



SPE-209262-MS

Detection of 2.187 gallon pipeline leakage by optical sensor based on coherent interaction of pulse and depleted pump technology

Lufan Zou and Omur Sezerman

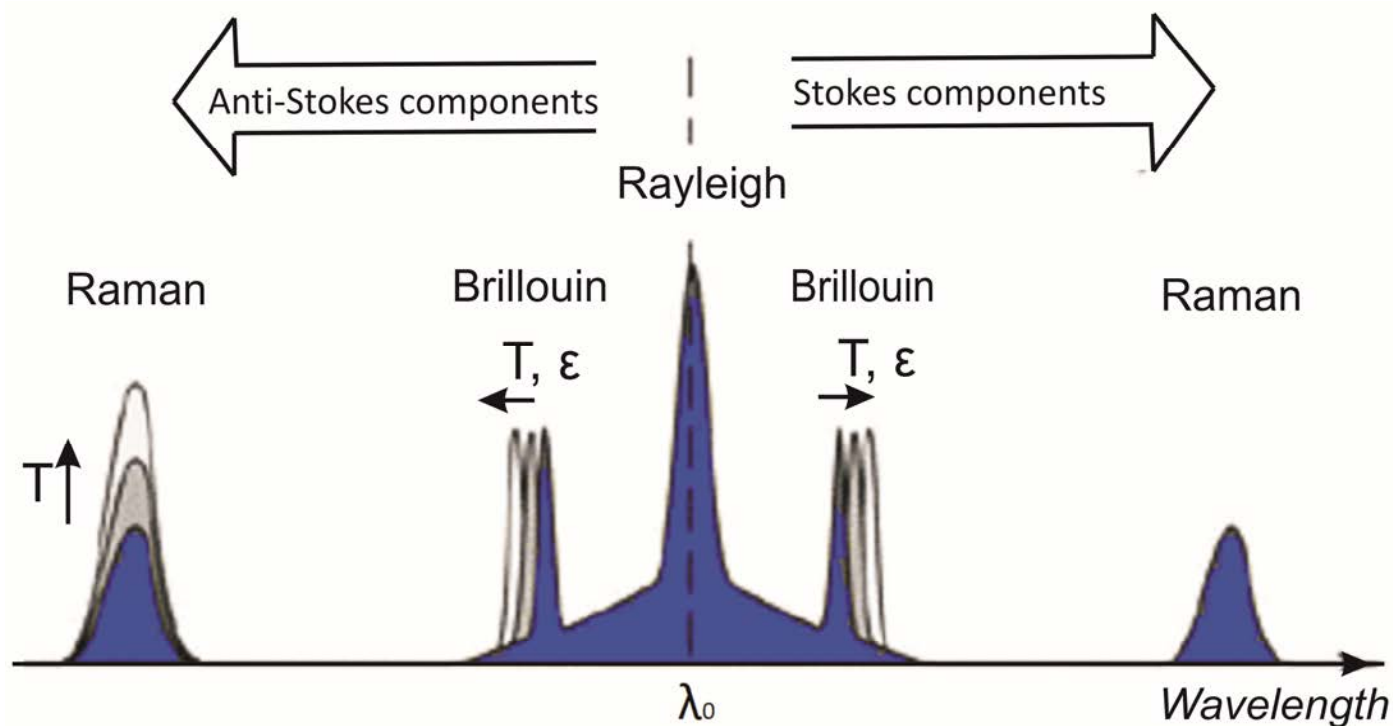
*OZ Optics Ltd., 219 Westbrook Road
Ottawa, ON, Canada K0A 1L0*

Lufan Zou: [SPE-209262-MS](#) Detection of 2.187 gallon pipeline leakage by optical sensor based on coherent interaction of pulse and depleted pump technology

