Phase shift gratings

SPIE Smart structure 9098-13

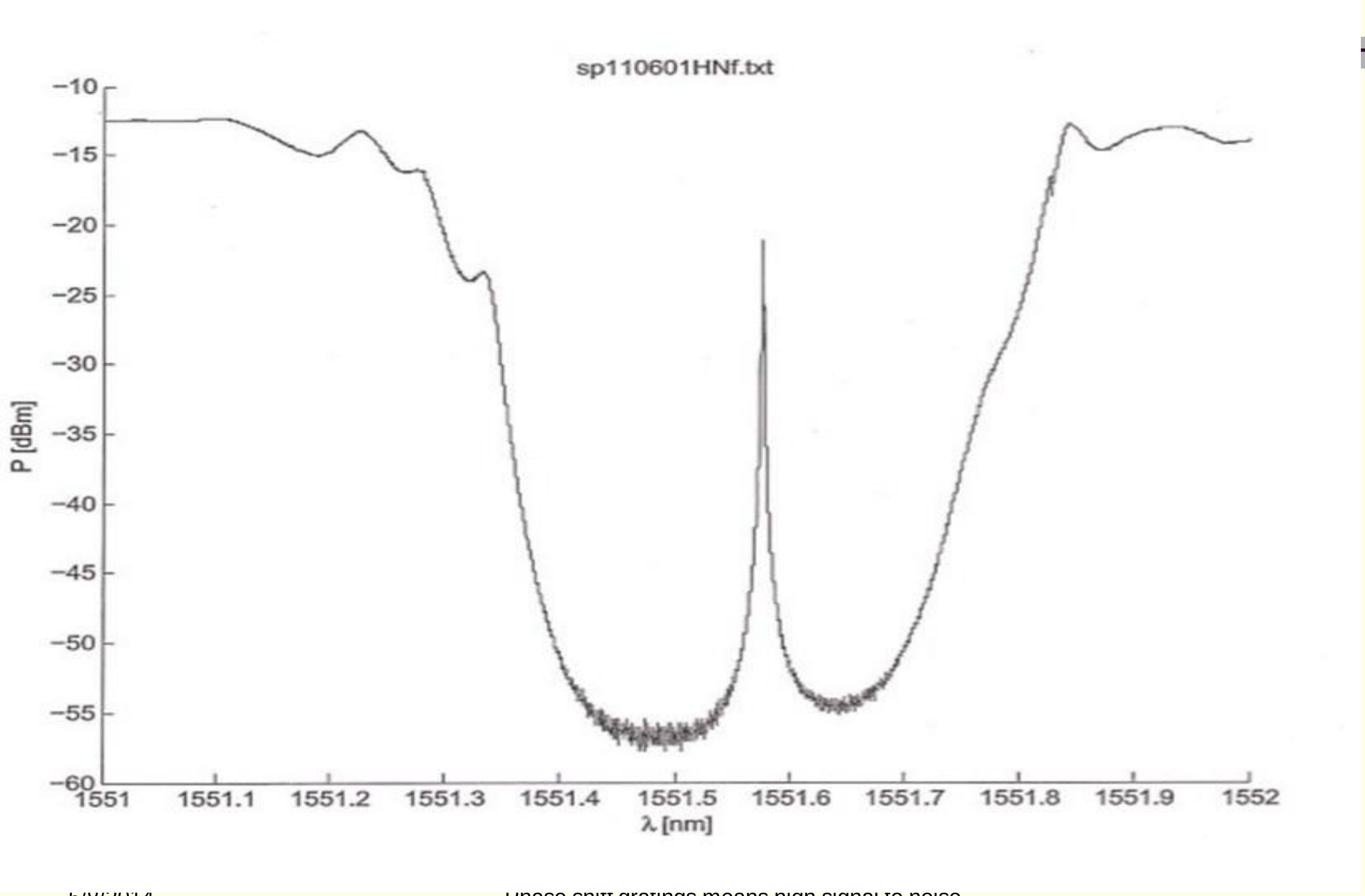
May 2014

By Peter Kung QPS

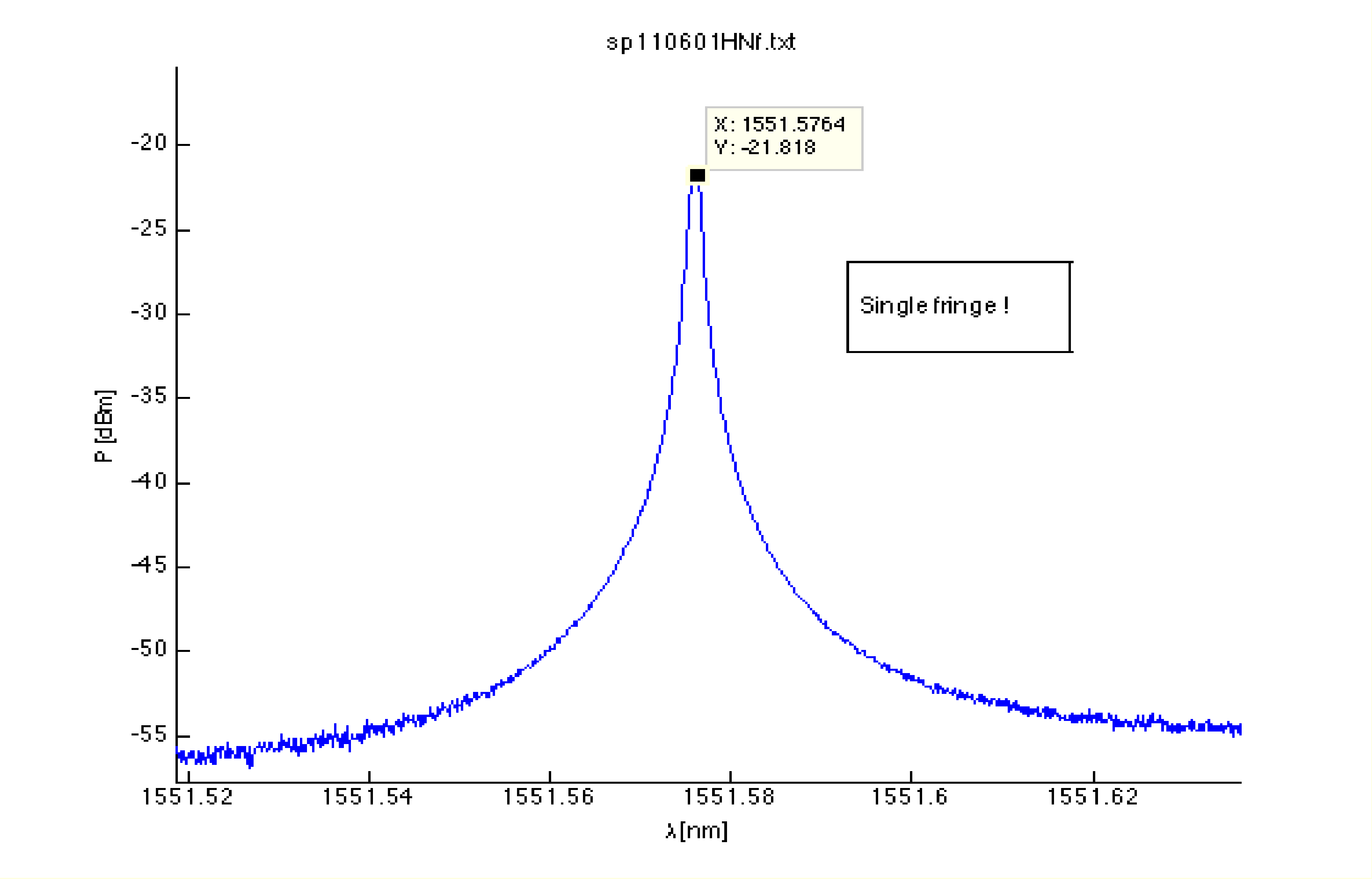
Agenda

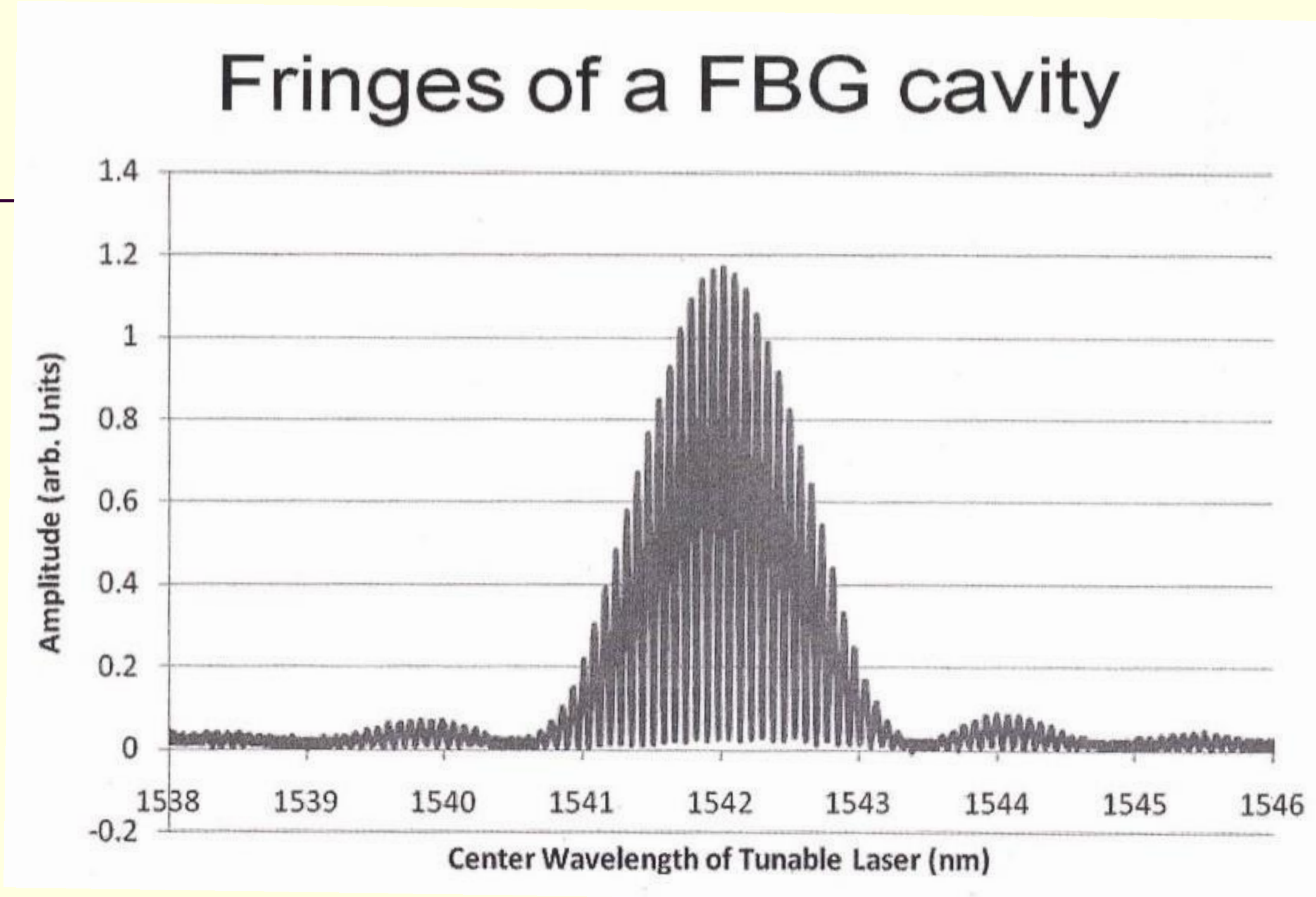
- Introduction to the Phase shift gratings
- Comparison with the cavity performance narrower bandwidth and higher precision
- The optical Lock-in Pound Drever Hall (PDH) receiver
- Typical system configurations

The Actual spectrum of a Phase Shift Grating with a single 1,2 picometer transmission notch

