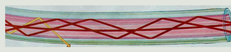
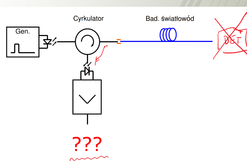
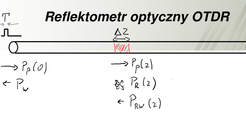
Pomiary światłowodów – reflektometr opt. Światłowody jako czujniki



Reflektometr optyczny OTDR



Reflektometr optyczny OTDR



$\rightarrow P_p(0)$ $\quad$ $\rightarrow P_p(z)$

$\leftarrow P_w$ $\quad$ $\leftarrow P_R(z)$

$$dP_p(z) = -\alpha P_p(z)dz \Rightarrow P_p(z) = P_p(0)e^{-\alpha z}$$

$$\Delta P_p(z) \approx -\alpha P_p(z)\Delta z = -\alpha_R P_p(z)\Delta z - \alpha_R P_p(z)\Delta z$$

$$P_{RW}(z) = s\alpha_R P_p(z)\Delta z = \gamma P_p(0)e^{-\alpha z}\frac{c}{n_g}T$$

$$\Delta z = \frac{c}{n_g}T$$

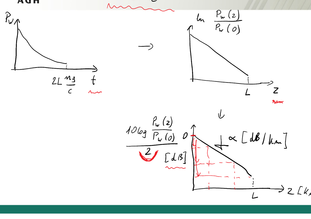
$$P_w(z) = P_{RW}(z)e^{-\alpha z} = \gamma P_p(0)e^{-2\alpha z}\frac{c}{n_g}T$$

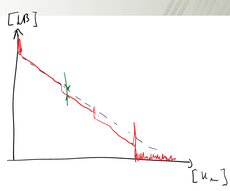
$$P_p(0) = 10\,mW, \quad T = 100\,ns$$

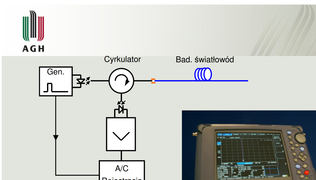
$$P_w(0) \approx 10\,\mu W$$

$$P_w(50\,km) \approx 30\,pW$$

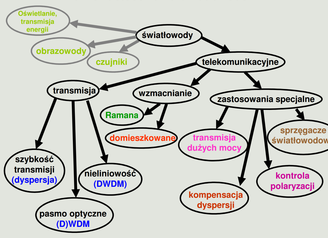
$$t = 2z\frac{n_g}{c}$$







Różne zastosowania światłowodów



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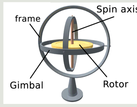
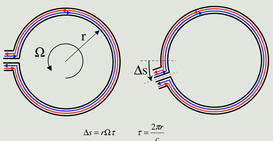


Zjawisko Sagnaca (1913)

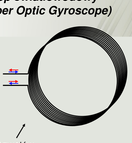


$$\Delta s = r\Omega\tau \qquad \tau = \frac{2\pi r}{c}$$

$$\Delta\Phi = \frac{2\pi\Delta s}{\lambda} = \frac{\Omega(2\pi r)^2}{\lambda c} = \frac{4\pi A\Omega}{\lambda c}$$

$$\Phi_S = \frac{8\pi A\Omega}{\lambda c}$$

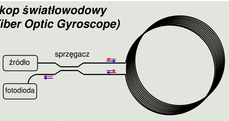
Żyroskop światłowodowy (FOG - Fiber Optic Gyroscope)

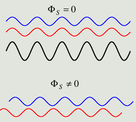


N zwojów

$$\Phi_S = \frac{8\pi NA\Omega}{\lambda c}$$

Żyroskop światłowodowy (FOG - Fiber Optic Gyroscope)

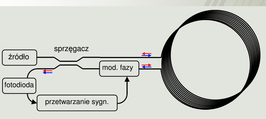




$$I = I_0(1+\cos\Phi_S)$$

Problemy:
- nierozróżnialność kierunku
- zerowa czułość dla $\Phi = 0$
- okresowość ch-ki

