MPPC absolute PDE measurement with continuous and pulsed light

PHOTODET 2012
LAL, Orsay, June

Vincent Chaumat, Cyril Bazin, Nicoleta Dinu, Véronique Puill, Jean-François Vagnucci

The absolute measurement of the Photo Detection Efficiency (PDE) of a SiPM over the whole visible range using continuous light is not a straightforward task as it requires the accurate determination of the detector gain. We have developed at LAL a process to achieve an absolute PDE with an accuracy of ± 5 %.

Test Bench Description

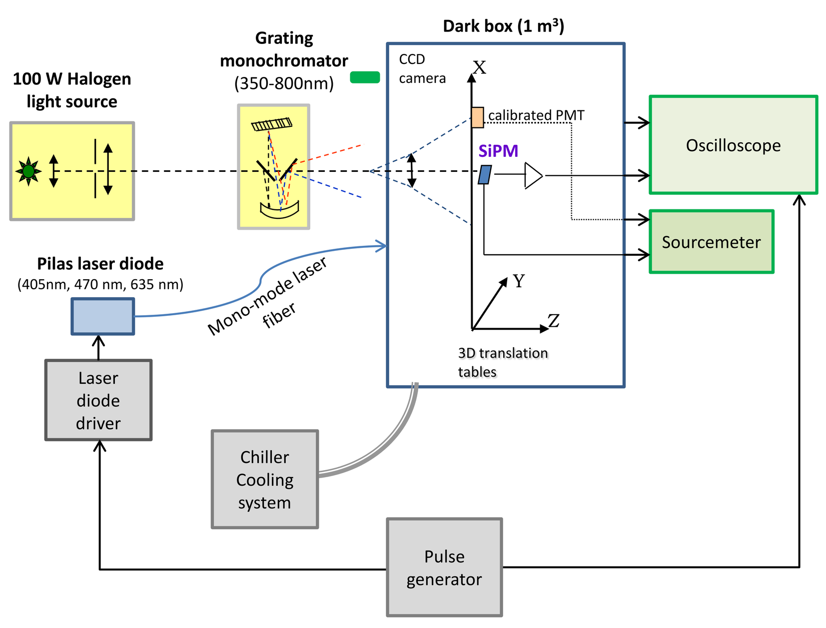
Test bench equipments:

- Lecroy 740Zi oscilloscope
- 2612 Keithley sourcemeter
- Pilas Laser diode (407, 467, 635 nm)
- Oriel grating monochromator
- Chiller cooling system
- Hamamatsu R7400U-02 calibrated PMT

Test bench performances:

- 20°C ±0.1°C
- 40000 events statistic
- 50 ps laser pulse width
- 1 nm wavelength control
- 1 nA current measurement sensitivity
- ± 5% light flux calibration

Calibrated and thermalized test bench



PDE measurement methods

$$PDE(\%) = 100 \times \frac{Nb\ Photon_{converted}}{Flux_{incident}}$$

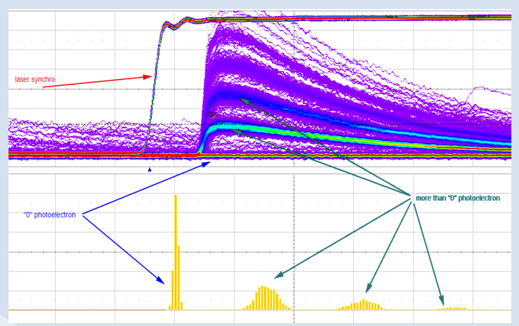
$$Flux_{incident}(ph/mm^2/s) = \frac{I_{PMT} \times \lambda \times q_e}{h \times c \times Rs_{PMT} \times G_{PMT} \times S_{PMT}}$$

I_{PMT} PMT photo generated current (A), RS_{PMT} PMT anode sensibility (A/W), G_{PMT} PMT gain, S_{PMT} PMT illuminated surface (mm²)

Counting method

- triggered laser → few photons Dirac pulses
- Poisson probability distribution law
- 40000 events statistic → ± 5% accuracy

$$Nb\ Photon_{converted} = -\ln(P(0))$$



P(0): probability of non converted events. ("0" photoelectron)

