Mechanism for in-situ measurement of GaN luminaire chip temperatures

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EMRP
European Metrology Research Programme
Programme of EURAMET

EURAMET
European Association of National Metrology Institutes

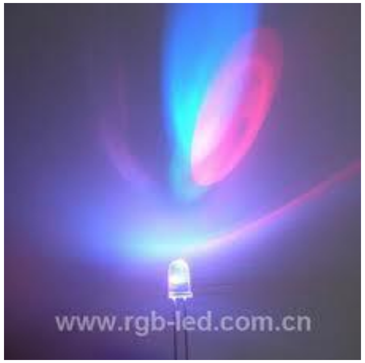
Motivation

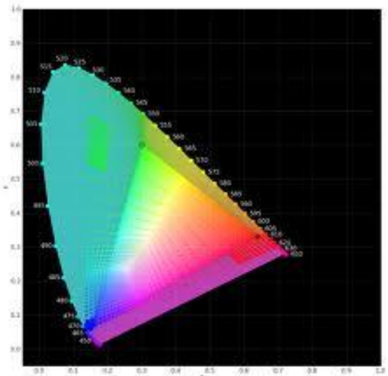
- Development of a measurement of junction temperature, independent of electrical behaviour

- 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





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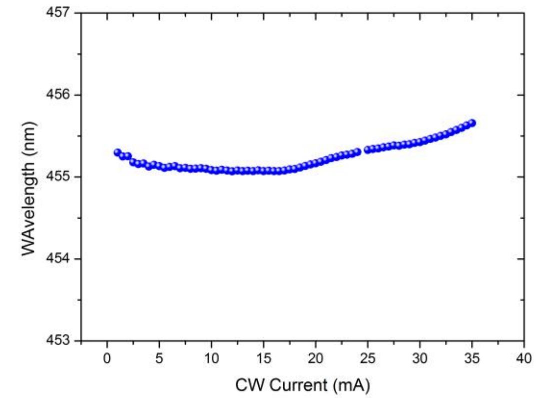
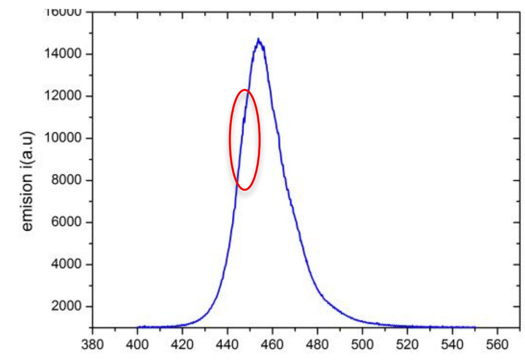
Existing methods

➢ Wavelength shift



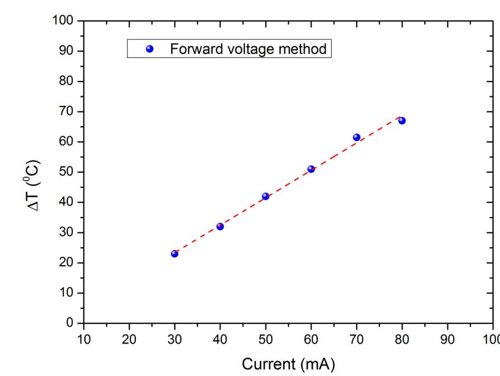
J. Senawiratne, A. Chatterjee, T. Detchprohm, W. Zhao, Y. Li, M. Zhu, Y. Xia, X. Li, J. Plawsky, C. Wetzel, “Junction temperature, spectral shift, and efficiency in GaInN-based blue and green light emitting diodes”, Thin Solid Films 518, 1732 (2010).

➢ Spectral analysis



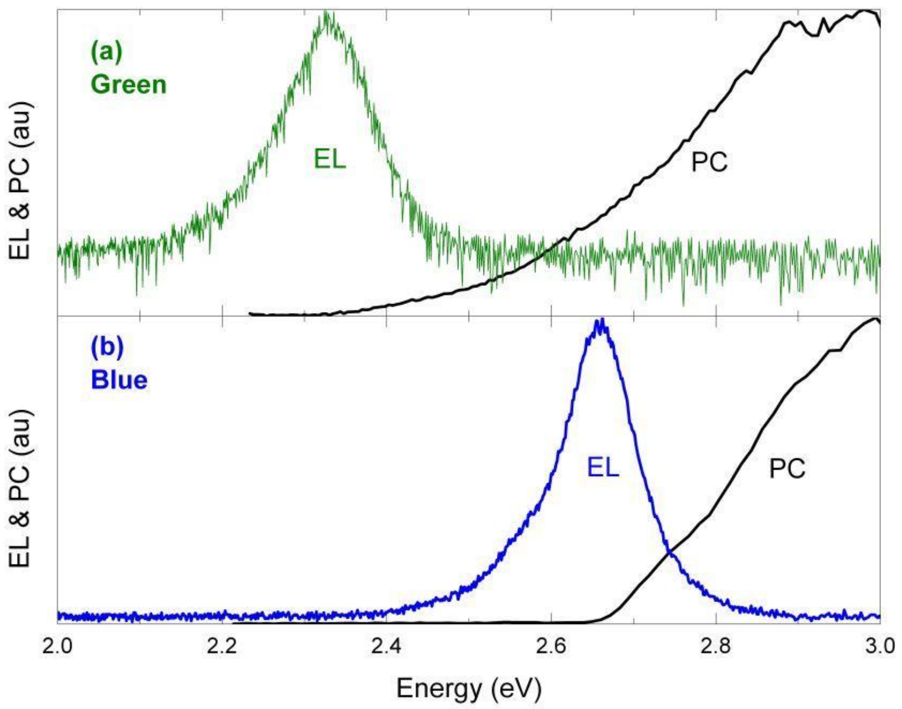
Z. Vaitonis, P. Vitta, and A. Žukauskas, "Measurement of the junction temperature in high-power light-emitting diodes from the high-energy wing of the electroluminescence band", J. Appl. Phys. 103, 093110 (2008)