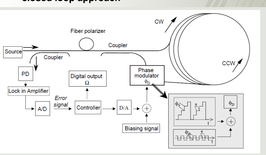
Żyroskop światłowodowy
Rozwiązanie bardziej praktyczne



$$\cancel{I = I_0(1+\cos\Phi_S)} \Longrightarrow I = I_0(1+\sin\Phi_S)$$

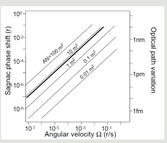
Problem: czułość / zakres pomiaru

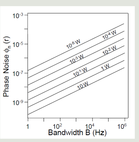
Żyroskop światłowodowy
Rozwiązanie jeszcze bardziej praktyczne closed loop approach



Zamiast mierzyć przesunięcie fazy Φ_S kompensujemy je w SZ; zatem eliminujemy *trade off* czułość / zakres

Żyroskop światłowodowy
Osiągalne parametry





źródło: SABINA MERLO, HANDBOOK OF FIBRE OPTIC SENSING TECHNOLOGY

Żyroskop światłowodowy
Zastosowania

Stabilizacja orientacji przestrzennej i kierunku ruchu
- samoloty, łodzie podwodne, rakiety, pociski, satelity itd. Itp.

Stabilizacja elementów na ruchomym podłożu (lufa czołgu, antena sat. na okręcie
Stabilizacja kierunku odwiertów
Żyrokompasy, nawigacja
Wykrywanie drgań sejsmicznych
itd

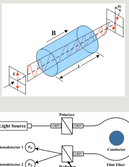
FOG

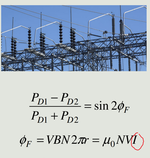
Inertial Measurement Unit (3 żyroskopy + 3 akcelerometry)

Inertial Navigation System

Żyrokompas okrętowy

(Faraday) Fiber Optic Current Sensor (FOCS)





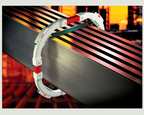
$$\frac{P_{D1} - P_{D2}}{P_{D1} + P_{D2}} = \sin 2\phi_F$$

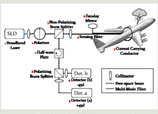
$$\phi_F = VBN2\pi r = \mu_0 NVI$$

Separator polaryzacji
Polarization Beam Splitter

ν – stała Verdeta

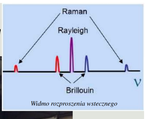
Fiber Optic Current Sensor (FOCS)

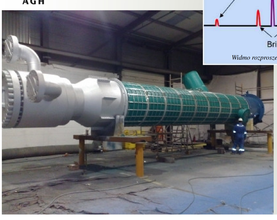




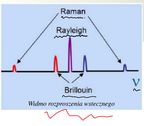
Pomiar wyładowań atmosferycznych na kadłubie samolotu

Światłowodowe rozproszone czujniki temperatury i naprężenia



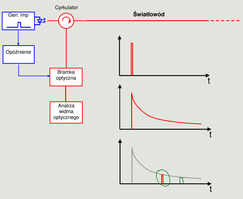


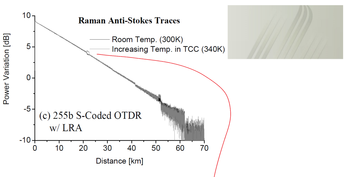
Światłowodowe rozproszone czujniki temperatury i naprężenia

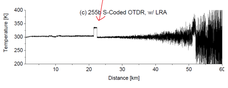


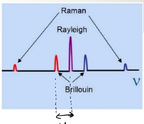
$$\frac{P_{RAMAN}}{P_{RAYLEIGH}} \propto \left[\exp\left(\frac{h\Delta\nu}{kT}\right)-1\right]^{-1}$$

Światłowodowe rozproszone czujniki temperatury i naprężenia – zasada lokalizacji





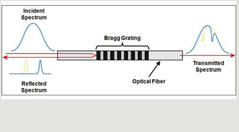


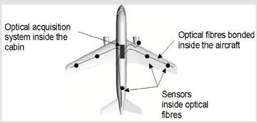


ν_B zależy od naprężenia ale też od temperatury...

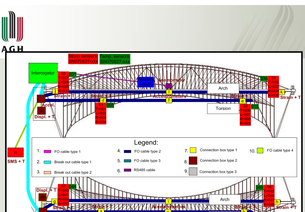
może drugi światłowód...

Czujniki z siatką Bragga
Fiber Bragg Grating Sensor





(Airbus)



Torsion
Torsion
Torsion