Outline

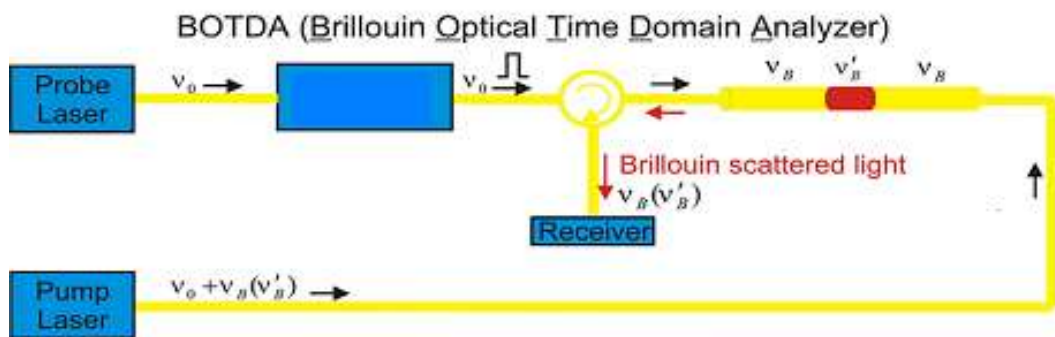
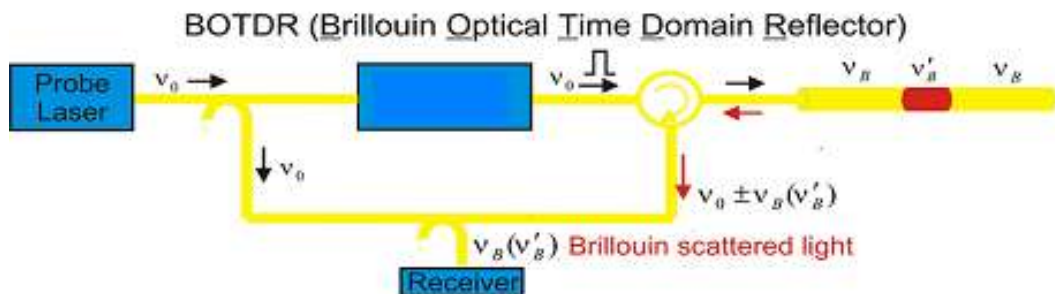
- Light scattering
- Distributed strain and temperature sensor (DSTS) based on coherent interaction of pulse and depleted pump (CIPDP) technology
- Pipeline leak detection by BOTDA based on CIPDP technology — joint project with SwRI sponsored by major oil companies
- Conclusion

Light scattering



Lufan Zou: [SPE-209262-MS](#) Detection of 2.187 gallon pipeline leakage by optical sensor based on coherent interaction of pulse and depleted pump technology

DSTS based on CIPDP technology



Laser beams beat frequency ν , Brillouin frequency of fiber ν_B .

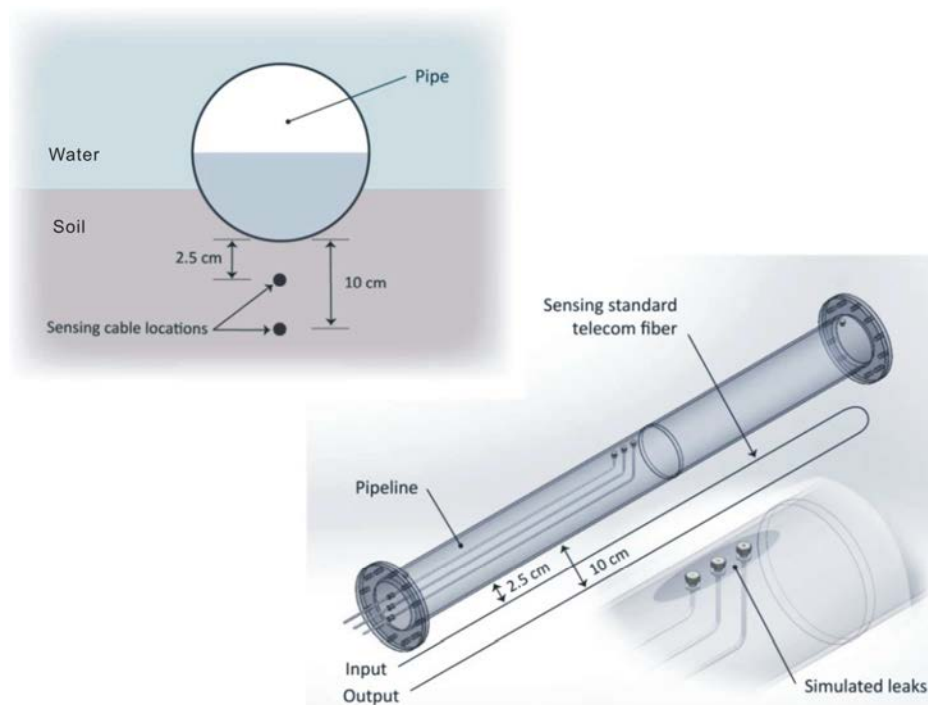
BOTDR: Spontaneous Brillouin scattering
BOTDA: Stimulated Brillouin scattering



