Blue Emitting Pt and Pd Complexes for Displays and Lighting Applications

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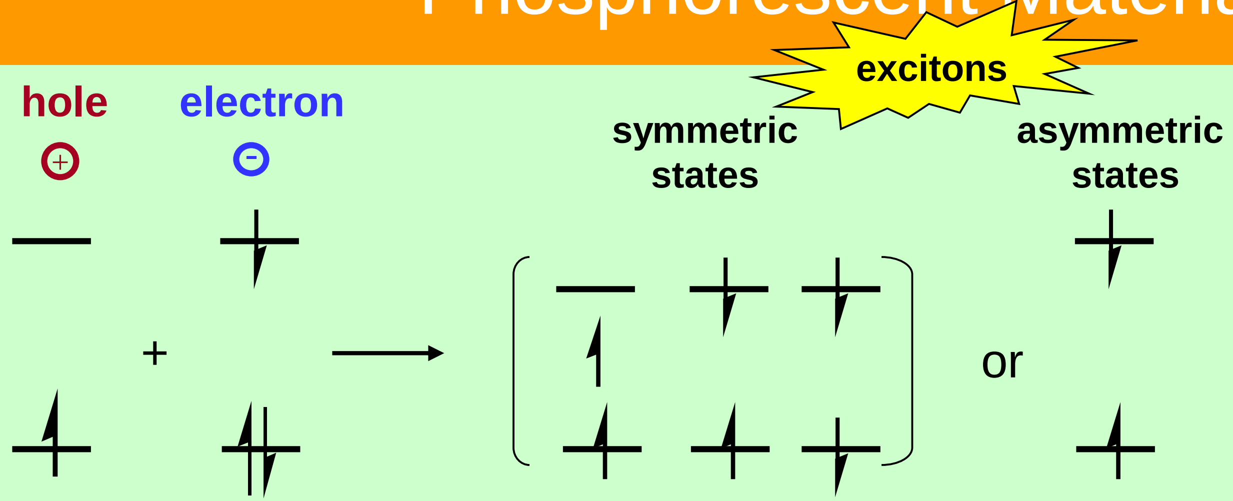
Phosphorescent Materials



quantum statistics of excitons

$S = |\uparrow\uparrow\rangle$

$S = |\downarrow\downarrow\rangle$

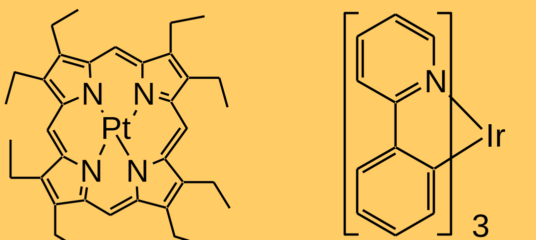
$S = \frac{1}{\sqrt{2}}\left(|\uparrow\downarrow\rangle + |\uparrow\downarrow\rangle\right)$

} **triplet**

$S = \frac{1}{\sqrt{2}}\left(|\uparrow\downarrow\rangle - |\uparrow\downarrow\rangle\right)$ **singlet**

triplet 75%

singlet 25%



PtOEP   *fac*-**Ir**(ppy)$_3$

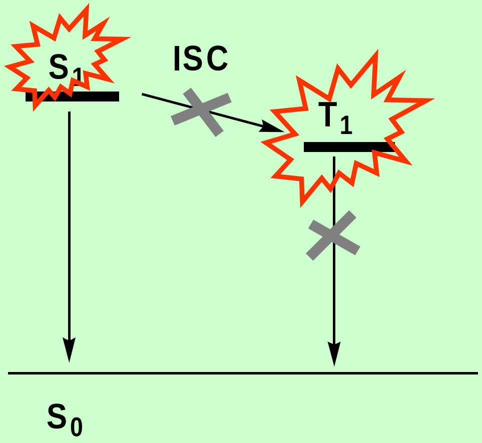
Heavy metal complexes, introduced by Forrest and Thompson since 1998.

