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Three Phase Flow Assessment with the Fiber Optic Sensor

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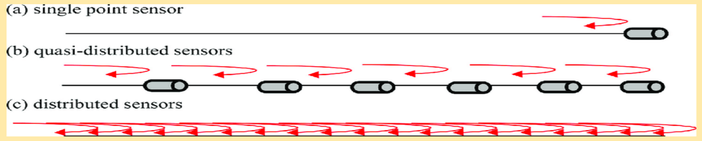
Introduction

Distributed Fiber Optic Cables (DFO)

- Sensors deployed on the FO cables
- Provides real-time and continuous measurements over the entire length of the FO cable.
- Inexpensive and accurate monitoring of multiphase flow.



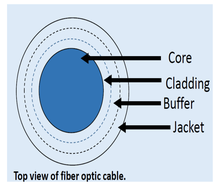
Source (Amanzadeh et al. 2018)

Applications
- Temperature, Pressure, Acoustic

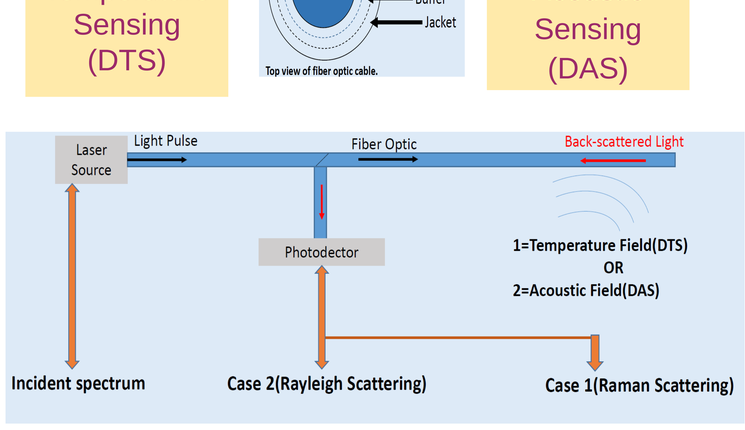
Optical Pulse released into the fiber. → Backscattered light of two-way travel time is measured. → Analyzed by interrogator:
- Temp. & strain
- Acoustic signal

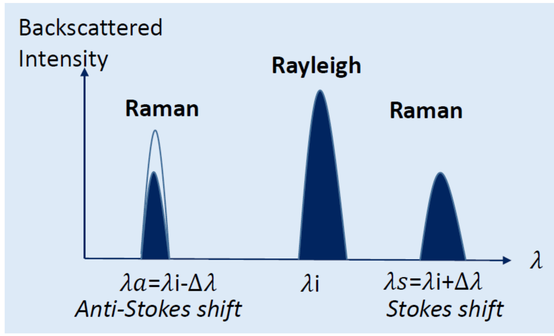
Working of Distributed Fiber Optic Cables

Working of Distributed Temperature Sensing (DTS)



Working of Distributed Acoustic Sensing (DAS)



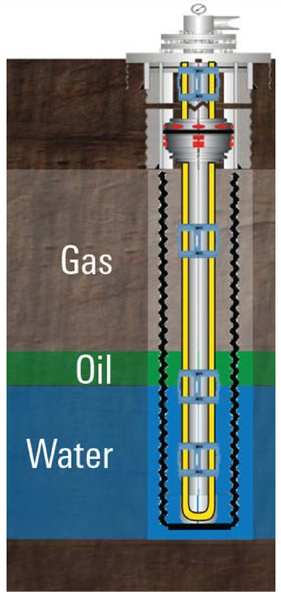


Working of the DTS using the laser pulses also depicting the backscattered light

Working of Distributed Acoustic

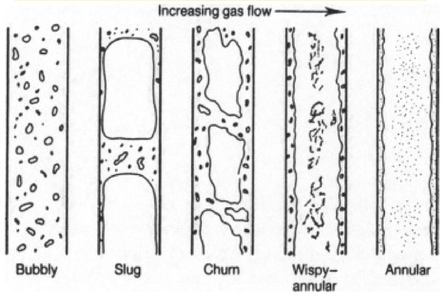
- Rayleigh scattering:
- Scattered photons have the same energy (wavelength, color, and frequency) of the incident photons.
- The scattered photons have different direction (phase) and intensity.

Problem statement



Wellbore representing the wellbore fluids within the casing (from: Case Study, Schlumberger)

- Identification of flow regime inside the wellbore
- Distributed Temperature Sensing (DTS) Distributed Acoustic Sensing (DAS) for wellbore monitoring.



Flow regimes in vertical pipeline(from: Natural Gas Processing 2014)

Distributed Fiber Optic Sensing

Raman scattering	**Amplitude (anti-Stokes)**	**Temperature (distributed temperature sensing, DTS)**
Brillouin scattering	**Frequency, amplitude**	**Temperature, strain**
Rayleigh scattering	**Amplitude, phase shift**	**Acoustic (distributed acoustic sensing, DAS)**

Working of Distributed Temperature Sensing

- Raman scattering.
- Scattered photons have the lower energy (wavelength, color, and frequency) of the incident photons.
- A molecule gained vibrational energy from an incident photon of a visible laser and shifted to lower energy.
- The shift in energy gives information about the vibrational modes in the system and thereby the exact temperature change.
- Temperature is obtained from the ratio of intensities of stokes to aniti-stokes.

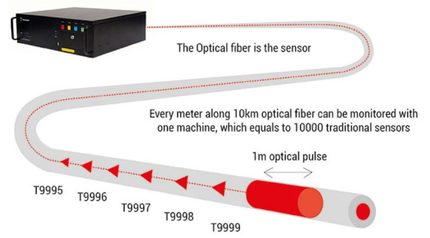


Figure 3: DAS with the optical fiber (taken from: Bandweaver)

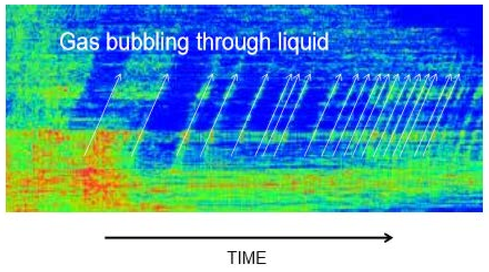


Figure 4: Slugging Condition (from: Hveding, Frode, 2014).

Conclusion

- Temperature and acoustic sensing of different flow regimes solid/liquid and gas/liquid
- Characterization of flow, i.e. bubbly, slug, stratified or annular flow in the wellbore.
- DTS resolution of 0.01°F and DAS sampling rate of 10KHz
- Maximum operating conditions are up to 300°F and 20,000 psia.
- The system works for pH 7.1, chlorine concentration of 150ppm, steam quality of up to 80%, specific gravity of 38°API, fluid viscosity of 300 cP, and up to 1280 ft well.
- Need more experimental and field data for developing the technology.
- Oil and gas field can be digitally upgraded using DTS and DAS.

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