1-1. Measurement and Evaluation of Photochemical Processes

Overview

The development of short laser pulses has significantly contributed to improving the temporal resolution for detecting photochemical processes. Today, a temporal resolution of 10^{-15} seconds can be applied relatively easily, enabling the tracking of reactions within a molecular vibration period. Furthermore, measurements with attosecond resolution are now possible. For the space-resolved measurements, fluorescence detection at the single-molecule level has been established as a super-resolution technique.

Current Status and Frontiers

The development of short laser pulses has significantly contributed to improving the temporal resolution of direct detection for photochemical processes. Research using stable femtosecond lasers is now commonplace, enabling reaction tracking within one molecular vibration period. While limited to specific systems and targets, measurements with attosecond resolution are also achievable. Research employing various time-resolved methods has also been performed for spectroscopic measurements such as Raman, IR, ESR and so forth, leading to a more detailed elucidation of photochemical processes. As a technique enabling more direct detection of molecular or crystal structures, time-resolved X-ray diffraction is also applied. For photochemical reactions occurring at surfaces or interfaces, measurements combining femtosecond lasers with probe microscopes such as STM are also being conducted.

Meanwhile, measurements of single-molecule fluorescence began several decades ago and have now become a major research area. These methods have provided insights into the evolution of individual molecules that were unobservable with conventional bulk measurements, enabling the experimental verification of fundamental issues in quantum and statistical mechanics, such as spectral uniformity/heterogeneity widths. The development of fluorescent dyes with excellent properties over the past several decades also contributes to single-molecule measurements and super-resolution fluorescence imaging.

The following sections of 1-1 cover these methods and subjects based on laser-matter interactions, providing an overview and future projections.

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