harvested only by phosphorescent dyes

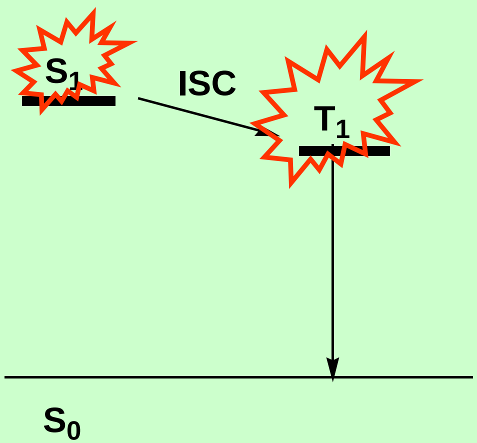
harvested both by fluorescent and phosphorescent dyes

Max theoretical quantum efficiency	Fluorescent	Phosphorescent
Internal	25%	100%
External	5%	20%

How to harvest 100% electro-generated excitons?



fluorescence

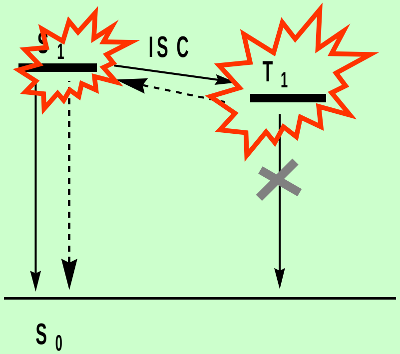


phosphorescence

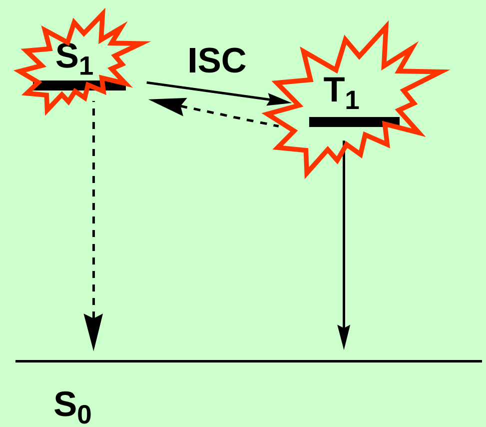
PHOLED:
1) Baldo *et.al.*, Phys. Rev. B (1999)
2) Baldo *et.al.*, Nature (1998)

TADF:
1) Uoyama *et.al.*, Nature (2012)
2) Hashimoto *et.al.*, JACS (2011)
3) Czerwieniec *et.al.* Inorg. Chem. (2011)

MADF:
Li *et.al.*, PCT/US13/66793



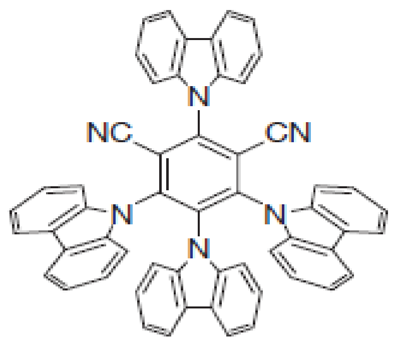
Thermal Activated Delayed Fluorescence (TADF)



Metal Assisted Delayed Fluorescence (MADF)