Lufan Zou: [SPE-209262-MS](#) Detection of 2.187 gallon pipeline leakage by optical sensor based on coherent interaction of pulse and depleted pump technology

Pipeline leak detection by BOTDA based on CIPDP technology

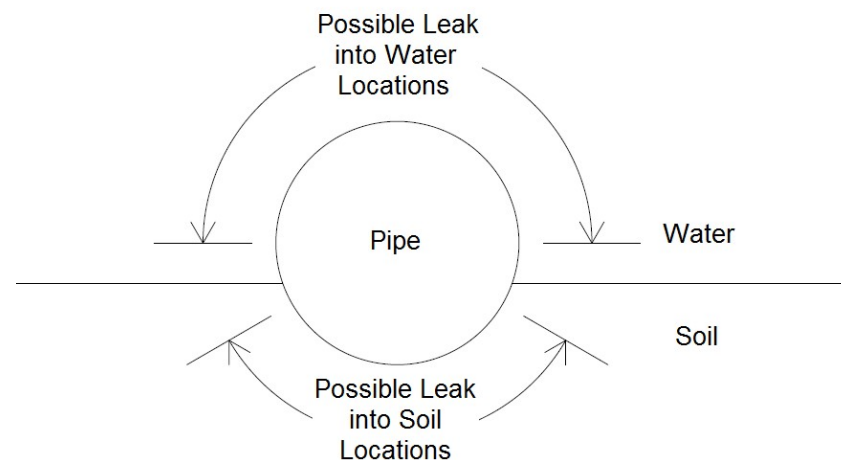
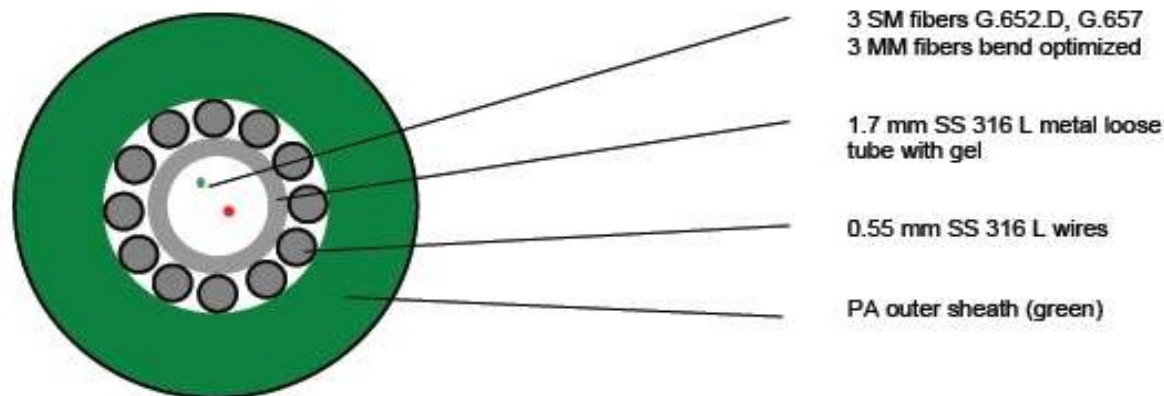
— joint project with SwRI sponsored by major oil companies



