Characterization of remote phosphor type of LEDs

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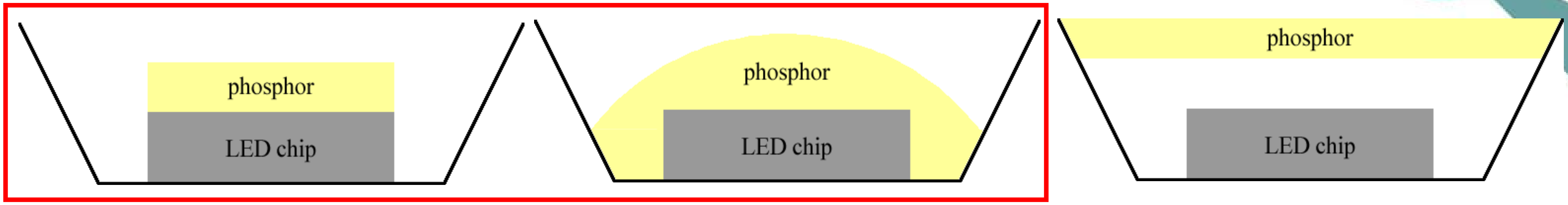
questions – research goals



What affects phosphor temperature?

Effect of phosphor temperature on LED output?

Optimal phosphor design?

Quantum efficiency of remote phosphors?

experiments

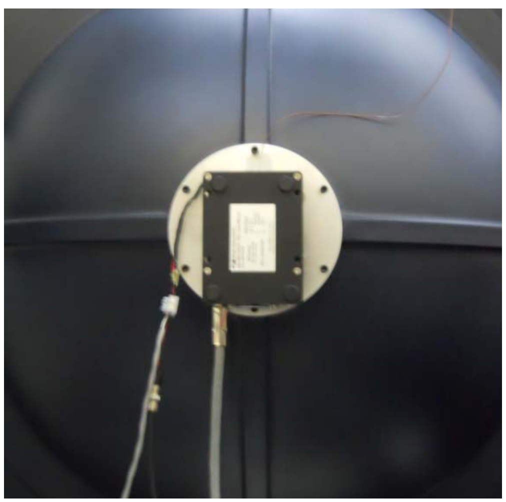
- 6 HPLEDs with planar phosphor:
  - 3 proximate
  - 3 remote

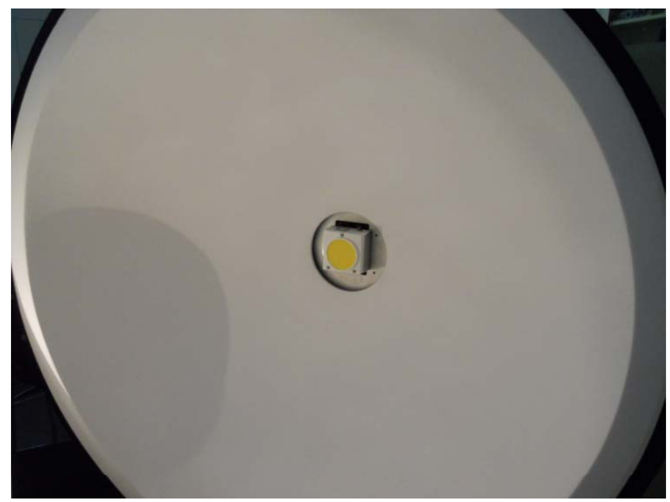
- 1 m Thermostatic Photometric Sphere

- CCD-array spectrometer

- independent variation of current,
  board (or junction) temperature, and ambient temperature

