

## Ultrashort Electron Beam Science RIKEN-Hakubi Research Team (2022)

RIKEN Hakubi team leader: Yuya Morimoto (Ph.D.)



### (0) Research fields

CPR Subcommittee: Chemistry

**Keywords:** ultrashort electron beam, electron beam imaging, nonlinear optics, attosecond science, atomic collisions

### (1) Long-term goal of laboratory and research background

Electron beams are used for example in electron microscopy and electron-beam lithography, where high spatial resolution is required. By using state-of-the-art laser and electron-beam technologies, we aim at controlling the temporal structure of an electron beam with ultimate attosecond resolution (attosecond = one quintillionth of a second) and applying the controlled electron beams for imaging and controlling ultrafast chemical reactions. We explore the atomic-scale dynamics of electrons in a material which is the initial step of most photochemical reactions.

### (2) Current research activities (FY2022) and plan

The Ultrashort Electron Beam Science RIKEN-Hakubi research team was just established in October 2021. In FY2022, we continued to prepare for experimental research, such as construction of the laboratory and design and assembly of equipment. The number of laboratory members increased from one to three. Following is an achievement which was published in FY2022.

#### Measurement of few-cycle laser waveforms by electron beam

Ultrashort laser pulses in which the electric field oscillates only a few times in a pulse (hereafter referred to as few-cycle pulses) are used in various research fields, such as attosecond laser light generation, particle accelerators, and petahertz electronics. In those research fields, it is important to precisely measure the electric-field waveform of a few-cycle pulse on a sample.

We have developed a new measurement method using an electron beam. Electrons have an electric charge and respond linearly to the electromagnetic field of laser light. To mediate the interaction between the electrons and the laser beam, we placed a nanometer-thick film on which the electron beam and the laser beam intersect. Electrons passing through the thin film fly in different directions (called deflection or streak), depending on the laser waveform at the moment of passage. We have succeeded in obtaining the waveform of the few-cycle pulse by analyzing the image of the deflected electron beam. By combining this method with electron microscopy, we succeeded in observing the laser waveform at each point on the sample with spatial resolution comparable to the wavelength of the light.

In the field of ultrafast laser science, it is known that the measurement of temporal shapes of ultrashort pulses requires a nonlinear optical process or a probe pulse that is shorter than the pulse being measured. However, the method using electron beams developed in this study uses a perfectly linear process and does not require an ultrashort probe pulse. Thus, we have developed a method that overturns the common belief in the field of ultrafast laser science.

***Future plan.*** we continue to develop electron-beam and laser equipment so that experimental studies using pulsed electron beams can be performed as soon as possible. We will also employ the novel method described above to perform experiments that will enable us to observe the response of micron- and nanometer-sized materials to a few-cycle pulse.

### (3) Members

(RIKEN Hakubi team leader)

Yuya Morimoto

(Postdoctoral Researcher)

Yuichi Tachibana

Marie Ouillé

### (4) Representative research achievements

1. Y. Morimoto, B.-H. Chen, and P. Baum, "Free-electron tomography of few-cycle optical waveforms",

- Ann. Phys.** 534, 2200193 (2022).
2. Y. Morimoto, “Attosecond electron-beam technology: a review of recent progress”, **Microscopy**, 72, 2-14 (2023).
  3. 森本裕也, “解説：中赤外パルスを用いたアト秒電子ビーム制御”, **レーザー研究**, 50, 308-312 (2022) .
  4. 森本裕也, “アト秒電子パルスの発生と実時間物性計測の試み”, レーザー学会学術講演会第 43 回年次大会, 名古屋, 1 月 19 日, (2023). Invited talk.
  5. Y. Morimoto, “Generation of attosecond electron beams and the potential applications to electron-atom collisions”, 14th Asian International Seminar on Atomic and Molecular Physics virtual meeting, Online, February (2023). Invited talk.

**Laboratory Homepage**  
<https://epulse.riken.jp>