Application Note 2004-006B

Wavelength Testing Using Gas Cells

Overview

This application note provides some background on how to check wavelength accuracy using standard gas cells.

Summary

The Model 2004 Optical CSA includes the capability to process gas cell absorption lines to check or calibrate wavelength accuracy in system. When used in combination with Option 310, the Wavelength Reference card, high wavelength accuracy can be achieved.

Checking Wavelength Accuracy

Gas cell test traces have been added to the CSA that can be used to check wavelength accuracy of swept or stepped measurements. To perform the test, a gas cell is connected between the "To DUT" optical output of the CSA and the input to one of the power measurement modules. More than one gas cell may be tested at the same time by using multiple channel cards, one for each gas cell type.

Recommended Settings

The following settings are suggested when doing gas cell testing.

Power Reference: ON
This minimizes the impact of TLS power fluctions on the detection of gas cell lines in the swept data.

Reading Spacing: 0.001 to 0.005 nm
Gas Cell line widths vary from about 0.015 to 0.040 nm depending on the cell type and wavelength. It is important to maintain high resolution of the cell lines for accuracte determination of center wavelength of the cell lines. As reading spacing increases, accuracy decreases.

System Filter: OFF in Continuous Swept Mode
The system filter adds a time shift to the measured data which shows up as a frequency shift relative to the wavelength reference module. This time shift becomes more significant with high sweep rates.

System Filter: ON in Step Mode
The system filter time shift is insignificant in stepped operation. Therefore, turning the filter on has the beneficial effect of increasing S/N ratio of the measured gas cell data.

Laser Source Testing

To check the raw output of a TLS, operate the test with the wavelength reference disabled. When operating in continuous swept mode, make sure the Filter function is turned OFF under the CHANNELS menu. Filter should be ON when operating in stepped mode to maximize S/N. Filtering has the greatest impact when sweeping at fast rates such as 100 nm/s.

Run sweeps with gas cell correction OFF. Each gas cell trace will display wavelength error from the expected wavelength in units of picometers. In this display mode, the user can make adjustments to the system or laser to see impacts on wavelength accuracy. Things to adjust might include, filter on or off, trigger polarity, sweep rate, etc. Steps in wavelength error between 15 to 45 pm can be an indicator of mode hopping in laser operation. The shape of the wavelength error is an indicator of sweep rate

linearity and offset. We have found that some swept TLS sources have the best linearity when operating at their fastest speed.

System Testing

For best accuracy, it is recommended that Option 310, Wavelength Reference, be included in the system. The Wavelength Reference is capable of correcting for trigger jitter in a TLS output and correcting for errors in sweep rate. The Wavelength Reference will also correct for a jump in wavelength due to laser mode hopping[1]. In system testing is also useful to determine the impact of system components on final wavelength accuracy as well.

Typical Setup

Following is an example of a typical setup for running the gas cell test.

CSA setup

gas cell traces	enabled
gas cell corr	off
filter	off
sweep	continuous
start wavelength	1525 nm
stop wavelength	1565 nm
sweep rate	100 nm/s
reading spacing	0.001 nm
samples to average	1
trigger	external
wavelength reference	enabled
power reference	enabled

TLS setup

start	1523 nm
trigger	1525 nm
end	1570 nm

The difference between start and trigger wavelengths gives the TLS motor time to stabilize before the system starts to take data. The difference between end and stop wavelength also ensures that the motor does not start to slow down before data collection is complete and provides some margin in case TLS sweep rate is not accurate.

Data Logging

Each time a sweep is performed with the HCN Test Enabled, data is written to the HCNLOG.CSV data file located in the data directory of the CSA. This file is in CSV format and may be imported into Excel for evaluation. The user may delete or copy this file using the file menus.

