Article

ECORFAN-Bolivia Journal
June 2016 Vol.3 No.4 10-14

Acetylene sensor based on a fiber laser finely tunable with a silicon wafer

GUZMAN-CHAVEZ, Ana Dinora†*, VARGAS-RODRÍGUEZ, Everardo and LÓPEZ-CARDOSO, Carlos Augusto

Received January 7, 2016; Accepted June 15, 2016

Abstract

In this work a finely tunable erbium doped fiber laser based on a silicon wafer to detect acetylene is presented. Here, the silicon wafer acts like a Fabry-Perot interferometer which is used to select the emission line of the laser. The laser emission can be tuned when the silicon wafer temperature is changed since the maxima peaks of the interference spectrum are shifted. The temperature is finely varied and highly stabilized with a thermo electric cooler that is driven with a PID controller. The laser line emission has as minimum FWMH of 28 pm, emits around of 1530 nm and reaches a continuous tuning range of around 947 pm. The absorption lines of the acetylene molecule, measured with a photodetector and recorded with an oscilloscope, can be characterized with high precision when the fiber laser emission scans the molecule around such absorption lines. Finally it is shown that amplitude of the recorded signal depends directly on the acetylene concentration.

Fiber laser, Fabry-Perot interferometer, acetylene sensor, silicon wafer

Citation: GUZMAN-CHAVEZ, Ana Dinora, VARGAS-RODRÍGUEZ, Everardo and LÓPEZ-CARDOSO, Carlos Augusto. Acetylene sensor based on a fiber laser finely tunable with a silicon wafer. ECORFAN Journal-Bolivia 2016, 3-4: 10-14

---

* Correspondence to Author (email: ad.guzman@ugto.mx)

† Researcher contributing first author.

Introduction

Gas censorship is very important in applications of environmental monitoring, pollution, security, among others (Stewart, 1999). For example in the industry acetylene gas is used in welding and cutting equipment so it is necessary to monitor it to avoid accidents. Fiber optic sensors based on the absorption of light allow the remote detection of gases with additional advantages such as: immunity to electromagnetic interference, relatively fast response, non-contaminated and very accurate. Some applications of this type of optical sensors require optical fiber lasers whose emission lines can be continuously tunable and have a single frequency of operation (Weldon et al., 1995).

Therefore it is necessary to finely tune the laser emission with small tuning steps over the entire spectral region. Today there are several proposals for fiber lasers for the gas sensing but they have the limitation of not being continuously tuned (Ball & Morey, 1992; Whitenett et al., 2004). However, some laser-based lasers with continuous tuning have been reported (Paschotta et al., 1997; Shen et al., 2011) [5, 6]. For example, the laser proposed by (Paschotta et al., 1997) was tuned continuously around 0.72 nm by uniformly narrowing the elements of the optical cavity, two Bragg gratings at the ends of an erbium-doped fiber. Another example is the single frequency tunable laser proposed by [6], which relied on the heating of a fiber segment to tune the laser around 5 GHz.

In particular in the spectral region around 1530 nm the molecule of the acetylene has lines of absorption, reason why the optical lasers doped with Erbium are optimal for its sensate. In this work a simple acetylene gas sensor based on a fiber laser doped with continuous tuning erbium is presented.

Said laser has a silicon wafer which sets the laser emission wavelength. The emission line is finely tuned by varying the temperature of the wafer with a thermoelectric cooler (TEC) handled with a PID controller. It is shown that the laser has a minimum width at half height (FWHM) of 28 pm, emits around 1530 nm and reaches a tuning range of approximately 947 pm with a resolution of 84.6 pm / ° C, sufficient characteristics to scan or two lines of acetylene absorption. Finally the experimental results of characterizing an acetylene absorption line are presented, in which it is observed that as the power that reaches the detector varies as the wavelength of the laser is tuned. This way when the laser emits in the wavelength where the line of absorption is more intense is detected the smaller amount of power. The power will be lower as the acetylene concentration is higher.

Experimental arrangement of the acetylene sensor

Figure 1 shows the experimental arrangement that was implemented to sensitize acetylene. In which the arrangement of the erbium doped fiber laser based on a silicon wafer can be observed. In this arrangement is placed a circulator that serves to obtain the reflection of the silicon wafer which is positioned on the TEC. The reflected light is divided into two equal parts with the 50/50 coupler. One of the beams is passed through a variable optical attenuator (VOA) and then enters a wave division multiplexer (WDM) which serves to close the ring and generate the laser emission generated by erbium-doped fiber, EDF. The laser emission is monitored by the other output of the 50/50 coupler, considered as the output of the laser.

