: 100
Delay (ns)	: 0
Time Calibration (ns)	: 0.09766

Reps	: 1
Acq Time (m:s)	: 01:33.8
Ex Arm Parameters:	
WaveLength (nm)	: 362.50
Bandwidth (nm)	: 0.01
Lightpath	: TCSPC Diode
Em Arm Parameters:	
WaveLength (nm)	: 515.00
Bandwidth (nm)	: 1.00

IRF: A=Fluorescein Solution

Lifetime Parameters:	
Time Range (ns)	: 0.00000 to 99.90234 step 0.09766
Channel Range	: 0 to 1023
Mode	: TCSPC
TAC (ns)	: 100
Time Calibration (ns)	: 0.09766
Reps	: 1
Acq Time (s)	: 11.4
Ex Arm Parameters:	
Intensity	: 50
WaveLength (nm)	: 362.50
Bandwidth (nm)	: 0.01
Lightpath	: TCSPC Diode
Em Arm Parameters:	
WaveLength (nm)	: 362.50
Bandwidth (nm)	: 4.19

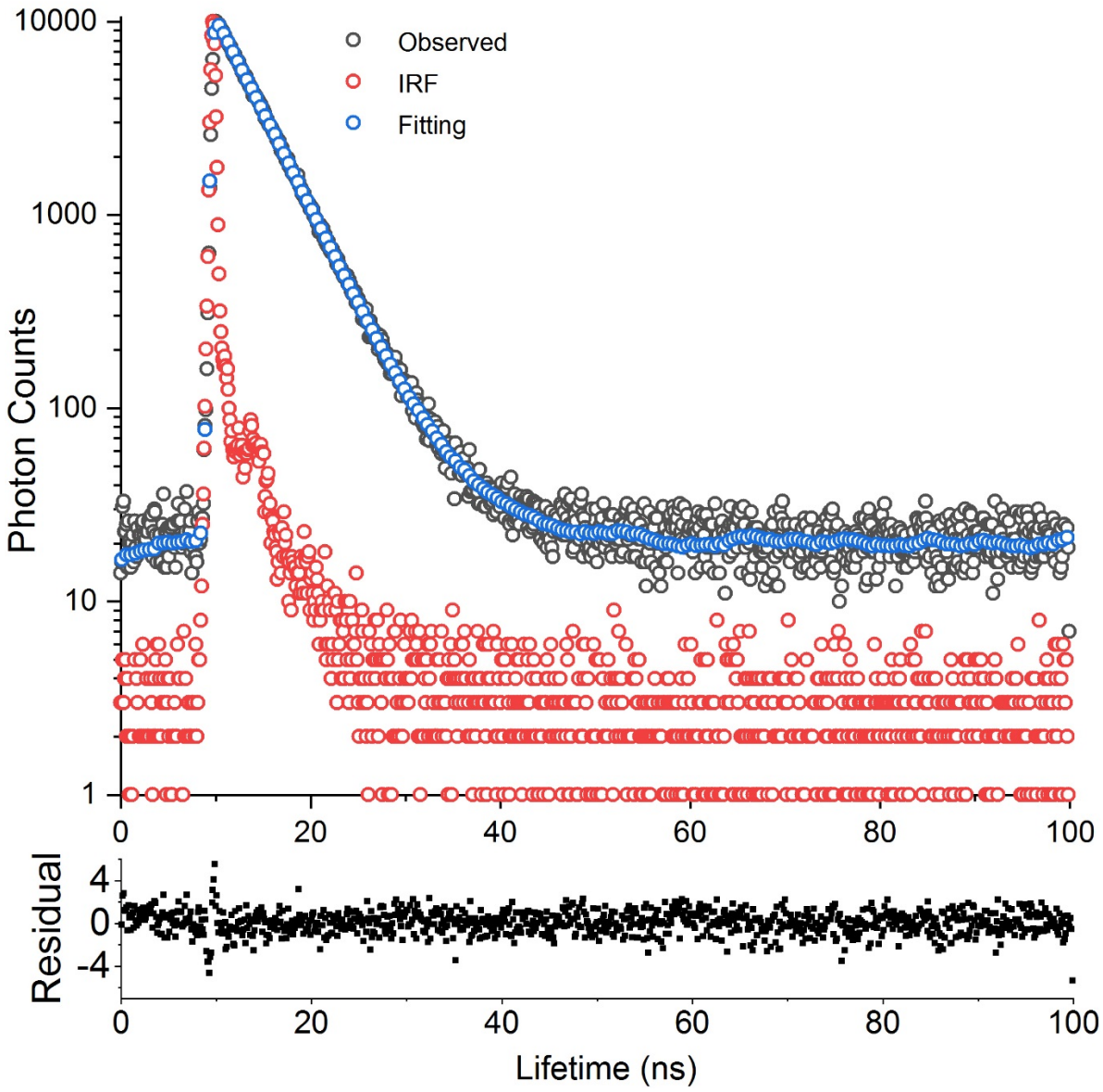

Figure S16. Lifetime decay profile of A+B solution (i.e. Rhodamine B and Fluorescein) measured for the emission maximum at 515 nm.

