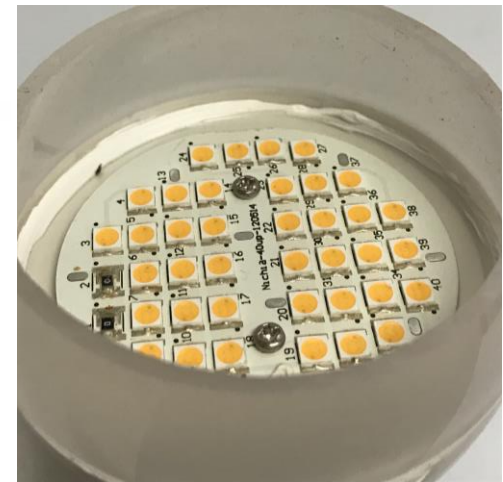




Pacific Light Technologies



Enabling Efficiency and Color with On-Chip Quantum Dots

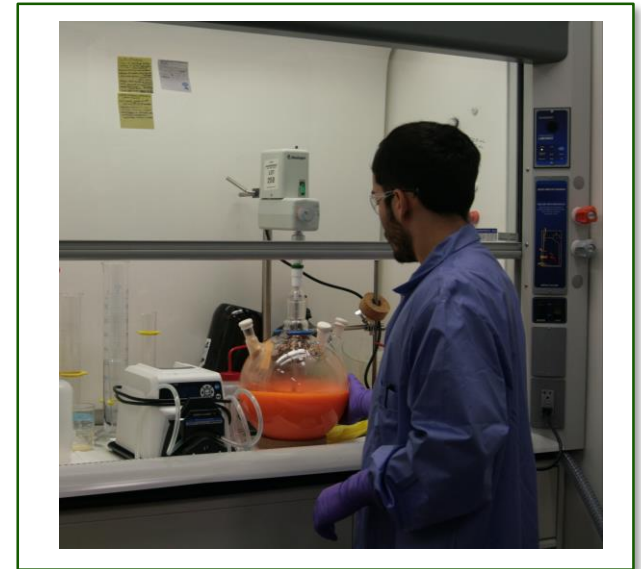
February 2017



Pacific Light Technologies

The Leader in Quantum Dot On-Chip Technology

- Founded in 2011
- Headquartered in Portland, Oregon
- Creates the **toughest and most versatile quantum dots in the market**
 - Able to function directly in LED packages
 - Applications in both the display and illumination markets, without the need for protective films or assemblies (quantum-dot level encapsulation)
- Production ramp in early 2016, shipping kilograms of quantum dot powder
- Well-positioned to capture significant market share with its on-chip quantum dot technology
- Over **70 patents issued and pending**



The Quantum Dot Market Opportunity

Growing demand from LED market

- Solid state LED illumination is growing; over 10% growth expected through 2020
- Displays shipped containing quantum dot expected to grow at a 64.2% CAGR from 2016 to 2020

Quantum Dots provide the next wave of advantages

- Improved color gamut for display vs both phosphor and OLED
- Up to 25% efficiency gain in solid state lighting

“We forecast **quantum dot components will have a rapid penetration into LCDs from 2016 to 2026.** Touch Display Research forecasts that the **quantum dot display and lighting component market will reach \$10.8 billion by 2026.**”