Current method

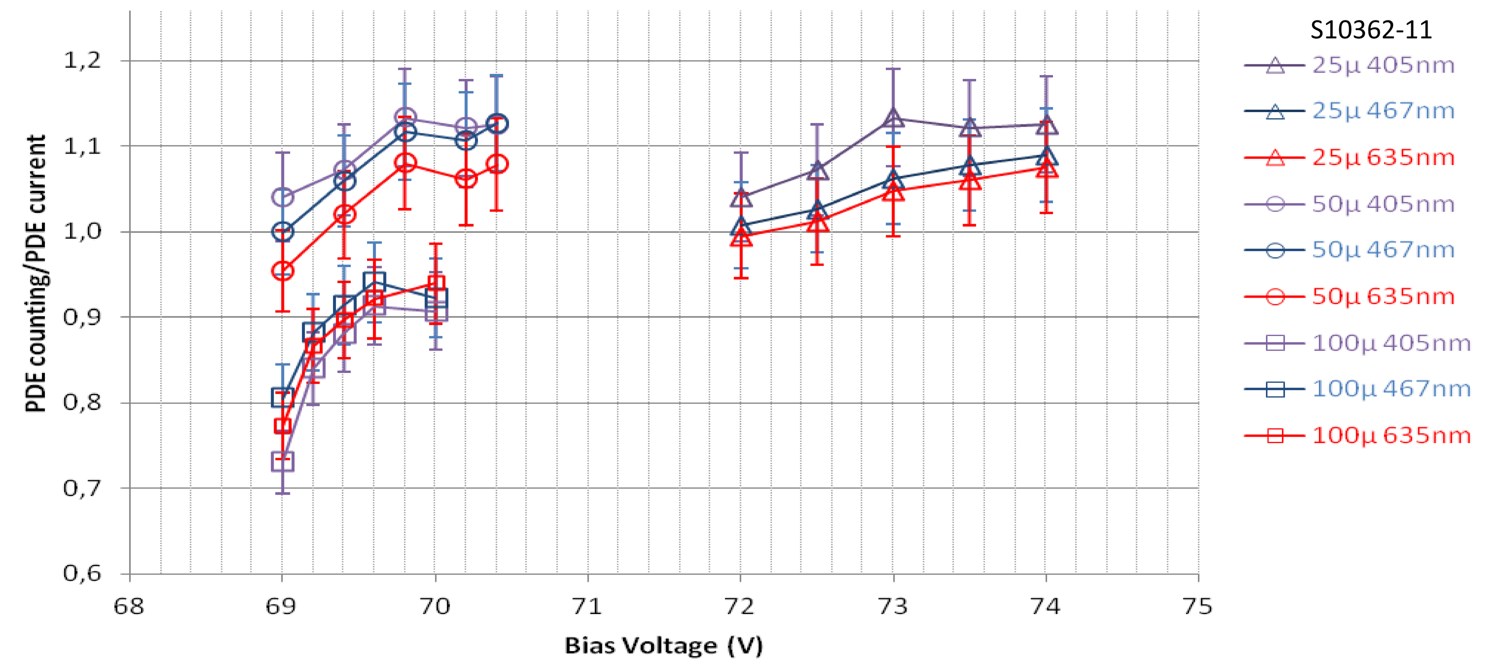
- continuous monochromatic source
- incident flux <10⁷ ph/mm²/s << SiPM saturation

$$Nb\ Photon_{converted} = \frac{(I_{light} - I_{dark})}{q_e \times G_{SiPM}}$$

G_{SiPM} : SiPM gain measured in dark conditions
I_{light}: SiPM photo generated current (A)
I_{dark}: SiPM dark current (A)

Absolute PDE of MPPC S10362-11 @ 20°C
Comparison of the 2 methods

"Counting" PDE with laser /"Current" PDE with monochromator



PDE ratio:

- 0.8 < ratio < 1.1
- ratio ↗ with V_{bias}
- wavelength uncorrelated

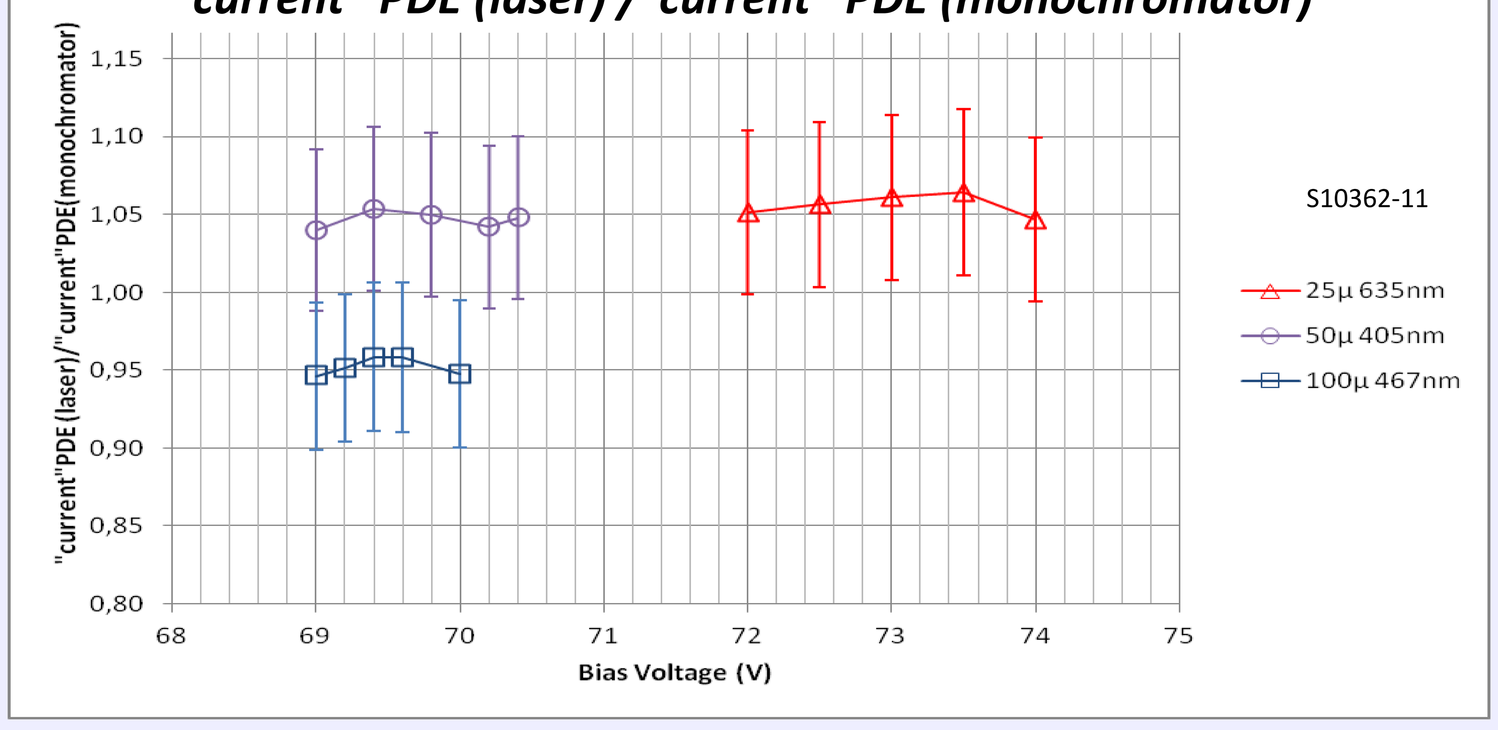
Hypothesis:

- error in incident flux estimation ? → no, calibration of the bench @ ± 5 %
- error in the SiPM gain measurement ? → maybe …
- variation of the temperature ? → no, variation = ± 0,1 °C

PDE measurement with laser & monochromator using the "Current method"

2 different light sources, the ratio of the PDE is independant from the SiPM gain

