

# Integrated 90deg Hybrid Balanced Receiver

## 1. INTRODUCTION

This document describes one of Optoplex's innovated products, a 90deg optical hybrid integrated with balanced photo-receivers, which can be used in optical sensing applications, particularly the coherent Doppler wind LIDAR (light detection and ranging). A photo of the product can be seen in Figure 1.1.

Coherent detection has been widely found in applications for RF and optical communications. In the past few years, coherent technology has been advanced dramatically in high-speed optical communications. With this advancement, key parts and components are commercially available and cost-effective for many applications beyond telecommunications, such as narrow linewidth lasers, optical hybrid, balanced photo-receivers, and DSP, etc.

High-performance 90deg optical hybrid is an important part in optical coherent detection. Optoplex's free-space, micro-optics-based, and passive 90deg Optical Hybrid is a mixer in *coherent detection* and has been widely used in both 40Gbps and 100Gbps coherent transmission systems in optical communications. In addition to 90deg optical hybrid, 2x4 coherent mixer and 2x8 coherent mixer, Optoplex has developed and supplied integrated 40G and 100G coherent receivers as well.

In Doppler LIDAR applications, 90deg optical hybrid is a must-have component. Compared to conventional mixer using fiber optic couplers, it won't be able to provide information about wind vector. While, because 90deg optical hybrid provides the 90deg phase information between I- and Q- paths, it can yield to the wind vector information.

Figure 1.2 on the left illustrates the functional block diagram of the integrated 90deg optical hybrid with balanced photoreceivers.

The integrated 90deg hybrid receiver has a 3dB bandwidth of about 100MHz. The RF output swing is +/-3.6V for high impedance load ( $\pm 1.8$  V into 50  $\Omega$ ). The CMRR is better than 25dB (with a typical value of 35dB).



Figure 1.1, Photo of an Integrated 90deg Optical Hybrid Balanced Receiver

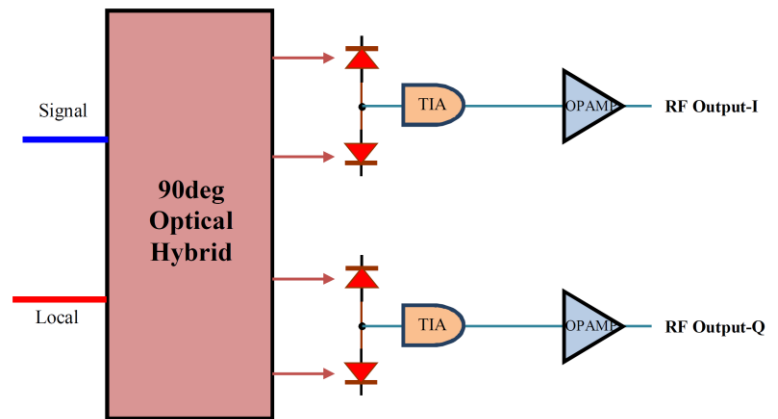


Figure 1.2, Functional illustration of the integrated 90deg hybrid with balanced photo-receiver.

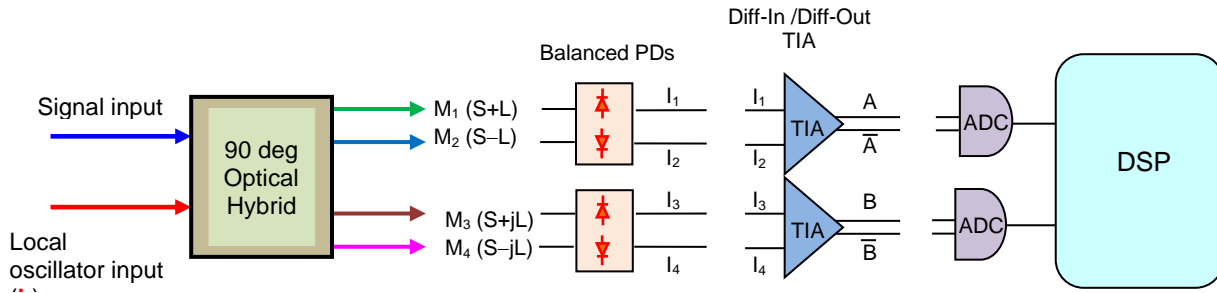
### Features

- Free-space optics based 90deg optical hybrid
- Accurate 90deg phase difference, small temperature, wavelength and polarization dependence
- Superior optical performance (IL, TDL, PDL, Skew, etc.)
- Low dark current
- High CMRR
- High PER