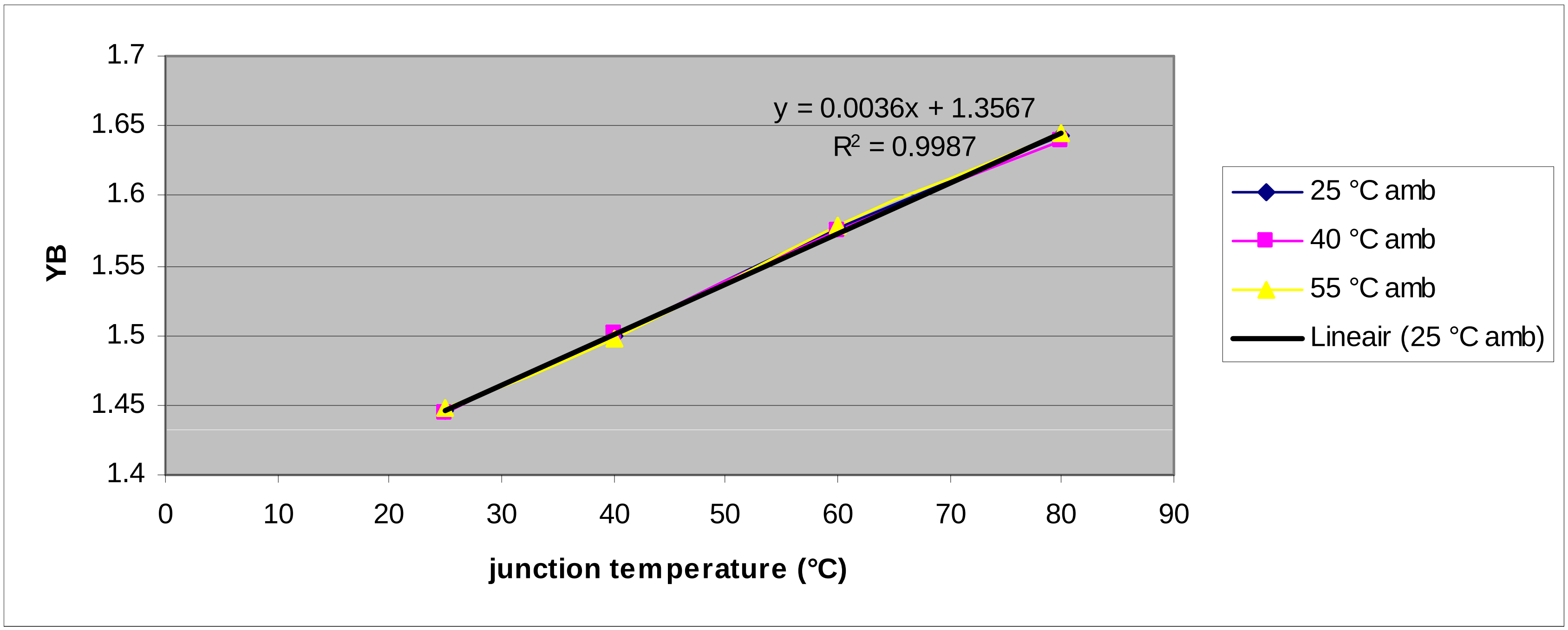
experiments





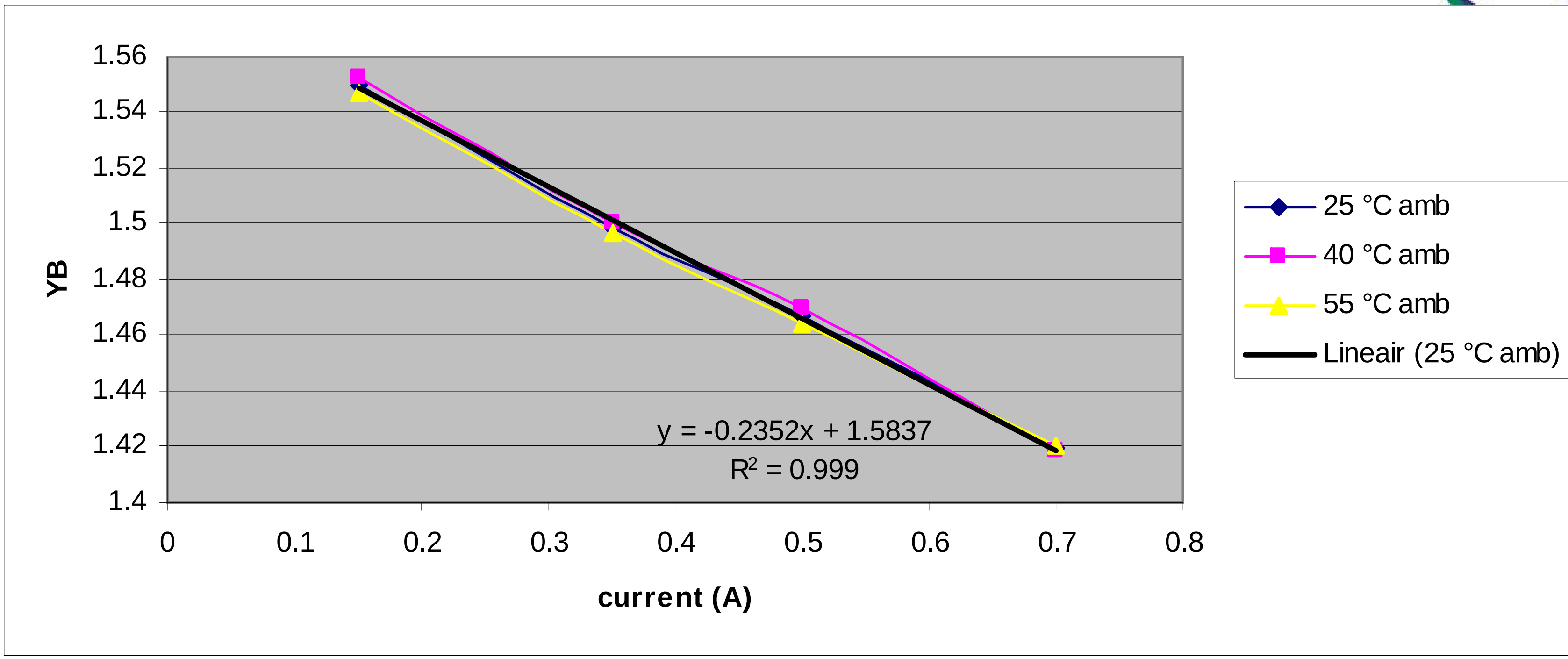
proximate phosphor type of LEDs

direct phosphor temperature meas. impossible → YB



