Photo-thermoelastic mechanical beam chopper at a low frequency

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Photo-thermoelastic mechanical beam chopper at a low frequency

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A simple beam chopper advantageously using the thermoelastic bending due to photothermal effect is reported. The mechanical vibration for chopping is generated due to the modulated irradiation from a laser diode so that the chopper is remotely operated.

There is currently a high level of interest in photoacoustic and photothermal techniques because of their potential for spectroscopy and nondestructive evaluation.[1] In the photothermal effect, the thermal wave induces several effects, including the generation of an acoustic wave. Some of the common photothermal effects are categorized into four physical phenomena, which are temperature rise, refractive-index gradient changes in the sample or in the surrounding gas, surface deformation, and infrared thermal radiation. They are successfully used for several applications.[1]

Recently, it has been reported that mechanical vibration due to the thermoelastic bending (drum effect) is dominant under some photothermal experimental conditions.[2,3] The amplitude of the vibration as a function of the modulation frequency has been analyzed by the characteristic frequency, which is equal to the thermal diffusivity divided by the square of the sample thickness. For modulation frequencies below the characteristic frequency, the amplitude of the vibration becomes constant, while it is inversely proportional to the modulation frequency for frequencies higher than the characteristic frequency.

With the above remarks in mind, we report a new application of the mechanical phenomenon caused by the photothermal effect. A simple mechanical beam chopper has been designed by using the flexural vibration at the mechanical resonance. Figure 1 shows the schematic diagram of the system. The actuator of the chopper consists of a thin plate (A) and a mechanical oscillator (B, C). The periodic light irradiation of the laser light (830-nm wavelength) generates a thermal wave along the plate thickness, and thus the plate A deflects like a bimorph. However, the deflection caused by the laser irradiation is generally less than 1 μm at a laser power of about 10 mW. For magnifying the periodic deflection to be of the order of millimeter, a mechanical oscillator (B, C) is connected to the end of plate A, and the vibration at a resonance of oscillator is used for chopping a beam. The irradiation of modulated laser light on plate A produces a relatively large vibration of C only subject to the condition that the modulation frequency coincides with the first resonance of the mechanical oscillator. Plate A consists of a borosilicate glass plate (Matunami No. 00) and an aluminum sheet (15-μm thickness) attached on the irradiated side of the glass. The surface of the aluminum sheet is painted black with dry ink. The dimensions of the glass plate are 0.8×5.0-mm rectangle and 80-μm thickness. The mechanical oscillator (B, C) consists of a glass rod B (125 μm in diameter, 11.5 mm in length) and a weight which serves as a chopping plate C of the beam. Plate C is a piece of glass (4.0×9.0 mm, 80-μm thickness) covered by a chromium coating. The periodic irradiation of 21.5-mW laser light at the first resonance frequency 43.6 Hz of the mechanical oscillator generated a vibration of plate C with 1.0-mm amplitude, and it was used for chopping a He–Ne laser beam of about 1 mm in diameter. The half-value bandwidth of the resonance oscillation was measured to be 1.8 Hz. Figure 2 shows the oscillogram of the chopped beam detected by a photodiode as a function of time. The amplitude of vibration was proportional to the power of the laser diode.

Changing the mechanical parameters B and C, the characteristics of the resonance vibrations were examined in a similar experimental arrangement. Vibrational magnitudes in the range of a few tenths of a millimeter to 7 mm were obtained with a bandwidth less than 5 Hz at the respective resonance frequencies between 200 and 10 Hz. Vibrations at the higher modes were also observed in the experiments;

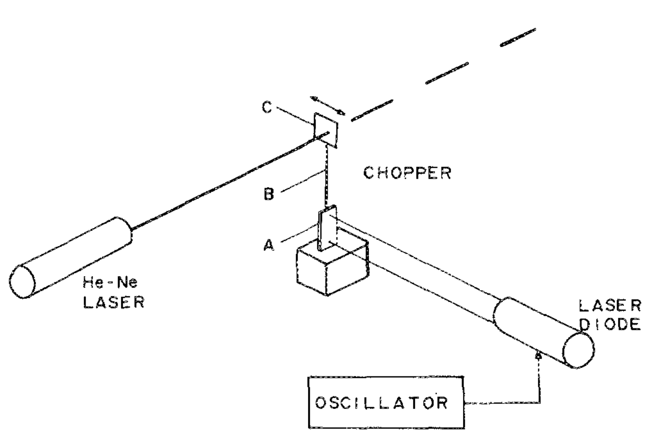

FIG. 1. Schematic diagram of the chopping system.