Example:

"HCNLOG.CSV"\r\n
"HCn Gas Cell Test Data"\r\n
,,,,1528.0541,1528.4862,1528.9271,1529.3762,1529.8376,1530.3061,1530.7856,1531.2764,153
1.7738,1532.2825,1532.8024,1533.3291,1533.8671,1534.4159,1534.9723,1535.5401,1536.117,
1536.7034,1537.2997,1537.9069,1538.5224,1539.1494,1539.7855,1540.4314,1541.0872,1541.7

[1] Depending on the version of the wavelocker, there will either be a section of data where wavelength error is high due to the mode hop or a section of data where there is a gap in data.

53,1543.1148,1543.8094,1544.5147,1545.2314,1545.9563,1546.6902,1547.4354,1548.1904,154
8.9554,1549.7302,1550.5149,1551.3106,1552.1157,1552.9308,1553.756,1554.5892,1555.4346,
1556.2919,1557.1573,1558.0329,1558.9185,1559.8143,1560.7185,1561.6344,1562.5625\r\n
\r\n
"Date
Time","WaveRefOn","Learn","Use","R25","R24","R23","R22","R21","R20","R19","R18","R17","R16
","R15",
"R14","R13","R12","R11","R10","R9","R8","R7","R6","R5","R4","R3","R2","R1","R0","P1","P2","P3"
,"P4","P5","P6",
"P7","P8","P9","P10","P11","P12","P13","P14","P15","P16","P17","P18","P19","P20","P21","P22","
P23","P24","P25"\r\n
12/19/2001 13:34:56,1,0,0,-1.6727e-003,-2.74698e-003,-2.87355e-003 *(51 total data points)*
12/19/2001 13:35:00,1,0,0,-2.00675e-003,-2.58446e-003,-2.93249e-003
12/19/2001 13:35:04,1,0,0,-2.51929e-003,-2.4872e-003,-2.89088e-003
12/19/2001 13:35:08,1,0,0,-2.53536e-003,-2.57752e-003,-2.8588e-003
12/19/2001 13:35:12,1,0,0,-1.87958e-003,-2.7774e-003,-2.53134e-003
12/19/2001 13:35:25,1,0,0,-3.70712e-003,-2.54291e-003,-3.03554e-003
12/19/2001 13:35:29,1,0,0,-2.83607e-003,-2.56618e-003,-2.95667e-003
12/19/2001 13:35:33,1,0,0,-2.38158e-003,-3.18056e-003,-2.44158e-003
12/19/2001 13:35:38,1,0,0,-2.65925e-003,-2.69809e-003,-2.95932e-003
12/19/2001 13:35:42,1,1,0,-3.19305e-003,-2.61484e-003,-3.0269e-003
12/19/2001 13:35:46,1,1,0,-3.30787e-003,-2.59655e-003,-2.96919e-003
12/19/2001 13:35:50,1,1,0,-3.12693e-003,-2.75687e-003,-2.86553e-003
12/19/2001 13:35:55,1,1,0,-2.96497e-003,-2.86185e-003,-2.80016e-003
12/19/2001 13:35:59,1,1,0,-2.70381e-003,-3.16305e-003,-2.47877e-003
12/19/2001 13:36:03,1,0,1,-1.63964e-004,-1.15869e-004,4.42659e-005
12/19/2001 13:36:07,1,0,1,-2.65143e-004,1.9406e-004,-1.66054e-004
12/19/2001 13:36:12,1,0,1,-5.90449e-004,3.58569e-004,-4.91308e-004
12/19/2001 13:36:16,1,0,1,-4.30951e-004,2.35805e-004,-4.82749e-004
12/19/2001 13:36:21,1,0,1,1.64787e-004,-3.08678e-004,2.71075e-005
12/19/2001 13:36:26,1,0,1,-1.29748e-007,-1.07169e-004,-1.96677e-004
12/19/2001 13:36:30,1,0,1,-2.34812e-004,1.53896e-004,-4.73581e-004
12/19/2001 13:36:38,1,0,1,-7.54382e-004,5.45728e-004,-6.95375e-004

The third line in the log file includes the wavelength for each line of the HCn gas cell in units of nanometers. The fifth line includes labels for each column of subsequent data. The first column is date and time of the sweep, the next column indicates if the wavelength reference is on(1) or off(0). The next column indicates if it is Learn mode is on(1) or off(2). The next column indicates if the gas correction is on(1) or off(0). The rest of the columns show wavelength error for the 51 data points in units of nanometers. If for some reason, one of the gas cell lines was not found, then a blank space will be inserted into the data and will show up as a blank cell if imported into Excel.

