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Quadrature Amplitude Modulator

QAM

1 – Description

Kylia proposes two QAM products: QAM16 and QAM64.

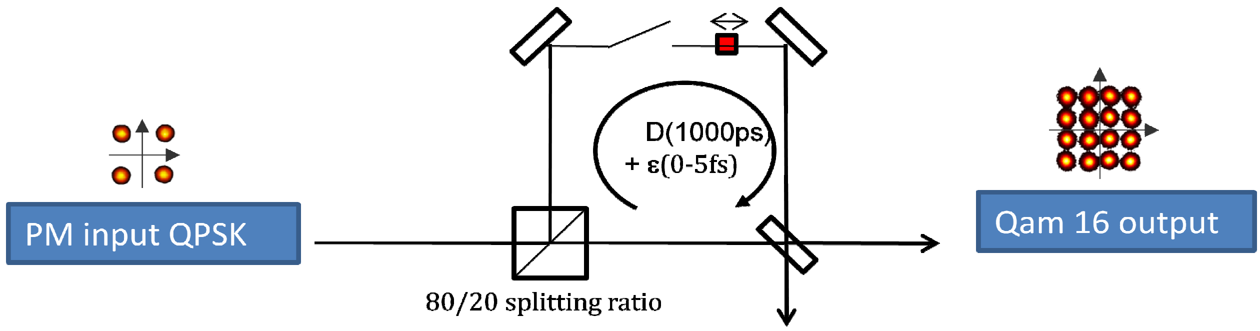
The QAM16 emulator is a device that enables to emulate a QAM16 signal from a QPSK signal. The device has one PM input by which a QPSK signal is launched. First the signal is split in a very precise 80/20 ratio. One part is delayed by 1ns in order to de-correlate both parts of the signal. Then the two parts are combined to make them interfere and thus emulate a QAM16 signal which is injected in the PM output fiber. A phase tuning element enables to adjust the delay between both arms to a multiple of bit-time in order optimize the interferences pattern. Moreover an ON/OFF switch enables to visualize only one arm of the QAM16 emulator.

The QAM64 emulator is a device that enables to emulate a QAM16 or QAM64 signal from a QPSK signal. The device has one PM input by which a QPSK signal is launched. It is then split twice thanks to tunable couplers and the three parts are finally recombined together after one has been delayed by 500ps and another by 1ns. The interference of these three signals enables a QAM654 signal injected in the PM output of the device.

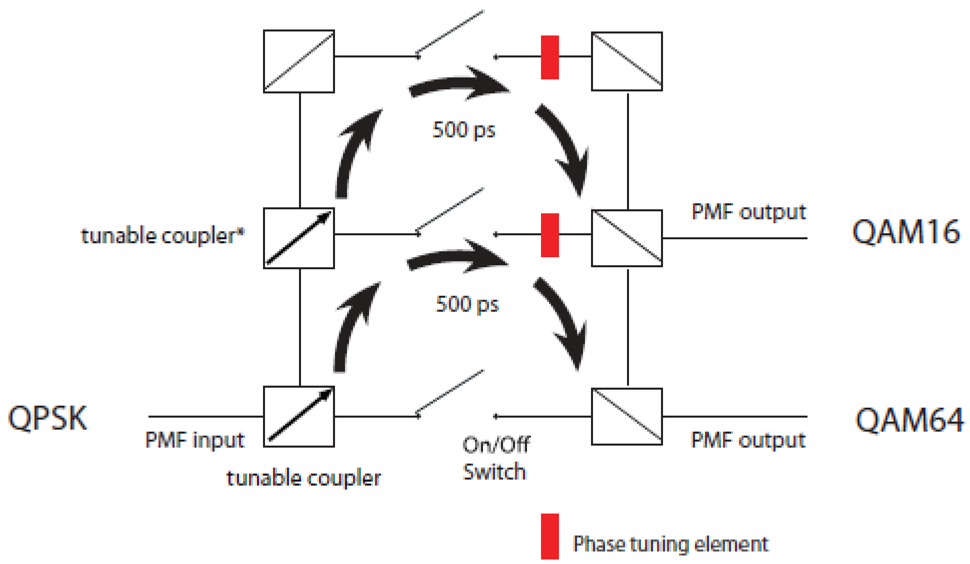
Phase tuning elements enable to precisely adjust the delay between the several arms depending on the wavelength used.