Dr. Jennifer Colegrove, Touch Display Research

Market Drivers for QD Adoption in LEDs



1 Wider color gamut



5 No new fab investment needed



2 Efficiency gains



6 Simple drop in design



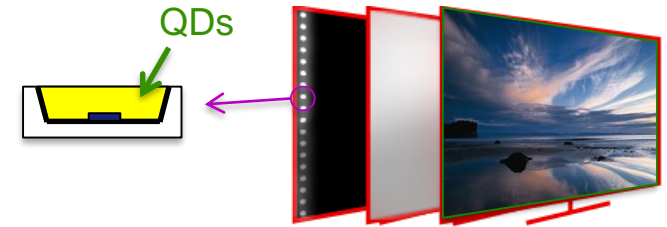
3 Better color accuracy



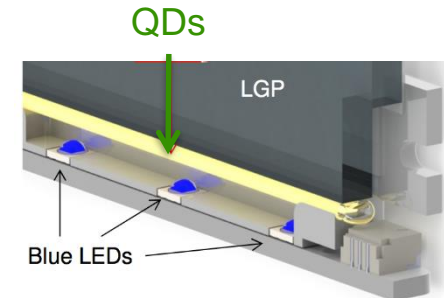
4 Low cost LED-based systems

Three methods of QD integration into LED applications

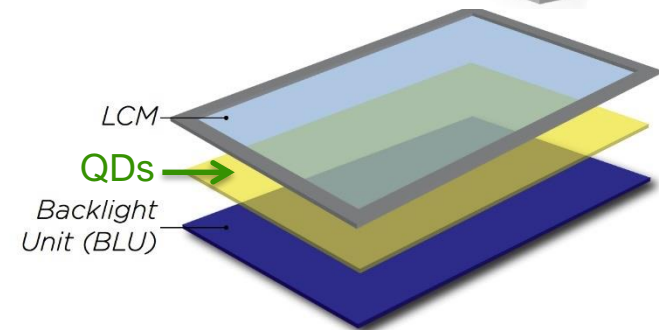
- On-chip:
 - *Drop-in* replacement, QDs in the LED package
 - Minimum material quantity requirements
 - Maximum temp and flux performance demand
 - **No re-design required, lowest cost to end user**



- On-edge:
 - Sealed filament between LEDs and edge-lit BLU
 - Medium material quantity
 - Intermediate material and performance demands



- On-surface:
 - Film covers entire screen area
 - Maximum material quantity required
 - Minimum temp and flux performance demand
 - **Highest cost to end user**



Primary drivers for on-chip materials: SSL market, Cost

“The long term play is on-chip quantum dots that are part of the LED solution the way phosphors are packaged today. That requires stability in a high flux environment – something **no one has solved yet** - to offer a commercial product.”

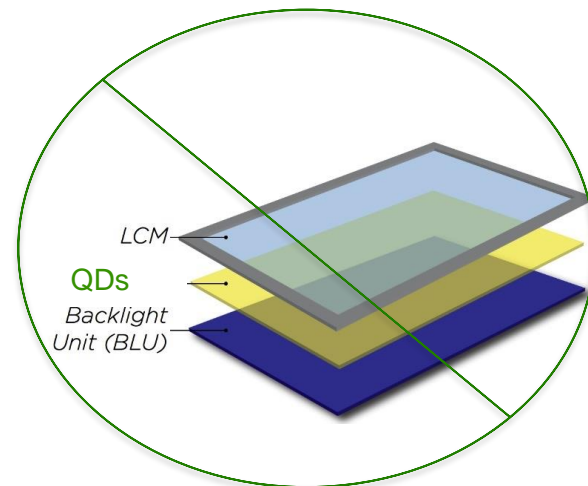
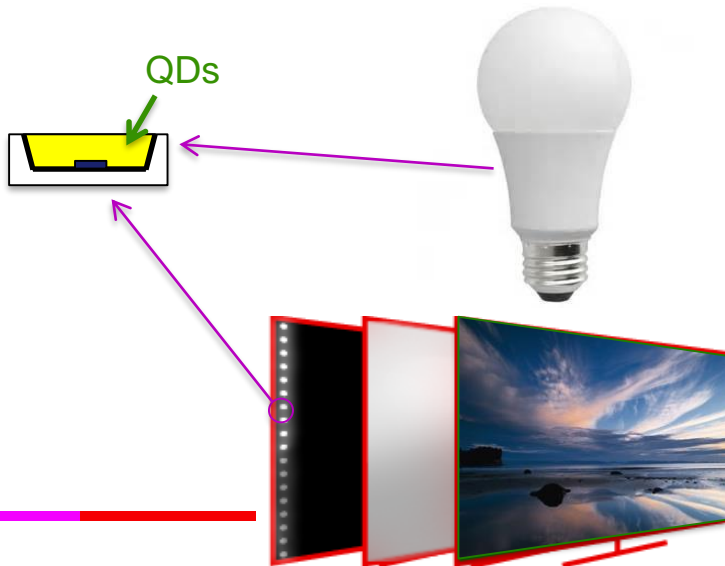
Chris Chinnock, Insight Media

“Lighting-specifically general illumination, will provide the real lift in LED revenue for the next five years.”