Lufan Zou: [SPE-209262-MS](#) Detection of 2.187 gallon pipeline leakage by optical sensor based on coherent interaction of pulse and depleted pump technology

Pipeline leak detection by BOTDA based on CIPDP technology

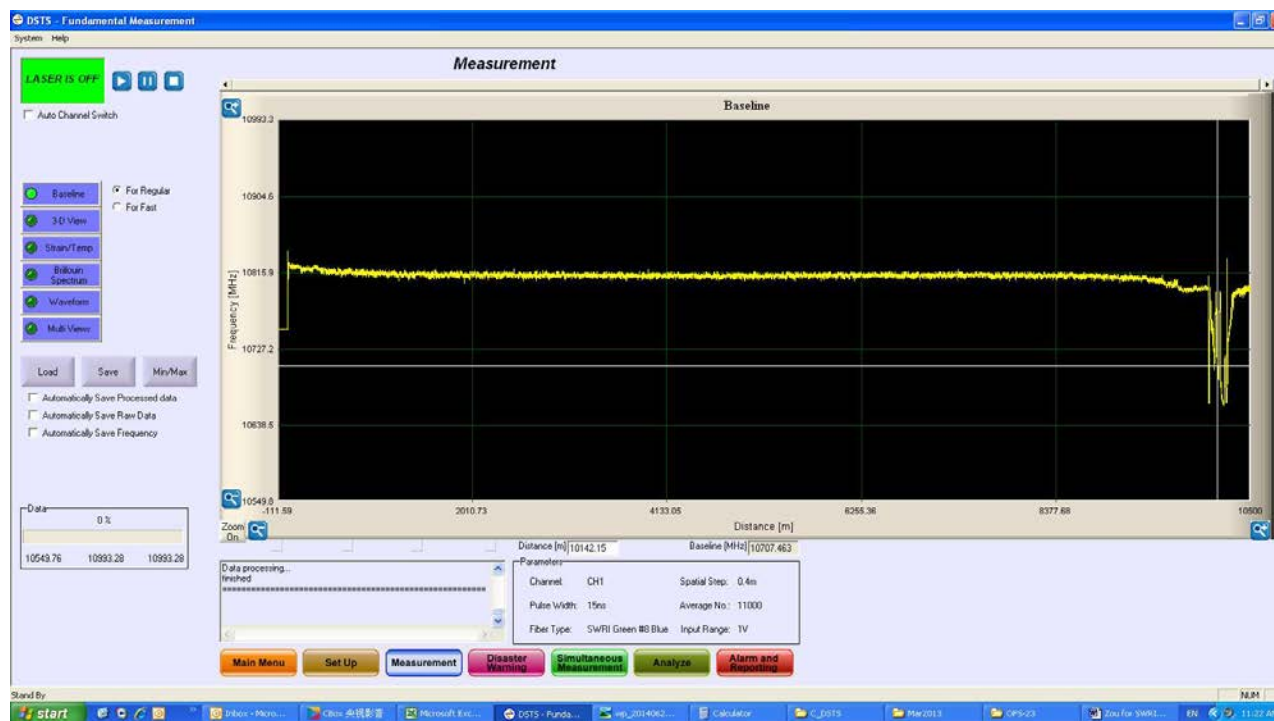
— joint project with SwRI sponsored by major oil companies



Lufan Zou: [SPE-209262-MS](#) Detection of 2.187 gallon pipeline leakage by optical sensor based on coherent interaction of pulse and depleted pump technology

Pipeline leak detection by BOTDA based on CIPDP technology

— joint project with SwRI sponsored by major oil companies



Brillouin frequencies along 10.245 km as the baseline taken at 11:02 on June 2nd.