junction T = phosphor T

proximate phosphor type of LEDs

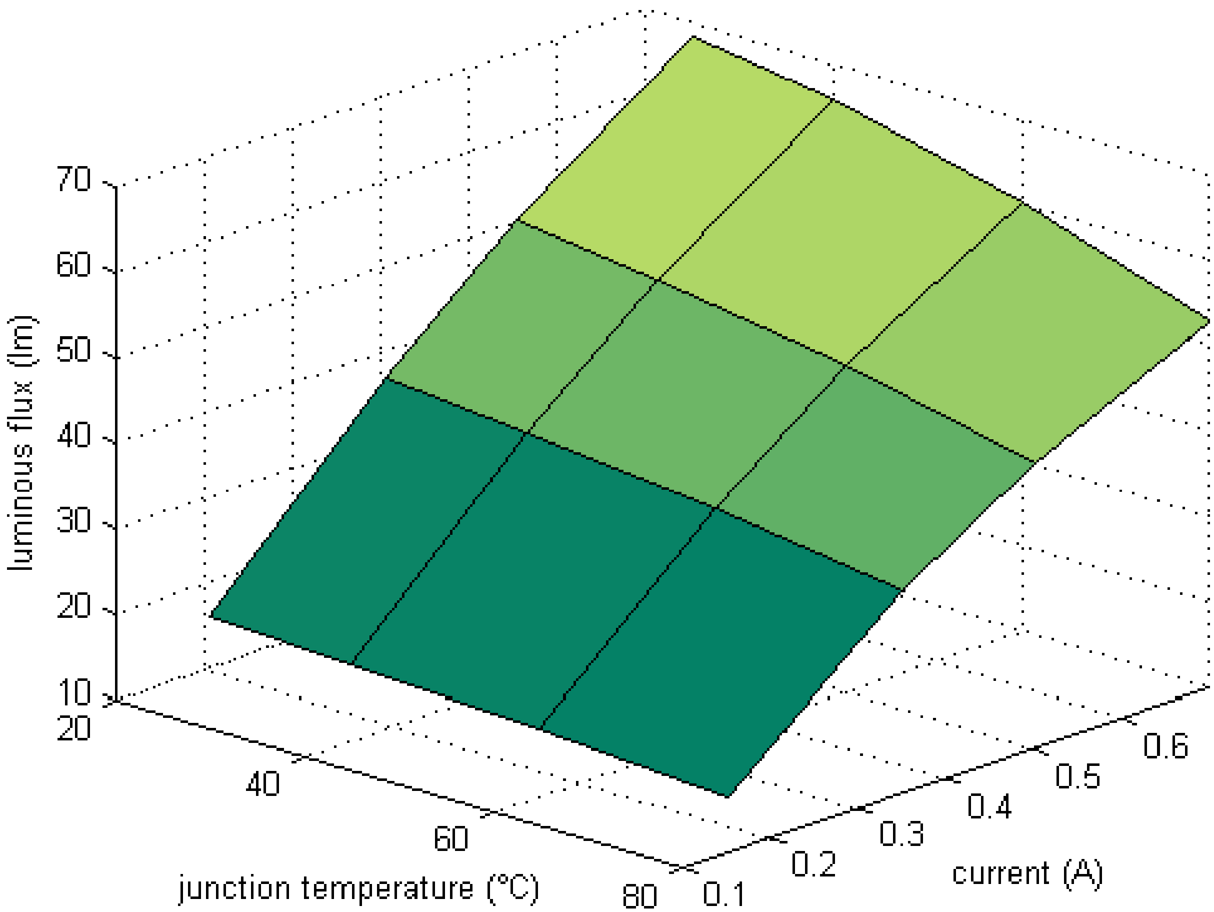


→ quantum efficiency decrease with