Reference design 11

Wavelength Calibration System Using Out of Band Gas Cell Lines

BACKGROUND

This document relates to the use of gas cell absorption lines to calibrate the wavelength scale of an optical instrument where the gas cell lines fall within a wavelength range that the instrument operates but outside of the specified measurement range.

Gas molecular absorption has been used a calibration source for optical instrumentation especially in the fiber optic communication dense wavelength division multiplexing (DWDM) bands around 1550nm. A typical use would be the calibration of optical spectrum analyzers or channel monitors. The National Institute of Standards and Technology (NIST) offers several Standard Reference Materials (SRMs) for this purpose. These SRMs are cells that are fitted with fiber optic collimators and contain a tube filled with a gas that absorbs radiation in well defined narrow absorption lines that are very accurately known. Light from the input fiber is collimated into a beam, traverses the tube undergoing selective absorption, and exits another collimator to be refocused on the output fiber. Two versions of the SRM are presently offered. One version, SRM2517A, uses a tube filled with carbon 12 acetylene gas and covers the frequency rang from 198 Terahertz (1515nm) to 194.7 Terahertz (1540nm). The other version, SRM 2519 uses carbon 13 hydrogen cyanide and covers the frequency range from 195.9 Terahertz (1530nm) to 191.9 Terahertz (1565nm). These frequency/wavelength references provide highly stable and accurate frequency standards.

A typical use for the gas cells would be to calibrate an optical spectrum analyzer or DWDM channel analyzer. This analyzer in the case of DWDM signals would typically have a wavelength range of 1520 to 1570nm. The spectrum analyzer generally contains a tunable filter, often a tunable etalon. The tunable etalon operates as a comb filter and at any setting allows light to be transmitted at a comb of frequencies that are spaced by what is known as the free spectral range. For maximum resolution the free spectral range, which is a design variable, is typically taken to be just a little larger then the measurement range of interest. A typical measurement range might be 1520nm to 1570nm with a free spectral range of about 70nm, slightly larger then the 50nm measurement range. If the filter was set to transmit at 1550nm it would also transmit at 1480nm, 1410nm, 1340nm, 1270nm, etc. As the etalon is scanned all orders of the etalon will scan inexactly the same way as described by the etalon model. For maximum accuracy the model will need to include effects such as dispersion of the medium used for the filter but these corrections are typically small and quite well known. The transmission of multiple orders does not lead to confusion if it is known that the signal only exists over a restricted wavelength range. Most tunable etalons are scanned be piezoelectric devices that exhibit various temperature humidity, and history effects. Thus tunable etalons need to have the wavelength scale of the scanning signal calibrated in order to be accurate.

BRIEF SUMMARY

We can rely on the repeating nature of the tunable filter to characterize the wavelength/ frequency scale in one wavelength range outside of the measurement range and infer the wavelength/frequency scale within the measurement range. This is done by using a gas cell that contains a gas with absorption bands outside the measurement range as well as a broadband emitter that emits in gas cell line range. Using commercially available wavelength multiplexers the calibration signal is multiplexed into the measurement signal at the input and demultiplexed at the output without affecting the measurement signal, allowing for calibration as well as measurement on the same scan. Wavelength References offers a gas cell containing hydrogen fluoride which has strong absorption lines from 1255nm to 1335nm, which covers a broader wavelength range then either acetylene or hydrogen cyanide. The use of a gas cell with hydrogen fluoride to calibrate a tunable filter in the 1550nm band offers a number of advantages::

1. Provide a wavelength/frequency calibration of a tunable filter by calibration outside of the measurement range of interest
2. Have the calibration be able to be done simultaneously with the measurement scan.
3. Utilize lower cost components such as broadband emitters that are available in other wavelength ranges
4. Utilize gas absorption species that have absorption lines over a larger wavelength range then that offered by species available within the measurement range itself