Lufan Zou: [SPE-209262-MS](#) Detection of 2.187 gallon pipeline leakage by optical sensor based on coherent interaction of pulse and depleted pump technology

Pipeline leak detection by BOTDA based on CIPDP technology

— joint project with SwRI sponsored by major oil companies

Principle of Brillouin sensors for temperature detection:

$$v_B = v_{B0} + C_T(T - T_0) + C_\varepsilon(\varepsilon - \varepsilon_0)$$

Data sheet resolution:

- Beat frequency uncertainty
- Ours: 5kHz \Rightarrow Strain/Temperature resolution: $0.1\mu\varepsilon/0.005^\circ\text{C}$
- Others: 100 kHz \Rightarrow Strain/Temperature resolution: $2\mu\varepsilon/0.1^\circ\text{C}$

Lufan Zou: [SPE-209262-MS](#) Detection of 2.187 gallon pipeline leakage by optical sensor based on coherent interaction of pulse and depleted pump technology

Pipeline leak detection by BOTDA based on CIPDP technology

— joint project with SwRI sponsored by major oil companies

No leaks:



Lufan Zou: [SPE-209262-MS](#) Detection of 2.187 gallon pipeline leakage by optical sensor based on coherent interaction of pulse and depleted pump technology

Pipeline leak detection by BOTDA based on CIPDP technology

— joint project with SwRI sponsored by major oil companies



Below 6 o'clock 2.5cm (10118.06m) and 10cm (10166.65m) 105 psi injection pressure, 39°F (21.6°C), temperature difference, 1/8" orifice, Leak volume of **2.187gal** has been detected in 1min after a leak happened, shown as the red peak (**1.95°C**) at 10118.06m, blue-5min and green-9min

Lufan Zou: [SPE-209262-MS](#) Detection of 2.187 gallon pipeline leakage by optical sensor based on coherent interaction of pulse and depleted pump technology

Pipeline leak detection by BOTDA based on CIPDP technology

— joint project with SwRI sponsored by major oil companies

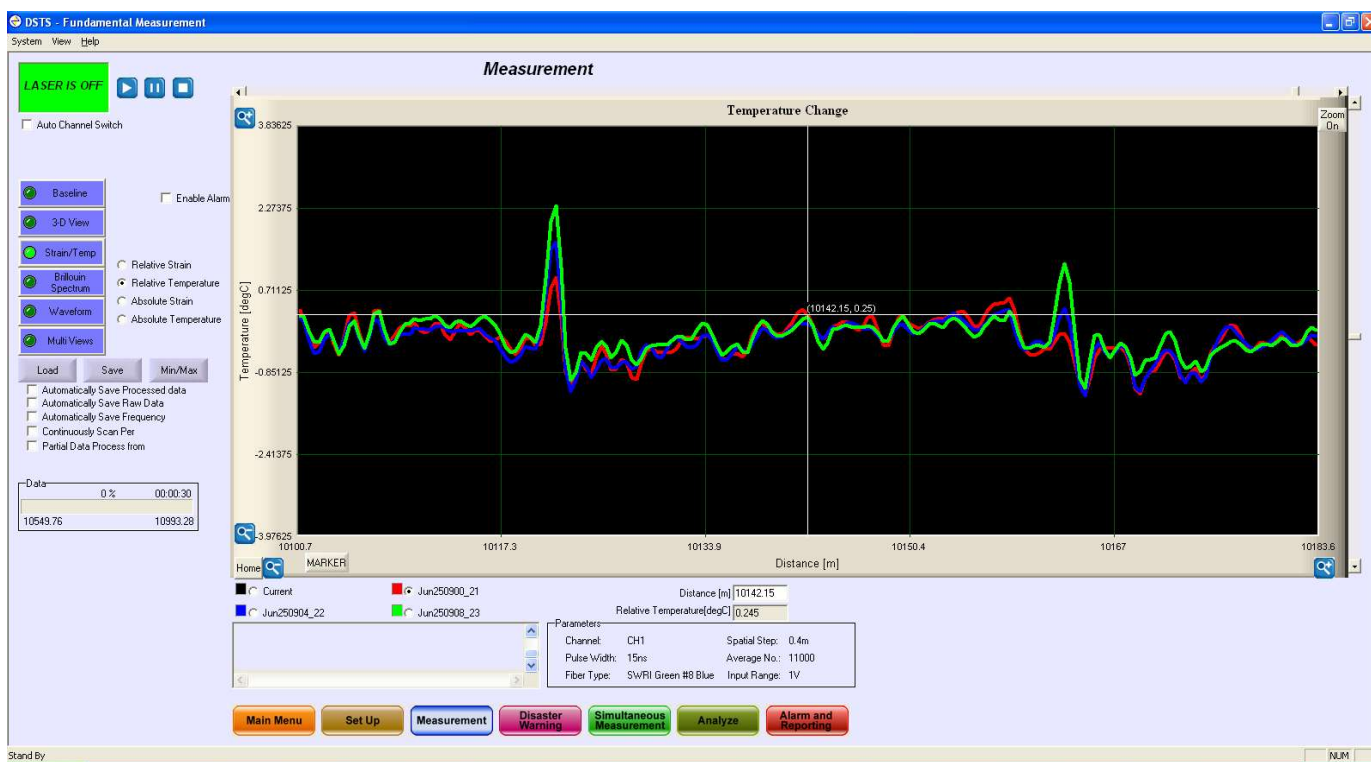
In 1min, 5min, and 9min after the leak occurred under 50psi injection pressure and 21°F (11.7°C) temperature difference, the DSTS detects the leaks at 10118.06 m by temperature changes of 0.80°C (red), 1.96°C (blue), and 2.33°C (green), from 1/8" orifice respectively.