temperature larger for pump than for phosphor

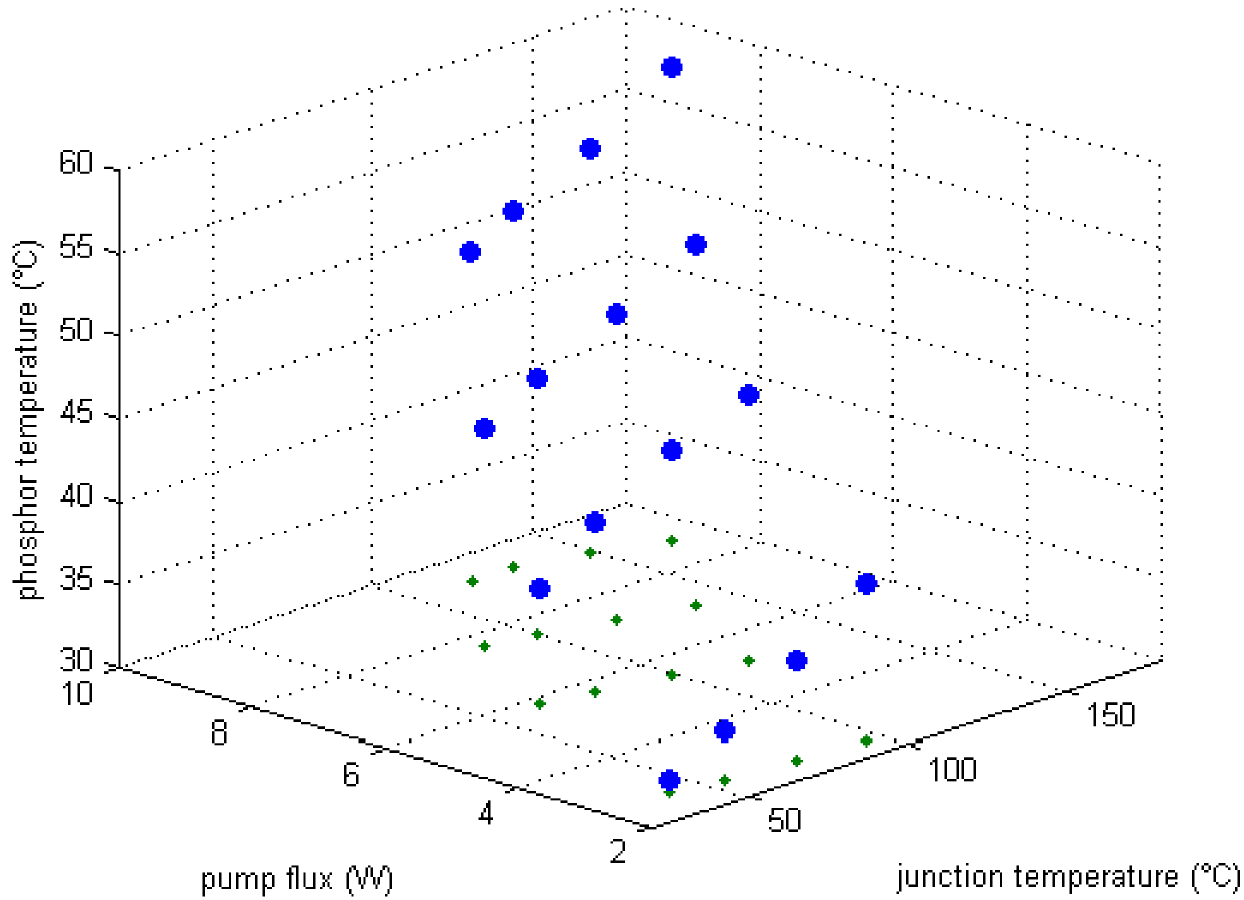
→ quantum efficiency decrease with current larger for phosphor than for pump