DF/PH Emitter

TADF Materials in literature domain

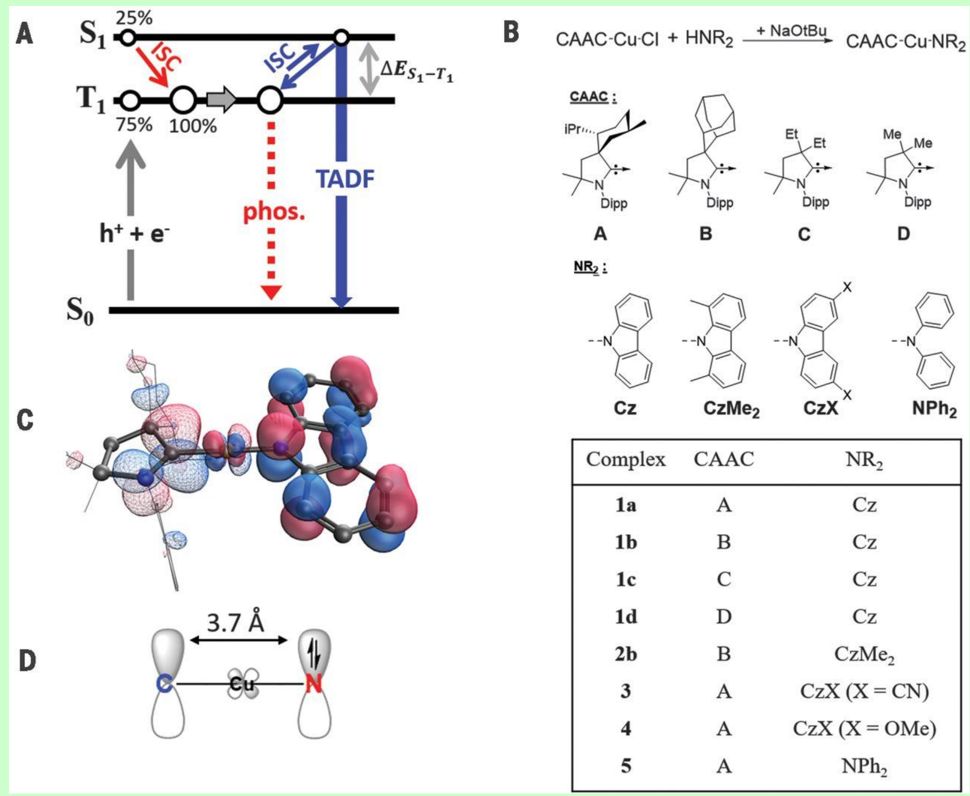


4CzIPN

Uoyama and Adachi et al. Nature (2012)

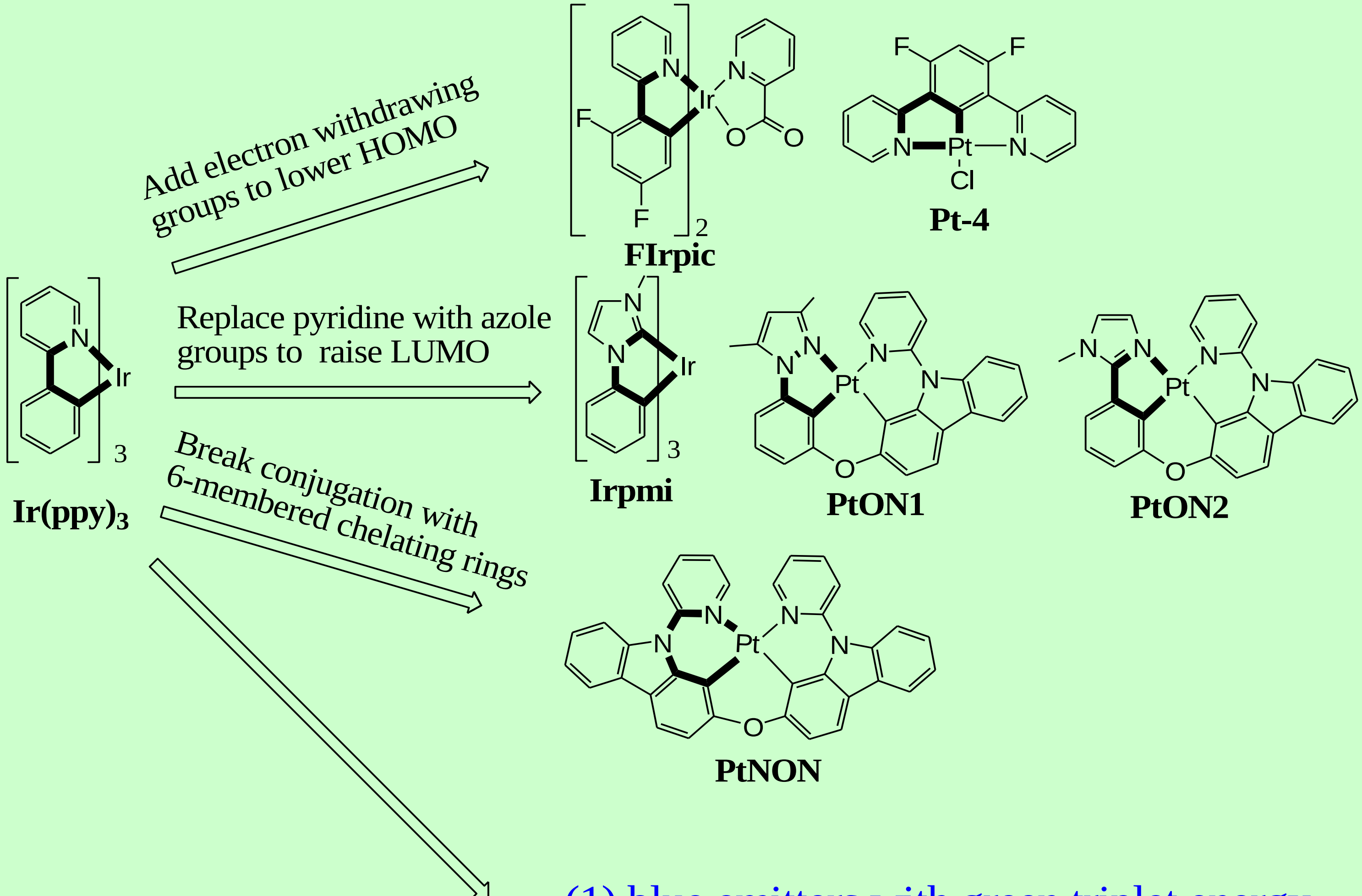
Maintaining a Φ of close to 1 and a τ of close to 1 μs.

