

Dynamics of the Amplitude-to-Phase Coupling of 1.5 μ m High Bandwidth Commercial Photodiodes



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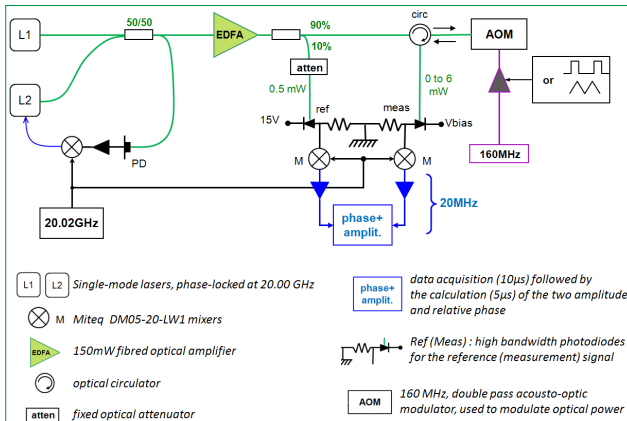
ABSTRACT

We investigate the power-to-phase coupling in two commercial high bandwidth P-i-n near-IR photodetectors. We observe that a sudden change of the optical power induces a transient of the phase of the 20 GHz signal, at different time scales. The temperature rise of the photodetector junction is likely to be involved in this dynamical behaviour. The value of the bias voltage applied to the photodetector appears to control the size of the phase transients, as well as the optical power for which the slope of the amplitude-to-phase coupling cancels. These results are important in optimising RF optical links.

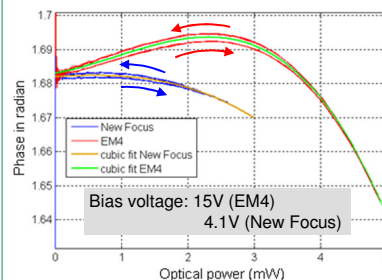
Manufacturer data for the two photodetectors

Photodetector	New Focus 1417	EM4 EM169
V _{bias} max	(V _{bias} is fixed at ≈4.1V)	25V
Junction diameter	25 μ m	32 μ m
Substrate dimensions (μ m)	N/A	450x450x152
Bandwidth	25GHz	20GHz
Fibered	no	yes
Wavelength range	950-1650nm	1280-1620nm
Max. safe DC optical power	5mW	20mW
Max. peak optical power	100mW	N/A
Max. operation optical power	2mW	6mW
Responsivity	0.7 A/W	0.9A/W

Measurement set – up



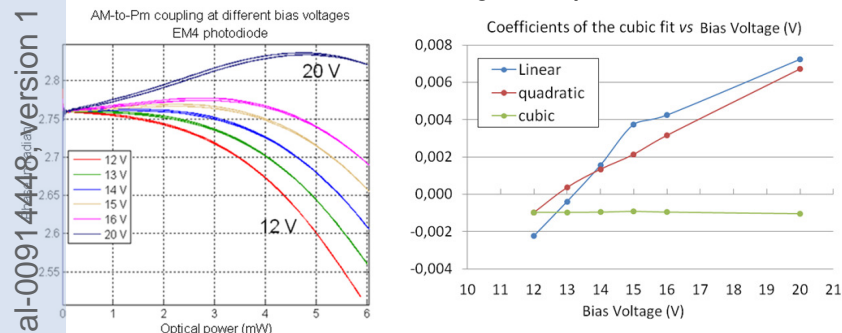
RF phase versus optical power



Cubic fit: $y = ax + bx^2 + cx^3 + offset$

Photodiode	a	b	c
EM4	$3.6 \cdot 10^{-3}$	$2.86 \cdot 10^{-3}$	$-1.05 \cdot 10^{-3}$
New Focus	$1.2 \cdot 10^{-3}$	$-7.3 \cdot 10^{-4}$	$-3.37 \cdot 10^{-4}$
Unit	rad/mW	rad/mW ²	rad/mW ³