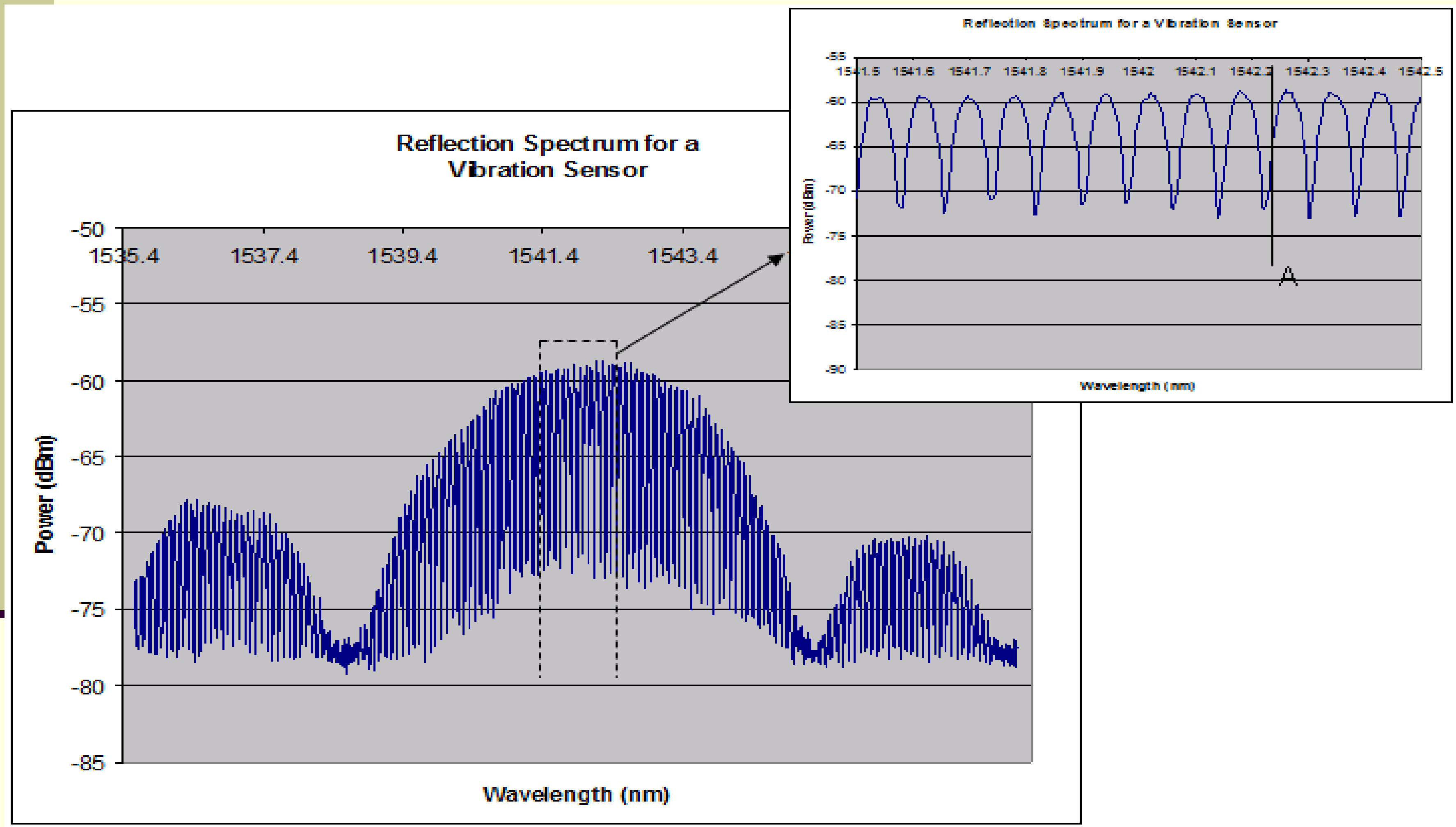


Detailed look at the narrow transmission Notch



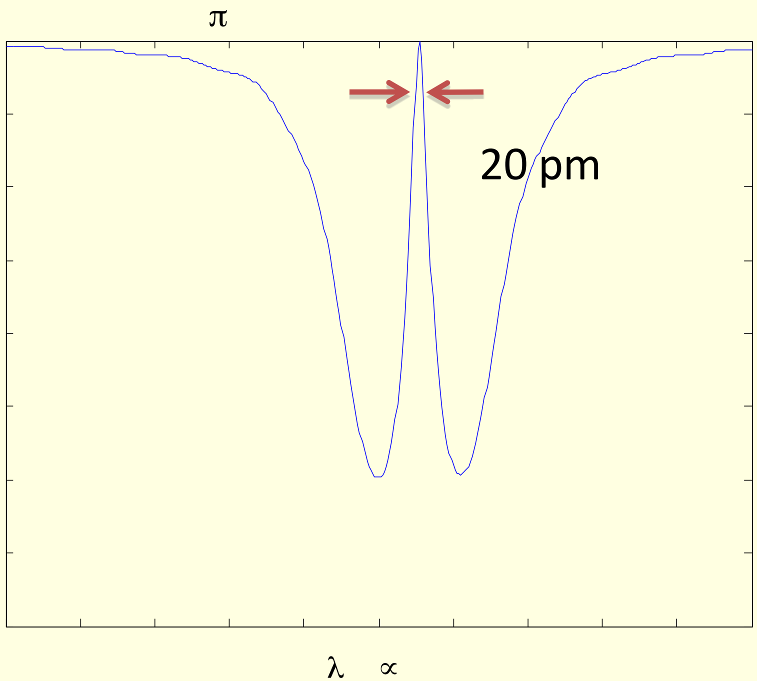

Fringes of a FBG cavity
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
Amplitude (arb. Units)
1538
1539
1540
1541
1542
1543
1544
1545
1546
Center Wavelength of Tunable Laser (nm)

It is used as a vibration sensor

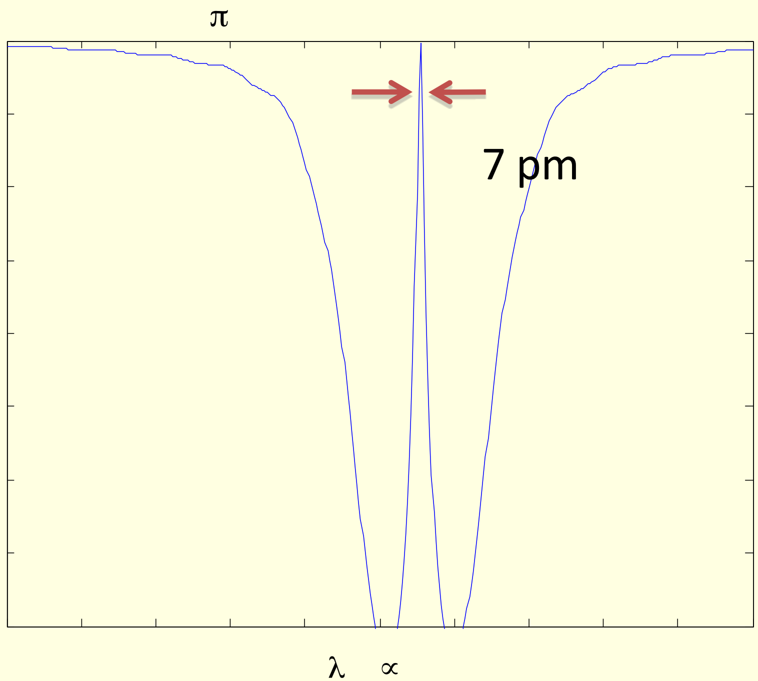


Numerical simulation of Pi-shifted phase grating

Linewidth of transmission band affected by grating strength.



Length = 8 mm