Lufan Zou: [SPE-209262-MS](#) Detection of 2.187 gallon pipeline leakage by optical sensor based on coherent interaction of pulse and depleted pump technology

Pipeline leak detection by BOTDA based on CIPDP technology

— joint project with SwRI sponsored by major oil companies



Injection pressure 22 psi, temperature difference 20°F (11.1°C), 1/8" orifice, in 5min after the leak occurred, a red peak of 0.96°C at 10118.06m shows the detected leak of 6.72gal leakage volume, and blue-9min-12.10gal and green-13min-17.47gal.

Lufan Zou: [SPE-209262-MS](#) Detection of 2.187 gallon pipeline leakage by optical sensor based on coherent interaction of pulse and depleted pump technology



Pipeline leak detection by BOTDA based on CIPDP technology

— joint project with SwRI sponsored by major oil companies

Date	Start Time	Stop Time	Duration (min)	Orifice	Soil Temp Before Test (F)	Injection Pressure (psi)	Line Temp (F)	Temp Delta (F)
3-Jun	10:26 AM	10:35 AM	09:00.0	1/16"	70	250	95	25.0
4-Jun	11:15 AM	11:25 AM	10:00.0	1/32"	70.5	440	91	20.5
4-Jun	11:37 AM	11:44 PM	07:00.0	1/16"	70.5	385	91	20.5
5-Jun	11:46 AM	11:54 AM	08:00.0	1/8"	85	400	115	30.0
5-Jun	4:12 PM	4:21 PM	09:00.0	1/8"	78	250	119	41.0
6-Jun	1:57 PM	2:10 PM	13:00.0	1/8"	73	105	112	39.0
9-Jun	2:39 PM	2:58 PM	19:00.0	1/8"	70.7	50	113	42.3
10-Jun	2:48 PM	2:58 PM	10:00.0	1/8"	71.5	30	148	76.5
12-Jun	9:06 AM	9:18 AM	12:00.0	1/8"	71	30	105	34.0
12-Jun	10:36 AM	10:49 PM	13:00.0	1/8"	77.5	36	96	18.5
12-Jun	2:40 PM	2:58 PM	18:00.0	1/8"	74	50	95	21.0
13-Jun	10:40 AM	10:50 AM	10:00.0	1/8"	71	38	87	16.0
13-Jun	11:54 AM	12:05 PM	11:00.0	1/8"	73	50	90	17.0
16-Jun	10:26 AM	10:42 AM	16:00.0	1/8"	71	34	87	16.0
16-Jun	11:50 AM	12:09 PM	19:00.0	1/8"	77.5	30	96	18.5
16-Jun	4:16 PM	4:31 PM	15:00.0	1/8"	75	30	103	28.0
17-Jun	10:47 AM	10:56 AM	09:00.0	1/8"	72	150	170	98.0
17-Jun	11:23 AM	11:33 AM	10:00.0	1/8"	72	82	160	88.0
17-Jun	2:38 PM	2:53 PM	15:00.0	1/16"	73	750	150	77.0
23-Jun	10:38 AM	10:48 AM	10:00.0	1/8"	72	52	99	27.0
23-Jun	11:15 AM	11:28 AM	13:00.0	1/8"	72	51	100	28.0
23-Jun	1:54 PM	2:06 PM	12:00.0	1/8"	74	50	101	27.0
23-Jun	2:13 PM	2:25 PM	12:00.0	1/8"	75.5	50	106	30.5
23-Jun	3:23 PM	3:33 PM	10:00.0	1/8"	80	50	105	25.0
23-Jun	3:52 PM	4:05 PM	13:00.0	1/8"	81	51	108	27.0
24-Jun	8:06 AM	8:16 AM	10:00.0	1/8"	73	50	95	22.0