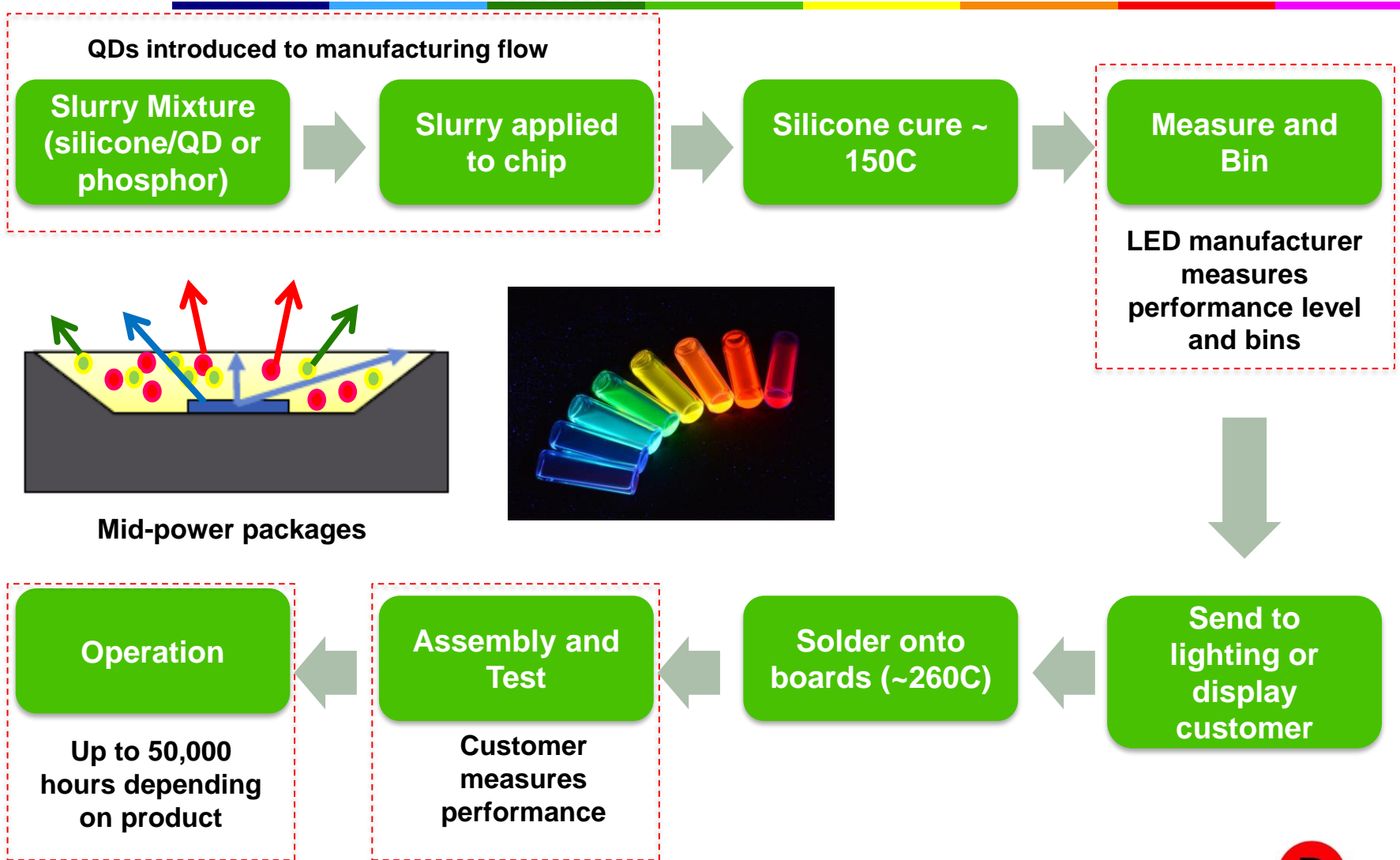
LED Magazine

PLT On-chip QDs: Easily replace existing phosphors

- Drop-in LED replacement in the system
- Powder QDs mean no re-design required
- Works for all size display AND lighting
- Lowest cost QD solution**
- The ONLY QD solution for lighting**



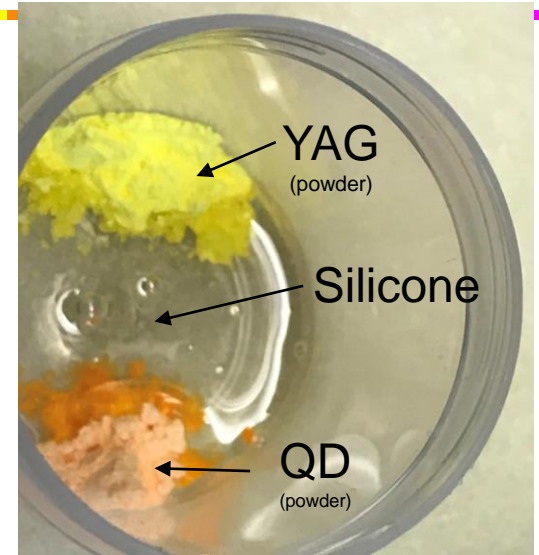
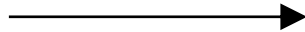
PLT's QDs are drop-in replacements for Phosphors