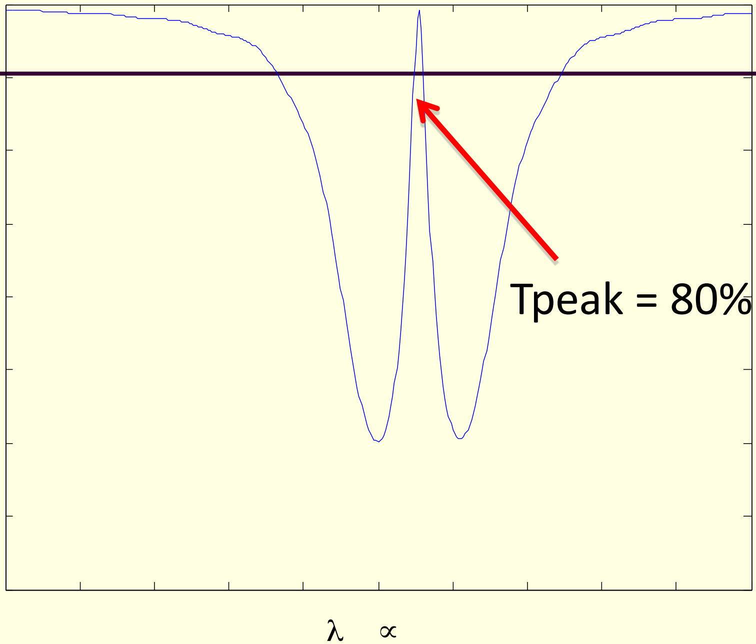
Length = 10 mm

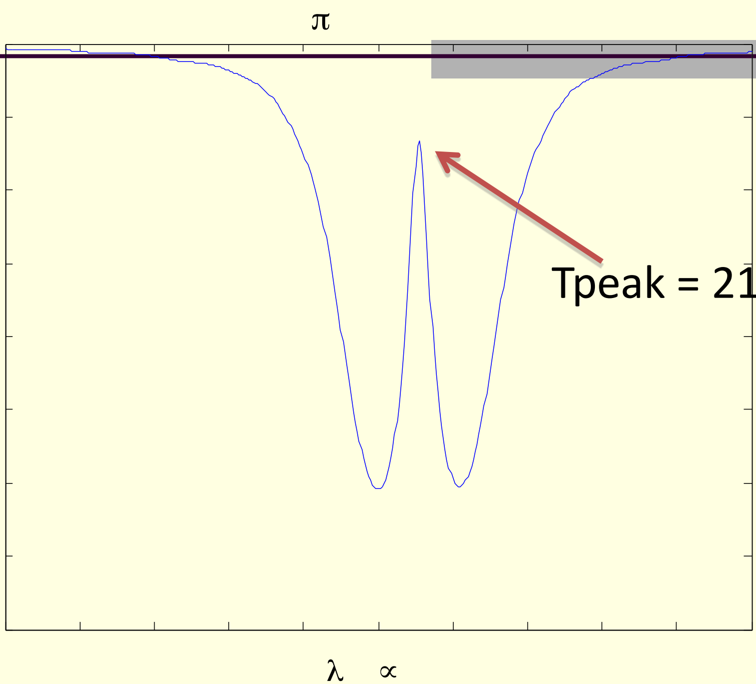
Simulation made using transfer matrix method

Parameter : Gaussian apodization (FWHM = 0.3*L), index modulation of 4e-4

Fiber loss and saturation effect not taken into account.

Position of the defect





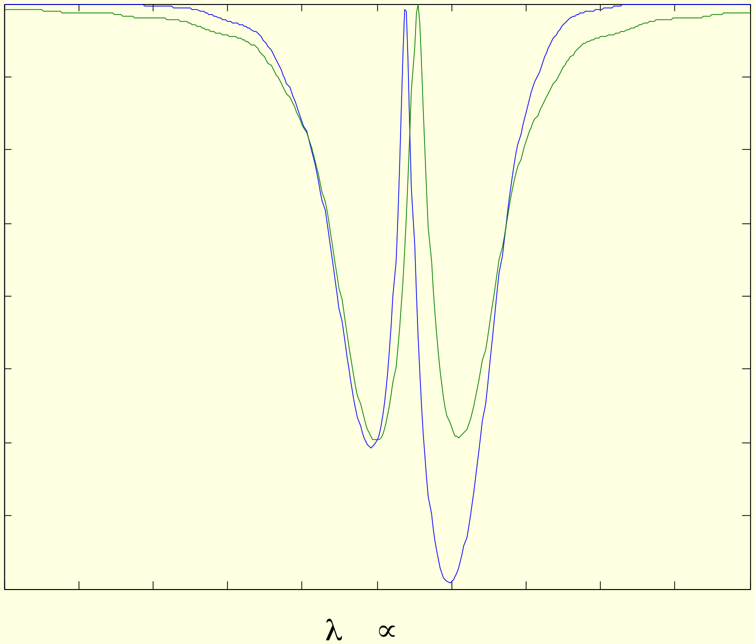
100 um off-center

500 um off-center

Better than 100 um accuracy is attainable with proper electronic control.
Transmission loss is expected to come mostly from cladding mode coupling not simulated here.

