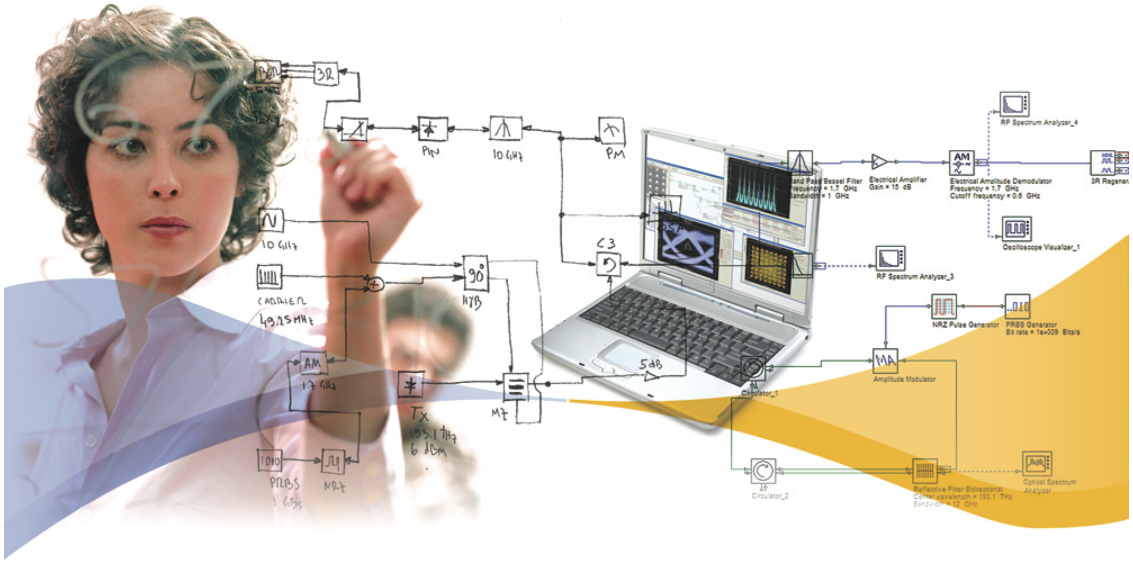
Optiwave



Fiber Optic Gyroscope Systems Design

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DC detection method

- With ideal components, the output photo-generated current (*I*) is,

$$I = I_o(1 - cos\phi_s) \qquad (1)$$

where φ_s is the Sagnac phase shift and I_o is the current at zero angular speed given by

$$I_o = \frac{\sigma P}{2} \qquad (2)$$

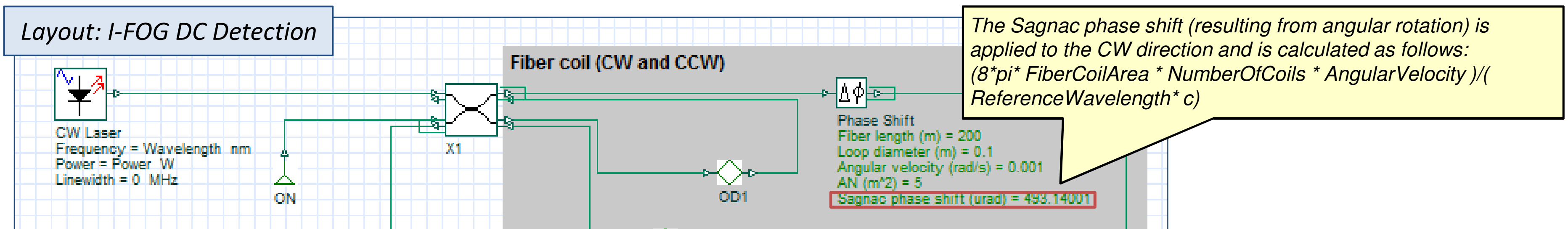
- *P* is the source optical power and σ is the photodetector responsivity (in our case this is equal to 1). The reason for dividing the optical power by 2 in equation (2) is because half of the power is lost at the coupler. Once φ_s is determined we can use

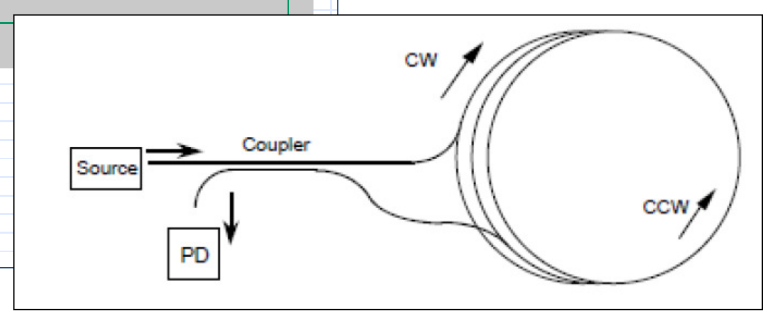
$$\phi_s = \frac{2\pi L D \Omega}{\lambda c} \qquad (3)$$

where *L* is the length of the fiber, *D* is the diameter of the loop, *λ* is the wavelength of the source, to determine the angular speed of the loop Ω. Notice that since equation (1) has a cosine relation, the DC technique cannot distinguish between positive and negative velocities.