PLT's unique Quantum Dots: On-Chip Application



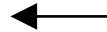
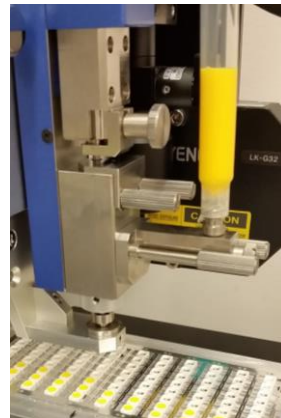
Handles like a
Phosphor



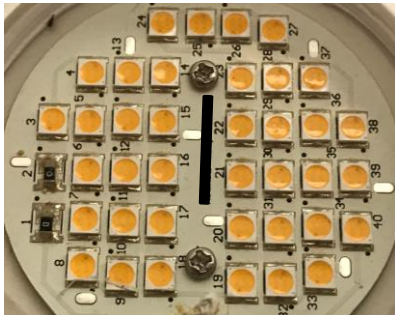
After a short mix



Ready for
the auto
dispenser

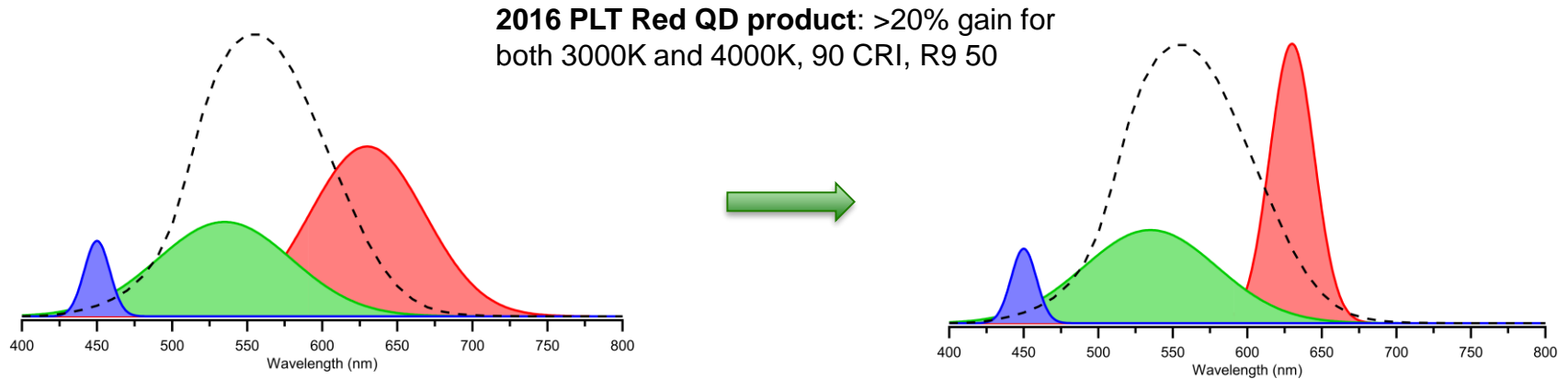


Luminaire or
backlight unit



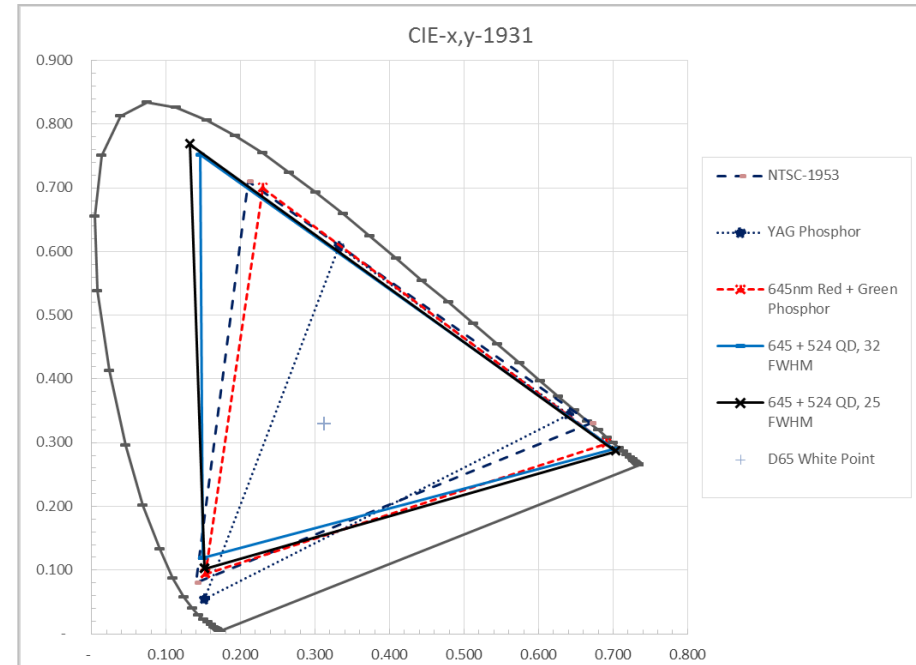
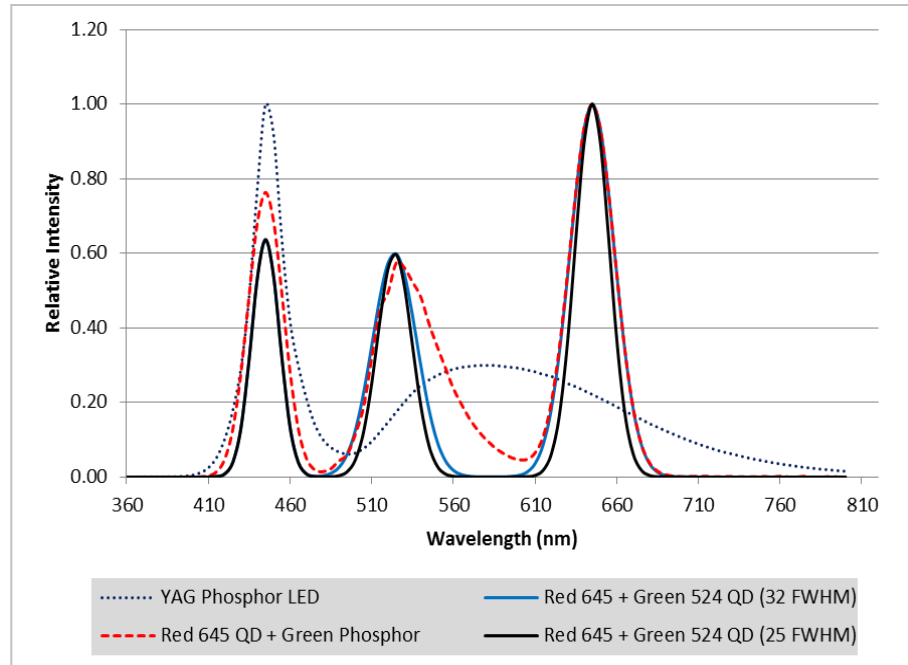
Quantum Dots vs. Phosphors

Phosphors	PLT Red Quantum Dots
Broad spectrum leads to wasted energy	Narrow spectrum increases efficiency by up to 25%
Difficult to adjust emission	Emission adjustable within ± 1 nm across visible spectrum
Poor overlap of absorption with blue pump	Highly absorbing at wavelengths < 475 nm
Long lifetimes—incompatible with fast modulation	Nanosecond lifetime
There is no widely available red phosphor for lighting with FWHM ¹ < 70 nm	FWHM < 35 nm



1. Full width half max

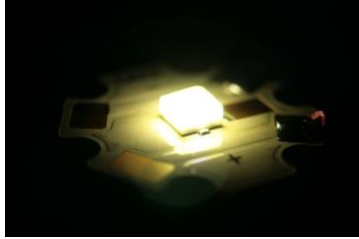
Full Color Gamut BLUs – Backlight Technology



Backlight Source	% NTSC x,y	% DCI-P3 x,y
YAG Phosphor	69.1%	71.9%
645nm QD + Narrow Green Phosphor	98.1%	102.1%
645nm QD + 524nm QD, 32nm FWHM	110.7%	115.3%
645nm QD + 524nm QD, 25nm FWHM	117.2%	121.9%
OLED (LG 2016)	94%	97.8%

Pacific Light Technologies: Enabling Optimal Color Quality and Maximum Efficiency Using Quantum Dots

Maximum Efficiency



- Up to **25% efficiency gain** for solid state lighting versus phosphors
- >20% gain for 3000K, 90CRI, R9 50, customer verified
- >20% gain for 4000K, 90 CRI, R9 50, customer verified

Optimal Color Quality



- Vastly **improved color gamut** for LCD-based displays
- 125% OLED gamut at LCD prices
- Optimal **absorption and emission wavelengths**

Seamless Integration



- Quantum-dot-level encapsulation technology **reduces manufacturing cost and complexity**
- Quantum dots in powder form are only true drop-in replacement for phosphors
- No glass or film protection needed