Pi-Shifted vs Phase-Shifted

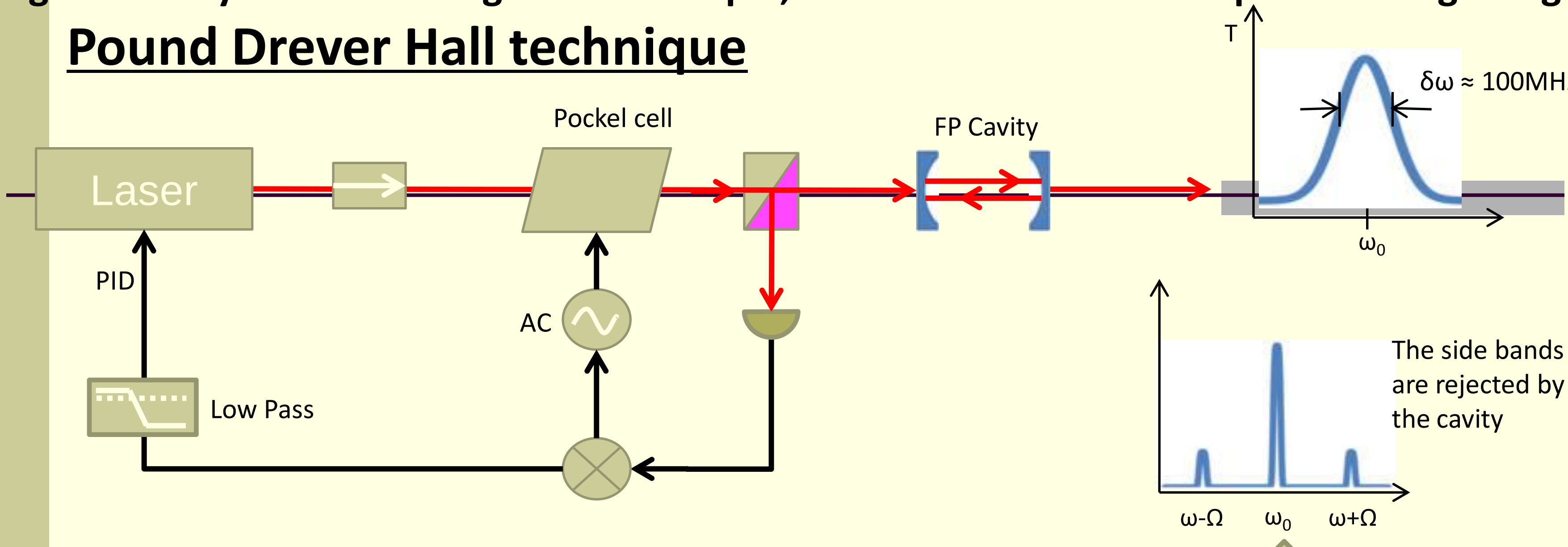
If no appropriate phase mask is available, phase shift can be obtained by applying a timed offset voltage on the dithering signal.



Green curve : Ideal Pi-shift defect
Blue curve: Phase shift with 1mm long center suppression.

Fig. 6 Theory of the interrogation technique, the lock- in element is a phase shift gratings

