光学 精密工程
OPTICS AND PRECISION ENGINEERING
核心期刊
主管：中国科学院
主办：中国科学院长春光学精密机械与物理研究所
中国仪器仪表学会
主编：曹健林

光学精密工程 2013, 21(11) 2771-2777 ISSN: 1004-924X CN: 22-1198/TH DOI:10.3788/OPE.20132111.2771

现代应用光学

可调谐半导体激光吸收光谱方法的多组分气体浓度同时在线监测技术

张志荣*，夏滑，董凤忠，庞涛，吴边

中国科学院 安徽光学精密机械研究所 安徽省光子器件与材料重点实验室，安徽 合肥 230031

摘要： 由于线宽窄，可调谐半导体激光吸收光谱技术(TDLAS)一般情况下只能对一种气体进行检测。为了实现多气体同时或近同时在线检测，本文以1 578 nm-H2S和1 747 nm-HCl混合气体同时在线监测为例，研究了3种检测方法：(1)同频10 kHz正弦波和两路同频30 Hz不同步的分时锯齿信号法；(2)同频10 kHz正弦和30 Hz锯齿信号的光开关检测法；(3)多频(10 kHz和20 kHz正弦信号)正弦调制法。实验结果表明：分时锯齿信号法除幅值略有微小变化外，在使用前后对测试结果影响很小；光开关法在切换过程瞬间会略有不稳定，但不影响后期的浓度反演；多频正弦法的信噪比和抗干扰能力均有所提高，进行HCl探测和H2S探测时，信噪比在激光器关闭和打开情况下分别提高了0.95倍和3.17倍。以上3种方法操作简单，可以方便地实现多气体组分的同时在线监测，提高了TDLAS仪器的竞争力。

关键词： 可调谐半导体激光吸收光谱(TDLAS) 多组分气体 分时锯齿信号 光开关 多频正弦波调制

Simultaneous and on-line detection of multiple gas concentration with tunable diode laser absorption spectroscopy

ZHANG Zhi-rong*, XIA Hua, DONG Feng-zhong, PANG Tao, WU Bian

Anhui Provincial Key Laboratory of Photonic Devices and Materials,
Anhui Institute of Optics and Fine Mechanics, Chinese Academy of Sciences, Hefei 230031, China

Abstract: Generally, Tunable Diode Laser Absorption Spectroscopy (TDLAS) can detect only one kind of gas because of its narrow line-width. To detect the multi-component gas in real time simultaneously or near simultaneously, three kinds of detection methods were reported by taking 1 578 nm-H2S, 1 747 nm-HCl and N2 mixture for examples. The three methods are called timeshare-sawtooth method (10 kHz sin wave, 30 Hz asynchrony sawtooth wave), optical-switch method (same frequency 10 kHz sin wave, 30 Hz sawtooth wave) and multi-frequency modulation method (10 kHz and 20 kHz sin wave). The experimental results for the three methods show as follows: the method one gives fewer effects on measuring results apart from amplitude changes. The method 2 shows slightly unstable moments in the switching process, but it has no effect on concentration inversion in the later stage of the experiment. Moreover, in the method 3, the Signal-to-noise Ratio (SNR) and the anti-interference ability are improved, and the SNR has increased about 0.95 and 3.17 times for monitoring HCl and H2S when lasers are on or off. The three methods mentioned above have advantages on less investment, simple adjusting, and easy operation, also they can monitor many kinds of gases with the changing modulation parameters or switch channels, simultaneously.

Keywords: Tunable diode laser absorption spectroscopy (TDLAS) Multi-component gases Timeshare-sawtooth Optical-switch Multi-frequency sin-wave modulation

收稿日期 2013-07-19 修回日期 2013-08-21 网络版发布日期 2013-11-22

基金项目:

国家自然科学基金项目资助

通讯作者: 张志荣

作者简介: 张志荣(1981-)，男，山东淄博人，博士，助理研究员，2011年于中国科学院安徽光学精密机械研究所获得博士学位，主要从事环境光学监测新技术，高灵敏激光光谱燃烧过程诊断等方面的研究工作。
作者Email: zhangzr@aiofm.ac.cn

参考文献：

[1]李亚萍,张广军,李庆波.空间双光路红外CO2气体传感器及其测量模型[J]. 光学 精密工程, 2009, 17(1):14-19. LI Y P, ZHANG G J, LI Q B. Infrared gas sensor based on space beams and its measurement model[J]. Opt. Precision Eng., 2009,17(1):14-19. (in Chinese) [2]潘卫东,张佳薇,戴景民,等. 可调谐半导体激光吸收光谱技术检测痕量乙烯气体的系统研制[J]. 光谱学与光谱分析,2012, 32(10): 2875-2878. PAN W D, ZHANG J W, DAI J M, et al.. Tunable diode laser absorption spectroscopy system for trace ethylene detection[J]. Spectroscopy and Spectral Analysis,2012, 32(10): 2875-2878. (in Chinese) [3]董凤忠,刘文清,刘建国,等.机动车尾气的道边在线实时监测(上) [J]. 测试技术学报,2005,19(3): 237-244. DONG F ZH, LIU W Q, LIU J G, et al.. On-line roadside vehicle emissions monitoring (part 1)[J]. Journal of Test and Measurement Technology,2005,19(3): 237-244. (in Chinese) [4]张志荣,董凤忠,王煜,等.基于数字控制模块的工业有毒气体在线监测仪[J]. 光学学报,2010,31(s1): s100304. ZHANG ZH R, DONG F ZH, WANG Y, et al.. On-line monitoring of industrial toxic gases with a digital-control module[J]. Acta Optica Sinica, 2010,31(s1): s100304. (in Chinese) [5]LI F, YU X L, CAI W W, et al.. Uncertainty in velocity measurement based on diode-laser absorption in nonuniform flows[J]. Applied Optics, 2012, 51(20): 4788-4797. [6]SAPPEY A D, MASTERSON P, HUELSON E, et al.. Results of closed-loop coal-fired boiler operation using a TDLAS sensor and smart process control software [J]. Combustion Science and Technology, 2011, 183(11): 1282-1295. [7]XING C, JEFFRIES J B, HANSON R K. Real-time, in situ, continuous monitoring of CO in a pulverized-coal-fired power plant with a 2.3 μm laser absorption sensor [J]. Applied Physics B,2013, 110 (3): 359-365. [8]LOU X T, SOMESFALEAN G, CHEN B, et al.. Simultaneous detection of multiple-gas species by correlation spectroscopy using a multimode diode laser [J]. Optics Letters, 2010, 35(11): 1749-1751. [9]陈洪耀,张黎明.基于特征吸收波长板的色散型高光谱传感器光谱定标技术[J]. 光学 精密工程, 2010, 18

(12):2442-2646. CHEN H Y, ZHANG L M. Spectral calibration for dispersive hyper spectral sensor based on doped-reflection standard panel[J]. Opt. Precision Eng., 2010,18(12):2442-2646. (in Chinese) [10]COOPER D E, WARREN R E. Frequency modulation spectroscopy with lead-salt diode lasers: a comparison of single-tone and two-tone techniques [J]. Appl. Opt., 1987, 26:3726-3732. [11]陈宵,隋青美,苗飞,等,高灵敏度腔增强吸收式乙炔气体检测系统[J]. 光学 精密工程, 2012, 20 (1):9-16. CHEN X, SUI Q M, MIAO F, et al.. High sensitivity acetylene detection system based on cavity enhanced absorption technique [J]. Opt. Precision Eng., 2012, 20(1):9-16. (in Chinese) [12]陈宵,隋青美,苗飞,等.应用单一超窄线宽激光