Detection of photothermal deflection signals with conjugate masks

Anup Sharma, Gabriel Ycas, Zeyad Alahmed, and Rajendra Gupta

A new detection technique for photothermal deflection spectroscopy and photoacoustic deflection spectroscopy is presented. The technique uses a pair of matched multiple slits placed in the path of the probe beam and oriented to block the probe light from the detector in the absence of a deflection signal. Significant improvement in the signal-to-noise ratio and in the frequency bandwidth compared with those available with current techniques is demonstrated.

OCIS codes: 300.6430, 120.0120.

1. Introduction

Photothermal spectroscopy, along with the related technique of photoacoustic spectroscopy, has developed into a useful applied spectroscopy technique over the past 25 years or so.[1,2] Both techniques are valuable in applications for which fluorescence techniques are not appropriate, such as in environments in which nonradiative decay rates are dominant. These techniques have been applied to many diverse areas, such as analytical chemistry, combustion diagnostics, pollution monitoring, semiconductor diagnostics, nondestructive evaluation, materials and surface studies, and medical, biological, and agricultural sciences.[3] The principle of photothermal technique is as follows: A laser beam (pump beam) tuned to the absorption line of the species or material being investigated passes through the medium. If the nonradiative decay rate of the excited state (quenching rate in the case of vapors) is much faster than the radiative rate, most of the optically absorbed energy will appear in the thermal modes of the medium. This will result in a change in the refractive index of the laser-irradiated region. This change in refractive index can be detected by a second, weaker laser beam (probe beam) in any of several ways.[4] In one of the them, one monitors the refractive change by observing the deflection of the probe beam. The probe beam is deflected, much as in the mirage effect, by the refractive-index gradient produced by absorption of the pump beam. The deflection of the probe beam is generally measured by a bi-cell (a two-element detector) or by the knife-edge technique. The photothermal technique can be used with either a cw pump beam or a pulsed pump beam. If a cw beam is used, it is generally modulated such that phase-sensitive detection techniques can be used. The heating of the laser-irradiated region is also accompanied by a change in the pressure of this region. A pressure wave or a pressure pulse, for a modulated or a pulsed pump beam, respectively, propagates outward from the laser-irradiated region. This is the principle of photoacoustic spectroscopy. Although the photoacoustic spectroscopy signal is generally detected by microphones, it can also be detected by the deflection of a probe beam[5,6] because the pressure change is accompanied by a refractive-index change. In this paper we give a proof-of-principle demonstration of a new detection technique that reduces noise drastically, at least in a certain range of signal amplitudes, compared with the bi-cell and the knife-edge techniques. Moreover, a much higher detection bandwidth (or time resolution in the pulsed case) can be obtained. This detection technique can be implemented with both photothermal deflection spectroscopy (PTDS) and photoacoustic deflection spectroscopy (PADS).

Our technique involves use of a pair of matched multiple slits placed in the probe beam, upstream (mask I) and downstream (mask II) of the absorbing medium being investigated with PTDS or PADS, as

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Received 13 August 2004; revised manuscript received 21 December 2004; accepted 12 January 2005.

0003-6935/05/153110-07$15.00/0

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قياس الانحراف الفوتوحراري بواسطة الأقنعة المركبة

مختصر:
لقد تم التوصل لطريقة جديدة لقياس طيف الانحراف الفوتوحراري والفوتوصوتي. في هذه الطريقة يتم استخدام زوج متطابق من الاقنعة مكونة من ثقوب على شكل خطوط مستقيمة يمر من خلالها الضوء. يوضع زوج الأقنعة في المسار الضوئي للشعاع الاختباري بحيث يمنع مرور الضوء الى جهاز القياس في حالة غياب اشارة الانحراف. هذه الطريقة تقدم تحسن كبير في نسبة معامل الإشارة الى التشويش وكذلك نطاق التردد مقارنة مع ما هو متوفر حالياً ومستخدم لنفس الغرض.