REF: http://www.jgorasia.com/Files/Spring10/Instrumentation/FOGreport.pdf (Accessed 24 Jan 2017)

Layout: I-FOG DC Detection





Phase modulation method (1)

FOG systems design

- The DC method is not as accurate when trying to measure very low angular rotation rates and instead a phase modulation technique is commonly used. For this configuration the photo-detected signal is given by [REF]:

$$\frac{I}{I_0} = 1 + \left[J_0(\Phi_m) + 2\sum_{k-1}^{\infty} J_{2k}(\Phi_m) cos2k\omega_m t \right] cos\phi_s + \left[2\sum_{k-1}^{\infty} J_{2k-1}(\Phi_m)\cos(2k-1)\omega_m t \right] sin\phi_s \qquad (4)$$

- Choosing the phase modulator amplitudes as +/-0.9 rad gives the term Φ_m = 1.8 above for which $J_1(\Phi_m)$ = 0.581517 is maximized. We extract the Fourier cosine coefficient for modulation frequency ω_m to give

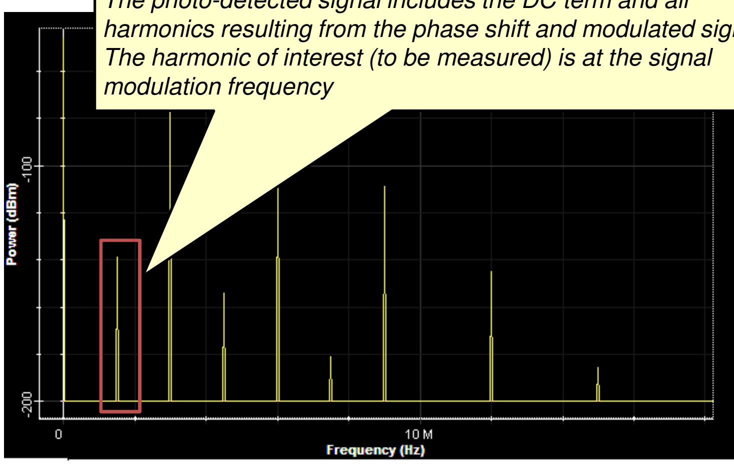
$$I_\omega = I_o 2J_1(1.8)\sin(\phi_s) \qquad (5)$$

  which we can re-arrange to find ϕ_s and then use equation (3) again to find the angular velocity. Note that in this case, since equation (5) has a sine relation, we can determine both the magnitude and direction of the angular velocity.

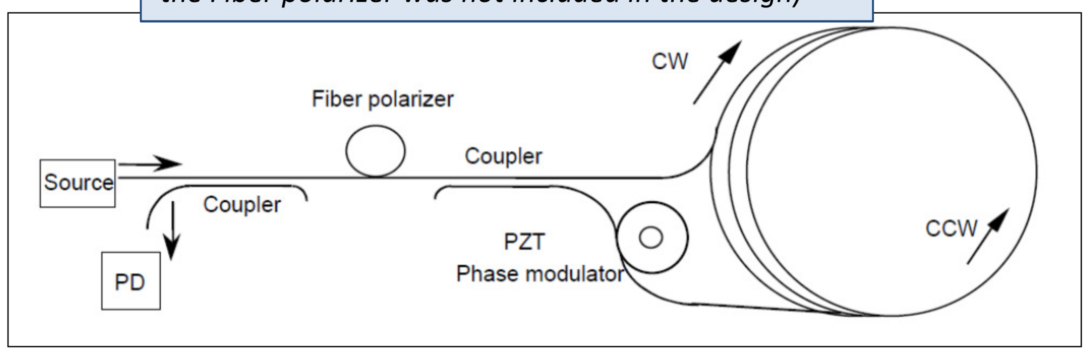
- In addition, in this situation, the zero velocity electrical current is not $I_o = \frac{\sigma P}{2}$ as in equation (2), but $I_o = \frac{\sigma P}{8}$ because by the time the light has reached the photodiode, its power has been halved three times by the couplers.

REF: http://www.jgorasia.com/Files/Spring10/Instrumentation/FOGreport.pdf (Accessed 24 Jan 2017)

The photo-detected signal includes the DC term and all harmonics resulting from the phase shift and modulated signal. The harmonic of interest (to be measured) is at the signal modulation frequency



Schematic of modulation technique (Source: REF) upon which the OptiSystem design was built (Note: the Fiber polarizer was not included in the design)



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Phase modulation method (2)

FOG systems design

- For the OptiSystem design below the angular velocity has been set to 7.27e-5 rad/s (rotation rate of the earth). The settings for the I-FOG are shown in the red box (under Global parameters). The Sagnac phase shift is applied by using the Phase Shift Component and is calculated as follows:
  $4\pi \cdot (LoopDiameter/2) \cdot FiberLength \cdot AngularVelocity / (\lambda \cdot c)$
- Here we have used our **C++ Component** to calculate the angular velocity based on the equations from the previous slide. The measured angular velocity (shown as a result below the **C++ Component**) is 7.29e-5 rad/s

Simulation | Signals | Spatial effects | Noise | Signal tracing

Name	Value	Units
Simulation window	Set time window	
Reference bit rate	☐	
Bit rate	8.533333333333321e+006	bit/s
Time window	30.00000000000004e-006	s
Sample rate	1.092266666666665e+009	Hz
Sequence length	256	bits
Samples per bit	128	
Guard Bits	0	
Symbol rate	2.5e+009	symbols/s
Number of samples	32768	
Cuda GPU	☐	
AngularVelocity	72.7e-006	rad/s
FiberLength	200	m
LoopDiameter	0.1	m
Wavelength	850	nm
ModulationFrequency	1.5e+006	
Power	0.001	

Layout: I-FOG Phase Modulation