➢ Forward voltage technique



Xi and E. F. Schubert, "Junction–temperature measurement in GaN ultraviolet light-emitting diodes using diode forward voltage method", Appl. Phys. Lett. 85, 2163 (2004).

Theory of measurement



- ➢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

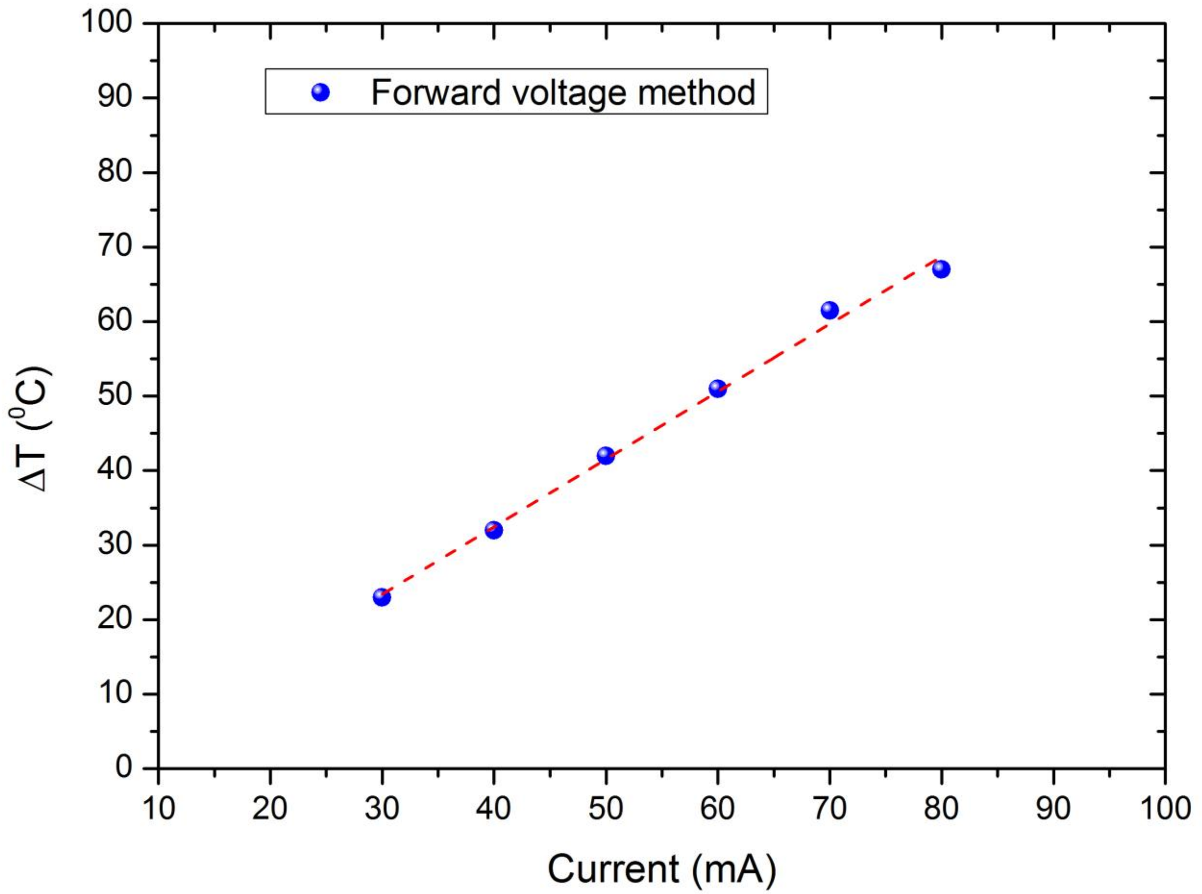
- ➢Urbach tail is $\propto$ T and is a material property

