Two photon spectroscopy— Stepladder to the laser

A combination of laser and microwave radiation produces a spectroscope of great power and flexibility for the study of molecules.

Spectroscopy has been called the "fingerprinting of matter". Dr. Takeshi Oka of the National Research Council's Herzberg Institute of Astrophysics has recently perfected a technique which greatly increases the accuracy and sensitivity of this important probe of nature. By combining radiation from laser and microwave sources in a Two Photon Spectroscope he has made possible the accurate investigation of the vibrations and rotations of small molecules.

The pattern of lines, which constitutes a spectrum, is characteristic of the particular molecule involved and may therefore be used in its identification. Knowledge of its spectrum permits the presence of a molecule to be detected in laboratory specimens or, by examination of the radiation reaching the earth, in planetary atmospheres, comets or interstellar space. Since the spectral lines are sensitive to a molecule's environment, it becomes possible, by examining the appearance and shift in position of these lines, to deduce the physical properties of the environment and the chemical reactions in which the molecule is involved.

A molecule which has absorbed energy is said to be in an excited state, or to have undergone a transition to a higher energy level. This excited state may involve, for example, vibrations or rotations of the molecule and even some internal rearrangement of its constituent atoms. Since each of these processes is associated with a definite quantity of energy, an accurate knowledge of molecular energy levels gives scientists valuable information concerning the structure and behavior of molecules.

Spectroscopy provides measurements of the energy, in the form of electromagnetic radiation, necessary for molecular excitations and furnishes information on the particular energy levels involved by recording the frequencies at which this radiation is absorbed. However, the radiation source employed in conventional spectroscopic instruments possesses a stability and intensity which does not meet the rigorous needs of today's scientists. With the advent of the laser, spectroscopy was supplied with a radiation source of exceptional power and stability making it possible to perform experiments with hitherto unexpected accuracy. Despite these advantages, the laser exhibits a drawback to spectroscopists in that its radiation is emitted at a single frequency. For a given molecule, it becomes a matter of chance whether this frequency coincides with any of the molecular transitions. As Dr. Oka expresses it, "the infrared laser is a beautiful radiation source, intense, monochromatic and stable, but its frequency is just not tuneable."

In the visible radiation region, the development of tunable dye lasers has made laser radiation available over a range of frequencies. Dr. Oka, however, who studies the vibrations of molecules, requires variable radiation in the infrared region for which no tuneable machine is available. "Laser experts are working on this problem but we just could not afford to wait," he recalls. The problem, as seen by Dr. Oka, was to exploit the advantages of the laser and at the same time overcome the inflexibility of its single frequency. But how could he adapt this single frequency to cover a range of molecular energies? "It's rather like trying to reach something on a shelf but you can't quite make it. Then someone hands you a ladder and your reach is more flexible," he says.

In addition to accommodating conventional observational astronomy using visible light, the new Canada-France-Hawaii telescope (model shown here) is capable of observations in the infrared region of the spectrum. Astronomical observations of the infrared spectrum of ammonia in interstellar dust clouds may be correlated with Dr. Oka's terresterially-based measurements to provide valuable information about the nature of our universe.

Tout en permettant de faire des observations traditionnelles dans le visible, le nouveau télescope Canada-France-Hawaii (dont on peut voir un modèle ici) se prête aux observations dans l'infrarouge. L'ammoniac se trouvant dans les nuages de poussières interstellaires peut être observé dans l'infrarouge et les résultats obtenus peuvent être comparés aux mesures faites en laboratoire par le Dr Oka pour obtenir des renseignements intéressants sur la nature de l'univers.

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