### Applications

- Coherent Doppler LIDAR system
- Coherent detection in fiber sensing
- Coherent detection in OCT and other biomedical sensing/imaging systems
- Coherent spectroscopy instrumentation
- Coherent detection in optical communications

## 1.2. Balanced Detection



Assuming the phase different between S and L is  $\phi$ , with balanced detection by a pair of balanced photodetectors, the four outputs (intensity) from the balanced PDs are

$$I_1 = L^2 + S^2 + 2LS \cos(\phi)$$

$$I_2 = L^2 + S^2 - 2LS \cos(\phi)$$

$$I_3 = L^2 + S^2 + 2LS \sin(\phi)$$

$$I_4 = L^2 + S^2 - 2LS \sin(\phi)$$

With differential-in TIA, the output from the TIAs are

$$A = 4LS \cos(\phi)$$

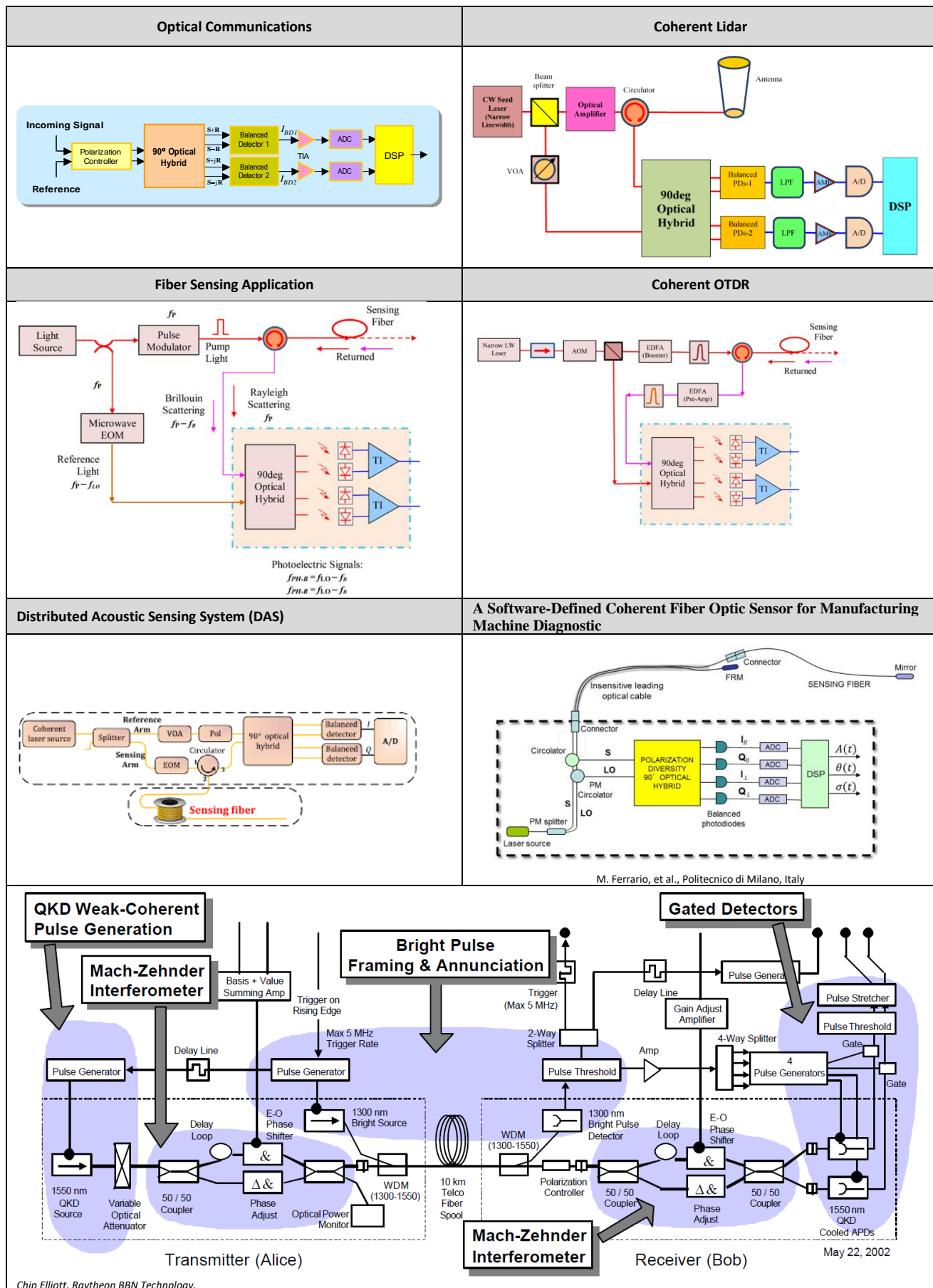
$$B = 4LS \sin(\phi)$$

A and B will be processed by a DSP (after ADC), the phase difference,  $\phi$ , can be extracted from

$$C = B / A = \tan(\phi)$$

$$\phi = \arctan(C)$$

# 1.3 Examples of Coherent Detections



Chip Elliott, Raytheon BBN Technology.