Forward voltage measurement

green (NSPG510S)
Nichia InGaN LED

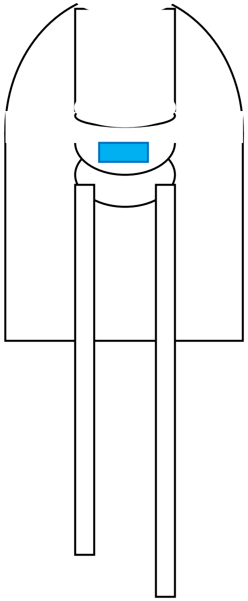
ΔT is the measured
J_t – Bulk T

Pulsed duty
cycle < 0.1 %



F_v = 87 ^{0}C (ΔT is 67 ^{0}C + 20^{0}C bulk) at 80mA

Experimental set-up



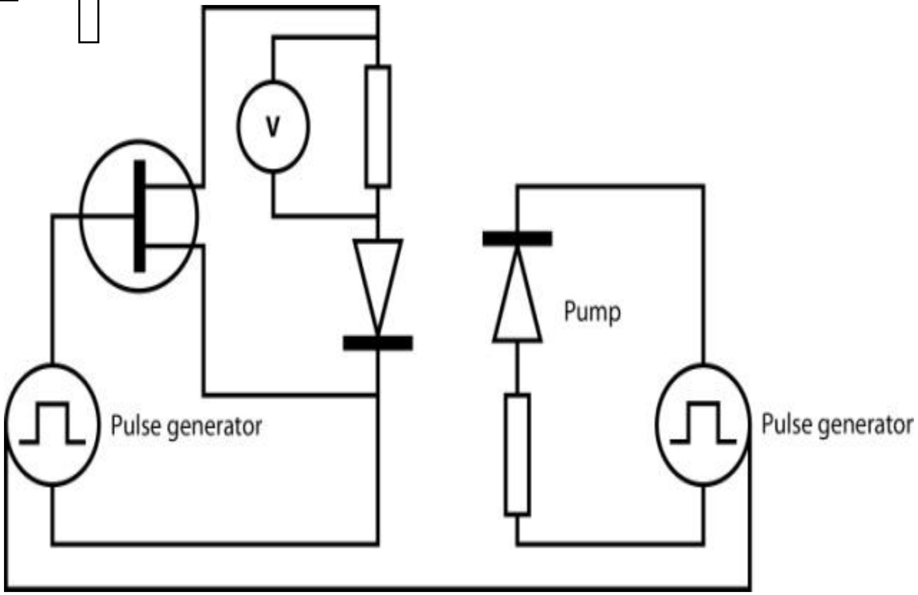
Devices drilled to accept POF then polished

Nichia blue (NSPB510s)
Nichia green (NSPG510S)

Two pulse generators with a linked trigger

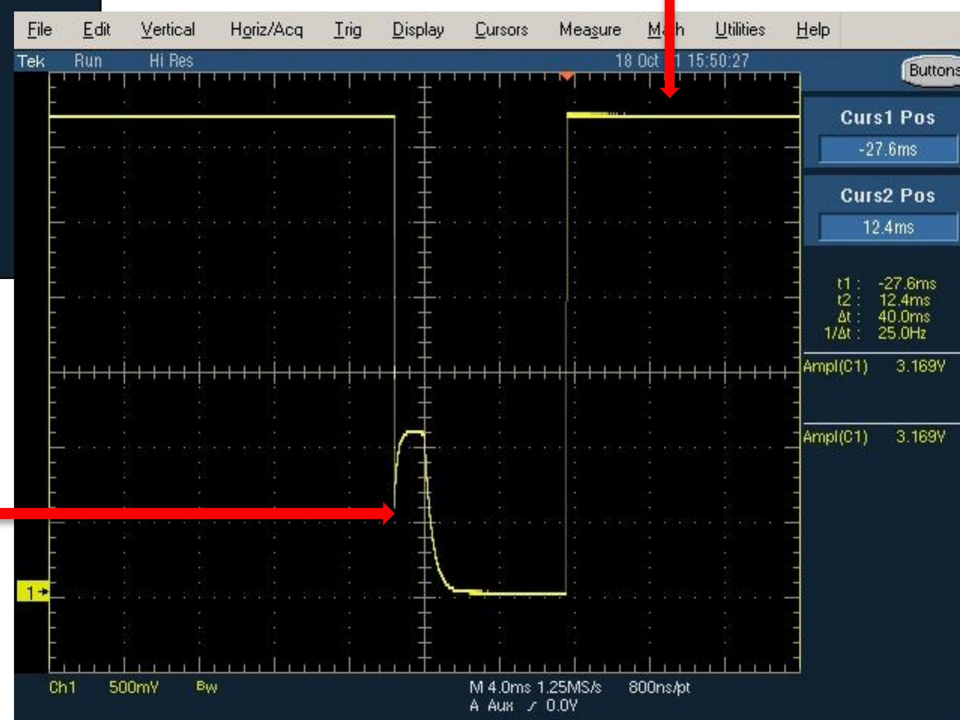
Voltage measurement is across a 47Ω resistor

