SAND2011-4290P

U.S. DEPARTMENT OF ENERGY

National Nuclear Security Administration
Defense Nuclear Nonproliferation

Office of Nonproliferation and Verification Research & Development

SNM Movement Detection / Radiation Sensors and Advanced Materials Portfolio Review

RadSensing2011

Advanced Plastic Scintillators

Patrick Feng

Sandia National Laboratories

June 09, 2011

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Project Goals

Goal:
•Design plastic scintillators capable of n/γ discrimination

Project Team
Patrick Feng, PI
F. Patrick Doty, Sandia staff
Stan Mrowka, Sandia staff
Brian Wong, Sandia staff
Andy Vance, Sandia staff

Technical Approach:
•Induce triplet harvesting through heavy-atom effect
    •Fast (sub-microsecond) phosphorescence

Advantages:
•Solid-state materials
•Tunable wavelength and timing characteristics
    •Particle discrimination via two methods: SSD, PSD
•Exponential triplet decay characteristics

Budget
FY11: $530 K

Technical Challenges:
•Alignment of electronic states for efficient Dexter energy transfer
•Emission wavelengths outside of peak sensitivity range for bialkali PMTs.

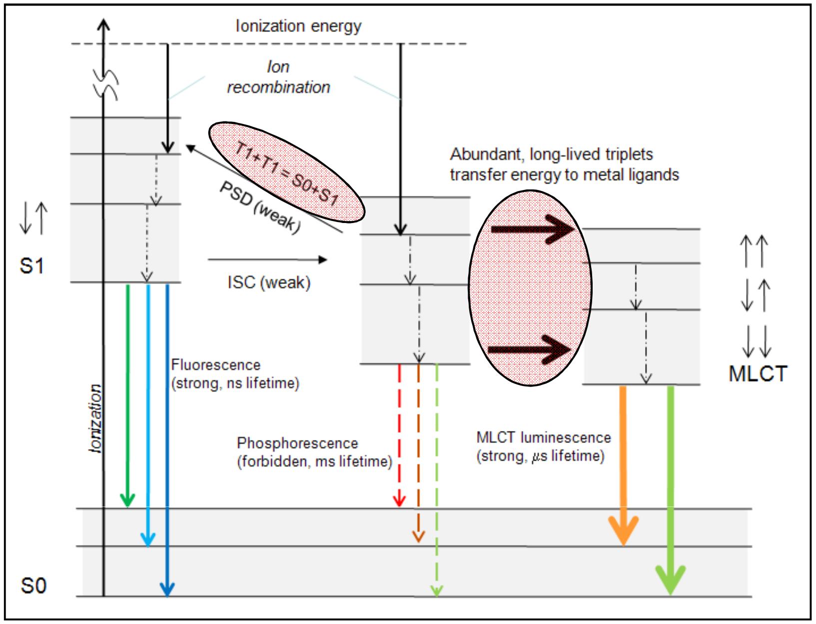
Task 1: Material synthesis and preparation

Task 2: Material characterization

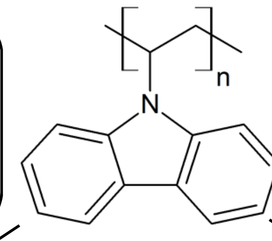
Task 3: Modeling of new materials

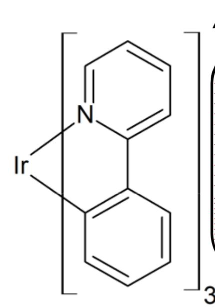
Task 4: Analysis and reports

Triplet Harvesting



Host:
N-polyvinylcarbazole
λ_{em} = 420 nm
Δ_{stokes}= 65 nm
τ_0 = 30 ns

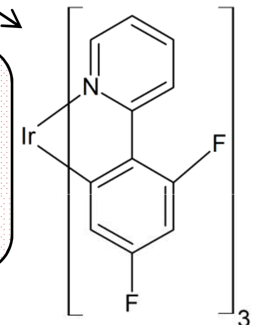




Guests:

fac-Ir(ppy)$_3$
λ_{em} = 512 nm
Δ_{stokes}= 230 nm
τ_0 = 830 ns

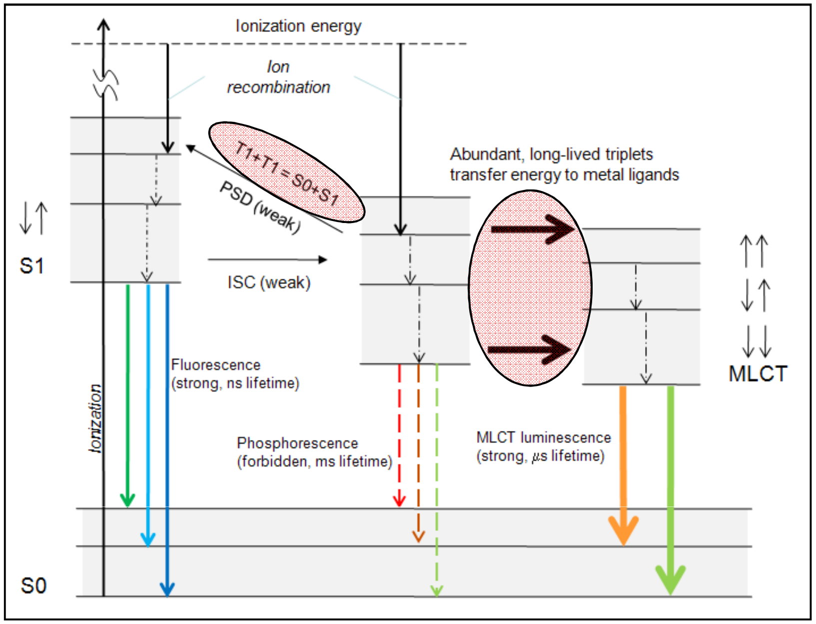
fac-Ir(ppy-F$_2$)$_3$
λ_{em} = 480 nm
Δ_{stokes}= 220 nm
τ_0 = 890 ns



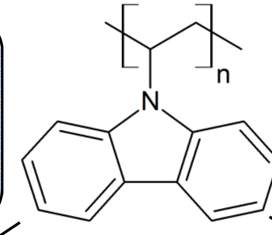
- Iridium spin-orbit coupling converts non-emissive triplet states to ^{3}MLCT states
- Sub-microsecond triplet lifetimes
- Low doping requirements: Φ_{phos}=1.00

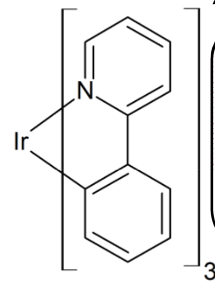
Efficient triplet energy transfer previously demonstrated in Iridium-doped OLEDs

Triplet Harvesting



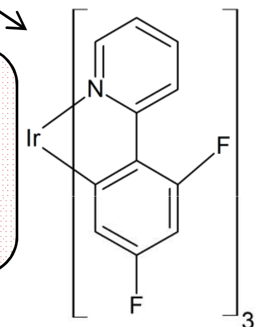
Host:
N-polyvinylcarbazole
λ_{em} = 420 nm
Δ_{stokes} = 65 nm
τ_0 = 30 ns

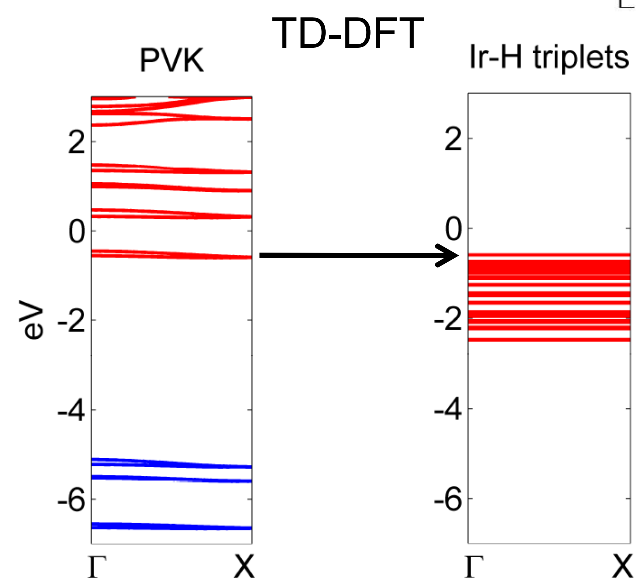




Guests:

fac-Ir(ppy)$_3$	*fac*-Ir(ppy-F$_2$)$_3$
λ_{em} = 512 nm	λ_{em} = 480 nm
Δ_{stokes} = 230 nm	Δ_{stokes} = 220 nm
τ_0 = 830 ns	τ_0 = 890 ns