proximate phosphor type of LEDs

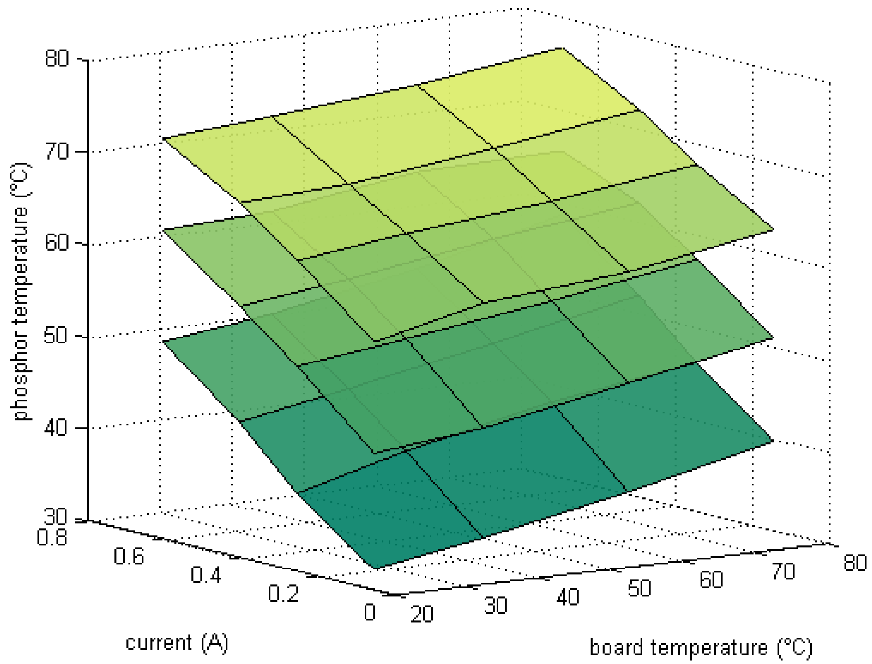
variations independent of ambient temperature

