Plasma Quantum Processes

Organized Session: Nov. 9th, 9:00am - 11:30am & 6:15pm – 6:45pm (JST)

Scope and aim of the organized session:

Spectra of electromagnetic emission and absorption due to quantum interactions between electrons, ions, atoms, and molecules in plasmas (excitation, ionization, recombination, dissociation, chemical reaction, etc.) provide vital clues to elucidate species and states of the plasma particles, their temperature and density, velocity fields, and electromagnetic fields in plasmas. Also, the microscopic quantum interactions between the plasma constituents and the radiation and electromagnetic fields of the plasmas may result in development of macroscopic structures of the plasmas.

The Plasma Quantum Processes unit will be launched in NIFS to promote and accelerate joint research in Japan and overseas on atomic and molecular processes in plasmas and development of plasma spectroscopy, theory, simulation, and modeling with the aid of detailed atomic and molecular processes. The unit also aims to create new research fields through interdisciplinary collaborations on atomic and molecular process research and database development. These will be performed by forming a research center network with universities and institutions.

This organized session aims to present academic plans for our unit, and to discuss prospects of our future. The session consists of three parts. In the first part, our unit theme and academic plans will be presented by Prof. Izumi Murakami (NIFS). Then, a main issue of our research subjects: development of collisional radiative model for non-LTE plasmas and atomic and molecular databases, will be discussed in detail by Dr. Yuri Ralchenko (NIST, USA). In the last part devoted to discussions for prospects of emerging collaborations, three relevant invited talks on highly charged ion physics and spectroscopy by Prof. Nobuyuki Nakamura (ILS/UEC), high-power laser matter interaction by Prof. Yasuhiro Kuramitsu (Osaka Univ), and muon catalyzed fusion by Prof. Yasushi Kino (Tohoku Univ), will be presented.

Plans for invited talks:

- Dr. Yuri Ralchenko, National Institute of Standards and Technology (USA)
  (45+10min)
  Although historically plasmas were primarily associated with classical physics, it was soon found that quantum processes play a crucial role in such important phenomena as, e.g., plasma radiation, behavior of non-ideal plasmas, and interactions of electromagnetic fields with plasmas. I will present an overview of the most advanced technique for determination of light emission from diverse plasmas, namely, the collisional-radiative modeling [1], that involves calculation of large amounts of high-quality atomic data for various radiative, non-radiative, and collisional processes in plasmas. I will also describe the recent trends in development of atomic databases, in particular, the critically evaluated databases for atomic structure and spectra [2].
  [1] See, e.g., Modern Methods in Collisional-Radiative Modeling of Plasmas, edited by Yu. Ralchenko (Springer, New York, 2016).
  [2] URL https://www.nist.gov/pml/atomic-spectroscopy-databases.

- Prof. Nobuyuki Nakamura, The University of Electro-Communications
  (25+5 min)
  An electron beam ion trap (EBIT), consisting of a Penning-like ion trap and a quasi-mono energetic electron beam traveling through the trap, is a highly useful device for studying atomic processes of highly charged ions relevant to plasmas. At the University of Electro-Communications in Tokyo, we have been using two complementary EBITs, a high-energy device called the Tokyo-EBIT, and a compact and low-energy device called CoBIT, for studying processes over a wide range of parameters. In this talk, recent studies relevant to solar corona and fusion plasmas are presented after a brief introduction of the devices.
  [1] Priti et al., Phys. Rev. A 102 (2020) 042818. https://doi.org/10.1103/PhysRevA.102.042818
  [2] N. Nakamura et al., ApJ 921 (2021) 115. https://doi.org/10.3847/1538-4357/ac1c6f

- Prof. Yasuhiro Kuramitsu, Osaka University
  (25+5 min)
  Recent development of ultra-intense laser technologies opened up a new regime of laser plasma science such as relativistic electron and other quantum beam generations. However, it is still difficult to generate relativistic ions; the highest proton energy has not reach 100 MeV yet. In this talk our recent efforts on energetic ion acceleration using graphene will be presented. Graphene is a single atomic layer thick, two-dimensional material made of hexagonal carbon lattice. We have developed large-area suspended graphene (LSG) as a target of laser-driven ion acceleration, and have conducted a series of experiments with LSG. We discuss unique features of graphene ion acceleration and a path to the relativistic ion acceleration.
  [1] Y. Kuramitsu et al., Sci. Rep. 12 (2022) 2346. https://doi.org/10.1038/s41598-022-06055-4

- Prof. Yasushi Kino, Tohoku University
  (25+5 min)
  A muon is an elementally particle simar to an electron, and can strongly squeeze the distance between hydrogen nuclei forming a muonic molecule in which nuclear fusion reaction occurs because of the 207 times heavier mass than an electron. The cyclic processes including this intermolecular nuclear reaction is called the muon catalyzed fusion (μCF). We proposed and demonstrated a new kinetics model of μCF [1] considering resonant muonic molecules by a newly developed quantum few-body theory. The new kinetics model reproduces experimental observations, showing higher cycle rates as the temperature increases, over a wide range of target temperatures (T<800 K) and tritium concentrations. We are planning to experimentally confirm the new model and to utilize it for new fusion reactor designs.
  [1] T. Yamashita, Y. Kino, et al., Sci. Rep. 12 (2022) 6393.
  https://doi.org/10.1038/s41598-022-09487-0

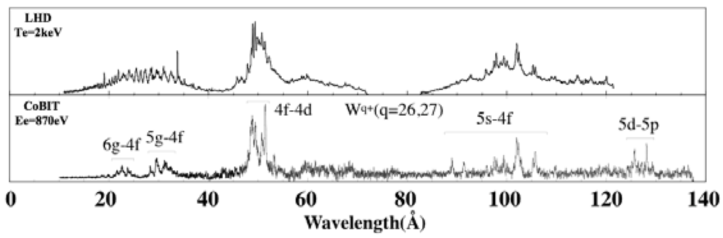

Figure 1. Tungsten spectra measured with Large Helical Device (LHD) and compact Electron Beam Ion Trap (CoBIT) for extreme ultraviolet wavelength range.

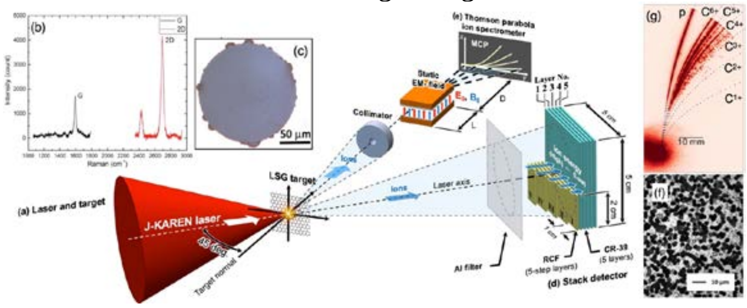

Figure 2. Relativistic ion acceleration by irradiating large area suspended graphene with an ultra-intense laser.

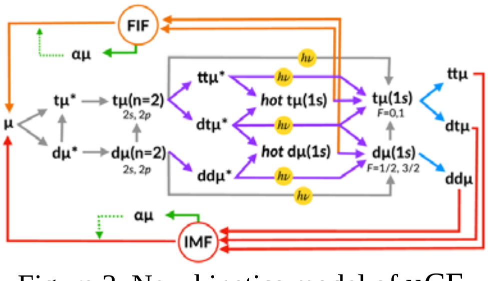

Figure 3. New kinetics model of μCF.