Pump fixed at 100 mA for all measurements



Pulse Regimes

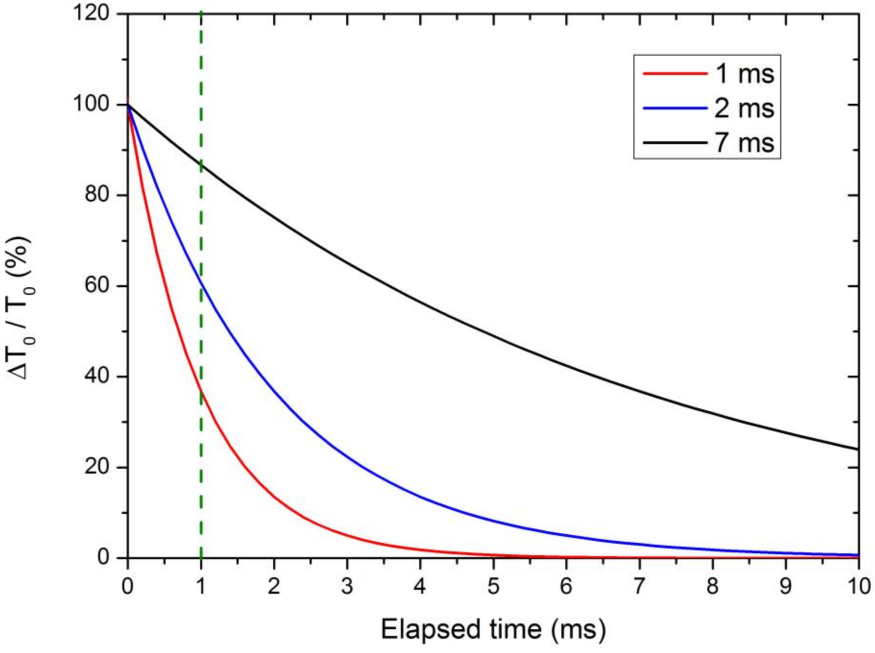
Green device Pulse



Blue pump Pulse

Thermal Co-efficients

$$T(t) = T_0 + \Delta T_0 e^{-t/\tau}$$



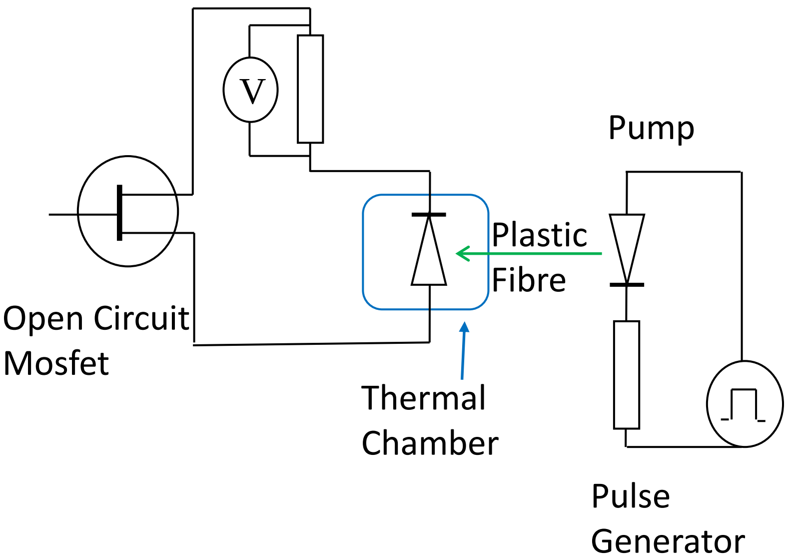
where T(t) is the time (t) dependence of the absolute device temperature, T_0 is the ambient temperature and ΔT_0 is the initial temperature above ambient.