QAM64

2 – Block diagram



Block diagram: QAM16



Block diagram: QAM64

3 – Absolute maximum ratings

Parameter	Symbol	Min	Typ.	Max	Unit	Remarks/Conditions
Maximal optical input power	OpIn			300	mW	
Storage temperature range	STR	-10.0		80	°C	
Humidity	RH	5		85	%	non condensing
Fiber bend radius		20			mm	
Maximal input voltage	V_{max}			4	V	

4 – Operating conditions

Parameter	Symbol	Min	Typ.	Max	Unit	Remarks/Conditions
Operating wavelength	OWR	1530		1570	nm	
Operating temperature range	OTR	0		70	°C	
Operating tuning voltage	OTV	-4		4	V	

5 – Specifications

QAM16 specifications:

Parameter	Symbol	Min	Typ.	Max	Unit	Remarks/Conditions
Insertion loss	IL	3.2	4.5	5.5	dB	Including 3dB from BS
Splitting ratio	R	78	80	82	%	
Path difference	D	990	1000	1010	ps	
Switch attenuation	Att	60			dB	
Tuning range	ε	360			deg	360deg is equivalent to approx. 5fs at 1550nm
Tuning voltage	OTV		2.5	3.5	V	Voltage needed for a 360deg tuning range
Power consumption	P			0.5	W	
OTV connector			BNC			

QAM64 specifications:

Parameter	Symbol	Min	Typ.	Max	Unit	Remarks/Conditions
Insertion Losses path 1	IL1			2.0	dB	Measured with tunable couplers optimized
Insertion Losses path 2	IL2			3.0	dB	
Insertion Losses path 3	IL3			4.0	dB	
Optical path delay 2-1	OPD_{21}	495		505	ps	
Optical path delay 3-2	OPD_{32}	495		505	ps	
Polarization Extinction Ratio	PER	19			dB	
Optical Return Loss	ORL	35			dB	
Tuning range				520	deg	
Tuning voltage	ϕ			3.0	V	Voltage needed to reach the tuning range
Tuning time constant	T			1.0	s	To reach 50% of the final state
Power consumption	P			0.5	W	
OTV connector			BNC			

OTV : The tuning voltage feeds a 33 Ohms heater attached to low thermal latency optical element. When heated, this element changes its refraction index, and adds an additional delay of several femtoseconds. This feature enables to finely tune the phase of both arms for a perfect QAM figure.

6 – Principle Mathematics

Let us call $A_{IN}(t)$ the electromagnetic field (EMF) of the input. Then for a QPSK signal we have:

$$A_{IN}(t) = e^{ik(t).\frac{\pi}{2}}$$

Where k(t) is an integer that changes every T seconds. T is the bit-time and equals 1/F where F is the modulation frequency of the signal. Typically, for a QPSK signal modulated at 40GHz, we have T=2.5ps and k(t) can take a value between [0,1,2,3] and will change every 2.5ps.

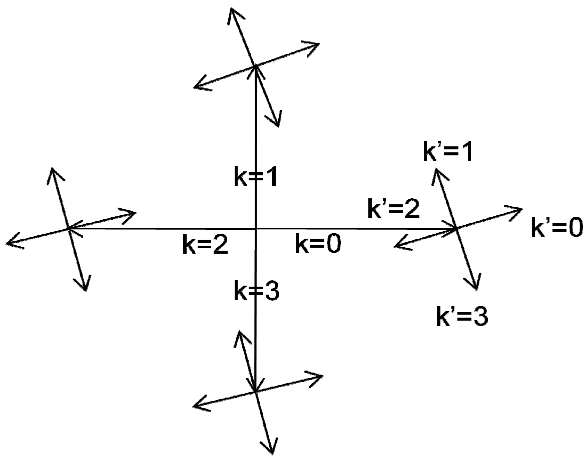
At the output of the QAM16, the EMF can be expressed by:

$$A_{OUT}(t) = \sqrt{R}.e^{ik(t).\frac{\pi}{2}} + \sqrt{(1-R)}.e^{i\left(\omega.(D+\varepsilon)+k(t+D+\varepsilon).\frac{\pi}{2}\right)}$$

Where:

- R is the splitting ratio (R=0.8)
- ω=2πf with f the optical frequency (for example f=193400GHz)
- D is the delay between both arms of the interferometer (D=1000ps)
- ε is the delay added by the tuning phase element (ε<5fs hence it does not change the value of k(t+D+ ε) but it enables ω*(D+ε) to be a multiple of 2π)

By now, let us call k'(t)=k(t+D+ ε) to simplify the notations. Then one can plot the EMF in phase and amplitude for the output as follow:



The spacing between the 16 points of the constellation is determined by the splitting ratio (R). The orientation of the sub-constellation k' has to be adjusted, depending on the modulation frequency, with the phase tuning element.