"current" PDE (laser) /"current" PDE (monochromator)



PDE ratio:

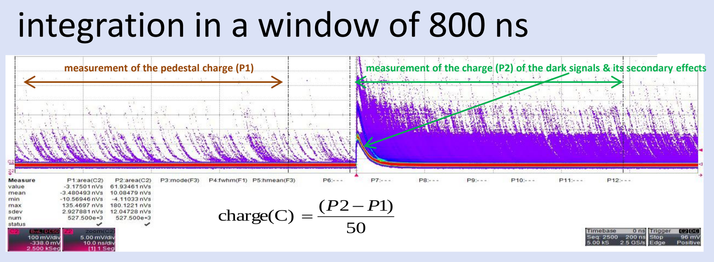
- ratio = 1± 5%
- no variation with V_{bias}

Conclusion:

error on the SiPM gain measurement = 10 – 20 %

SiPM Gain measurements

Measured dark Gain: mean SiPM charge integration in a window of 800 ns

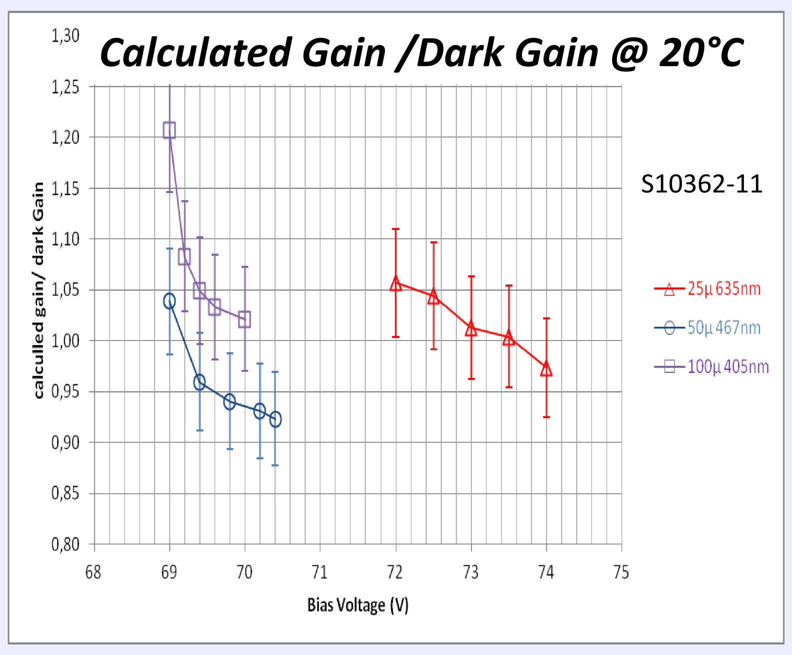


Calculated Gain: determined from the "Counting method" PDE (PDE_{count}) measurement and photo generated current (I_{light}-I_{dark}) :

$$Gain_{calculated} = \frac{(I_{light} - I_{dark})}{Flux_{incident} \times PDE_{count} \times q_e}$$

I_{light} SiPM photo generated current (A), I_{dark} SiPM dark current (A), $Flux_{incident}$ of the laser (ph/mm²/s).

Calculated Gain /Dark Gain @ 20°C



Gain ratio:

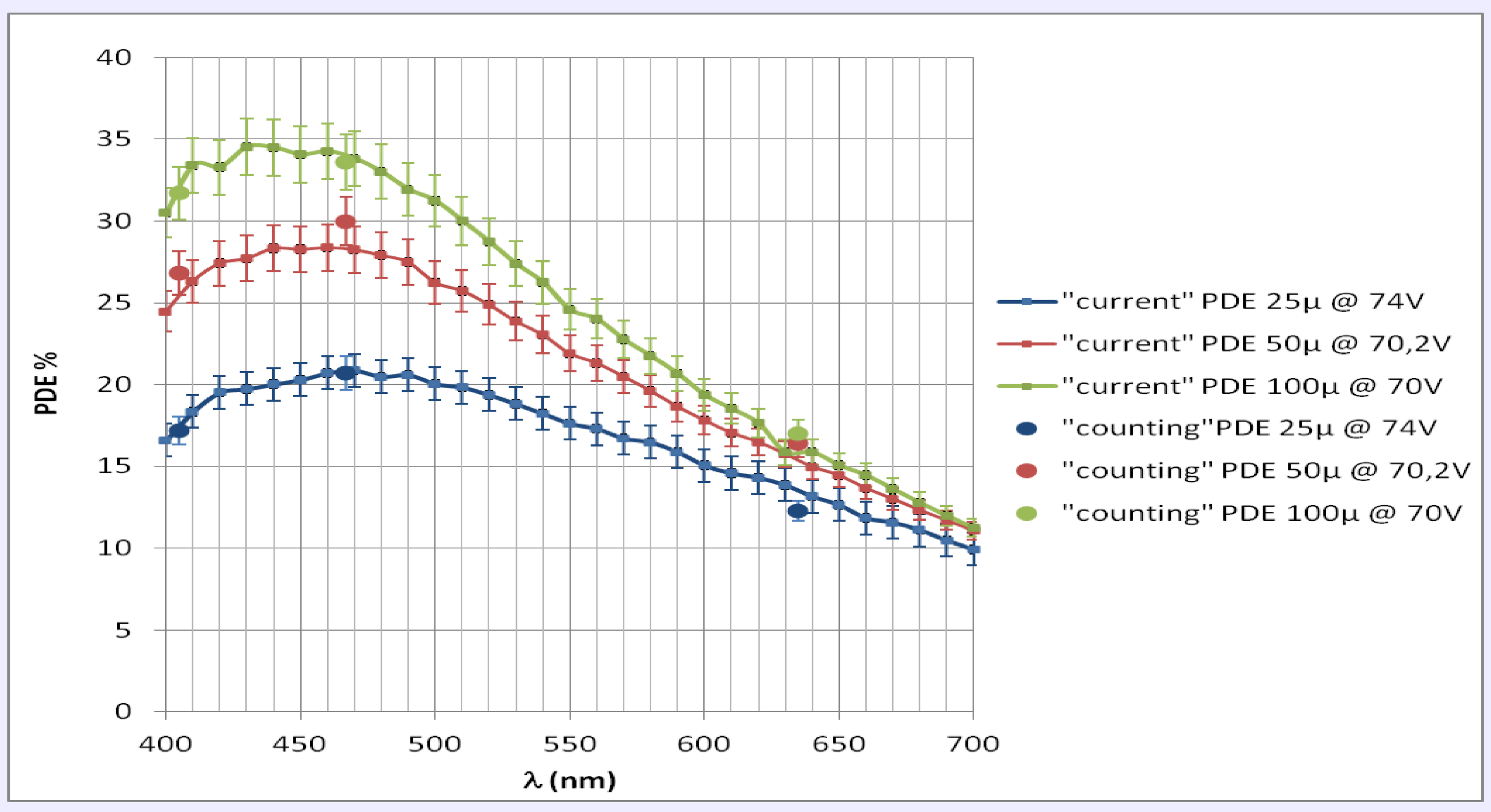
- 0.9 < ratio < 1.2 as expected
- ratio ↘ with V_{bias}

Conclusion:

the SiPM gain measured in dark condition is not precise enough to give an absolute PDE at 5 % → need of an indirect method to evaluate it (via the counting PDE)

S10362-11 absolute PDE
400 nm < λ < 700 nm @ 20°C

SiPM gain determined owing to the counting PDE measurement @ 405 nm



± 5% agreement between the measurements in pulsed and continuous light = limit of the bench calibration accuracy

Conclusion

- **5% absolutePDE accuracy @ all V_{bias} and λ (400 – 700 nm)**
- the SiPM gain is determined from the "current" PDE & "counting" PDE comparison → **need of a very well calibrated test bench**
- **the direct gain measurement in dark conditions gives errors of 10 to 20 %** → need of detailed analysis of secondary effects (after-pulses, crosstalk) and dark noise distribution (ongoing study in collaboration with Fermilab).