Hamze and Thompson et al., Science (2019)



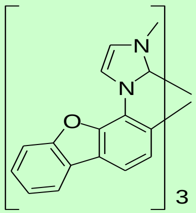
Complex	CAAC	NR$_2$
1a	A	Cz
1b	B	Cz
1c	C	Cz
1d	D	Cz
2b	B	CzMe$_2$
3	A	CzX (X = CN)
4	A	CzX (X = OMe)
5	A	NPh$_2$

Blue triplet emitter design

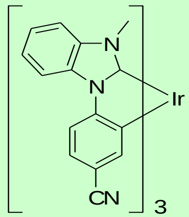


(1) blue emitters with green triplet energy
(2) ppy-based blue emitters

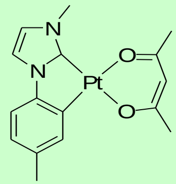
Tetradentate Pt Complexes



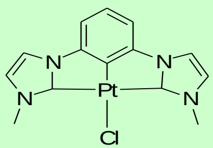
Ir(dpfmi)



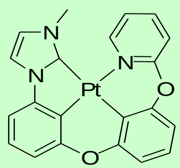
Ir(cnpmic)



Pt(Mepmi)

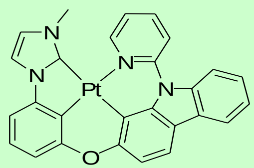


Pt-16



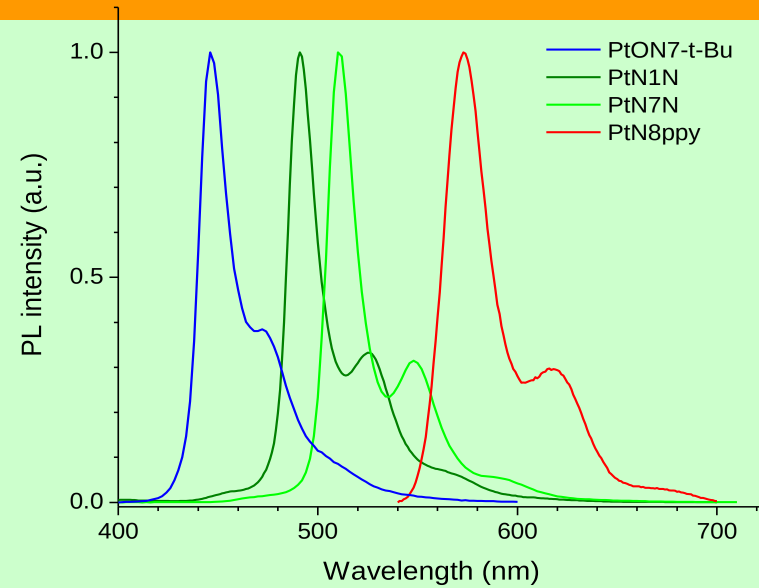
Pt[*pmi*-O-POPy]

