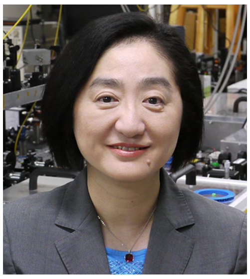
【Grant-in-Aid for Scientific Research (S)】

Broad Section D



Title of Project : Material evaluation technology that is opened up by spectroscopy principle based on the direct acquisition of optical response function

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Keyword : Optical frequency comb, Dual-comb spectroscopy, Optical phase control, Time-space characteristic

【Purpose and Background of the Research】

In recent years, a various type of materials has been developed. Knowing their properties in detail is not only interesting as basic science, but also important for their application. However, some of them have non-uniform and dynamical properties, therefore, it is difficult to evaluate them with a single property or a simple model. With existing technology, methodologies are often specialized for each property, thus it is necessary to change configurations each time, which prevents simultaneity and consistency among multiple properties. Moreover, evaluating properties with both high resolution and over a wide range is difficult. Therefore, it is highly demanded to establish new direct and comprehensive evaluation method.

In this study, in order to solve the issues above, we aim to develop a method to directly elucidate various material properties by direct acquisition of the optical response. In particularly, we aim to create a spectroscopic technique to acquire comprehensive properties with high speed, high accuracy, wide range, and multimodality. Thereby, we aim to establish the scientific principle of spectroscopy that has the wide applicability for various materials (Figure 1).

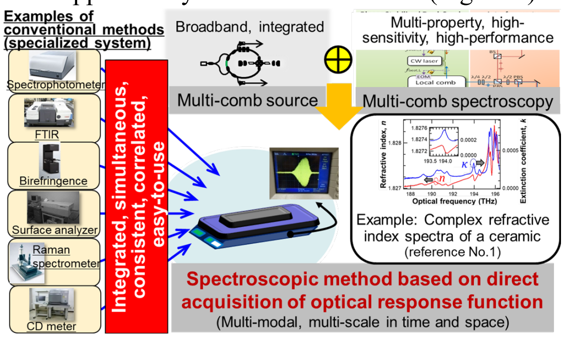

Figure 1. Concept of the spectroscopic technology

【Research Methods】

In this study, to achieve the above-mentioned objectives, we introduce a rapidly emerging technology for control and manipulate light waves with high accuracy and flexibility to the material evaluation technique. By comprehensively analyzing the electric fields waveform of optical pulses, material properties can be obtained as the input and output responses thereof. For this purpose, we utilize an optical frequency comb as a key technology, that have a precisely equally spaced comb-shaped spectrum and, at the same time, is a precisely controlled ultrashort optical pulse train.

In particular, we will develop an original principle, so-called "optical spectral network analyzer", which is a technique to directly obtain the electric field waveform of optical pulse in several hundred THz region based on a multi-heterodyne detection using a dual-comb spectroscopy with two different combs. Specifically, we will develop a practical comb source technology in various wavelength region, a technique that precisely and dynamically controls and manipulates a mutual coherence of multiple ultrashort optical pulse trains, and then a high-performance spectroscopic technique. Furthermore, by applying this new principle of spectroscopy to material properties evaluation, we will develop a technique that has "three multiples"; multiple properties and functions simultaneously; multiple time-scale from ultrafast to long-term; and multiple space scale from microscopic to macroscopic. Finally, we will develop a basic technology to integrate a comb source and spectroscopic system, and will establish the fundamental knowledge of spectroscopy.

【Expected Research Achievements and Scientific Significance】

This study aims to solve issues that exist in conventional techniques by utilizing fundamental principle of spectroscopy based on the nature of the interaction between the light and materials. Thus it is expected to bring broad impact for material science and application fields in future. For example, this technique could provide a comprehensive rapid first step evaluation method in material study, similar to the blood test in a medical examination. Furthermore, by accumulating a variety of material information, this is expected to contribute to new devices development utilizing Big Data and AI. The spectroscopic technology to be developed could provide fundamental tools not only in material evaluation, but for a broad science and technology fields such as a various sensing technology for Society 5.0.

【Publications Relevant to the Project】

· A. Asahara, A. Nishiyama, S. Yoshida, K. Kondo, Y. Nakajima, K. Minoshima, Dual-comb spectroscopy for rapid characterization of complex optical properties of solids, *Opt. Lett.* 41, pp. 4971-4974 (2016).
· A. Asahara, K. Minoshima, Development of ultrafast time-resolved dual-comb spectroscopy, *APL Photonics* 2, pp. 041301-1-6 (2017).

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