## 2. ABSOLUTE MAXIMUM RATINGS

No	Parameter	Symbol	Unit	Conditions	Ratings		Notes
					Min	Max	
2.1	Input Optical Power	$P_{in\_Max}$	<i>mW</i>		-	300	
2.2	Operating Temperature	$T_c$	$^{\circ}C$		-5	+70	
2.3	Operating Humidity	-	<i>%RH</i>	$T_c = +65^{\circ}C$ , Non-condensing	5	85	
2.4	Storage Temperature	$T_{stg}$	$^{\circ}C$		-40	+85	
2.5	Storage Humidity	-	<i>%RH</i>	$T_c = +85^{\circ}C$ , Non-condensing	5	85	

## 3. OPERATING CONDITIONS

No	Parameter	Symbol	Unit	Conditions	Ratings			Notes
					Min	Typ.	Max	
3.1	Input Optical Power	$P_{in\_Max}$	<i>mW</i>		-		300	
3.2	Operating Temperature	$T_c$	$^{\circ}C$		-5		+65	
3.3	Operating Humidity, Relative, 40 $^{\circ}C$ non-condensing	-	<i>%RH</i>		5		85	
3.4	Storage Temperature	$T_{stg}$	$^{\circ}C$		-40		+85	
3.5	Storage Humidity	-	<i>%RH</i>		5		85	

## 4. OPTICAL PERFORMANCE REQUIREMENTS OF 90DEG OPTICAL HYBRID

### 4.1 Functional Block Diagram

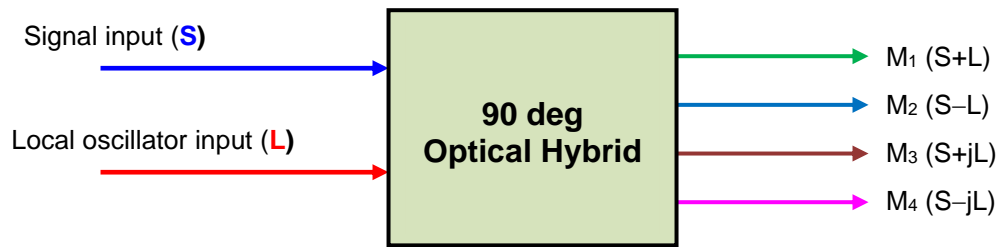


Figure 4.1, Functional block diagram of the 90deg hybrid

Table 4.1, Functional definitions of the 90deg hybrid

Port	Function	Phase Difference	Value	Note
1	Local		L	
2	Signal		S	
3	M <sub>1</sub>	0	S + L	
4	M <sub>2</sub>	$\pi$	S - L	
5	M <sub>3</sub>	$\pi/2$	S + jL	
7	M <sub>4</sub>	$-\pi/2$	S - jL	



## 4.2 Optical Performance Specifications

Table 4.1, Optical Performance Specification of the 90deg Hybrid

Parameter		Unit	Specification
Wavelength Range (C- or L-Band)		<i>nm</i>	1527 ~ 1567
Phase Difference <sup>1</sup> (between M <sub>1</sub> , M <sub>2</sub> and M <sub>3</sub> , M <sub>4</sub> )		<i>deg</i>	90 ± 10
Insertion Loss <sup>1</sup> (without connector)	S→M <sub>i</sub>	<i>dB</i>	< 8.5
	L→M <sub>i</sub>	<i>dB</i>	< 8.5
Insertion Loss Difference <sup>1</sup>	S→M <sub>1</sub> and S→M <sub>2</sub>	<i>dB</i>	< 0.7
	S→M <sub>3</sub> and S→M <sub>4</sub>	<i>dB</i>	< 0.7
	L→M <sub>1</sub> and S→M <sub>2</sub>	<i>dB</i>	< 0.7
	L→M <sub>3</sub> and S→M <sub>4</sub>	<i>dB</i>	< 0.7
	Between all other ports	<i>dB</i>	< 1
	Optical Return Loss	<i>dB</i>	> 27
Optical Path Difference (skew, between M <sub>1</sub> and M <sub>2</sub> and between M <sub>3</sub> and M <sub>4</sub> )		<i>ps</i>	< 5
Optical Path Difference (skew, between any other two outputs)		<i>ps</i>	< 5
PM Fiber and Connector Alignment		-	Slow Axis aligned to the key
PER		<i>dB</i>	> 18
Max. Input Optical Power		<i>mW</i>	300