With a 80/20 ratio, when the tuning element is correctly adjusted, points are equidistant one to each other then emulating a QAM16 signal. With the +/-2% precision on R of the QAM16 emulator, the error made on the QAM16 constellation will not induced a penalty of the BER vs OSNR more than 0.5dB.

The same reasoning applies for the QAM64 output with a third EMF adding to the first two.

Below are some results obtained with a QAM16 emulator:

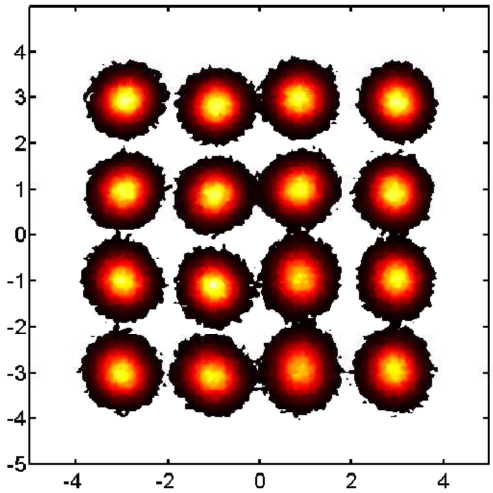


Figure 1: QAM16 constellation

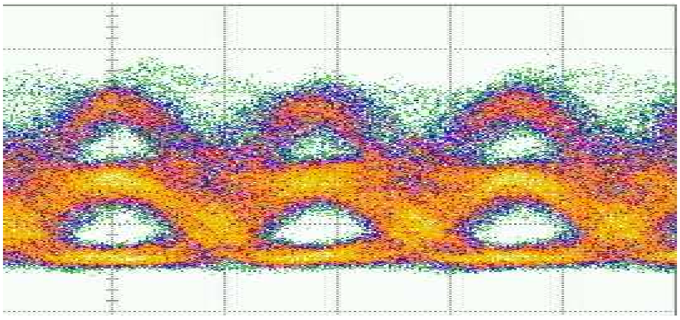


Figure 2: Eye diagram of the QAM16 signal emulated

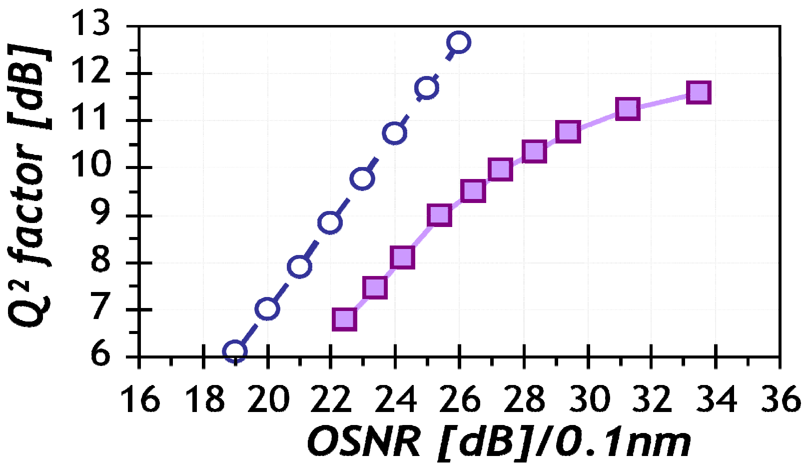
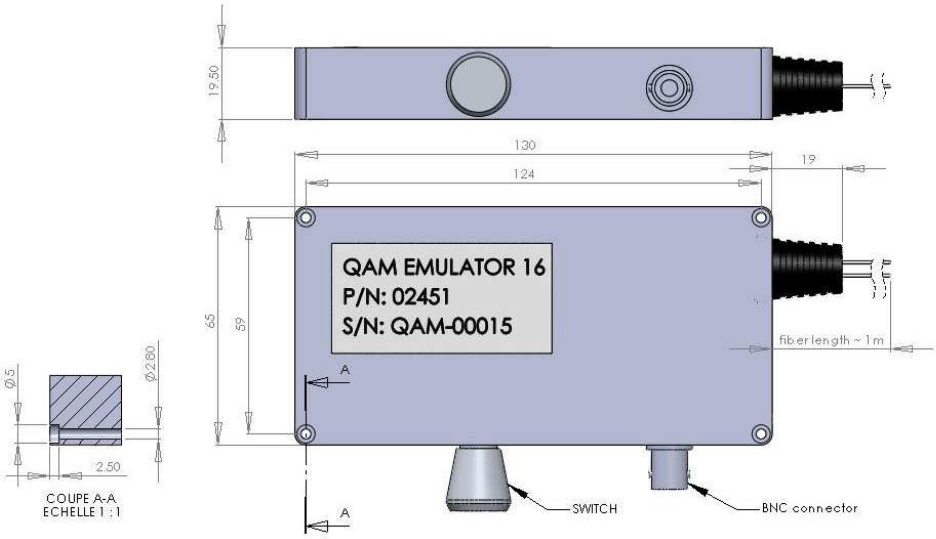
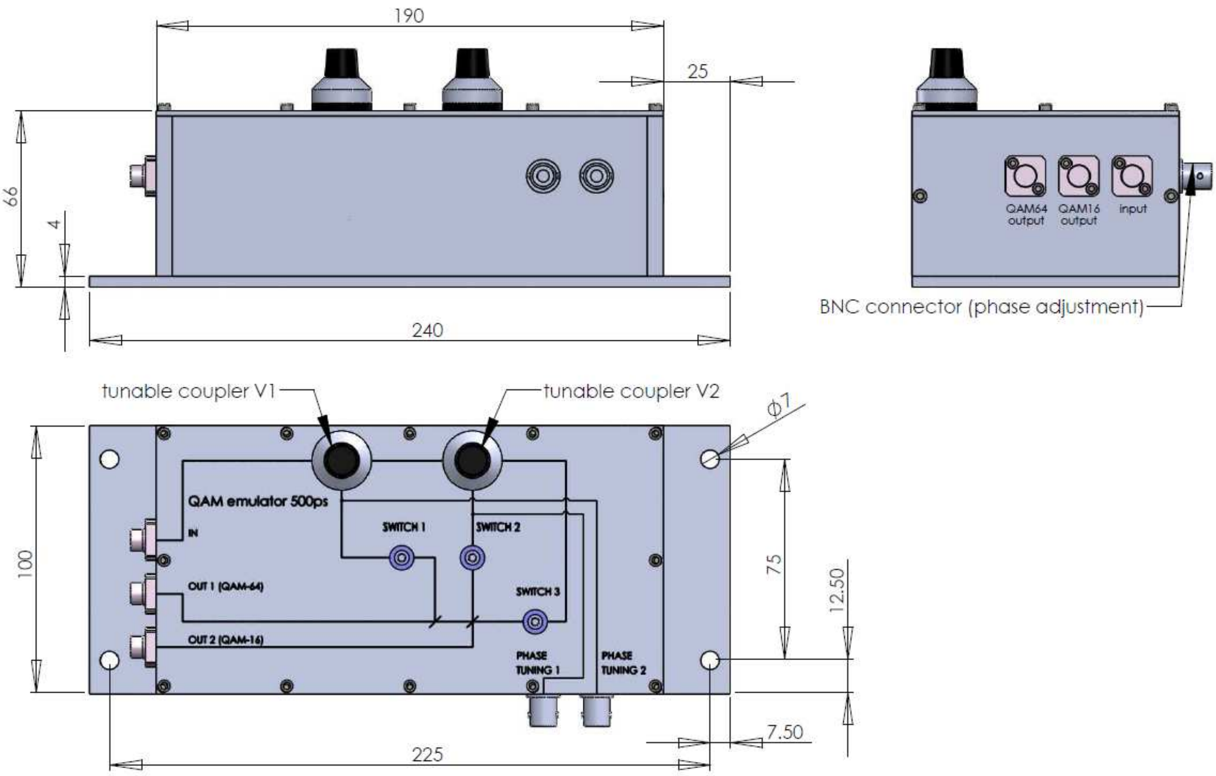


Figure 3: Measurement of the Q^2 factor

7 – Package layout



QAM16 packaging



QAM64 packaging

8 – Revision

date	version	Object
February 3rd, 2015	QAM V1.0	Creation