References indicate our LED type will have a 1-2 ms time co-efficient

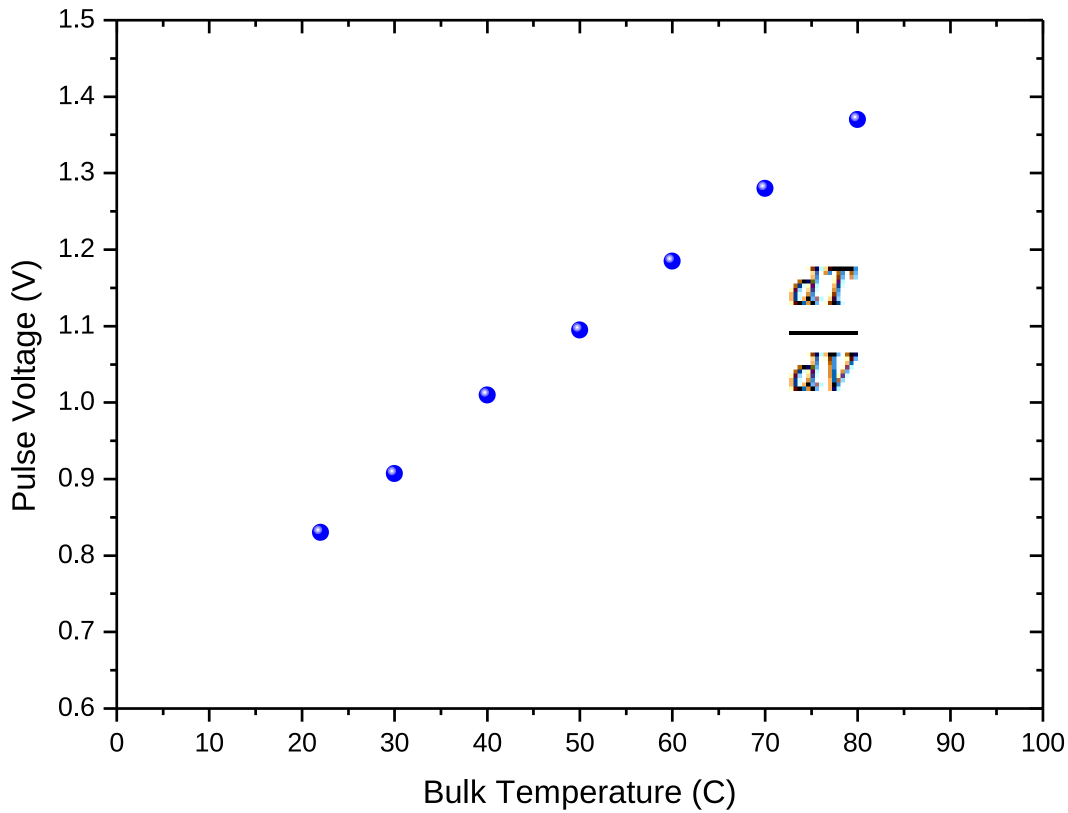
A measurement within 1 ms of the device switching off will be between ~ 30% and 60% of the device temperature at switch off

Q. Shan, Q. Dai, S. Chhajed, J. Cho, and E. F. Schubert "Analysis of thermal properties of GaInN light-emitting diodes and laser diodes", J. Appl. Phys. 108, 084504, 2010.
P. Vitta and A. Žukauskas "Thermal characterization of light-emitting diodes in the frequency domain" Phys. Status Solidi C 6, S877 (2009).

Calibration



Calibration Graph



Green device held open circuit

Blue pump set at 100 mA

Bulk temperature set by thermal chamber

Junction Temperature

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 ^{0}C

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

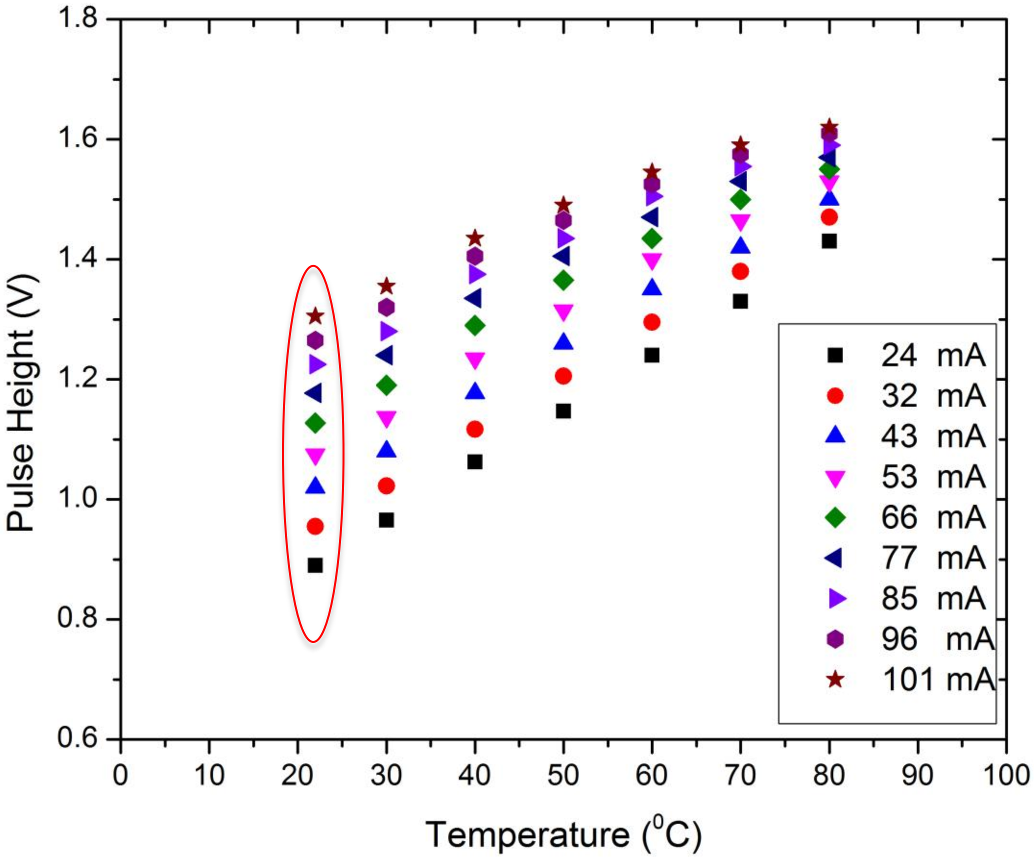
Where V_2 is the measured voltage under operation
And **γ** is the adjustment for temperature decrease