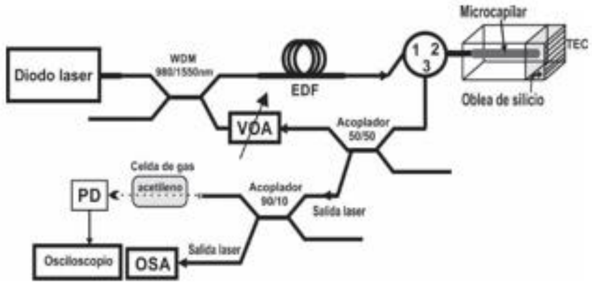


Figure 1 Experimental arrangement of the acetylene sensor

The laser output is spliced to a 90/10 coupler, of which the 10% output is connected to the Optical Spectrum Analyzer (OSA) in order to monitor the wavelength of the lasso, while the 90% output is Leads to the gas cell (see Figure 2). Finally, the beam passing through the cell affects a photodetector (PD) which is responsible for converting the optical signal to an electrical signal. In our case this electrical signal is coupled to an oscilloscope to monitor the sensor response.

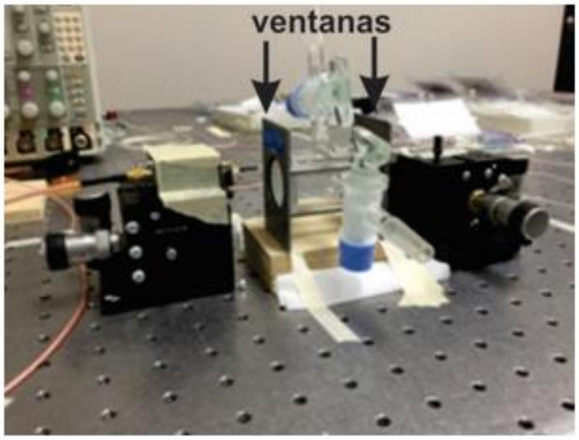
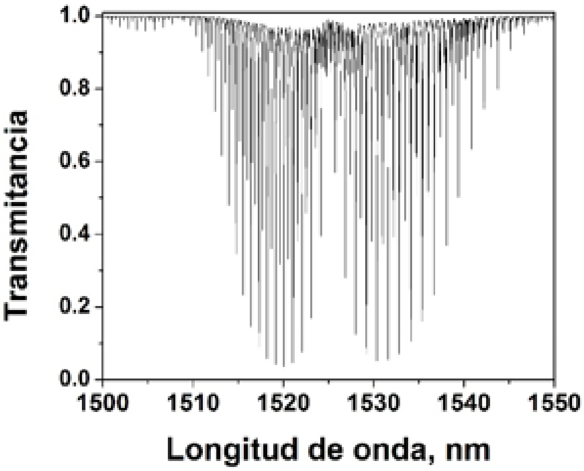


Figure 2 Celda de gas

Tunable laser

The wavelength of the laser emission is determined by the silicon wafer, which acts as a Fabry-Perot interferometer (FPI).

In this way the FPI generates a spectral interference pattern which affects the luminescence spectrum of the erbium, ranging from 1520 nm to 1570 nm. The interference pattern can be shifted spectrally allowing the laser to be tuned. It is also important to note that in order to generate a laser emission around 1530 nm, it is necessary to reduce the gain in the region of 1550 nm, in our case it was done with VOA. The achieved FWMH of the laser emission around 1530 nm was 28 pm. This value was measured with the OSA with a resolution of 20 pm.

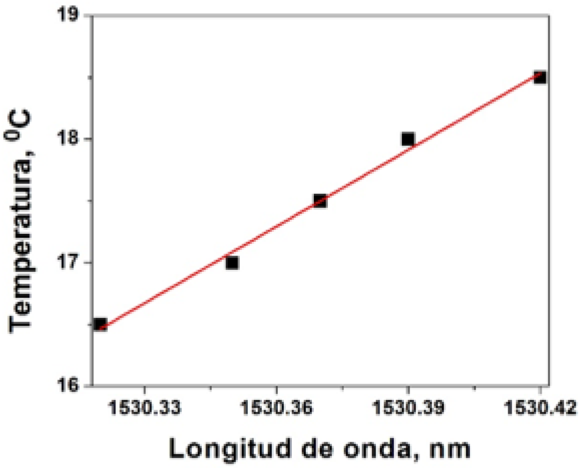


Graphic 1 Spectrum of vibrational absorption of acetylene in the region of 1530 nm.

The acetylene absorption lines are in the spectral region of 1530 nm, as shown in Figure 1. In order to scan one of the absorption lines of the molecule, it is necessary to shift the emission of the laser in the region where a line occurs Of C2H2 absorption, which was done using a TEC.

In turn, a PID controller was implemented to stabilize the temperature of the TEC and the silicon wafer. With this, it is possible to spectrally shift the maximum peaks of the interference pattern of the FPI and thus the emission line of the laser.

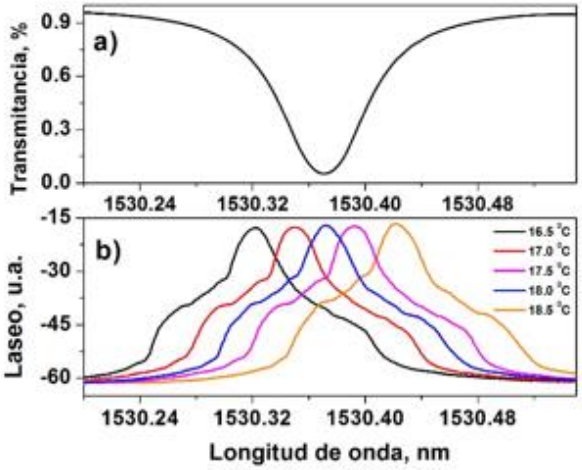
So the continuous tuning was achieved with fine changes in the temperature of the silicon wafer in a range of around 947 pm (see Chart 2) and a resolution of 84.6 pm / ° C, sufficient to scan an absorption line. Figure 2 shows that the variation of the wavelength as a function of temperature, which has a linear behavior.