Gas Cell Correction

The gas cell correction function has three modes: Off, Learn and On.

Off
Gas cell correction data is NOT applied to the sweep wavelength data. This is independent of wavelength reference operation.

Learn
While in learn mode, wavelength errors are accumulated and stored in the file GASCORR.CSV in the CSA data directory. The average error is accumulated and displayed so that the more sweeps are taken the less the error display will move from sweep to sweep. Each time the user enters Learn mode, the previous Learn data is cleared to zero. When the system is first turned on, the Learn data is loaded from GASCORR.CSV. 5 sweeps is typically plenty of sweeps to

average, however, if the system exhibits high noise on wavelength accuracy, more sweeps may be needed. Typical wavelength accuracy fluctuation is 0.5 picometers (1 sigma).

Learn mode should be operated in the same settings as the user intends to operate the system. Things such as sweep rate and TLS power level can have some impact on wavelength accuracy.

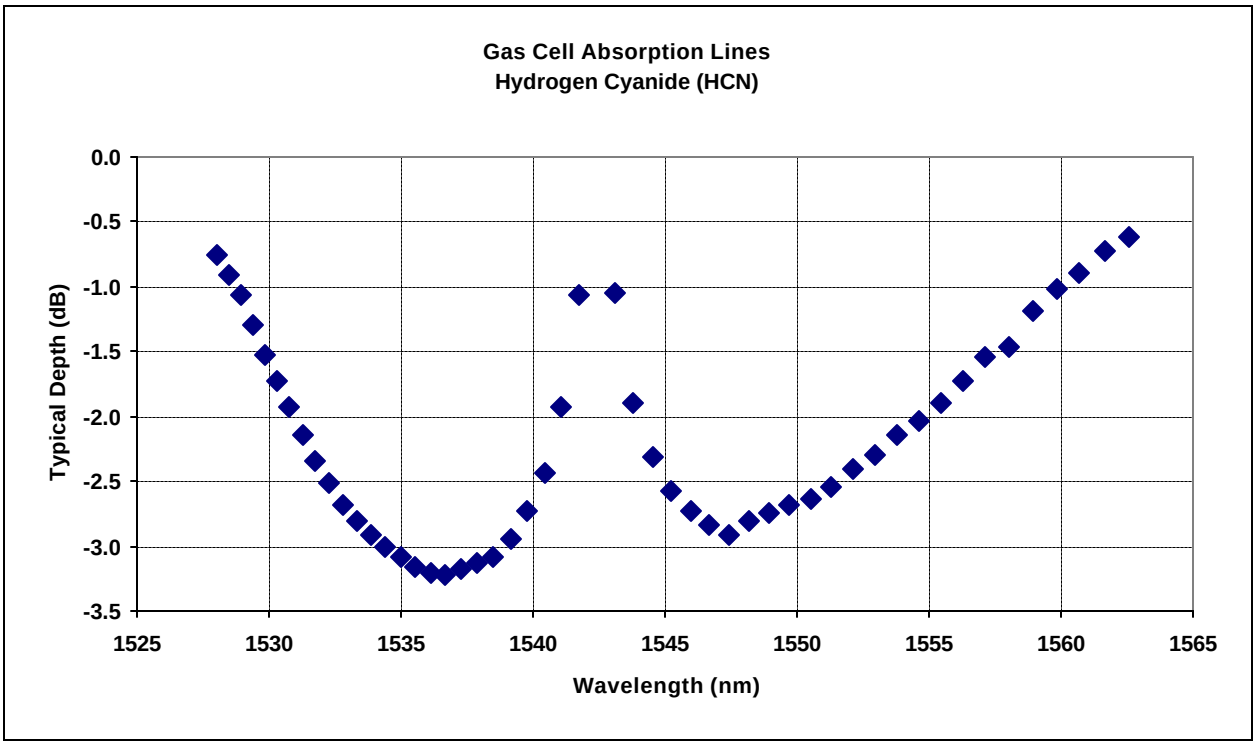
On
Wavelength correction data from the most recent Learn operation is applied to each sweep. The best wavelength accuracy is achieved with a wavelength reference in the system and gas cell correction 'Learned' and turned on.