PtOO7

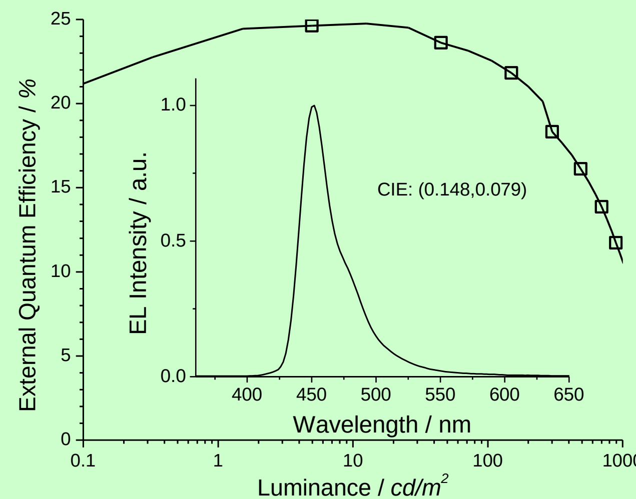


Pt[*pmi*-O-CbPy]

PtON7



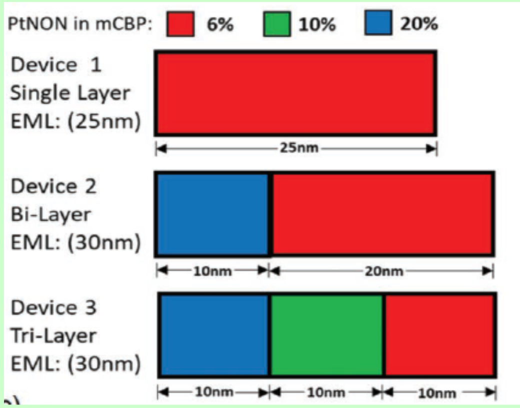
"Pure" Blue OLED (CIE_y <0.1) with EQE of over 20%