**Notes:**

1. Over the stated spectral and operating temperature ranges and all polarization states.

## 5. BALANCED PHOTORECEIVER

### 5.1 Optical-Electrical Characteristics for 100MHz Receiver

#	Parameter	Unit	Min	Typ.	Max	Note
5.1.1	Type of Detector		InGaAs			
5.1.2	Wavelength Range	<i>nm</i>	1510		1670	
5.1.3	Responsivity, Typical	<i>V/W</i>		8		
5.1.4	RF Output Bandwidth (3dB)	<i>MHz</i>	DC		100	
5.1.5	Common Mode Rejection Ratio (CMRR)	<i>dB</i>	20	30		
5.1.6	Transmission Gain	<i>V/A</i>		50x10 <sup>3</sup>		
5.1.7	Conversion Gain RF Output	<i>V/A</i>		50x10 <sup>3</sup>		
5.1.8	CW Saturation Power	<i>μW</i>		72		@1550nm
5.1.9	NEP (DC - 10MHz)	$\frac{pW}{\sqrt{Hz}}$		3.8		
5.1.10	Integrated Noise (DC - 100MHz)	<i>nW<sub>RMS</sub></i>		65		
5.1.11	Overall Output Voltage Noise	<i>mV<sub>RMS</sub></i>		2.2		
5.1.12	RF Output Impedance	$\Omega$		50		
5.1.13	RF Output Voltage Swing	<i>V</i>			+/-3.6	
5.1.14	DC Offset RF Output	<i>mV</i>			+/-3	
5.1.15	Max Optical Input Power	<i>mW</i>			20	
5.1.16	Power Supply, Voltage	<i>V</i>			+/-12	
5.1.17	Power Supply, Current	<i>mA</i>			200	
5.1.18	Electrical Output Interface		SMA			

