Mechanism for in-situ measurement of GaN luminaire chip temperatures

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Motivation

- Development of a measurement of junction temperature, independent of electrical behaviour
- Ability to measure in-situ within a luminaire without additional architecture
- Ability to measure both blue and green devices in RGB system to provide stability control for colour rendition

http://insansainsprojects.file
http://jjosph.org
Existing methods

- **Wavelength shift**

- **Spectral analysis**

- **Forward voltage technique**
Blue emitting devices have the ability to generate photocurrent in another blue device due to overlapping emission and absorption edges.

The large stoke shift of the green devices, show that a blue device should also be able to generate a photocurrent in a green device.

The emission of the Blue LED sits on the Urbach tail of both Green and Blue.

Urbach tail is $\propto T$ and is a material property.
green (NSPG510S) Nichia InGaN LED

$\Delta T$ is the measured $J_t - $ Bulk $T$

Pulsed duty cycle < 0.1 %

$F_v = 87^\circ C \ (\Delta T \ is \ 67^\circ C + 20^\circ C \ bulk) \ at \ 80mA$
Experimental set-up

Two pulse generators with a linked trigger

Voltage measurement is across a $47\,\Omega$ resistor

Pump fixed at 100 mA for all measurements

Devices drilled to accept POF then polished

Nichia blue (NSPB510s)
Nichia green (NSPG510S)
Pulse Regimes

Blue pump Pulse

Green device Pulse

Blue pump Pulse
\[ T(t) = T_0 + \Delta T_0 e^{-t/\tau} \]

where \( T(t) \) is the time \( t \) dependence of the absolute device temperature, \( T_0 \) is the ambient temperature and \( \Delta T_0 \) is the initial temperature above ambient. References indicate our LED type will have a 1-2 ms time co-efficient.

A measurement within 1 ms of the device switching off will be between ~ 30\% and 60\% of the device temperature at switch off.


Green device held open circuit

Blue pump set at 100 mA

Bulk temperature set by thermal chamber

Calibration Graph

Pulse Voltage (V) vs. Bulk Temperature (°C)
Bulk Temperature  \( \alpha = V_1 - V_0 \)

Where \( V_1 \) is the measured voltage under zero device drive current
And \( V_0 \) the voltage at 0 \(^\circ\)C

Voltage rise due to extra heating \((V_2 - \alpha) \gamma\)

Where \( V_2 \) is the measured voltage under operation
And \( \gamma \) is the adjustment for temperature decrease

Junction Temperature, \( T_j = (V_2 - \alpha) \gamma \frac{dT}{dV}\)

Where \( \frac{dT}{dV} \) is the gradient from the calibration graph
Initial measurements

Measurements of the Blue pump pulse height with increasing Green device drive current
Temperature co-efficient

With a 1 ms Blue pulse delay, the temperature co-efficient ($\gamma$) is between 30 to 90 % of the device temperature

We can plot 30%, 60% and 90% values of $\gamma$. From references we expect these devices to have $\sim$ 60 % due to their construction and packaging style

Comparison with Forward voltage techniques is consistent with 60%

$\Delta T$ is the measured $J_t$ – Bulk $T$

Results

Utilising a temperature coefficient of 60% we can see that there is good agreement with our measured forward voltage technique.

\[ J_T = 86 \, ^0C (\Delta T \text{ is } 66 \, ^0C + 20^0C \text{ bulk}) \text{ at } 80mA \]

\[ F_v = 87 \, ^0C (\Delta T \text{ is } 67 \, ^0C + 20^0C \text{ bulk}) \text{ at } 80mA \]
Further work

- Measurements of Urbach tail shift with temperature
- Application of this technique to blue devices
- Investigate the technique with the two devices close coupled
- Investigate the technique at raised temperatures
Conclusions

- We have demonstrated a novel technique for measuring junction temperature.

- Measurements of the junction temperature of a Green LED device has been shown. The technique should also work for Blue emitting devices.

- Comparison with the forward voltage technique shows good agreement.

- Technique is dependent upon Urbach tail and is therefore a material property.

GB Patent Application No. 1207503.2 – Apparatus and method for monitoring LED efficiency
GB Patent Application No.1207505.7 – Apparatus and method for monitoring LED colour mix
Why a much smaller range than RT
blue (NSPB510s) and green (NSPG510S) Nichia InGaN LEDs
Motivation for study

• Existing applications using visible emitters: full-colour displays, laser projectors, and high density, high definition Blu-ray disks storage.
• Desired *applications* next-generation solid state lighting.