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(54) **DUAL-ETALON CAVITY RING-DOWN  
FREQUENCY-COMB SPECTROSCOPY WITH  
BROAD BAND LIGHT SOURCE**

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**G01B 9/02** (2006.01)

(52) **U.S. Cl.**  
USPC ..... **356/454**; 356/497; 356/484

(58) **Field of Classification Search**  
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See application file for complete search history.

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

3,915,573 A \* 10/1975 Knoll et al. .... 356/454  
4,941,747 A \* 7/1990 Dakin ..... 356/454  
7,359,066 B2 \* 4/2008 Cummings et al. .... 356/519  
7,483,143 B2 1/2009 Sanders et al.

**OTHER PUBLICATIONS**

Alder, et al.—“Cavity-Enhanced Direct Frequency Comb Spectroscopy: Technology and Applications”—In Annual Review of Analytical Chemistry, vol. 3, pp. 175-205. Mar. 1, 2010.

Bernhardt et al.—“Cavity-enhanced dual-comb spectroscopy”—Nature Photonics, 4(1): 55-57, Jan. 10, 2010.

Cundiff et al.—“Optical frequency synthesis based on mode-locked lasers”—Review of Scientific Instruments, 72(1): 3749-3771, Oct. 2001.

Engeln et al.—“Polarization dependent cavity ring down spectroscopy”—In Frontiers in Low Temperature Plasma Diagnostics III. Book of Papers, pp. 39-49, Lausanne Switzerland, Feb. 1999. Centre de Recherches en Physique des Plasmas; Int. Union for Vacuum Sci. Tech. & Applications; Swiss Vacuum Soc.; et al., Ecole Polytechnique Federale de Lausanne. Proceedings of Workshop on Frontiers in Low Temperature Plasma Diagnostics III, Feb. 15-19, 1999, Saillon, Switzerland.

Engeln et al.—“Cavity enhanced absorption and cavity enhanced magnetic rotation spectroscopy”—Review of Scientific Instruments, vol. 69, No. 11, Nov. 1998.

(Continued)

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(57) **ABSTRACT**

In an embodiment, a dual-etalon cavity-ring-down frequency-comb spectrometer system is described. A broad band light source is split into two beams. One beam travels through a first etalon and a sample under test, while the other beam travels through a second etalon, and the two beams are recombined onto a single detector. If the free spectral ranges (“FSR”) of the two etalons are not identical, the interference pattern at the detector will consist of a series of beat frequencies. By monitoring these beat frequencies, optical frequencies where light is absorbed may be determined.

**21 Claims, 14 Drawing Sheets**