Decay: A+B Solution@515nm emission

Lifetime Parameters:	
Time Range (ns)	: 0.00000 to 99.90234 step 0.09766
Channel Range	: 0 to 1023
Mode	: TCSPC
TAC (ns)	: 100
Delay (ns)	: 0
Time Calibration (ns)	: 0.09766

Reps	: 1
Acq Time (m:s)	: 01:30.7
Ex Arm Parameters:	
WaveLength (nm)	: 362.50
Bandwidth (nm)	: 0.01
Lightpath	: TCSPC Diode
Em Arm Parameters:	
WaveLength (nm)	: 515.00
Bandwidth (nm)	: 1.00
Lightpath	: Standard Detector

IRF: A+B Solution @515nm emission

Lifetime Parameters:	
Time Range (ns)	: 0.00000 to 99.90234 step 0.09766
Channel Range	: 0 to 1023
Mode	: TCSPC
TAC (ns)	: 100
Delay (ns)	: 0
Time Calibration (ns)	: 0.09766
Reps	: 1
Acq Time (s)	: 11.3
Ex Arm Parameters:	
WaveLength (nm)	: 362.50
Bandwidth (nm)	: 0.01
Lightpath	: TCSPC Diode
Em Arm Parameters:	
WaveLength (nm)	: 362.50
Bandwidth (nm)	: 4.42