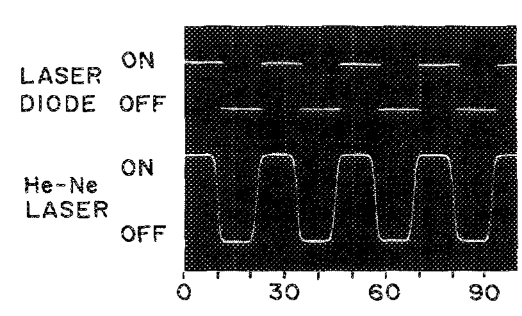

FIG. 2. Typical oscillogram of the chopped beams.

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however, sufficient amplitude for chopping the beam can be produced only at the first resonance mode.

Although the modulation frequency is limited only to the first resonance frequency with a narrow bandwidth defined by its mechanical property, the chopper is operated remotely without electric connecting wires and is free from lubricating oil which is used in a conventional chopper. Therefore, the chopper proposed can be especially useful for chopping an optical beam or a neutral molecular beam in the experiments carried out in a vacuum chamber and in an electrically shielded vessel.

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Discharge suppression system for a double focusing, atmospheric pressure ionization mass spectrometer

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An electrical discharge suppression system for a medium throughput (~2 l/s) pumping line has been devised that works up to potentials of ± 15 kV. This device permits atmospheric pressure ionization sources to be interfaced to high-resolution, magnetic sector mass spectrometers with source potentials of 6–10 kV.

Atmospheric pressure ionization (API) mass spectrometry is used to study trace constituents in air without sample concentration or separation prior to analysis.[1] Before we constructed our source, API mass spectrometry had generally been limited to quadrupole instruments that, at best, provide only unit resolution.[1-3] High-performance, magnetic sector mass spectrometers operate with source potentials in the kilovolt range where arcing between an API source and grounded surfaces along connecting gas lines can disrupt operation, damage electronic components, and expose human operators to the hazard of a high-voltage shock.

The specific problems associated with electrical discharges through gas lines connected to a chemical ionization (CI) source in a high-resolution mass spectrometer are known[4]; they relate in all but one respect to the circumstances associated with using an API source in such an instrument, the exception being that the throughput of gas in the main pumping line of an API source is about 1000 times greater than that in the sample introduction line of a CI source. We have devised an electrical discharge suppression system for a medium throughput (~2 l/s) pumping line that overcomes this problem. Our discharge suppression system has permitted us to operate a VG 7070E-HF mass spectrometer in an API mode at a resolution of 4800 (10% valley) at m/z 92[5]; this capability has, for example, already allowed us to assign molecular formulas to at least two, previously unresolvable photo-oxidation products of toluene generated in an irradiated smog chamber.[6]

Figure 1 is a schematic diagram of a corona discharge API source. The corona region, where ions are formed, is normally at atmospheric pressure, and the differentially pumped region, the so-called collisionally induced dissociation (CID) region, separating the corona region from the mass analyzer is maintained at ~1 Torr. Therefore, during operation, the pressure within the pumping line falls from ~1 Torr in the CID region to ~0.05 Torr at the head of the pump. As in the case of CI, the conditions along such a gas line are ideal for glow discharges, particularly in the pressure range 0.1–0.3 Torr.[4]

The conditions under which gases in the pressure range of 10^{-2} to 1 Torr conduct electricity have been characterized.[7-9] Such discharges are avalanche phenomena; their initiation occurs in accordance with Paschen's law, which states that the breakdown potential V_B of a gas between two electrodes is a function of the product of the gas pressure and the electrode separation.[8] Accordingly, for a given pressure

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