Pound Drever Hall technique

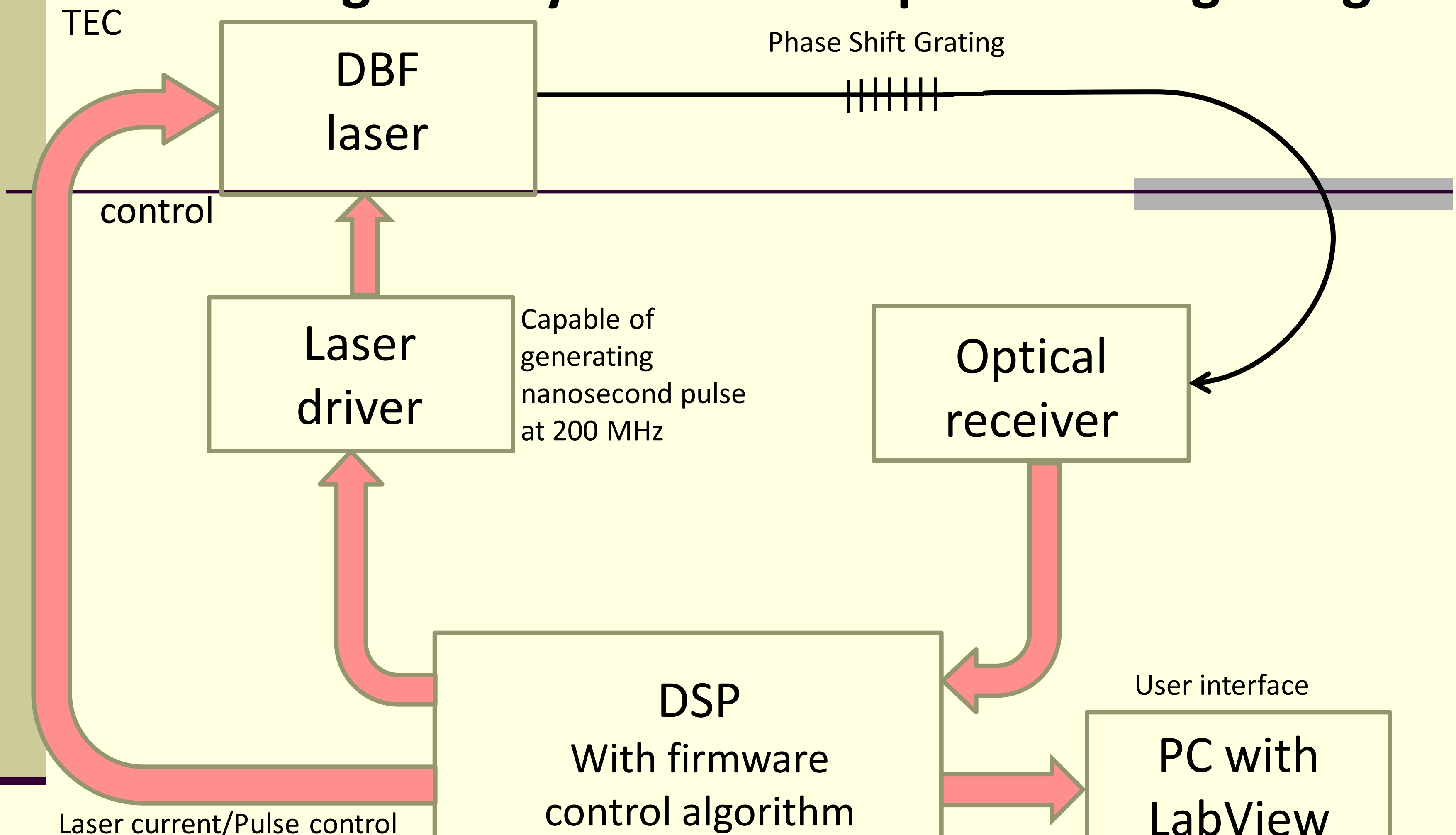


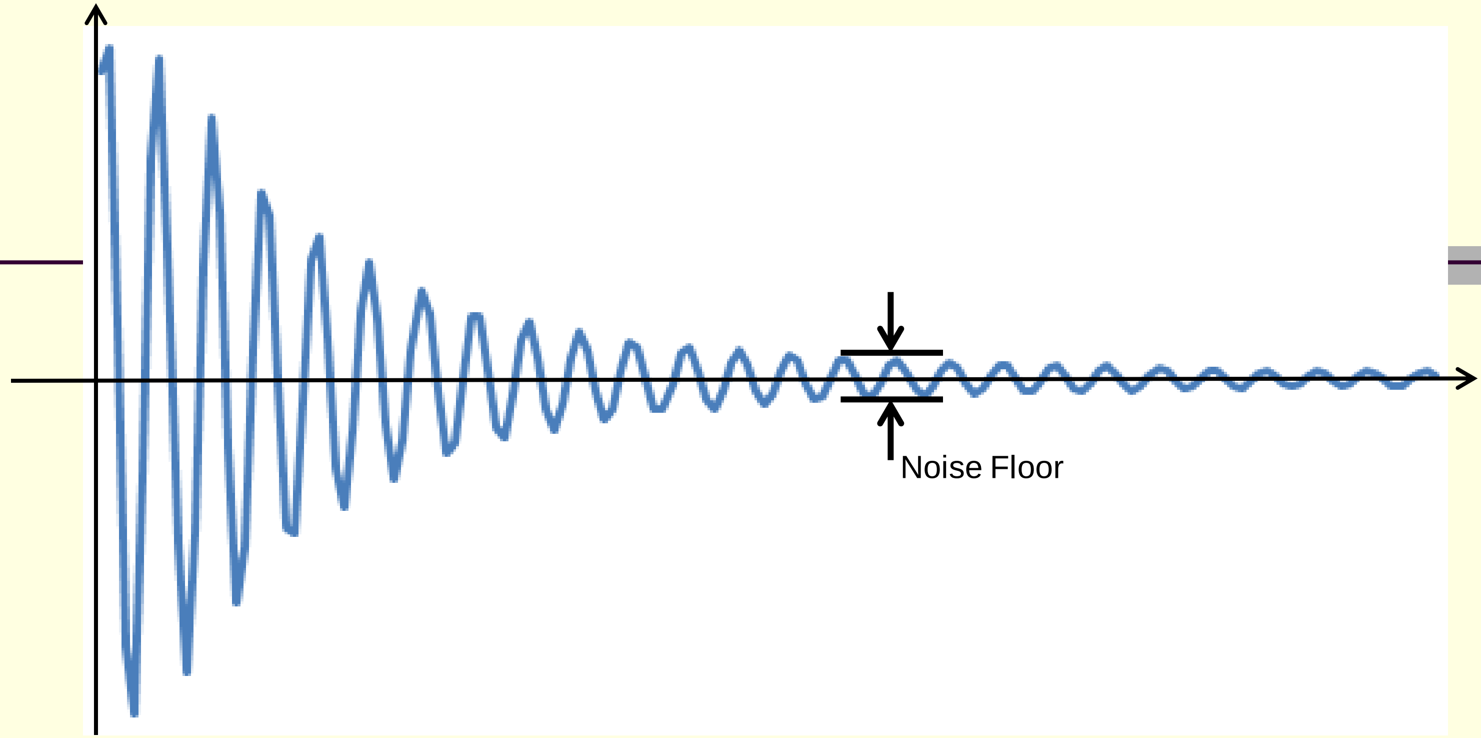
$$E(t) = E_0 e^{i\omega t + i\beta \sin(\Omega t)}$$
$$\approx E_0 \left[V_0 e^{i\omega t} + V_1 e^{i(\omega+\Omega)t} - V_1 e^{i(\omega-\Omega)t}\right]$$

- When the center frequency is perfectly tuned with the cavity ($\omega = \omega_0$), only the sideband return to the DET. The beat frequency at 2Ω is rejected by the electronics.
- When $\omega \neq \omega_0$, some fraction of $P(\omega)$ is reflected and beat with one of the sideband more than the others $R(\omega-\Omega) \neq R(\omega+\Omega)$. The resulting beat signal at frequency 2Ω is downconverted to a DC signal. The sign of this signal tell you on witch side of the transmission spectrum you are on. ($\omega>\omega_0$ or $\omega<\omega_0$)

- When the center frequency is perfectly tuned with the cavity ($\omega = \omega_0$), only the sideband return to the DET. The beat frequency at 2Ω is rejected by the electronics.
- When $\omega \neq \omega_0$, some fraction of $P(\omega)$ is reflected and beat with one of the sideband more than the others $R(\omega-\Omega) \neq R(\omega+\Omega)$. The resulting beat signal at frequency 2Ω is down-converted to a DC signal. The sign of this signal tell you on witch side of the transmission spectrum you are on. ($\omega>\omega_0$ or $\omega<\omega_0$)

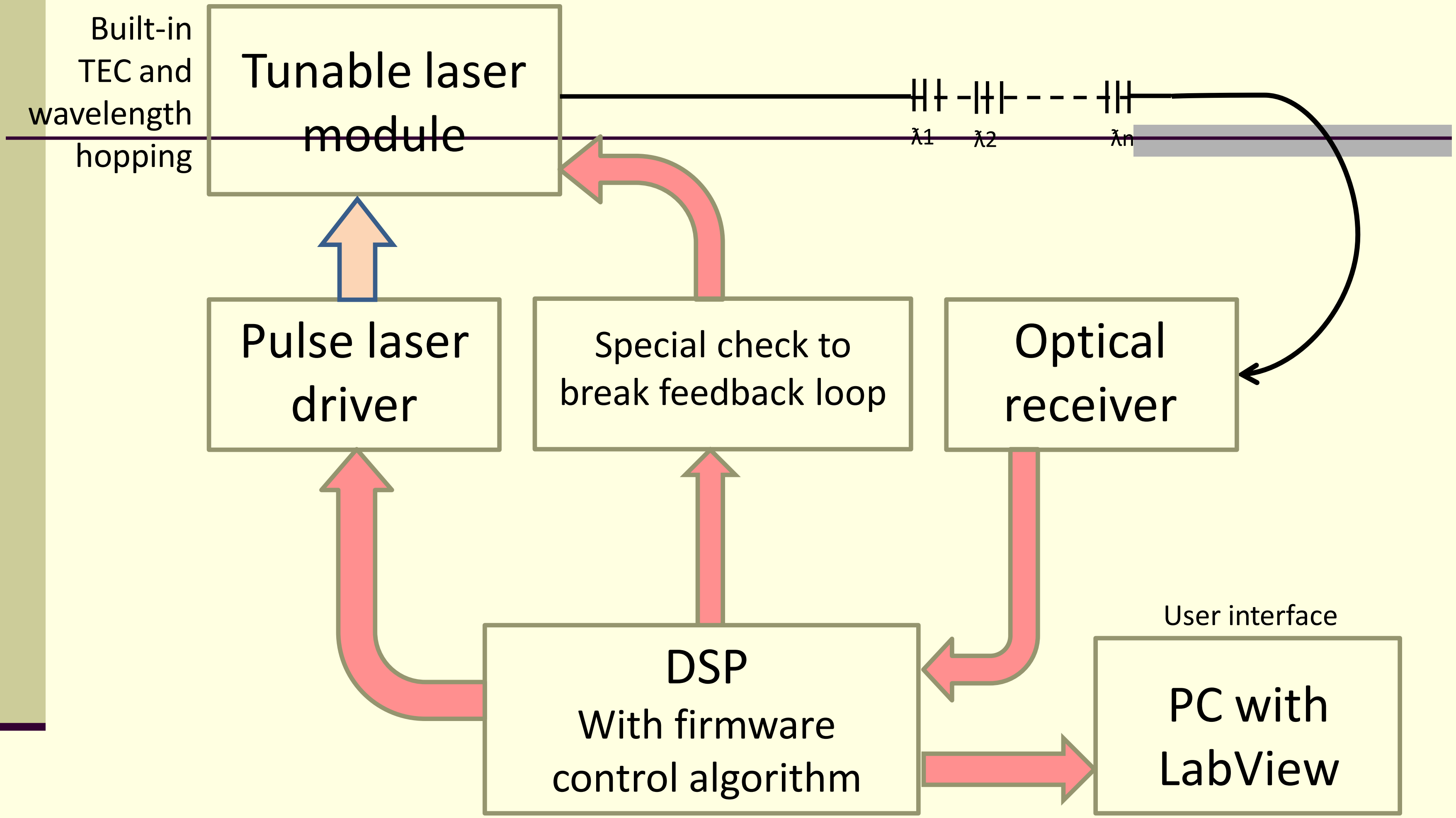
Interrogation system for the phase shift gratings





