1. PHD PROJECT DESCRIPTION (4000 characters max., including the aims and work plan)

1. Project goals

In the field of chemical physics, clarifying the details of chemical reactions such as elementary processes and reaction rate is a significant issue. The optical frequency comb-based spectroscopy has possibility of unraveling many unknown chemical reaction processes. The optical frequency comb is a laser having a broadband spectrum which consists of narrow modes with same interval. Thanks to the spectral property, comb-based spectrometers realize high resolution and accuracy, and broadband measurement range which are far superior to conventional spectrometers. In this project, I will develop a mid-infrared frequency comb-based time-resolved spectroscopy system aiming to apply the research of chemical reaction processes.

2. Work plan

Since a mid-infrared frequency comb (2.5-4.6 um) [1] has been built in the host laboratory, the project starts from developing the comb-based spectroscopic system. As the comb-based spectroscopy, we will build Fourier-transform spectroscopy (FTS) or virtually phased imaged array (VIPA) spectrometer depending on acquired budget.3

Comb-based FTS - The inexpensive FTS setup is constructed from a simple Michelson interferometer. Using special data processing [2], obtained spectra realize high frequency resolution and accuracy of comb modes by removing instrumental line shape functions of FTS system. Furthermore, the high spectral brightness and spatial and temporal coherence of the comb allow high signal-to-noise ratios in recording times orders of magnitude shorter than conventional FTS.

VIPA - The VIPA is a plate with high-reflective coatings on both sides [3]. After the VIPA which is placed with a small angle, the comb modes are separated in the vertical direction. A conventional diffraction grating separate vertically overlapped comb modes to horizontal direction, and then we can obtain a picture of completely resolved comb modes by a CCD camera. The VIPA spectrometer also achieve high frequency resolution and accuracy because the frequency of each spot is determined by the comb mode frequency.

Time-resolved spectroscopy system is developed based on the comb-based spectrometer. An ultra-violet (UV) pulse laser which starts chemical reaction will be installed to the host laboratory. The timing of the UV pulses and data acquisition with photo detector in FTS [4] (or CCD camera in VIPA system [5]) are controlled using a pulse generator. The experimental environments including the pulse generator operation are constructed using Labview program.

Simple photo dissociation processes such as fragmentation process of NH_2 radical will be the first target of time-resolved measurement. Formation processes of formamid (NH_2CHO) which is an interstellar molecule and important in the field of astronomy can be also investigated.

3. Required initial knowledge and skills of the PhD candidate

Basic knowledge of optics and spectroscopy is needed. Basic programing skill is better to have.

4. Expected development of the PhD candidate's knowledge and skills

Knowledge of laser physics to operate the system, quantum chemistry to analyze molecular spectra. Skills of programming to construct experimental setup and to analyze data.

5. Literature

1. F. Adler, et. al., Opt. Lett. **34**, 1330 (2009).
2. P. Maslowski, et al., Phys Rev A **93**, 021802 (2016).
3. S. A. Diddams, et. al., Nature **445**, 627 (2007).
4. E. L. Woodbridge, et al., J. Chem. Phys. 94, 4195 (1991).
5. B. J. Bjork, et. al., Science **354**, 444 (2016).