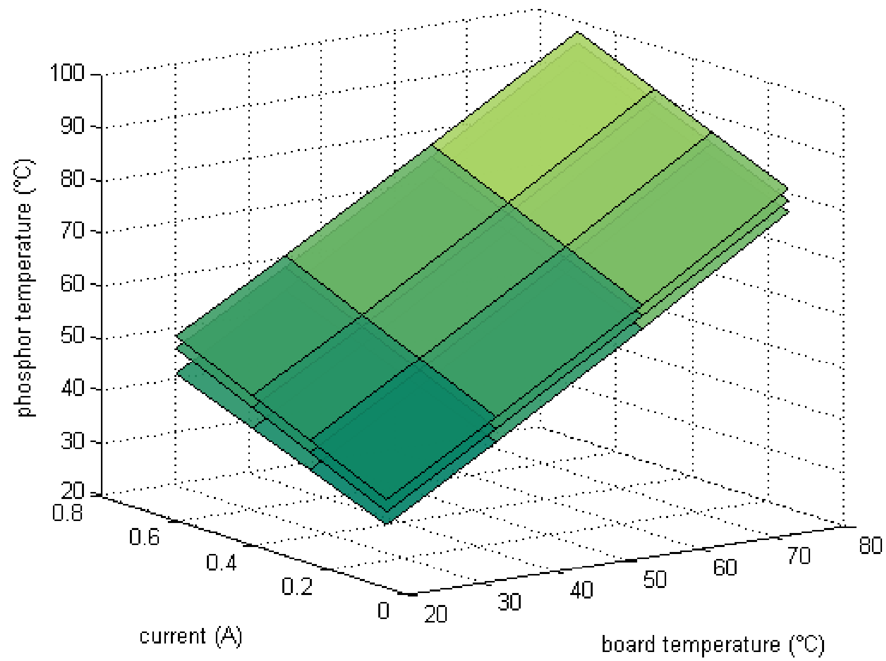


remote phosphor type of LEDs



remote phosphor type of LEDs



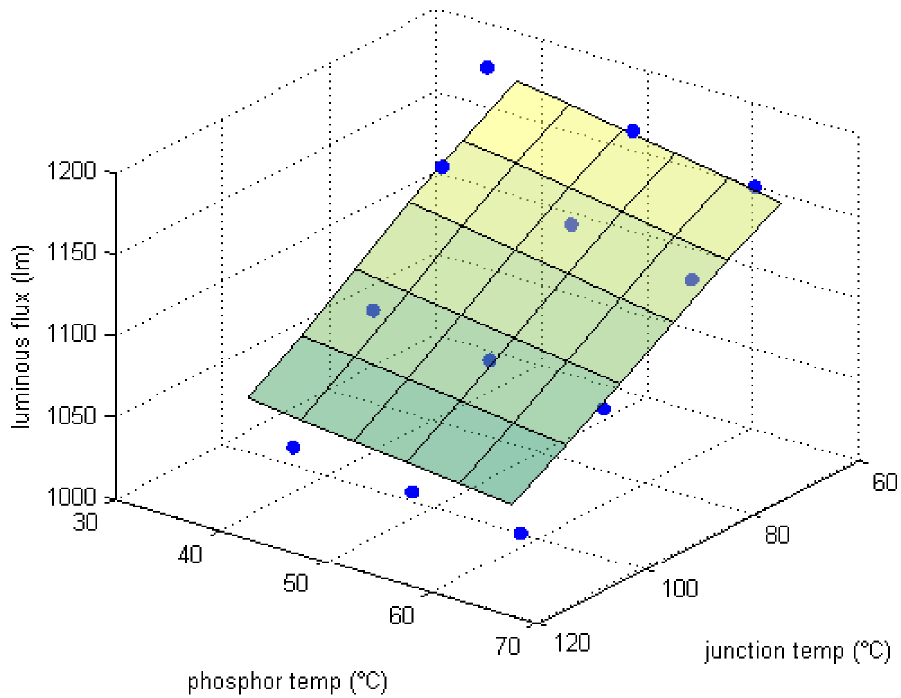


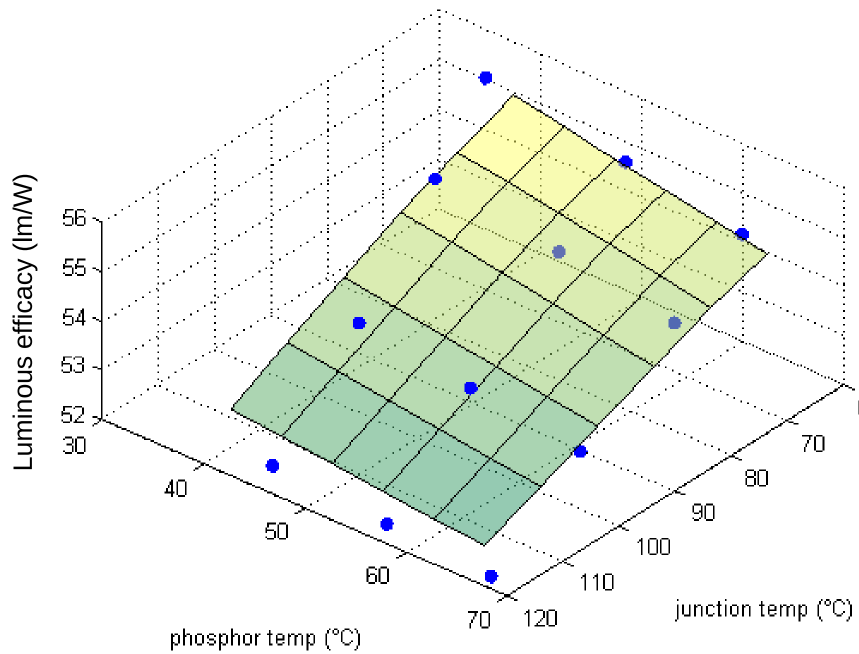
→ pump chip and phosphor are separate heat sources