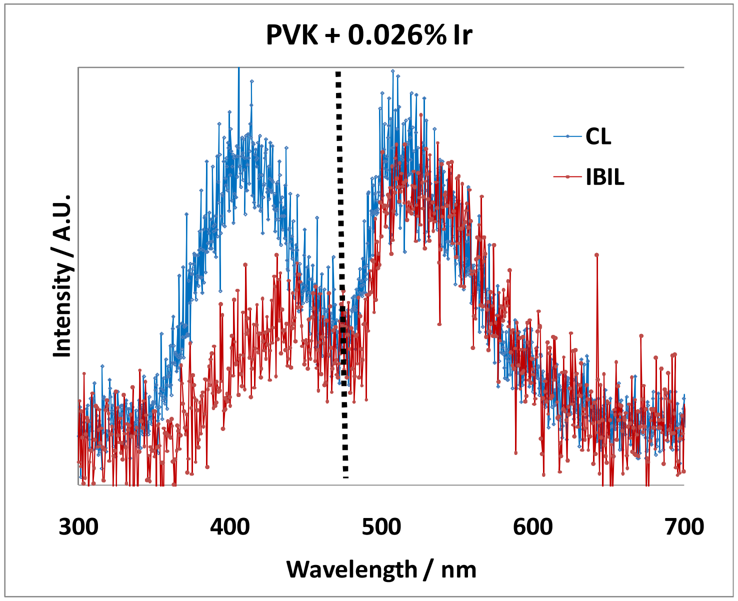


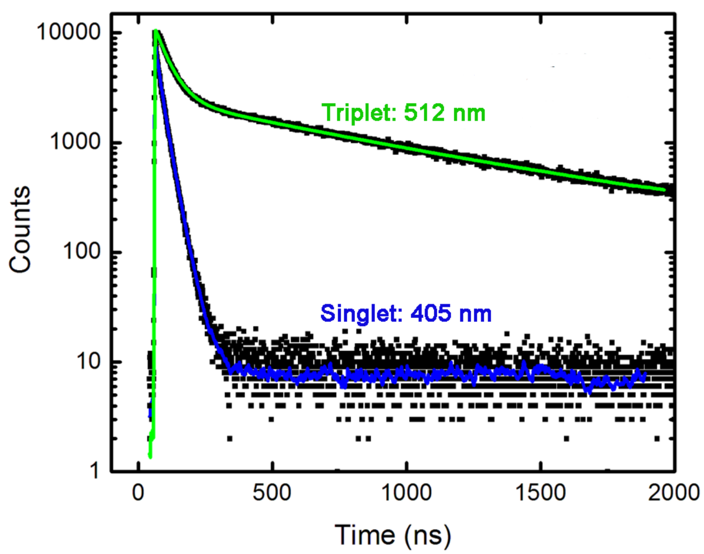
- Iridium spin-orbit coupling converts non-emissive triplet states to ^{3}MLCT states
- Sub-microsecond triplet lifetimes
- Low doping requirements: Φ_{phos}=1.00

Spectral-Shape Discrimination

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration Defense Nuclear Nonproliferation





Concept:

•Modify iridium chemistry and doping level to control wavelength and timing characteristics