(Continued next page)

Hydrogen Cyanide Gas Cell

The data below is for a cell containing one gas at the following partial pressure:

Hydrogen Cyanide	$H^{13}C^{14}N$	100 Torr

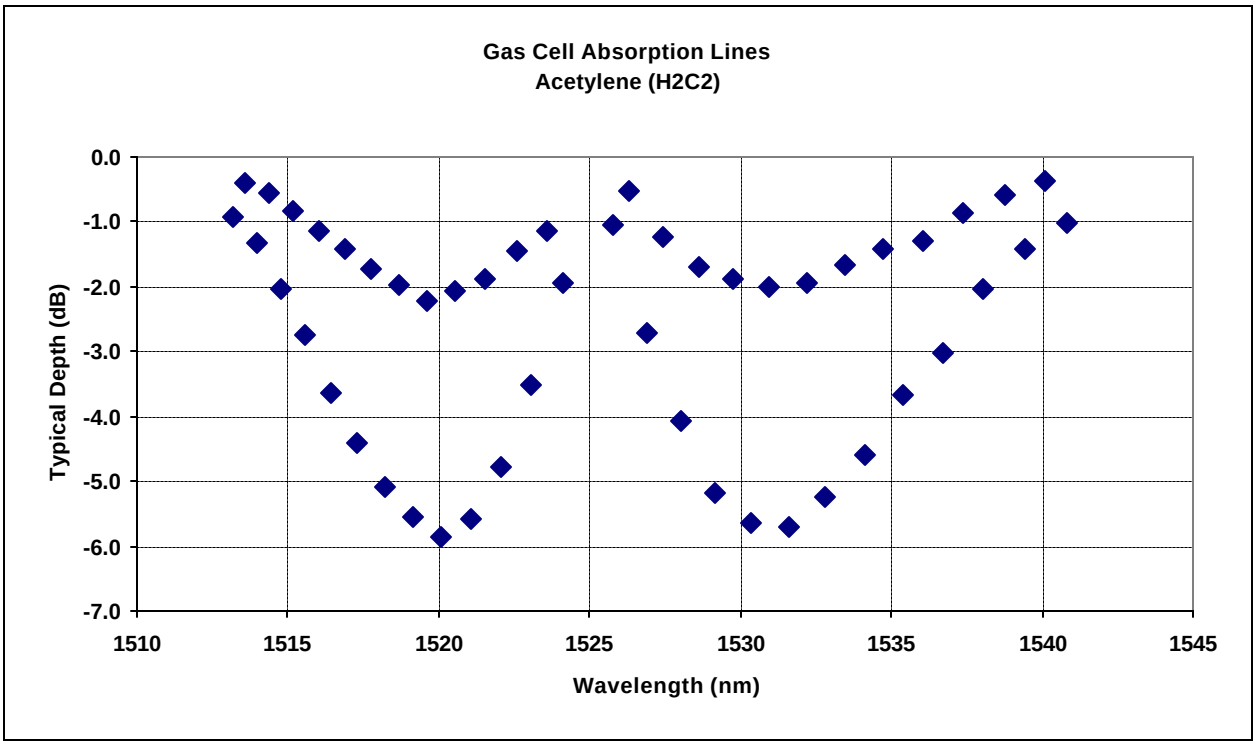


Hydrogen Cyanide Absorption Line Wavelengths (nm)			
1528.0541	1534.4159	1543.1148	1552.9308
1528.4862	1534.9723	1543.8094	1553.7560
1528.9271	1535.5401	1544.5147	1554.5892
1529.3762	1536.1170	1545.2314	1555.4346
1529.8376	1536.7034	1545.9563	1556.2919
1530.3061	1537.2997	1546.6902	1557.1573
1530.7856	1537.9069	1547.4354	1558.0329
1531.2764	1538.5224	1548.1904	1558.9185
1531.7738	1539.1494	1548.9554	1559.8143
1532.2825	1539.7855	1549.7302	1560.7185
1532.8024	1540.4314	1550.5149	1561.6344
1533.3291	1541.0872	1551.3106	1562.5625
1533.8671	1541.7530	1552.1157	

