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

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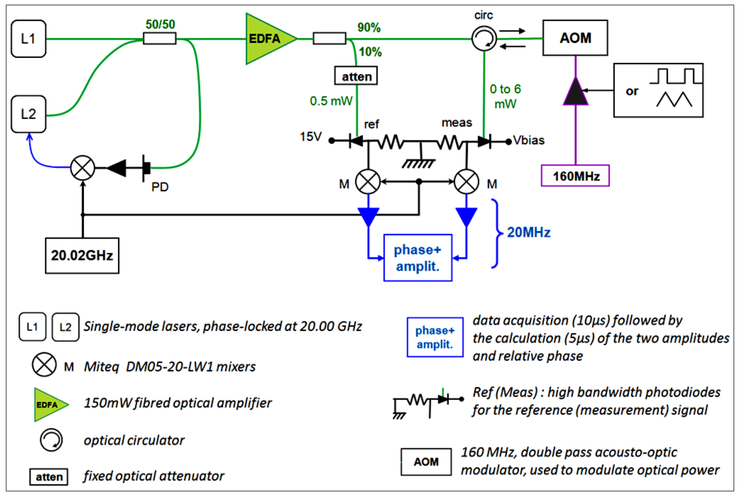
ABSTRACT

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.

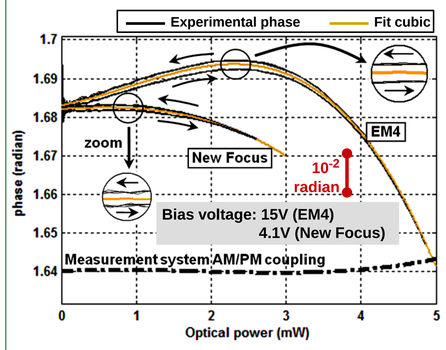
Manufacturer data for the two photodetectors

Photodetector	New Focus 1417	EM4 EM169
Vbias max	(Vbias is fixed at ≈4.1V)	25V
Junction diameter	25 µm	32 µm
Substrate dimensions (µm)	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
Linear operation optical power	2mW	6mW
Responsivity	0.7 A/W	0.9A/W

Measurement set – up



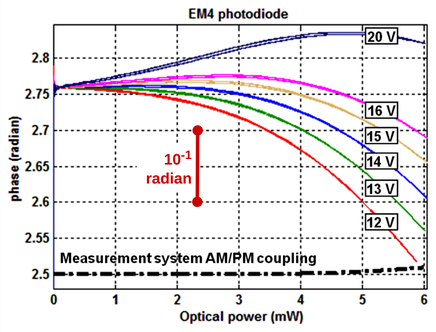
RF phase versus optical power

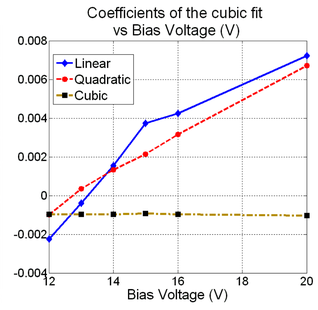


Cubic fit: $y = ax + bx^2 + cx^3 + offset$

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

AM to PM coupling at different bias Voltages, EM4 photodiode



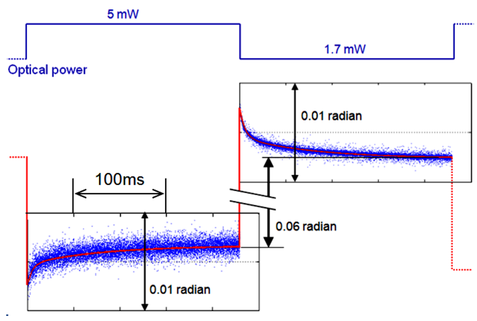


At small signal, monotonous increase of the phase offset with applied V_{bias}, slope 0.023 radian/V at 12V, and 0.017 radian/V at 20V.