AM-to-PM characteristics at different bias voltages. EM4 photodiode



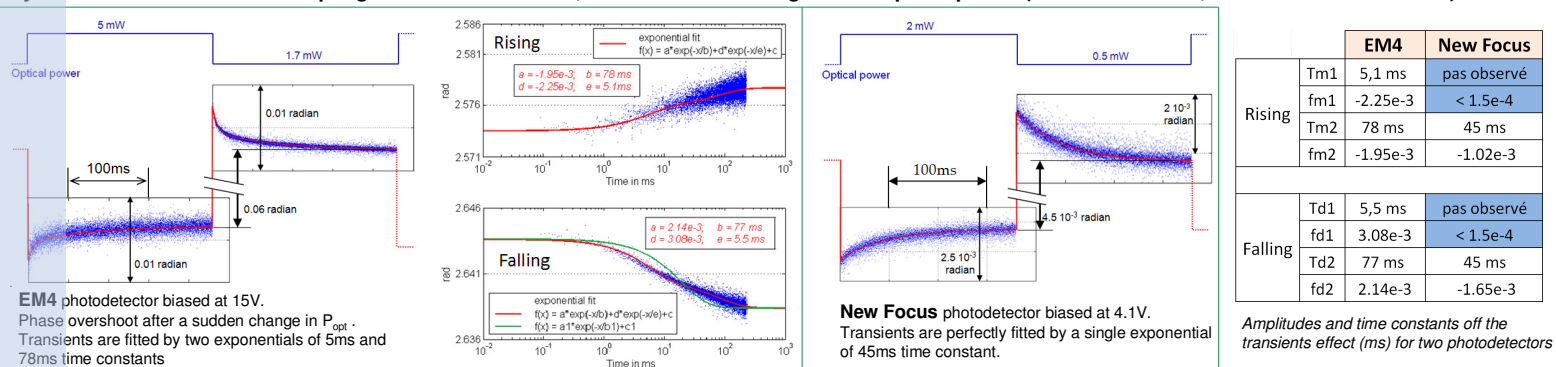
Monotonous increase of the phase offset with applied bias voltage, slope 0.023 radian/V at 12V, and 0.017 radian/V at 20V.

0.10 and 0.05 radian/V, respectively, when detecting at $P_{opt} = 6mW$.

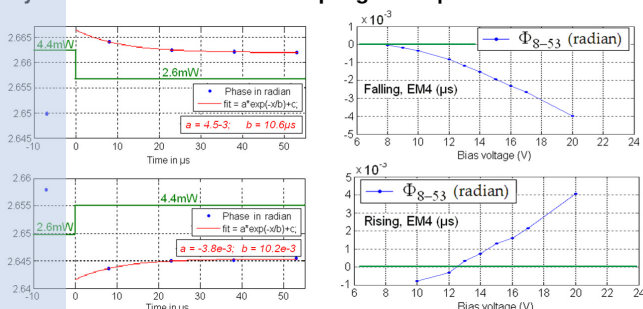
Major effect of V_{bias} is to continuously shift the optical power at which the AM-to-PM slope vanishes, from zero (at 13V) to 5mW (at 20V).

Constant value of the cubic coefficient. Contrasts with the linear and quadratic coefficients: roughly linear dependence upon V_{bias} .

Dynamics of the AM-to-PM coupling at the ms time scale, after a sudden change of the optical power (EM4: 5 \leftrightarrow 1.7mW, New Focus: 2 \leftrightarrow 0.5mW)



Dynamics of the AM-to-PM coupling at the μ s time scale



The time constants for the micro-second transients are similar with the two photodiodes (10.5 μ s for EM4 and 8 μ s for New Focus, and are likely to be associated with the temperature rise of the junction after the change of the $V_{bias} \times I_{photo}$ dissipated power. Using ANSYS software, we obtain time constants of 14 μ s (EM4) and 12 μ s (New Focus).

Conclusions

Quantitative investigation of the AM-to-PM characteristics (stationary + transient) of two commercial P-i-n InGaAs photodiodes,

Applied bias voltage controls the linear and quadratic coefficients of the power dependence => one can adjust at will the optical power at which the AM-to-PM slope cancels.

Transients are likely to be due to the heating of the junction by the $I \times V_{bias}$ dissipated power, => can be controlled through the applied bias voltage.

Bias voltage is a critical parameter in optimizing operating conditions

for low noise frequency reference optical distribution, or phase transients measurement.