Acetylene Gas Cell

The data below is for a cell containing one gas at the following partial pressure:

Acetylene	$^{12}C_2H_2$	200 Torr



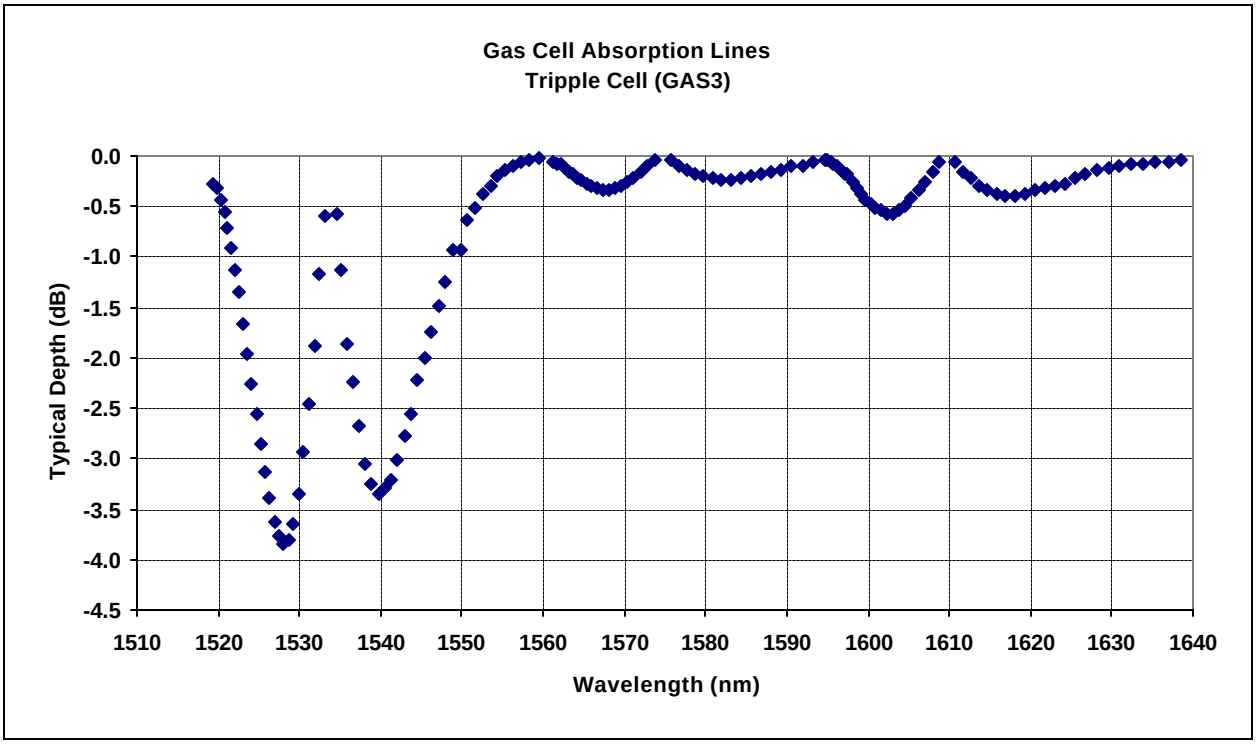
Acetylene Absorption Line Wavelengths (nm)			
1513.2007	1518.6725	1526.3147	1534.0995
1513.5839	1519.1376	1526.8751	1534.7433
1513.9733	1519.6090	1527.4419	1535.3935
1514.3690	1520.0867	1528.0151	1536.0502
1514.7710	1520.5707	1528.5946	1536.7134
1515.1793	1521.0611	1529.1806	1537.3830
1515.5939	1521.5579	1529.7730	1538.0590
1516.0148	1522.0610	1530.3718	1538.7416
1516.4419	1522.5704	1530.9770	1539.4306
1516.8754	1523.0862	1531.5886	1540.1261
1517.3152	1523.6084	1532.2067	1540.8281
1517.7613	1524.1369	1532.8312	
1518.2138	1525.7607	1533.4621	