## 5.2 PD Responsivity for 100MHz Receiver

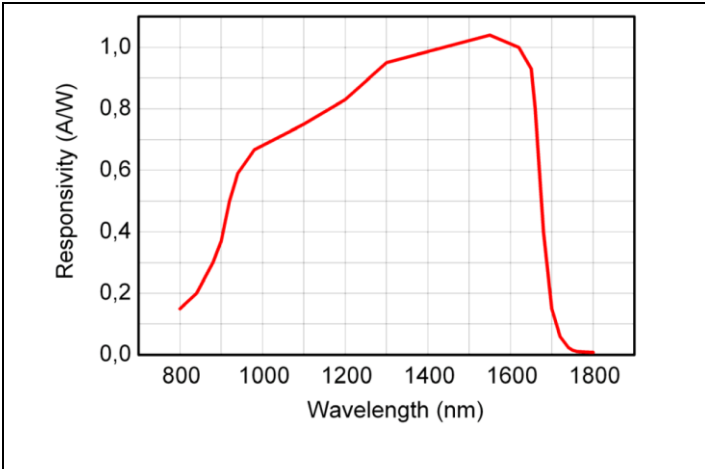


Figure 5.1, Responsivity

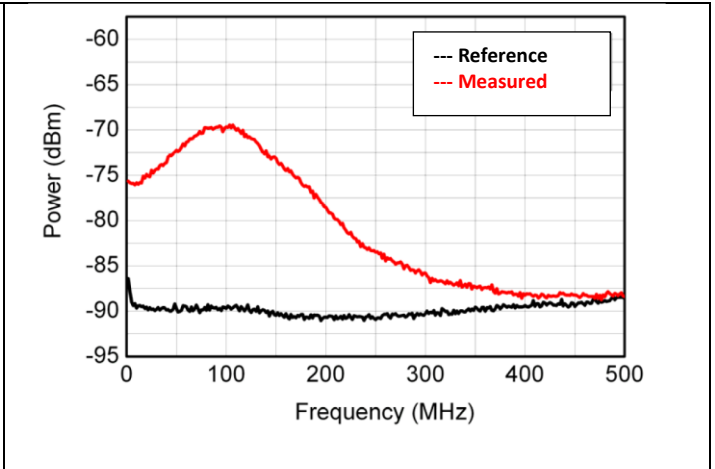


Figure 5.2, Spectral Noise

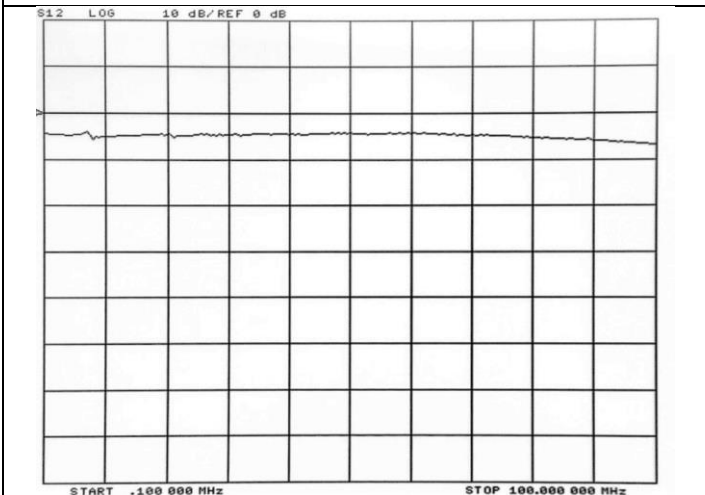


Figure 5.3, S21 of IM<sup>+</sup>

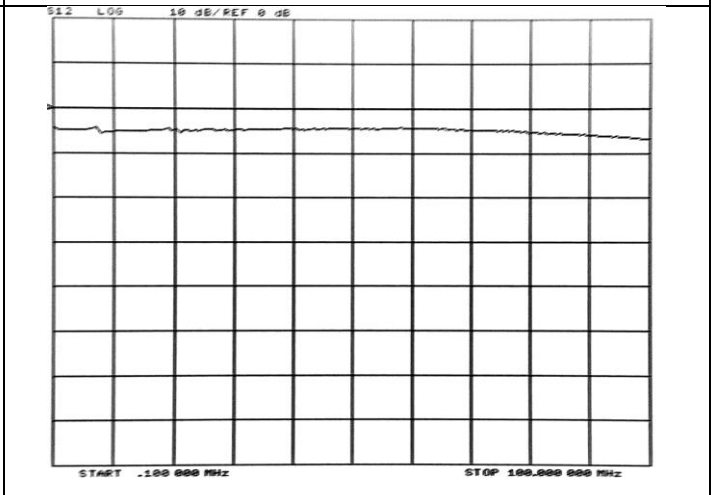


Figure 5.4, S21 of IM<sup>-</sup>