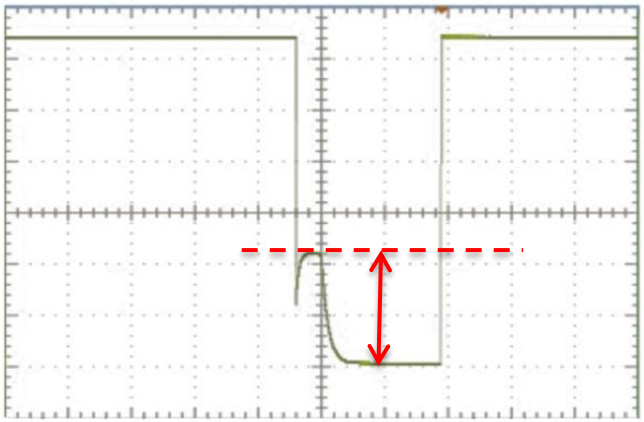
Junction Temperature, $T_j = (V_2 - \alpha)\,\gamma\,\frac{dT}{dV}$

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





Blue pump pulse height

Temperature co-efficient

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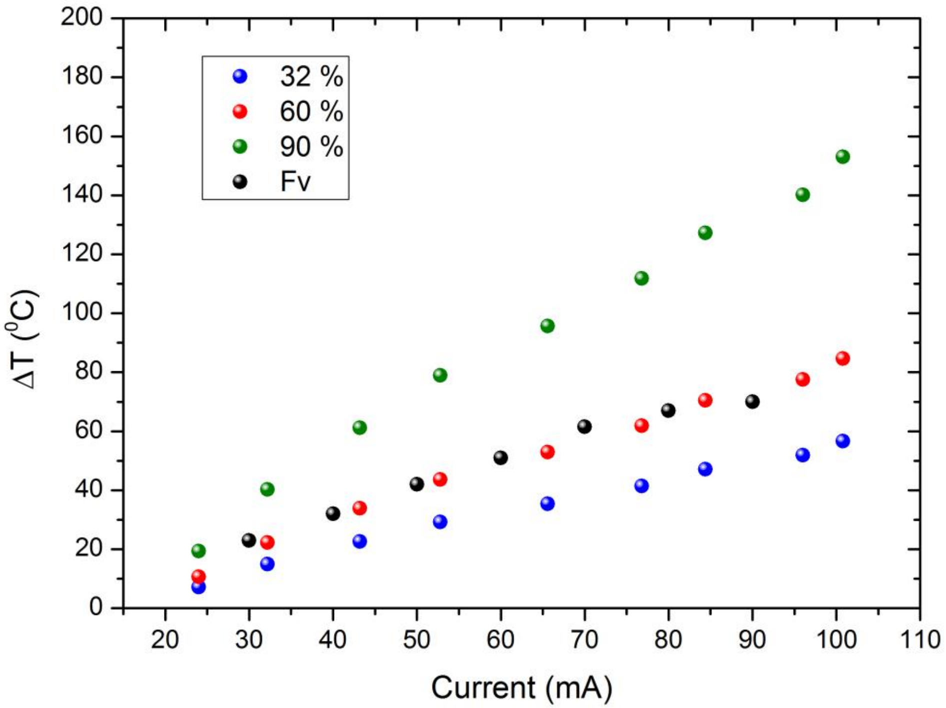
With a 1 ms Blue pulse delay, the temperature co-efficient (γ) is between 30 to 90 % of the device temperature