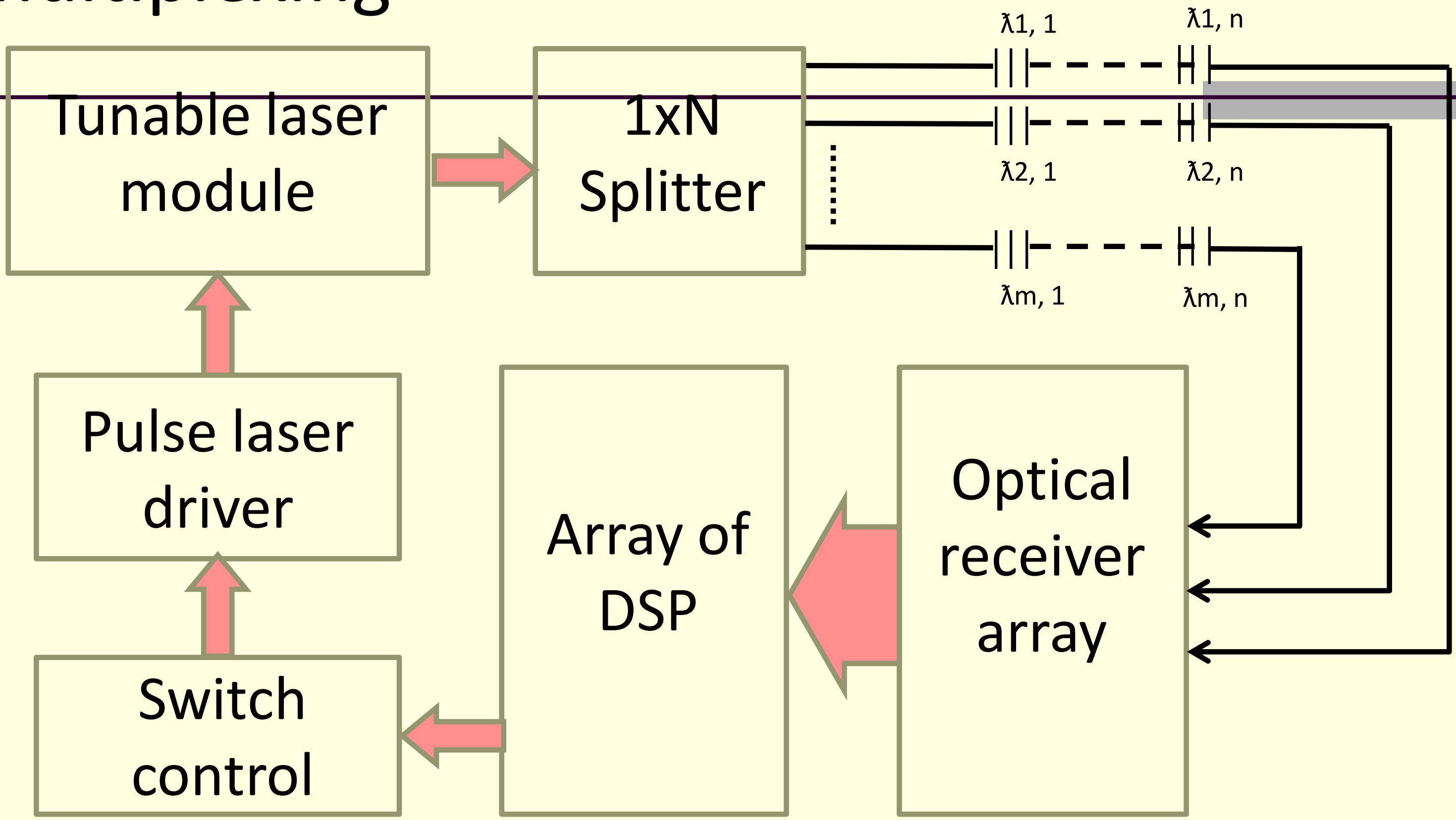
Acoustic emission signal from a PD events (frequency range from 30KHz to 300KHz).

System supporting an array of Phase Shift Gratings



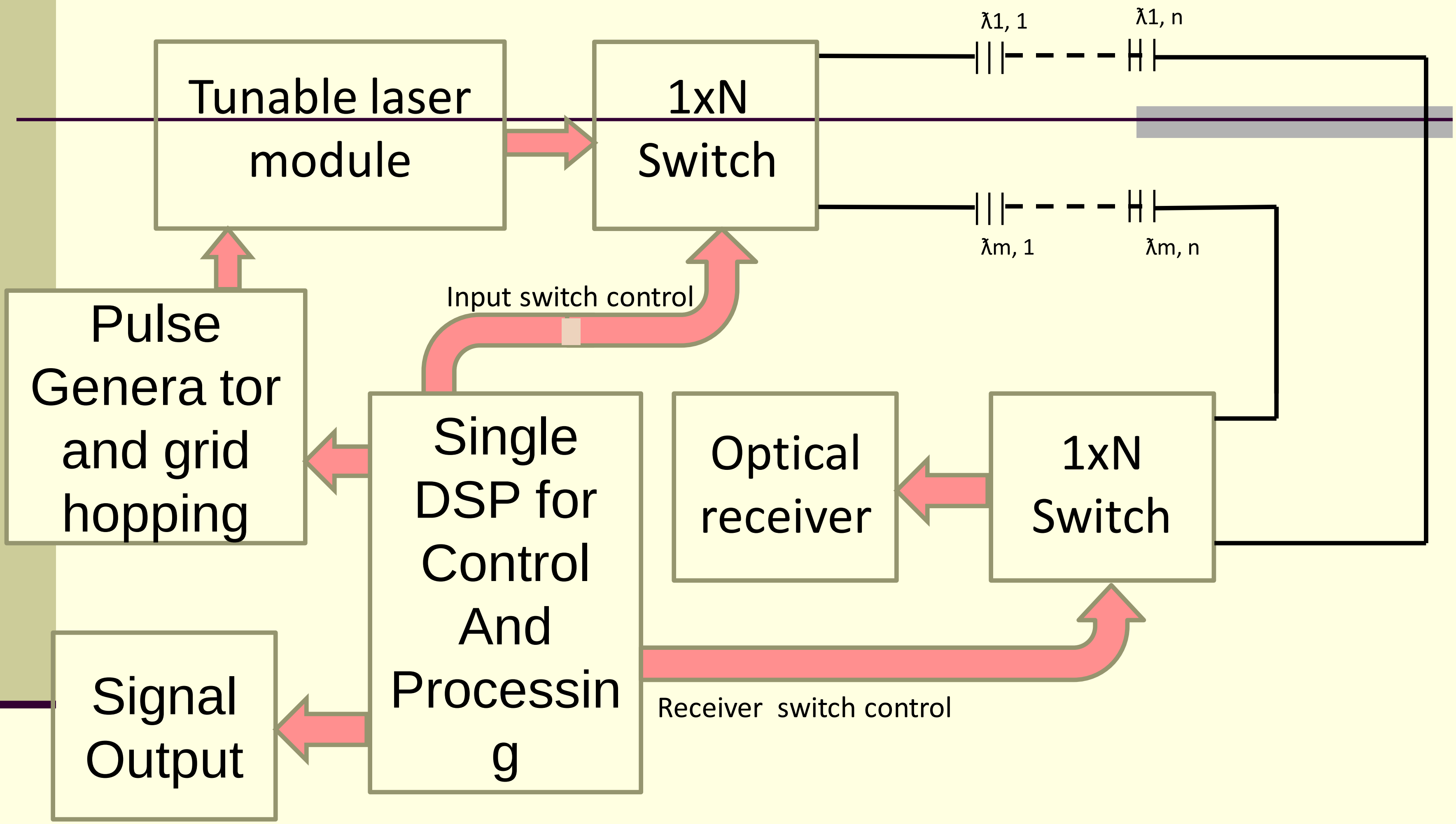
Useful to adapt the technology for detecting intrusion in long oil and gas pipelines and also Partial discharge inside the slots of the Stator of a power generator or locate the leaks in a large fuel tank, or how spots in the high voltage transmission lines