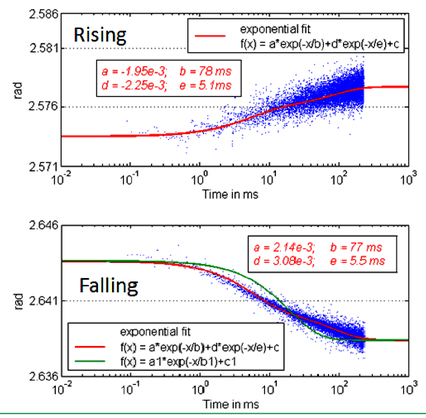
At P_{opt} = 6mW: 0.10 and 0.05 radian/V.

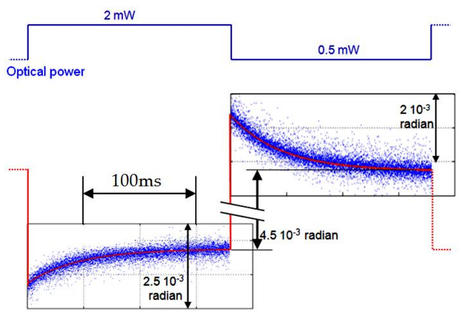
=> Use of V_{bias} to continuously shift the zero-AM/PM optical power, from zero (@13V) to 5mW (@20V).

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



EM4 photodetector biased at 15V.
Phase overshoot after a sudden change in P_{opt} .
Transients are fitted by two exponentials of 5ms and 78ms time constants



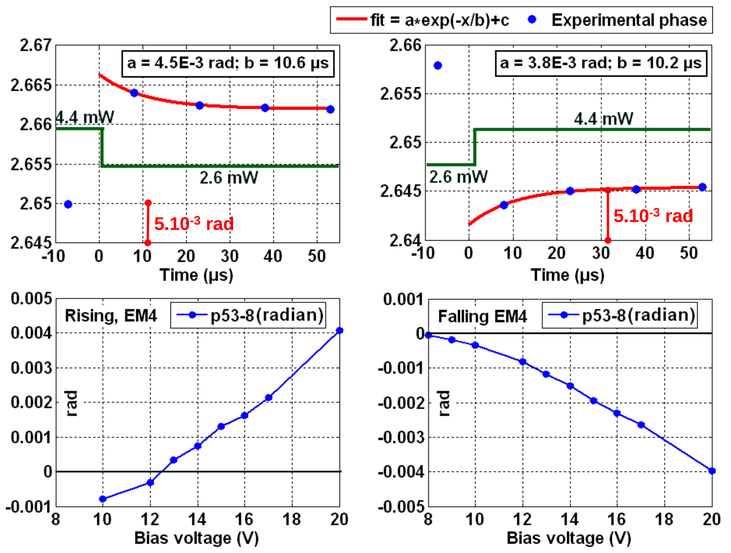


New Focus photodetector biased at 4.1V.
Transients are perfectly fitted by a single exponential of 45ms time constant.

		EM4	New Focus
Rising	Tm1	5,1 ms	Not observed
	fm1	-2.25e-3	< 1.5e-4
	Tm2	78 ms	45 ms
	fm2	-1.95e-3	-1.02e-3
Falling	Td1	5,5 ms	Not observed
	fd1	3.08e-3	< 1.5e-4
	Td2	77 ms	45 ms
	fd2	2.14e-3	-1.65e-3

Amplitudes and time constants of the transients effect (ms) for two photodetectors

Dynamics of the AM-to-PM coupling at the µs time scale



exp const.	Rising	Falling	*simulation*
EM4	10.2 µs	10.6 µs	*14.0 µs*
New Focus	7.1 µs	9.2 µs	*12.2 µs*

Simulation:
heat transmission equations solved using ANSYS software.

CONCLUSIONS

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

Applied bias voltage controls the power dependence => one can adjust at will the optical power at which the AM-to-PM cancels.

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

=> Bias voltage: critical parameter in reducing noise or systematics on phase measurements or phase transfer.