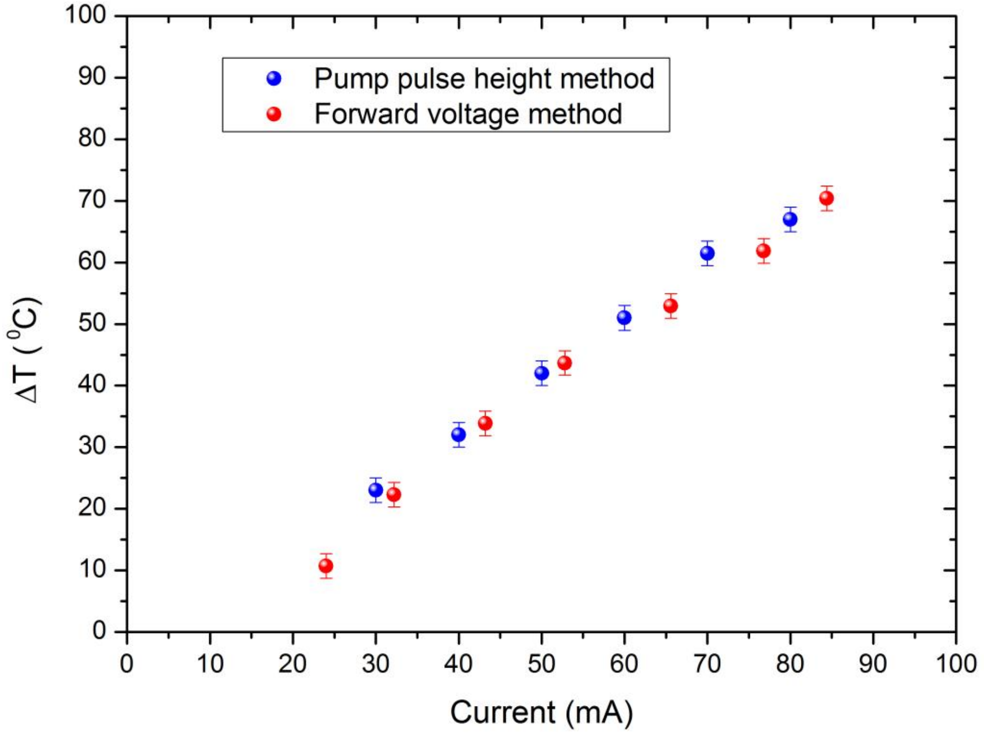
We can plot 30%,60% and 90% values of γ.
From references we expect these devices to have ~ 60 % due to their construction and packaging style

Comparison with Forward voltage techniques is consistent with 60%

ΔT is the measured J_t – Bulk T

Q. Shan, Q. Dai, S. Chhajed, J. Cho, and E. F. Schubert "Analysis of thermal properties of GaInN light-emitting diodes and laser diodes", J. Appl. Phys. 108, 084504, 2010.
P. Vitta and A. Žukauskas "Thermal characterization of light-emitting diodes in the frequency domain" Phys. Status Solidi C 6, S877 (2009).

Results



Utilising a temperature co-efficient 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

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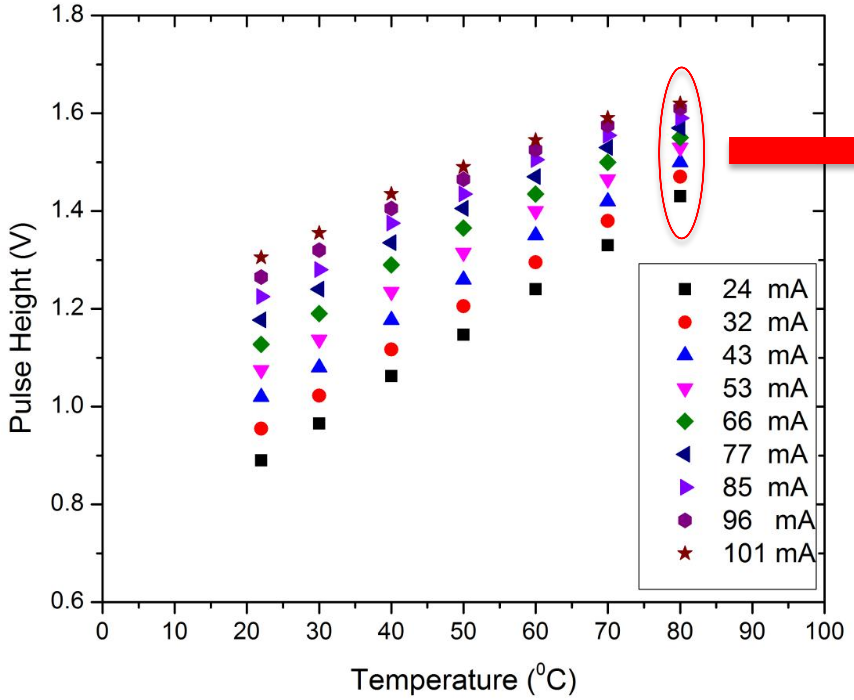
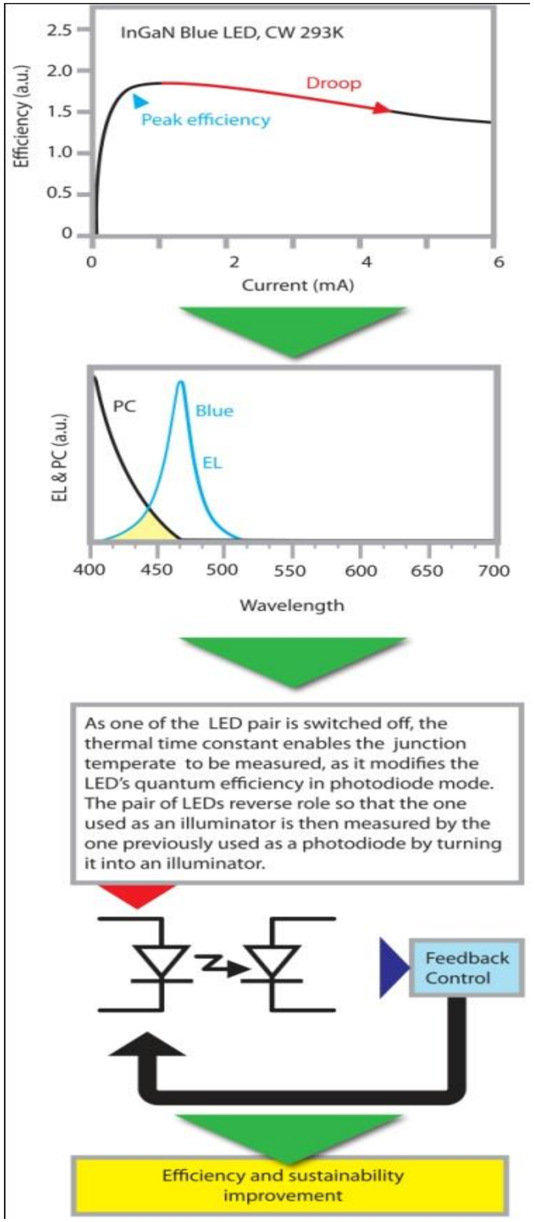
- We have demonstrated a novel technique for measuring junction temperature.
- Measurements of the junction temperature of a Green LED device has been shown. The technique should also work for Blue emitting devices.
- Comparison with the forward voltage technique shows good agreement.
- Technique is 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