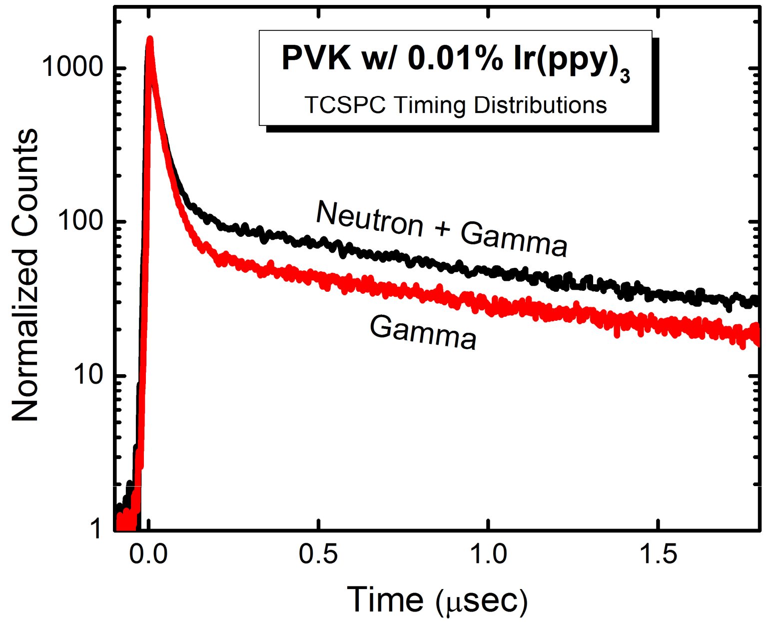
•SSD: Select host/guest to yield spectrally-resolved emission

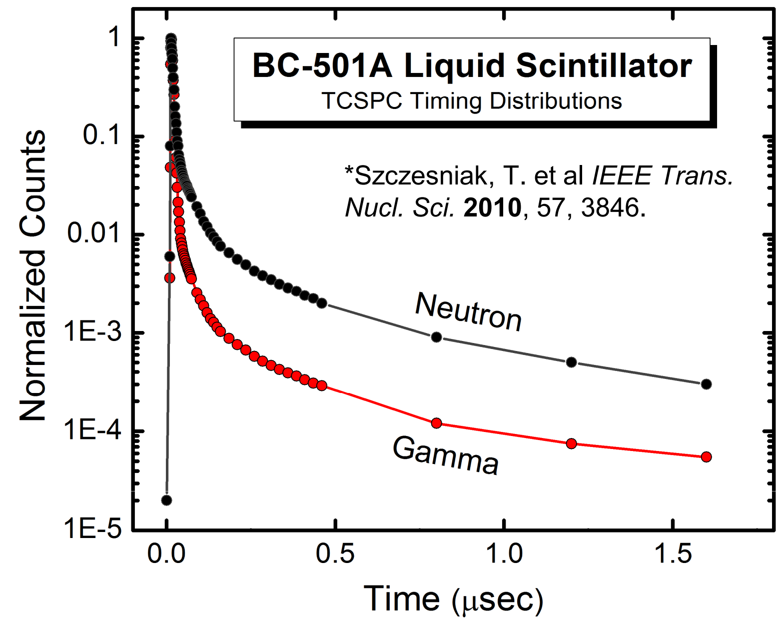
•**30 ns** prompt host fluorescence (405 nm)

•**830 ns** delayed guest phosphorescence (512 nm)

New (tunable) triplet luminescent state

Scintillation Timing Distributions: Neutron vs. Gamma

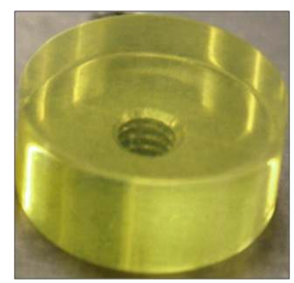




- Averaged (n+γ) timing distribution compared with pure γ decay data
- Establishes lower-limit for differential particle response

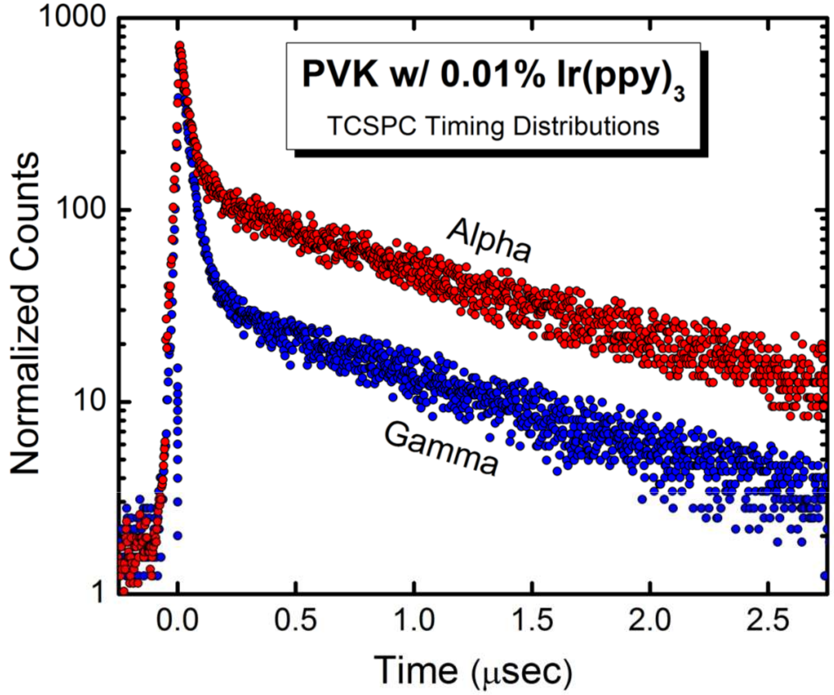
Pulse-by-pulse measurements are in progress