Graphic 2 Laser wavelength as a function of the temperature applied to the silicon wafe

Censing of acetylene

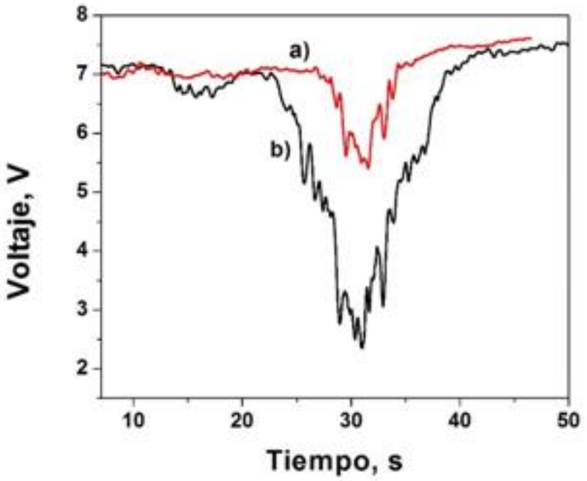
In order to sense acetylene by absorbing the laser light, it is necessary to pass the laser output beam through the gas cell. In order to obtain a good signal from the beam after it had been attenuated, it was necessary to collimate it to avoid high divergence in order to concentrate the greatest amount of energy in the photodetector and finally to monitor it on the oscilloscope (Figure 1). Subsequently, the temperature of the silicon wafer was changed to position the laser emission line in the region of 1530 nm, at a wavelength very close to one of the acetylene absorption lines, as shown in the Chart 3. After being in the starting position, the laser emission line began to tune in fine steps to characterize said absorption line, this was done by increasing the temperature of the silicon wafer.



Graphic 3 a) Acetylene absorption line and b) laser emission tuned to different temperatures.

To characterize the response of the sensor to the presence of acetylene, the cell was first completely filled with acetylene gas. Then on the arm that was connected to the OSA was verified that the emission wavelength. Afterwards, a scan of the laser line was performed in the spectral region where one of the acetylene absorption lines is located as shown in Graph 3. In doing so, the light intensity detected by the photodetector was decaying according to the line of Emission was approaching the maximum absorption of the ro-vibrational line (Graph 4a). In this case the minimum and maximum voltage detected by the photodetector is when the laser line is located at the point of greatest and lowest absorption, which occurs at 1530.37 nm and 1530.15 nm respectively, as shown in Figure 3a. Subsequently, the concentration of the gas inside was reduced and the sweep was repeated and the signal of Figure 4b was obtained.

When comparing the results derived from these two concentrations it can be observed that the depth of the measured signal depends on the concentration of acetylene. So the concentration value is directly proportional to the amplitude of the measured signal.



Graphic 4 Figure of the absorption line measured with the photodetector at different concentrations.

Conclusions

It was possible to implement an acetylene sensor, which is based on a tunable laser. In addition it was verified that the ability of the laser to move with very precise and reduced steps is high, making it a suitable laser for the sensing of the acetylene gas.

It was also demonstrated that the lack of mechanical components considerably increases the laser precision in the selection of the laser region. Finally it is necessary to continue exploring the capabilities of this laser, in order to look for reduction in size, which is highly probable.

References

Ball, G. A., & Morey, W. W. (1992). Continuously tunable single-mode erbium fiber laser. Optics Letters, 17(6), 420-422. doi:10.1364/OL.17.000420

Paschotta, R., Nilsson, J., Reekie, L., Trooper, A. C., & Hanna, D. C. (1997). Single-frequency ytterbium-doped fiber laser stabilized by spatial hole burning. Optics Letters, 22(1), 40-42. doi:10.1364/OL.22.000040

Shen, L., Ye, Q., Cai, H., & Qu, R. (2011). Mode-hop-free electro-optically tuned external-cavity diode laser using volume Bragg grating and PLZT ceramic. Optics Express, 19(18), 17244-17249. doi:10.1364/OE.19.017244

Stewart, G. (1999). Optical Fiber Sensor: Kluwer Academic Publishers, Dordrecht.

Weldon, V., O'Gorman, J., Phelan, P., Hegarty, J., & Tanbun-Ek, T. (1995). H2S and CO2 gas sensing using DFB laser diodes emitting at 1.57 mm. Sensors and Actuators B: Chemical, 29(1-3), 101-107.

Whitenett, G., Stewart, G., Yu, H., & Culshaw, B. (2004). Investigation of a tuneable mode-locked fiber laser for application to multipoint gas spectroscopy. Lightwave Technology, Journal of, 22(3), 813-819. doi:10.1109/JLT.2004.824530