→ effect of temperature variations depends on thermal resistance between pump and phosphor

flux and efficiency variation

luminous flux and efficiency decrease with increasing junction and phosphor temperature





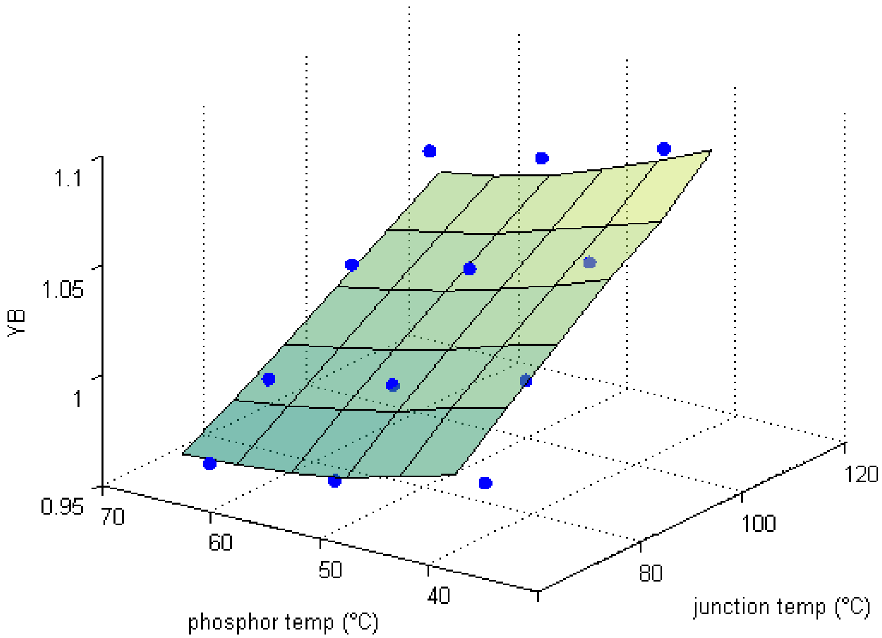
effect of current variations is biggest: pos for flux, neg for eff.