Multi channel Phase Shift Grating arrays by spatial multiplexing



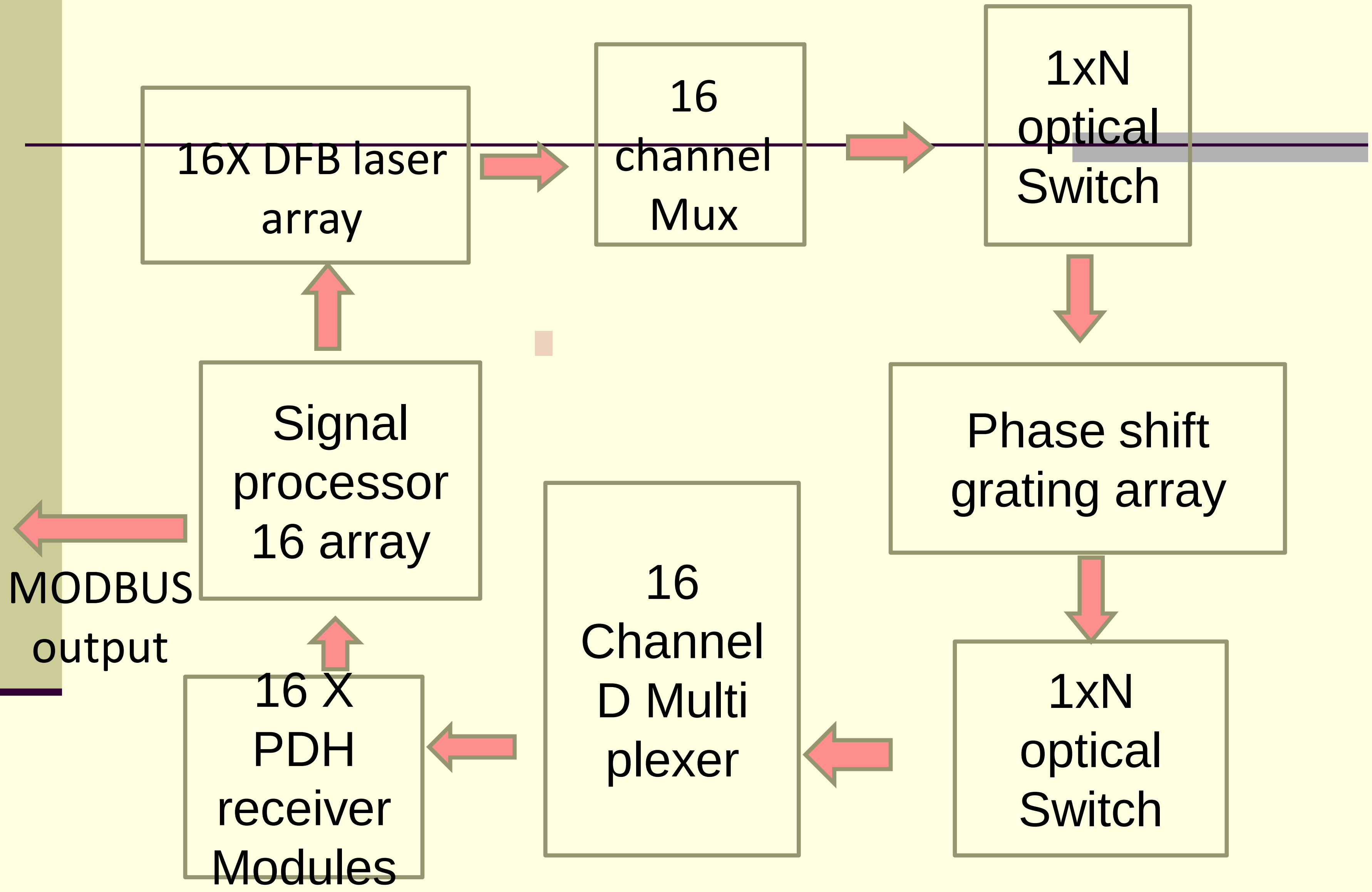
Provides a built in redundancy in the sensor network
adapt to pipelines that are structured like a Star
providing real time measurement on all branches

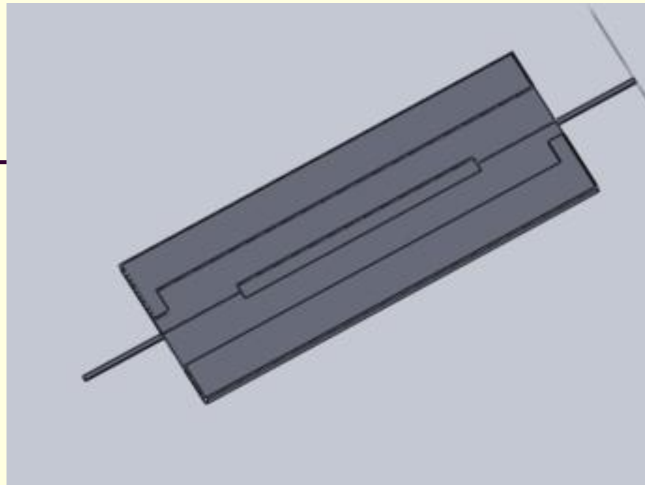
1 by N Multi-channels configuration

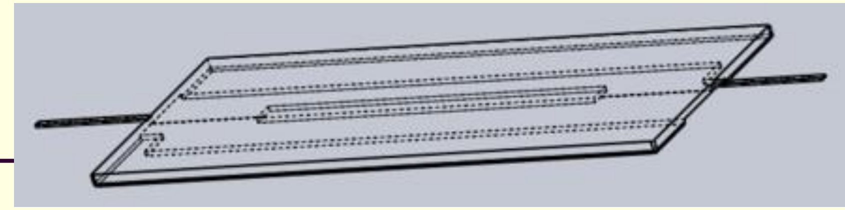


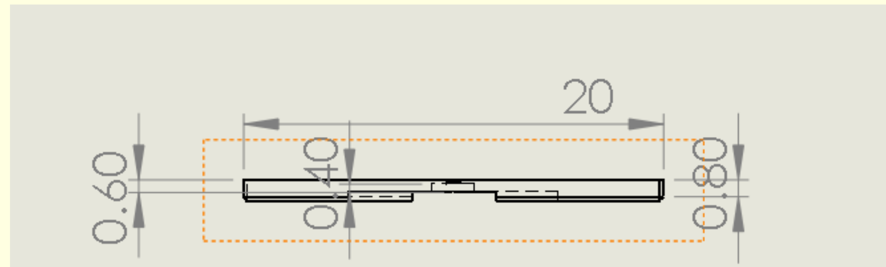
Optical switch will process one ray at a time

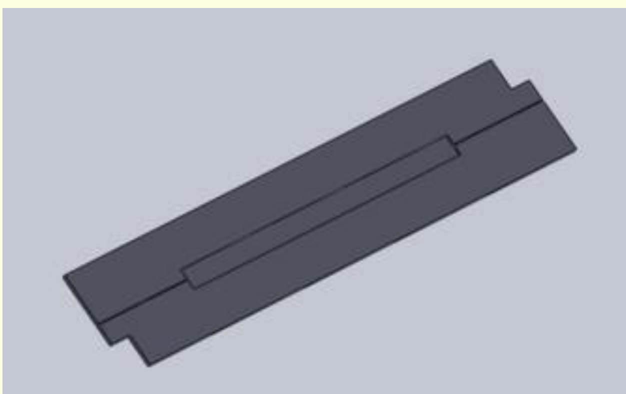
Real time signal detection in a Photonics Radar