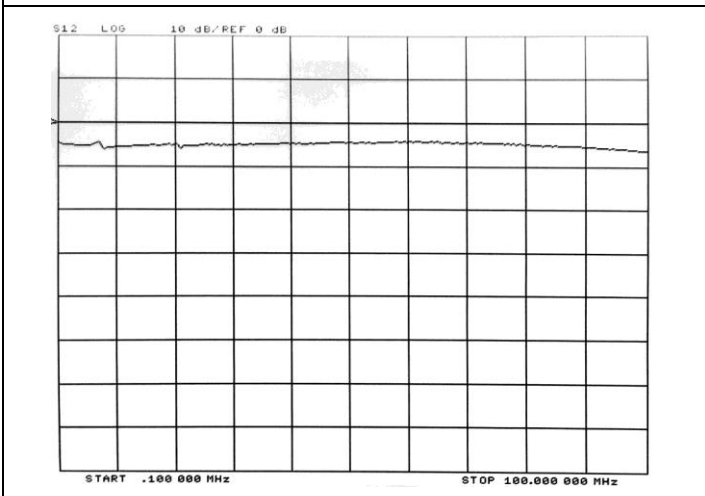


Figure 5.5, S21 of QM<sup>+</sup>

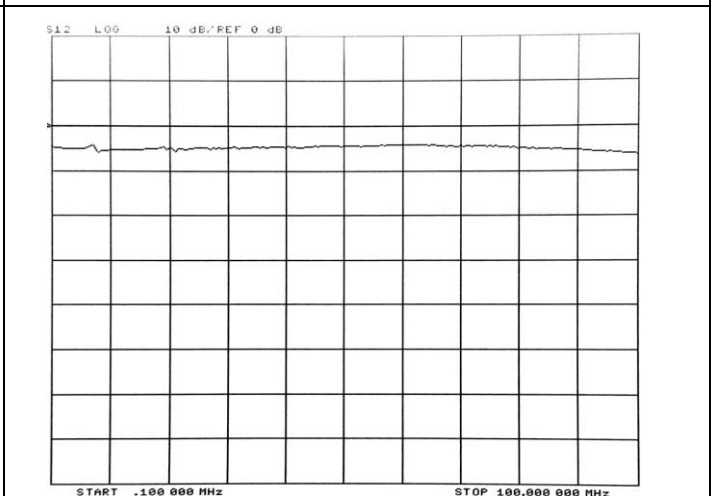


Figure 5.6, S21 of QM<sup>-</sup>



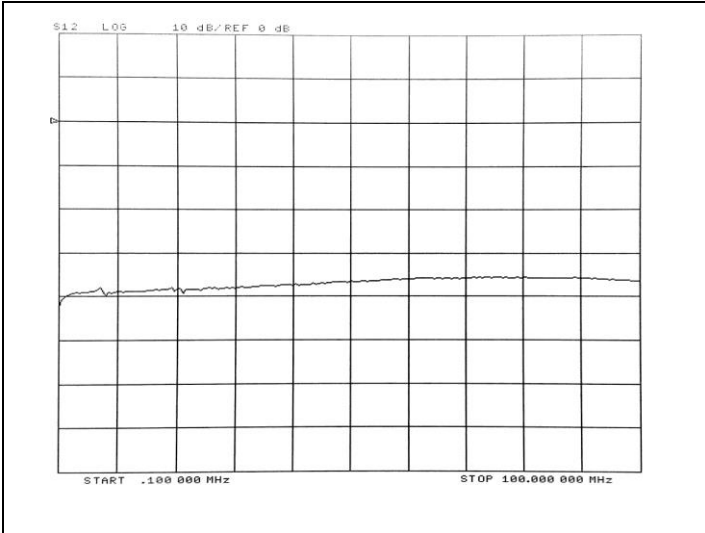


Figure 5.7, CMRR of Signal  $I_{RF}$

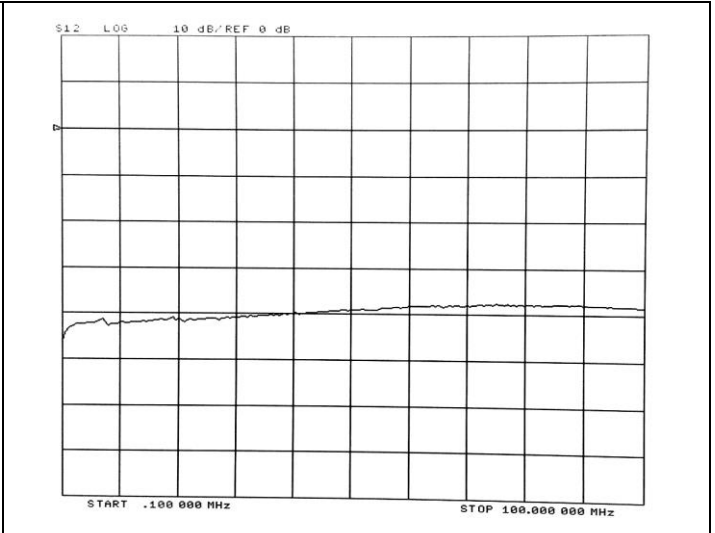


Figure 5.8, CMRR of Local  $I_{RF}$