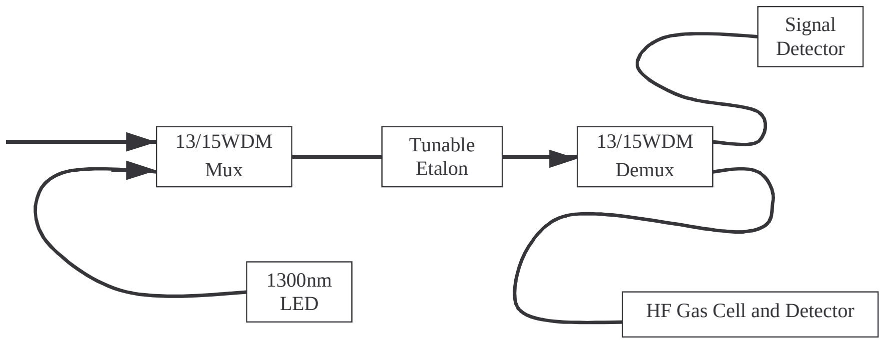
DETAILED DESCRIPTION

A tunable etalon is made from a cavity with partially reflecting mirrors at each end. This cavity will transmit light as described by the equations of the Fabry-Perot etalon. The etalon can be made to be tunable if the cavity can be adjusted, for example, by a piezoelectric device. The tunable etalon will transmitt signal at a comb of wavelengths each separated by the free spectral range. A typical free spectral range for a device intended for C-band channel monitor would be about 50nm The scan would typically be set to about 40nm. As the scan is swept by applying voltage to the piezo the filter will transmit at each corresponding point on the various orders of the filter. For example if the filter were set to transmit at 1550n m it would also transmit at 1500nm, 1450nm, 1400nm, 1350nm, and 1300nm. The quality of the etalon will vary in the different orders due to the mirror coating being optimized for one region. Typically the mirror coatings can be made to work over a fairly wide wavelength range . To calibrate the filter in the 1300nm band the finesse would not need to be as great as the desired finesse in the 1550nm band. The exact wavelength of transmission of the multiple orders is described by the equations of the Fabry-Perot etalon and will include effects such as the dispersion of the medium or mirror coatings.

An application drawing is shown in the figure The unknown input signal is multiplexed with the signal from the calibration source by a 13/15 multiplexer. The unknown signal has wavelengths within the DWDM band from 1528nm to 1562nm for the case of a C-band system but does not have signals at other wavelengths. The calibration source has wavelengths within a certain band not containing the signal wavelengths and nowhere else. The signal combining is typically done by using a WDM combiner such as the JDS WD1315 series. The calibration source is comprised of a broadband emitter and a Wavelength References hydrogen fluoride gas cell. Hydrogen fluoride has strong absorption line from 1255nm to 1335nm so inexpensive 1300nm LEDs may be used. These devices are available from several vendors such as MRV Inc. The multiplexed signal is applied to the tunable filter. The output of the tunable filter is applied to another WDM, this time acting as a demultiplexer which separates the wavelength bands from one another. The calibration and unknown signals are detected by separate detectors.

The techniques and apparatus described can be used to calibrate a tunable filter exhibiting a repeating transmission form, such as a Fabry-Perot tunable filter. The filter is calibrated in one order of the filter and the calibration in the other, signal measurement, order inferred by etalon equations. This allows the calibration and measurement process to proceed with a simultaneous scan, not dependent on the scan repeatability. In addition lower cost components available at other wavelength bands can be used as well as gas species having more advantageous absorption spectra.

DWDM Channel Monitor Calibration System



Reference design for "out of band" calibration system of a tunable etalon type filter

(Micron Optics TFFP, Nortel Networks MT-15, JDSUNPH TB2500, etc)

- Real time calibration
- Gas cell long term accuracy (ie subpicometer potential)
- Low overall system cost (use 1300nm LED for cal source, low cost gas cell)
- No mechanical switches