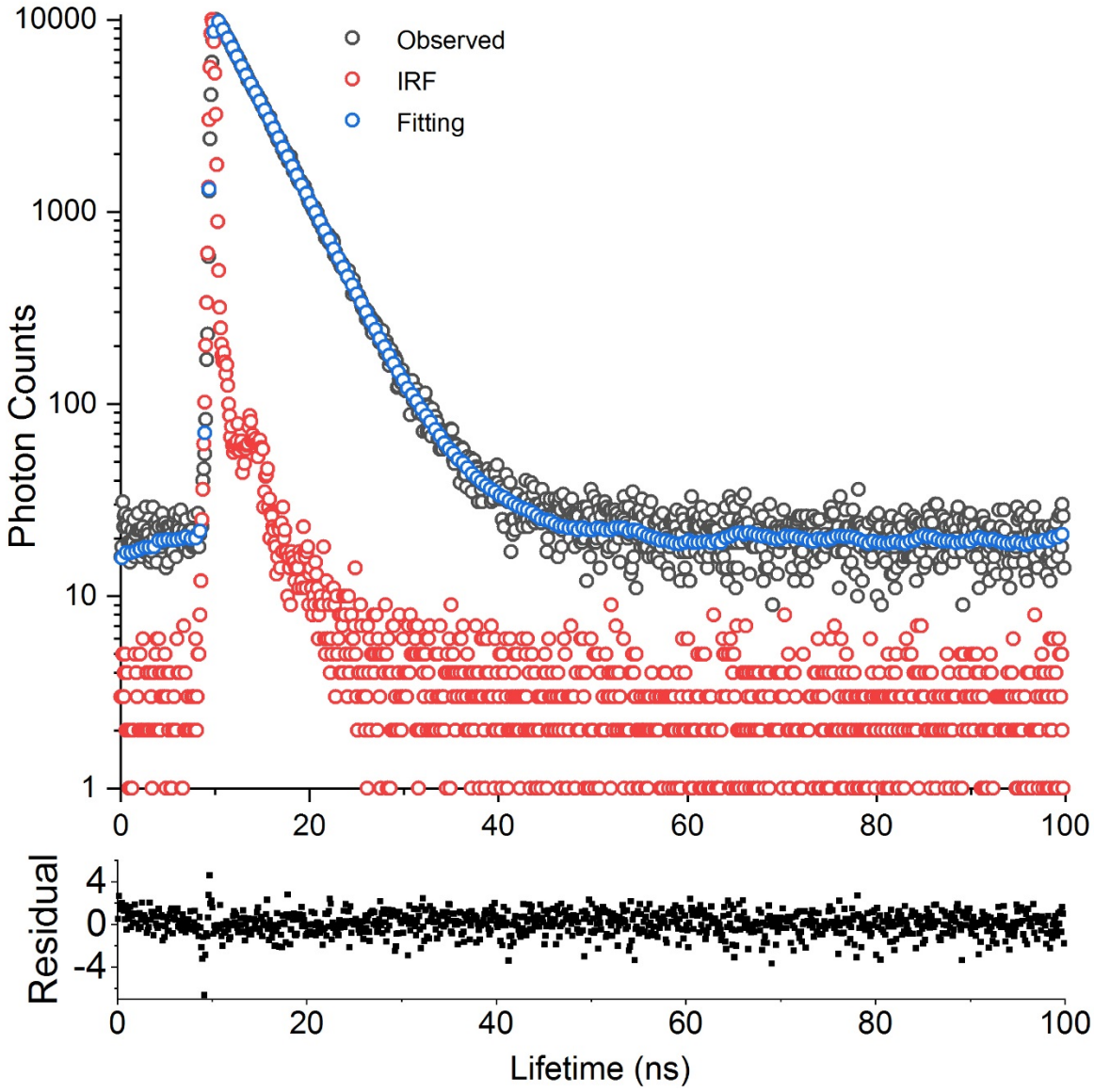

Figure S17. Lifetime decay profile of A+B solution (i.e. Rhodamine B and Fluorescein) measured for the emission maximum at 571 nm.

Decay: A+B Solution@571nm emission

Lifetime Parameters:	
Time Range (ns)	: 0.00000 to 99.90234 step 0.09766
Channel Range	: 0 to 1023
Mode	: TCSPC
TAC (ns)	: 100
Delay (ns)	: 0
Time Calibration (ns)	: 0.09766

Reps	: 1
Acq Time (m:s)	: 01:36.5
Ex Arm Parameters:	
WaveLength (nm)	: 362.50
Bandwidth (nm)	: 0.01
Lightpath	: TCSPC Diode
Em Arm Parameters:	
WaveLength (nm)	: 571.00
Bandwidth (nm)	: 1.01

IRF : A+B Solution@571nm emission

Lifetime Parameters:	
Time Range (ns)	: 0.00000 to 99.90234 step 0.09766
Channel Range	: 0 to 1023
Mode	: TCSPC
TAC (ns)	: 100
Delay (ns)	: 0
Time Calibration (ns)	: 0.09766
Reps	: 1
Acq Time (s)	: 11.3
Ex Arm Parameters:	
WaveLength (nm)	: 362.5
Bandwidth (nm)	: 0.01
Lightpath	: TCSPC Diode
Em Arm Parameters:	
WaveLength (nm)	: 362.50
Bandwidth (nm)	: 4.42
