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

Broad Section B

Title of Project： Establishment of high resolution laser spectroscopy in the vacuum ultraviolet region and its application to laser cooling of anti-hydrogen

KATSURAGAWA Masayuki

(University of Electro-Communications, Graduate School of Informatics and Engineering, Professor)

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Keyword：single frequency tunable laser, vacuum ultraviolet wavelength region, high resolution laser spectroscopy

【Purpose and Background of the Research】

Optical science has developed inextricably with development of extreme laser technologies. Almost all of areas regarding the extreme laser technologies appear to have been explored. However, if we look closely at the whole area, we realize that there are areas of laser technology that remain completely unexplored even today, although nearly 60 years have passed after the invention of laser. The single frequency tunable laser technology in the vacuum ultraviolet region (Frontier in Fig. 1) will be one of them.

The primary goal of this research project is to construct the vuv single-frequency tunable laser technology at an application level. We also aim to establish high resolution laser spectroscopy in the vuv on the basis of such laser technology, which may also enable to construct a quantitative scenario for laser cooling of anti-hydrogen atom.

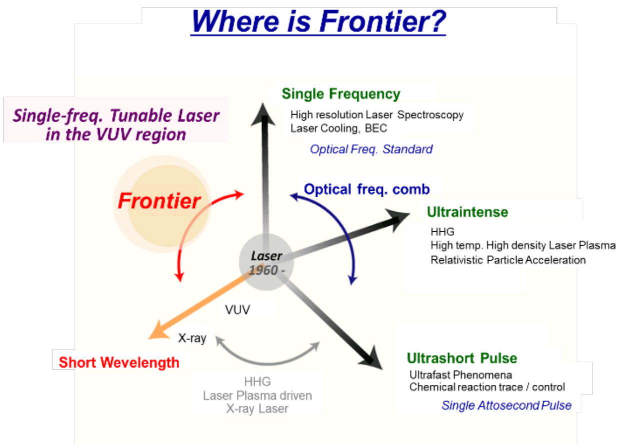

Figure 1. A variety of research fields in optical science complementary evolving to development of the extreme laser technologies.

【Research Methods】

We found that nonlinear wavelength conversions with quantum efficiency of unity can be achieved by incorporating artificial controls of optical phases in the nonlinear optical processes. So far, we have developed its theoretical framework and performed the corresponding proof-of-principle experiment. In this research project, we apply these achievements to higher-order stimulated Raman scatterings in gaseous para-hydrogen to realize a practical single-frequency, tunable laser in the vuv wavelength region. We also construct a scenario for the laser cooling of anti-hydrogen on the basis of experiments using atomic hydrogen as a test medium, where Lyman alpha transition (121.6 nm) is employed as the cooling transition.

【Expected Research Achievements and Scientific Significance】

The vacuum ultraviolet is a wavelength region where light and matter interaction is extremely strong. Establishment of the vuv single-frequency tunable laser as a practical technology will naturally pave the way to high-resolution laser spectroscopy in the vuv, which will also open a variety of frontiers in optical science, such as study of fundamental symmetries including gravity through the complementary high resolution laser spectroscopy of the laser cooled hydrogen and anti-hydrogen, study of future frequency-standard by using the nuclear transition (149 nm) in Thorium, and so on.

【Publications Relevant to the Project】

- T. Suzuki, M. Hirai, and M. Katsuragawa, Octave-spanning Raman comb with carrier envelope offset control, **Phys. Rev. Lett. 101**, 243602 (2008).　***Cover***
- J. Zheng and M. Katsuragawa, Freely designable optical frequency conversion in Raman-resonant four-wave-mixing process, **Scientific Reports 5**, 8874 (2015).
- M. Katsuragawa and K. Yoshii, Arbitrary manipulation of amplitude and phase of a set of highly discrete coherent spectra, **Phys. Rev. A**, 95, 033846 (2017).
- C. Ohae, J. Zheng, K. Ito, M. Suzuki, K. Minoshima, and M. Katsuragawa, Tailored Raman-resonant four-wave-mixing process, **Optics Express**, **26**, 1452 (2018).

【Term of Project】 FY2020-2024

【Budget Allocation】 112,800 Thousand Yen

【Homepage Address and Other Contact Information】

katsuragawa@uec.ac.jp