Triple Gas Cell

The data below is for a triple cell containing three gases, each at the following partial pressures:

Hydrogen Cyanide	$H^{12}C^{14}N$	10 Torr
Carbon Monoxide	$^{12}C^{16}O$	150 Torr
Carbon Monoxide	$^{13}C^{16}O$	150 Torr

Some of the carbon monoxide lines have been adjusted for a 150 Torr pressure shift by about 0.4 pm [2]. Some lines have been added to fill in gaps in coverage based on measurements at dBm Optics, and where possible, data from the HITRAN database[3]. Note that the HCN lines in this cell are shifted by about 8 nm from the NIST data[1] for HCN. This is because of the use of carbon-12 instead of carbon-13 in the HCN molecule.



Triple Cell Absorption Line Wavelengths (nm)				
1519.4216	1535.9533	1561.2581	1584.2664	1606.1579
1519.8459	1536.6810	1561.6767	1585.4679	1607.0051
1520.2805	1537.4192	1562.1218	1586.6974	1607.8787
1520.7255	1538.1681	1562.5935	1587.9548	1608.7787
1521.1809	1538.9277	1563.0918	1589.2402	1610.6583
1521.6465	1539.6978	1563.6166	1590.5539	1611.6380
1522.1226	1540.4787	1564.1679	1591.8958	1612.6443
1522.6090	1541.2703	1564.7459	1593.2656	1613.6773
1523.1058	1542.0725	1565.3505	1594.6648	1614.7371
1523.6130	1542.8854	1565.9818	1595.0222	1615.8237
1524.1306	1543.7091	1566.6398	1595.3745	1616.9373

1524.6586	1544.5435	1567.3244	1595.7528	1618.0778
1525.1970	1545.3886	1568.0358	1596.1573	1619.2453
1525.7459	1546.2445	1568.7740	1596.5874	1620.4400
1526.3051	1547.1112	1569.5390	1597.0434	1621.6620
1526.8748	1547.9886	1570.3308	1597.5252	1622.9112
1527.4550	1548.8768	1571.1495	1598.0331	1624.1878
1528.0457	1549.7759	1571.9952	1598.5668	1625.4919
1528.6468	1550.6858	1572.8679	1599.1266	1626.8236
1529.2583	1551.6065	1573.7676	1599.7123	1628.1826
1529.8804	1552.5381	1575.6485	1600.3241	1629.5700
1530.5130	1553.4805	1576.6297	1600.9619	1630.9846
1531.1561	1554.4339	1577.6383	1601.6257	1632.4276
1531.8098	1555.3955	1578.6742	1602.3156	1633.8986
1532.4740	1556.3715	1579.7375	1603.0317	1635.3978
1533.1487	1557.3645	1580.8283	1603.7739	1636.9253
1534.5298	1558.3585	1581.9467	1604.5423	1638.4812
1535.2363	1559.3685	1583.0927	1605.3370	

References

[1] SL Gilbert, WC Swann, and CM Wang, “Standard Reference Materials®: Hydrogen Cyanide Absorption Reference for 1530-1560 nm Wavelength Calibration-SRM 2519”, NIST Special Publication 260-137 (1998)

[2] N Picque and G Guelachvili, “Absolute Wavenumbers and Self-Induced Pressure Lineshift Coefficients for the 3-0 Vibration-Rotation Band of $^{12}C^{16}O$”, Journal of Molecular Spectroscopy, 185, pp. 244-248 (1997)

[3] HITRAN database, www.hitran.com

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