24-Jun	8:22 AM	8:32 AM	10:00.0	1/8"	72	52	94	22.0
24-Jun	9:21 AM	9:33 AM	12:00.0	1/8"	80	40	101	21.0
24-Jun	9:59 AM	10:11 AM	12:00.0	1/8"	79	40	103	24.0
24-Jun	11:37 AM	11:57 AM	20:00.0	1/8"	84	32	105	21.0
24-Jun	1:47 PM	2:08 PM	21:00.0	1/8"	76	31	109	33.0
24-Jun	3:12 PM	3:32 PM	20:00.0	1/8"	88	32	110	22.0
25-Jun	8:55 AM	9:10 AM	15:00.0	1/8"	74	22	94	20.0
25-Jun	10:58 AM	11:15 AM	17:00.0	1/8"	74	40	104	30.0
25-Jun	11:43 AM	11:53 AM	10:00.0	1/8"	76	41	108	32.0
25-Jun	1:31 PM	1:46 PM	15:00.0	1/8"	77	30	107	30.0
25-Jun	2:20 PM	2:33 PM	13:00.0	1/8"	80	21	111	31.0
25-Jun	2:57 PM	3:09 PM	12:00.0	1/8"	85	22	109	24.0
27-Jun	8:00 AM	8:06 AM	06:00.0	1/16"	73	501	159	86.0
27-Jun	10:27 AM	10:32 AM	05:00.0	1/16"	84	405	134	50.0

All leaks with different volumes controlled by injection pressure, orifice, line temperature, and duration were detected successfully.

Lufan Zou: [SPE-209262-MS](#) Detection of 2.187 gallon pipeline leakage by optical sensor based on coherent interaction of pulse and depleted pump technology

Conclusion

- Oil and gas pipeline leaks have been monitored using fiber optic Distributed Strain and Temperature Sensor (DSTS) based on Coherent Interaction of Probe and Depleted Pump (CIPDP) at the Southwest Research Institute in San Antonio, Texas, USA.
- Leak volume of 2.187 gal through a 1/8” orifice with the injection pressure of 105 psi and the difference of 39°F (21.6°C) between the line temperature and the soil temperature has been detected in one minute after a leak happened. Testing also showed that the temperature change caused by the leak increased with time during the 13-minutes leak.
- When the injection pressure dropped to 22 psi and the difference between the line temperature and the soil temperature dropped to 20°F (11.1°C), leak volumes of 6.72 gal could be detected in 5 minutes after the leak occurred.
- All leaks with different volumes controlled by injection pressure, orifice, line temperature, and duration were detected successfully.

Lufan Zou: [SPE-209262-MS](#) Detection of 2.187 gallon pipeline leakage by optical sensor based on coherent interaction of pulse and depleted pump technology

Special Thanks

- Mr. S. P. Siebenaler from Southwest Research Institute (SwRI)
- Mr. Nikos Salmatanis from Chevron

Thanks for your attention.

Questions?