PVK with 0.01% $Ir(ppy)_3$ (30 ppm Ir)

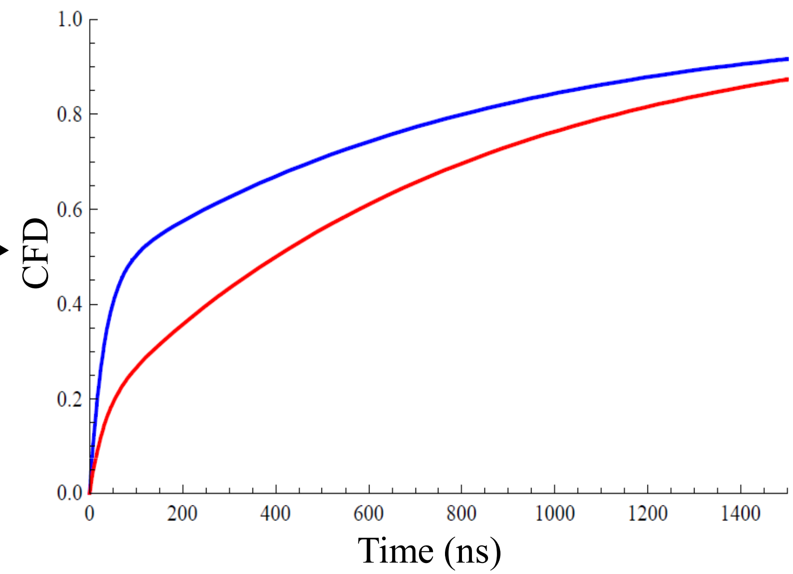


8 grams
3 cm x 1.5 cm

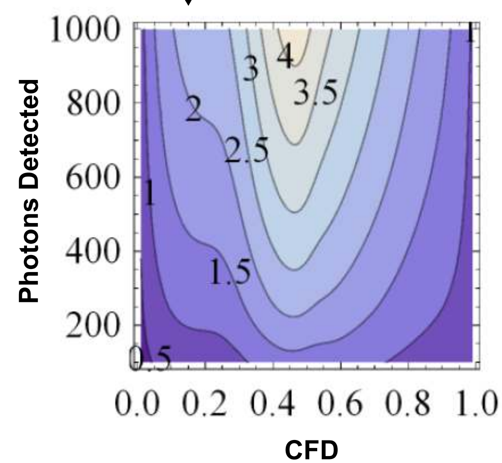
Scintillation Timing Distributions: Alpha vs. Beta/gamma



Integrate



FOM Simulation



- *d*E/*d*X quenching also seen for alphas vs. gammas
- Decay curves represent true scintillation pulse shapes

PSD-FOM ~4 for 1000 photons detected

Summary of Findings

- It is possible to exert systematic control over the triplet scintillation properties of plastic scintillators
- We have demonstrated spectrally-resolved particle discrimination (SSD)
- Differences in the scintillation pulse shapes are evident in scintillation timing distributions collected for different particle types (PSD)
- Matching of the host/guest energy levels is crucial for efficient energy transfer

Future Work

- Demonstrate pulse-by-pulse SSD and PSD for mixed n/γ sources
- Accurately quantify scintillation light yields
- Synthesize and incorporate fast- and blue-emitting iridium complexes
- Utilize Sandia's time-dependent DFT code as predictive tool for new doped scintillator compositions
- Investigate volume effects for larger samples. Apply wavelength-shifting fluors to reduce/eliminate self-absorption, if necessary.