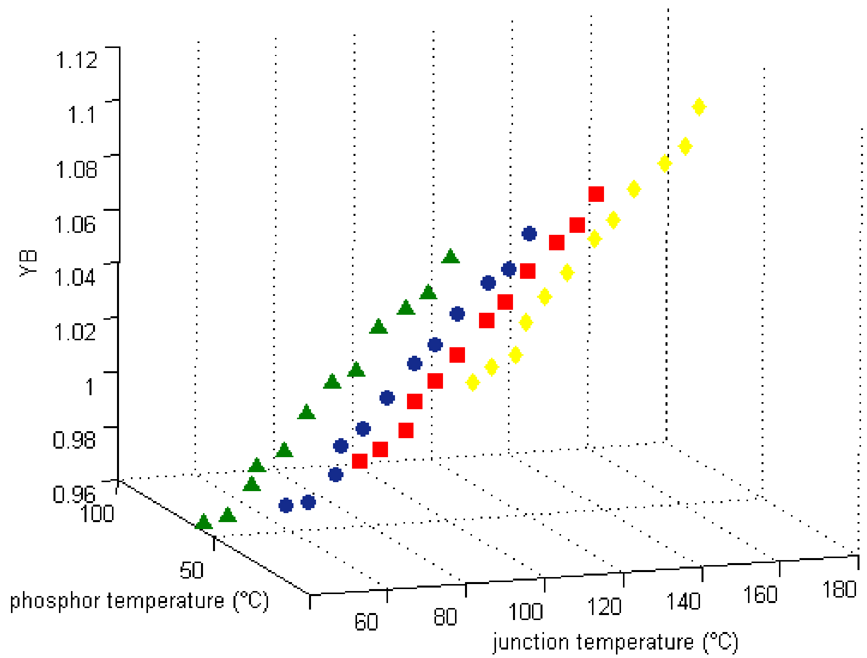
color variation

YB <u>increases</u> with increasing junction temperature

YB <u>decreases</u> with increasing phosphor temperature

YB <u>decreases</u> with increasing current





color variation

results correspond with proximate phosphor devices:

- increasing junction temperature → decreasing pump light efficiency → blue contribution in full spectrum decreases → higher YB
- increasing phosphor temperature → decreasing phosphor efficiency → smaller phosphor contribution in full spectrum → lower YB
- effect of junction heating larger than effect of phosphor heating
- quantum efficiency decrease with current larger for phosphor than for pump

phosphor design

luminous flux and efficacy:

keep junction and phosphor as cool as possible

→ sufficient heat sinking for junction

→ high thermal resistance between junction and phosphor

color:

phosphor temperature should increase faster than junction temperature does to obtain constant YB

→ low thermal resistance between junction and phosphor

module designer has to choose priorities!

remote phosphor quantum efficiency

number of absorbed, converted, transmitted pump photons by phosphor (package) relative to number of incoming photons

	FOR1	MOD1	XIC1
phosphor temp (°C)	37.0	44.1	34.5
pump flux (W)	5.820	2.319	4.179
absorbed (%)	34.4	68.7	53.8
converted (%)	54.4	28.4	37.4
transmitted (%)	11.2	2.9	8.8

remote phosphor quantum efficiency

distinction between cool white (4000 K) and warm white (3000 K) devices:

lower transmission ratio for latter

→ very high absorption ratio

→ increased phosphor temperature

	FOR1	MOD1	XIC1
phosphor temp (°C)	37.0	44.1	34.5
absorbed (%)	34.4	68.7	53.8
transmitted (%)	11.2	2.9	8.8

conclusions

- proximate phosphor type of LEDs:
  - junction temperature = phosphor temperature

- remote phosphor type of LEDs:
  - temperature difference between junction and phosphor
  - phosphor temperature highly depends on junction-phosphor thermal resistance

  - luminous flux and efficacy values decrease for increasing junction and phosphor temperatures
  - current variations have biggest impact on flux and efficacy values
  - current and temperature effects on YB can be explained analogously as for proximate phosphor devices

conclusions

- pump-phosphor design:
  - high thermal resistance between junction and phosphor optimizes flux and efficacy
  - low thermal resistance reduces color variations

- quantum efficiency of remote phosphor configurations:
  - distinction between cool white and warm white LEDs

Thank you for your attention!