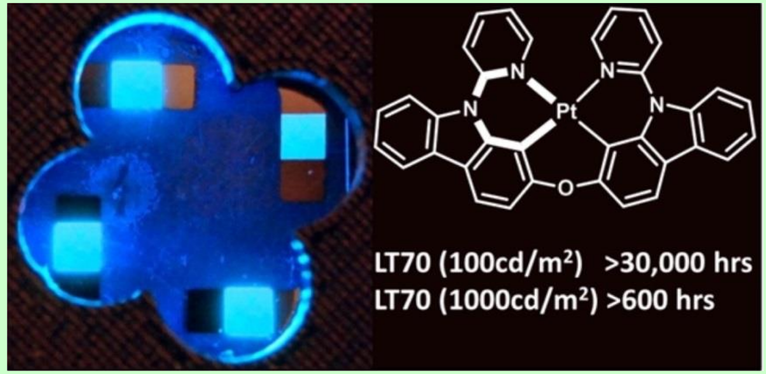


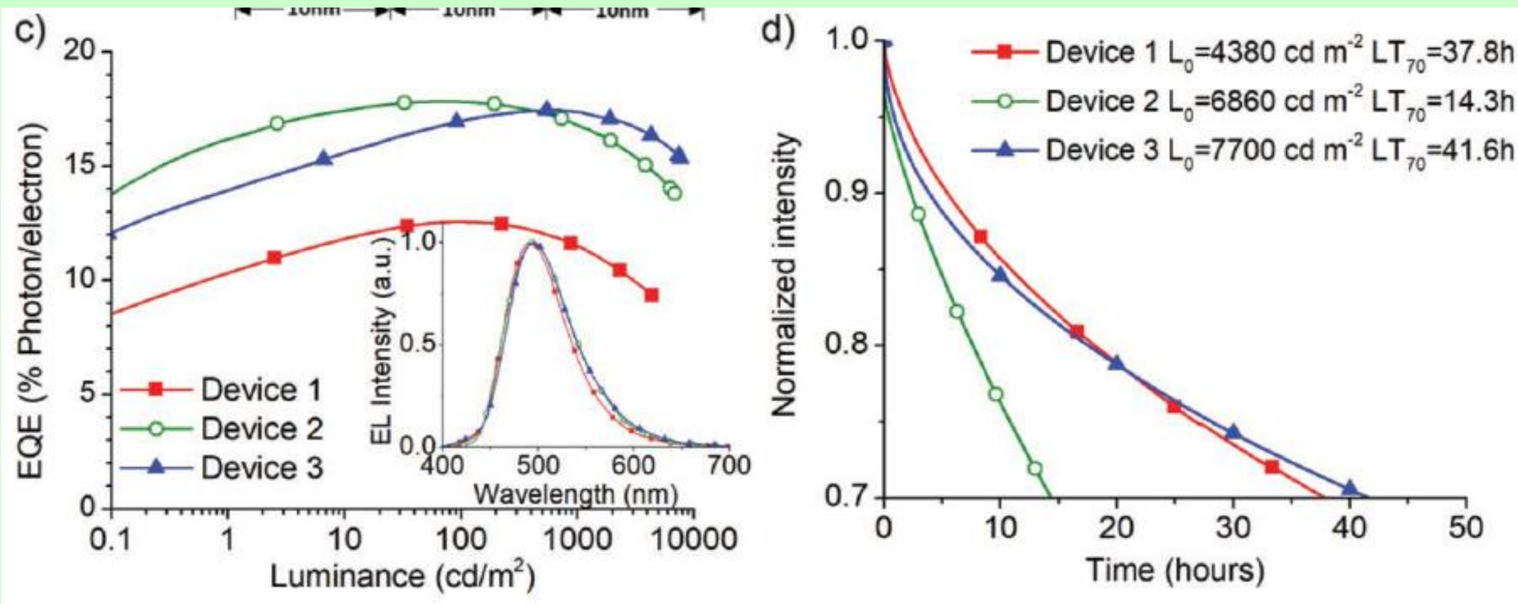
Complex	λ_{max} (nm)	Φ(%)	τ (μs)	k_r ($x10^4 s^{-1}$)	k_{nr} ($x10^4 s^{-1}$)
PtON7	452	89	4.1	21	2.6
PtOO7	442	58	2.5	23	17
Pt-16[9b]	450	32	5.1	6.3	13.3
Pt(Mepmic)[9a]	419	20	25	0.8	3.2
$Ir(cnpmic)_3$[7b]	425(sh), 450	78	19.5	4	1.1
Ir(dbfmi)[7a]	445	70[a]	19.6	3.6	1.5
PtON1	449	85	4.5	19	3.3

1) Hang et al. *Angew. Chem.* (2013); 2) Li et al. *Adv. Opt. Mater.* (2015); 3) Fleetham et al. *Adv. Mater.* (2014).