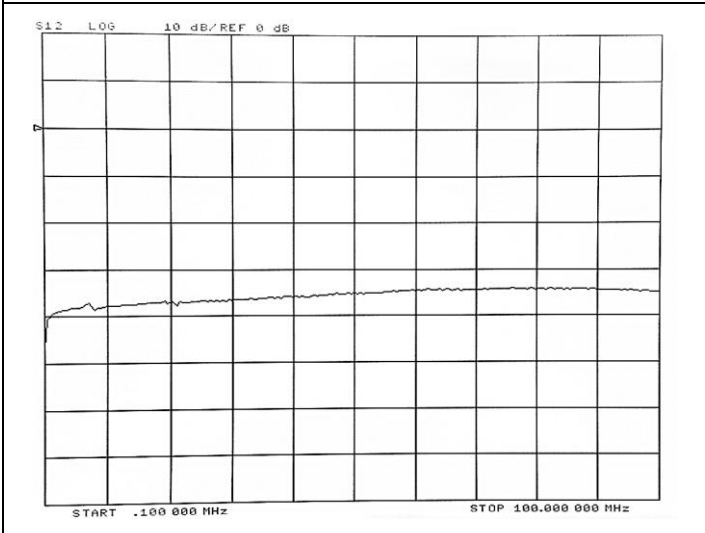


Figure 5.9, CMRR of Signal  $Q_{RF}$

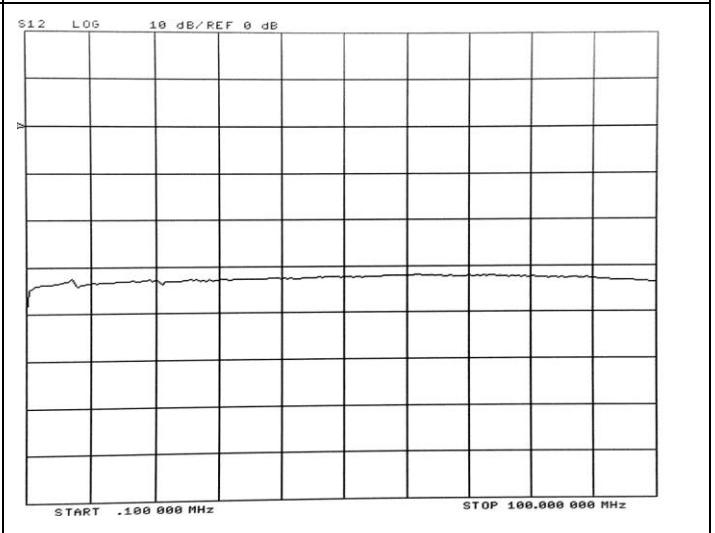


Figure 5.10, CMRR of Local  $Q_{RF}$

# 6. PHYSICAL REQUIREMENTS

## 6.1 Mechanical Specification

Dimension: 150 x 82 x 36 mm

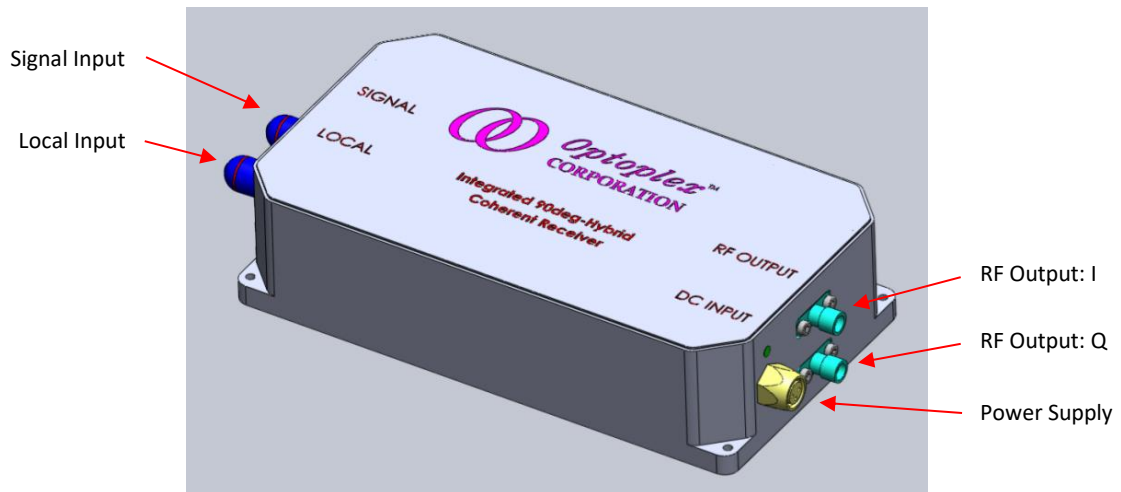
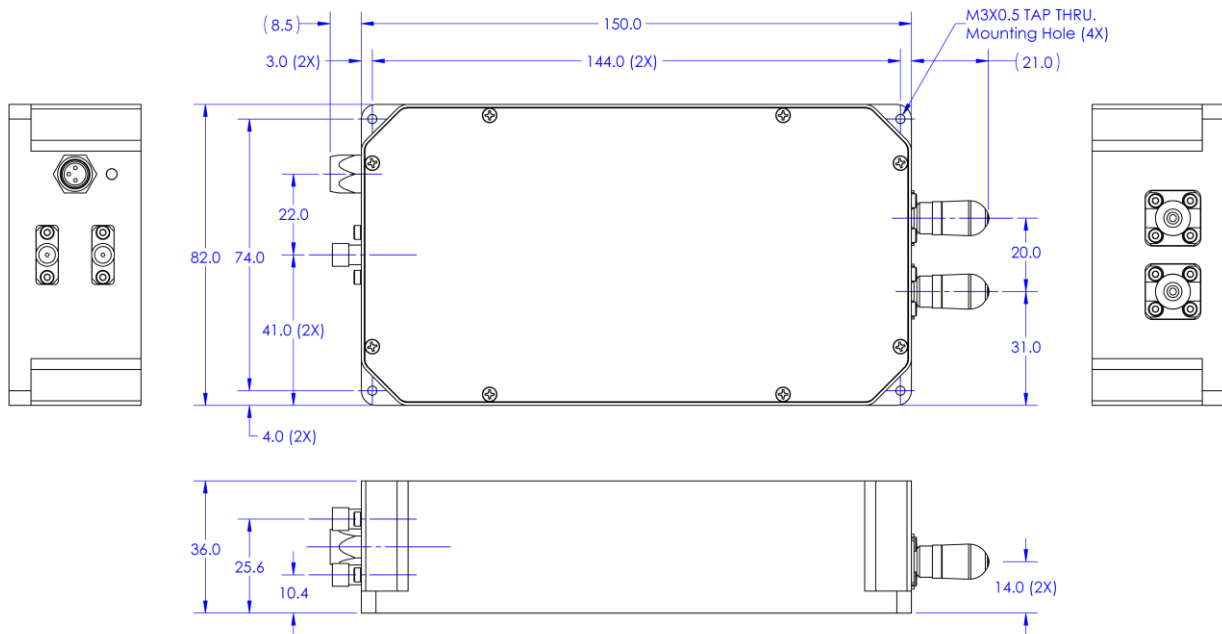