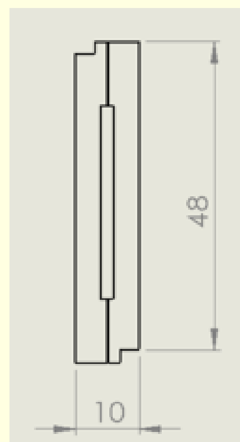


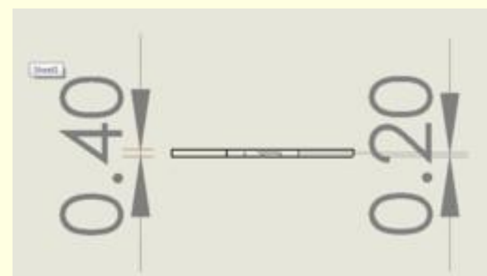




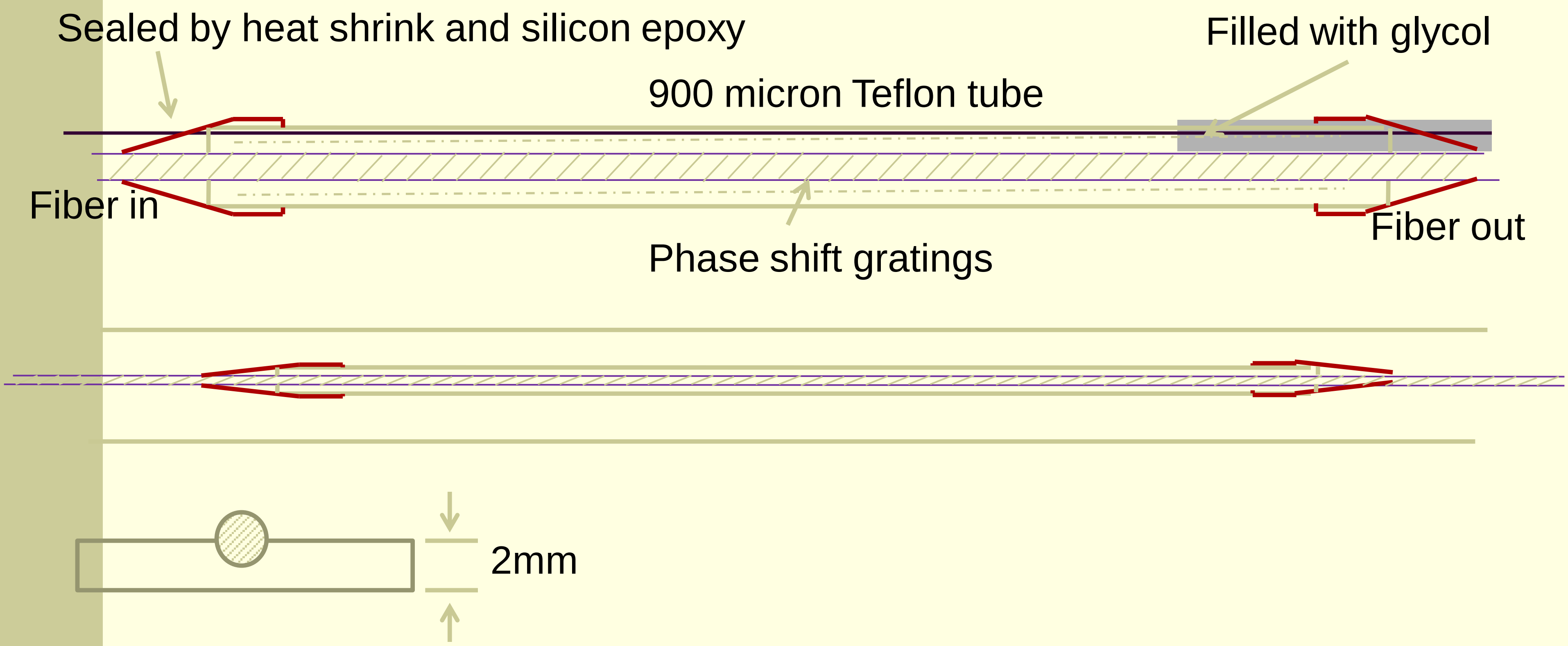




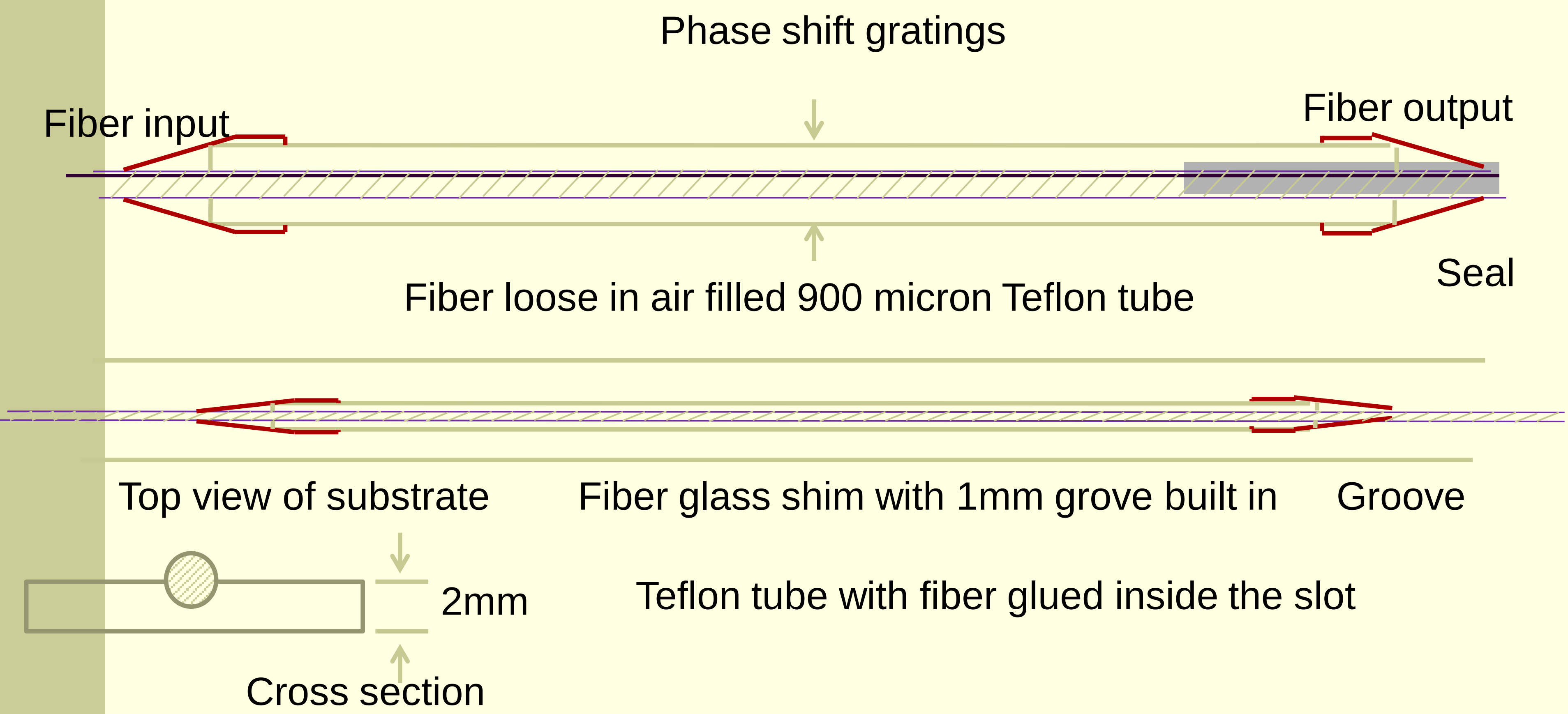




Sensor device packaged to fit inside the narrow slot inside the Stator structure



Sensor device embedded inside a narrow Teflon tube of 900 microns filled with propylene Glycol for measuring very small temperature change



Sensor device mounted inside the same narrow tube but only filled by air for sensing low frequency vibration

Thank you for your attention

Please contact Peter Kung for more discussion

- Telephone 1-514-697-4728
- Cell phone 1-514-578-6766
- Email peter@qpscom.com
- SKYPE: peter.kung.qps