First Blue Emitter with 6-membered Chelate Rings



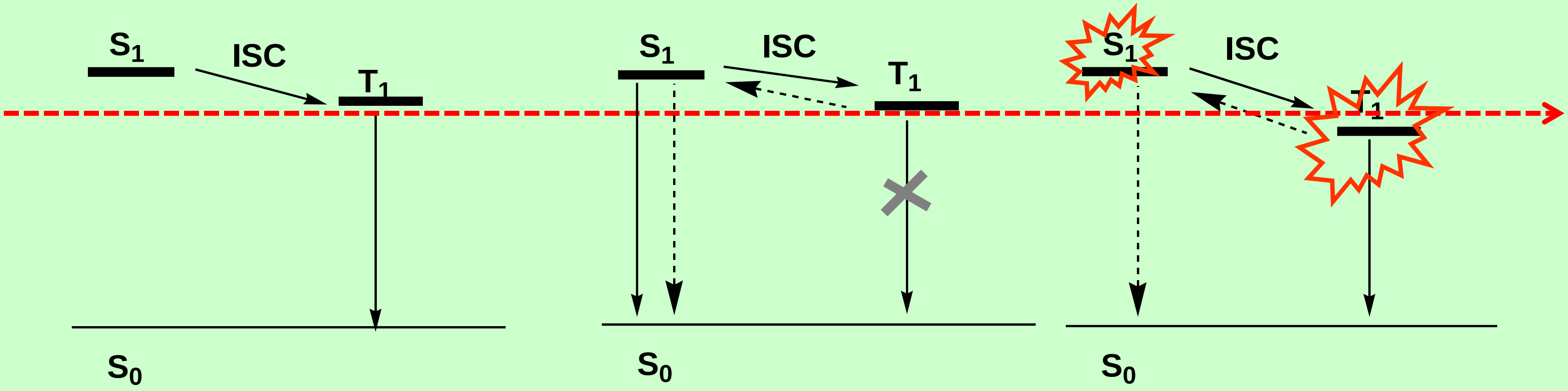




Estimated LT70 of 1337 hr @1000 nits, reported most stable blue emitters with triplet energy of over 2.8 eV.

Klimes et al. Adv. Funct. Mater. (2019)

Why MADF materials?



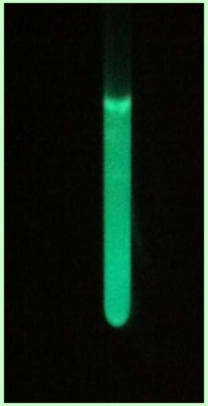
Limit set by carbazole host

phosphorescence

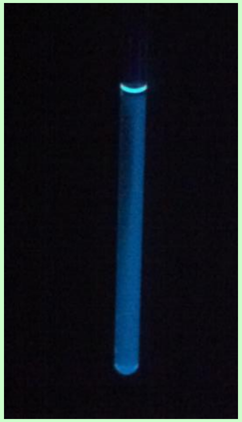
Thermal Activated Delayed Fluorescence (TADF)

Metal Assisted Delayed Fluorescence (MADF)

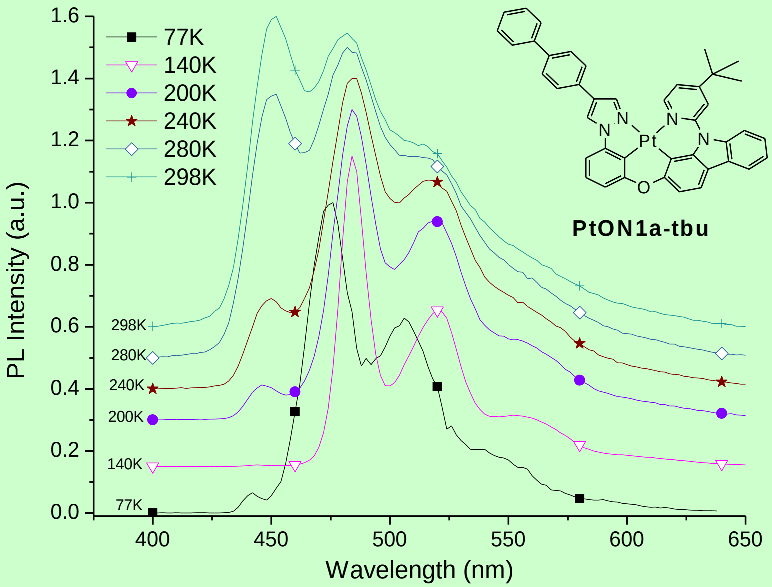
Magic of MADF?



77 K



RT



Take-home message

- New emitter design can play a key role of blue OLED development.