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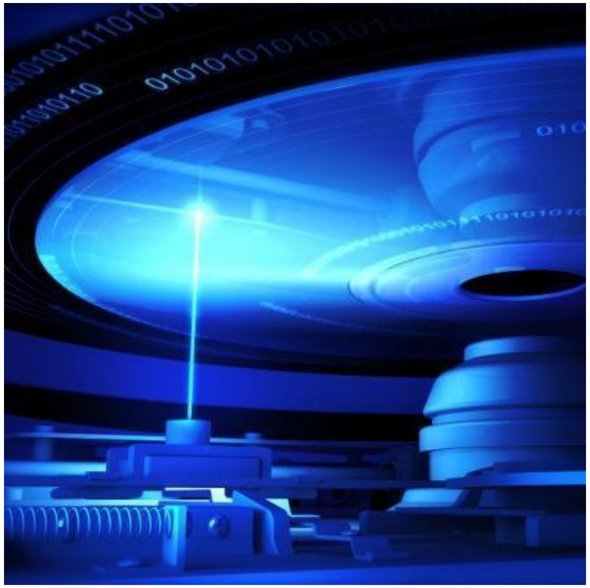


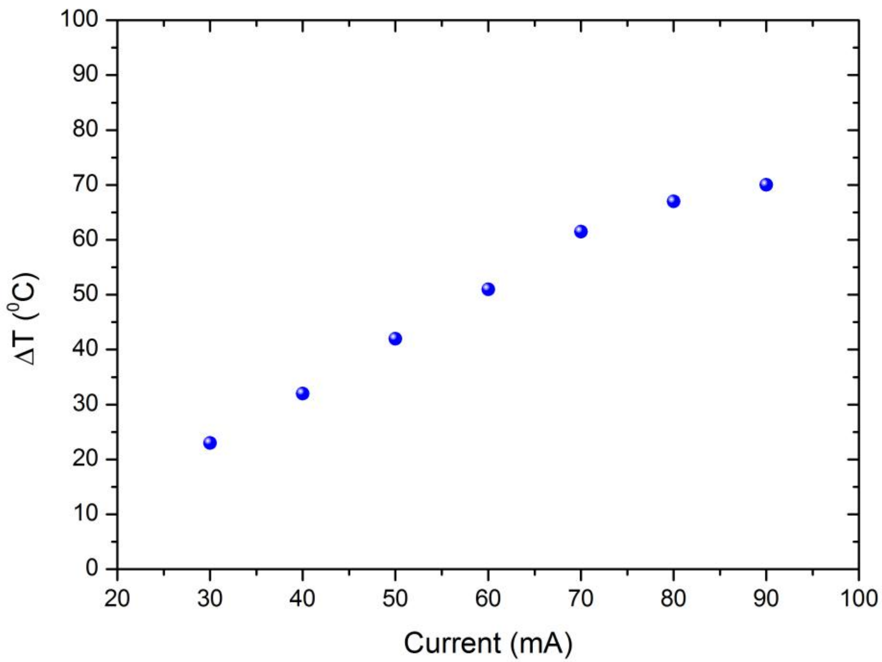
http://hdtv.biz-news.com/news/2008/09/19/0010

- 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.

http://detail.en.china.cn/provide/detail,1065692920.html

http://next.utu.fi/energy/pdf/Nakamura%20September%202007%20for%20high%20school.pdf

http://www.ledtubelights.org/wp-content/uploads/2010/01/bubls11.jpg



ΔT (⁰C)
Current (mA)
0
10
20
30
40
50
60
70
80
90
100
20
30
40
50
60
70
80
90
100