Figure 6.1, Mechanical drawing of the integrated 90deg hybrid with balanced receiver

## **6.2 Electrical Specification**

Power Supply:

- $\pm 12\text{V DC}$ , 800mA.

Electrical Output

- There are two sets of balanced photoreceivers inside the module. At the output, there are RF-Output-1 and RF-Output-2 with SMA connector

## **6.3 Optical Input Ports**

- Signal-Input Port: PMF or SMF, FC/APC
- Local-Input Port: PMF or SMF, FC/APC

## 90deg Optical Hybrid Integrated with Balanced Receivers

BW of the Balanced Receivers	Fiber Types of Input Ports		Part Numbers		
	Signal-	Local-	C-Band P/Ns	O-Band P/Ns	1064nm P/Ns
15MHz	PMF	PMF	RX-KC0015P811xx	RX-KQ0015P829xx	RX-KA0015P881
15MHz	SMF	SMF	RX-KC0015S812xx	RX-KQ0015S830xx	RX-KA0015S882
100MHz	PMF	PMF	RX-KC0100P801xx	RX-KQ0100P831xx	RX-KA0100P883
100MHz	SMF	SMF	RX-KC0100S802xx	RX-KQ0100S832xx	RX-KA0100S884
200MHz	PMF	PMF	RX-KC0200P803xx	RX-KQ0200P833xx	RX-KA0200P885
200MHz	SMF	SMF	RX-KC0200S804xx	RX-KQ0200S834xx	RX-KA0200S886
350MHz	PMF	PMF	RX-KC0350P805xx	RX-KQ0350P835xx	RX-KA0350P887
350MHz	SMF	SMF	RX-KC0350S806xx	RX-KQ0350S836xx	RX-KA0350S888
400MHz	PMF	PMF	RX-KC0400P807xx	RX-KQ0400P837xx	RX-KA0400P889
400MHz	SMF	SMF	RX-KC0400S808xx	RX-KQ0400S838xx	RX-KA0400S890
700MHz	PMF	PMF	RX-KC0700P809xx	RX-KQ0700P839xx	RX-KA0700P8xx
700MHz	SMF	SMF	RX-KC0700S810xx	RX-KQ0700S840xx	RX-KC0700S8xx
1.2GHz	PMF	PMF	RX-KC1200P811xx	RX-KQ1200P841xx	RX-KA1200P891
1.2GHz	SMF	SMF	RX-KC1200S812xx	RX-KQ1200S842xx	RX-KA1200S892
1.6GHz	PMF	PMF	RX-KC1600P815AC	RX-KQ1600P845AC	RX-KA1600P895AC
1.6GHz	SMF	SMF	RX-KC1600S816AC	RX-KQ1600S846AC	RX-KA1600S896AC

### Notes:

Part Number: RX-  
KCnnnnPnnnXX

XX = DC, DC coupled RF Output

XX = AC, AC coupled RF Output

For 1.6GHz, only AC-coupled output available

By default, the optical connector of the input ports is FC/APC

Other types of connector available

By default, the 90deg phase is 90+/-10deg.

Premium grade of 90+/-5deg possible at extra cost. Contact Optoplex



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