2018

Extreme-performance diagnostics in time-and-space for sources emitting terahertz transients for bio-medical examinations

［1］Organization

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［2］Research Progress

The research objective explores new methods of diagnostics, which could be applied for bio-medical examinations. A comprehensive understanding of the illuminating light source, optics, and detectors is especially important to bio-medical applications. The terahertz spectral and temporal signatures of bio-medical materials require an in-depth understanding to provide reliable and reproducible data, when medical diagnosis may lead to the discovery of severe illnesses and subsequent ethical issues.

A major part of this task is the development of terahertz micro-bolometers at Shizuoka University, which can be scaled in number and size to build optimized terahertz cameras.

The department of Accelerator Research at KIT is exploring new ways to detect short photon pulses consisting of terahertz transients, especially for new generations of electron accelerator-based sources envisioned to serve as light sources in materials and life sciences applications.

The collaborative research explores and develops new detection and imaging technologies in the terahertz range at RIE at Shizuoka University, to be employed at KIT for diagnostics of terahertz sources. While the accelerator and laser facilities at KIT are planned to provide substantial terahertz power, it can be envisioned to illuminate a larger number of pixels of a terahertz camera simultaneously and facilitate imaging with single terahertz pulses and thus bio-medical applications.

The short pulses in the time-domain and subsequently broad spectral coverage in the frequency-domain suggest that array technology with a pre-set splitting of spectral components by a grating or by filters or antennas directly mounted on each pixel element, similar to a filter bank, are suitable to enable multi-color spectral imaging and to facilitate bio-medical applications.

Dr. E. Bründermann, Karlsruhe Institute of Technology (KIT) and Prof. H. Inokawa, Assis. Prof. H. Satoh, Prof. J. Kondo and Prof. N. Hiromoto, Shizuoka Univ. (SU) had the Meeting for Cooperative Research Project at RIE on the research progress of “Extreme-performance diagnostics in time-and-space for sources emitting terahertz transients for bio-medical examinations”

on November 14, 2016 at Seminar room of the Graduate School of Science and Technology, SU. We discussed on the research targets of the collaboration between KIT and SU and also the future exchanges of researchers and students in this program under the Memorandum of Understanding (MOU) between KIT and SU.

［3］Results

（3－1）Research results

Within the research period E. Bründermann, H. Inokawa and N. Hiromoto in Shizuoka University, explore scientific concepts to detect and image terahertz transients and signatures. The efforts at KIT are under way to build up a suitable test environment for the detectors developed and pre-tested by the researchers at Shizuoka University. Several experiments [1-3, 5-7] and technology developments [1, 8] have been completed during the research period.

Novel optical components for the terahertz range have been developed [4] to enable cavity enhanced (CES) and cavity ring-down spectroscopy (CRD). CES and CRD methods are employed to detect ppm and ppt concentrations of molecules, e.g. for the analysis of human breath and medical diagnostics. The understanding of terahertz signatures progressed to distinguish different liquids [9] and materials [10].

For the purpose of a personal exchange E. Bründermann visited the Research Institute of Electronics during a JSPS Invitation Fellowship for Research in Japan, awarded by Japan Society for the Promotion of Science (JSPS) in 2016. During the visit the concepts of terahertz tomography were discussed and collaborators at Shizuoka University presented experiments and results on data acquisition and image reconstruction. In addition, novel metal thermistors based on platinum and titanium for terahertz microbolometers were discussed [11].

（3－2）Ripple effects and further developments

The collaborative work in this program is also governed by a Memorandum of Understanding (MOU) between Karlsruhe Institute of Technology (KIT), Germany, and Shizuoka University, Japan, including the Institute for Beam Physics and Technology (IBPT) and the Research Institute of Electronics (RIE). The MOU facilitates further exchange and collaboration.

［4］Achievements (List of Publications)

(1) M. Caselle, L.E. Ardila Perez, M. Balzer, A. Kopmann, L. Rota, M. Weber, M. Brosi, J. Steinmann, E. Bründermann*, A.-S. Müller, KAPTURE-2. A picosecond sampling system for individual THz pulses with high repetition rate, JINST 12, C01040 (2017). DOI: 10.1088/1748-0221/12/01/C01040

(2) J. L. Steinmann, E. Blomley, M. Brosi, E. Bründermann*, M. Caselle, J. L. Hesler, N. Hiller, B. Kehrer, Y.-L. Mathis, M.J. Nasse, J. Raasch, M. Schedler, P. Schönfeldt, M. Schuh, M. Schwarz, M. Siegel, N. Smale, M. Weber, A.-S. Müller, Frequency-comb spectrum of periodic-patterned signals, Phys. Rev. Lett. 117(37), 174802 (2016). DOI: 10.1103/PhysRevLett.117.174802

(3) M. Brosi, J. L. Steinmann, E. Blomley, E. Bründermann*, M. Caselle, N. Hiller, B. Kehrer, Y.-L. Mathis, M.J. Nasse, L. Rota, M. Schedler, P. Schönfeldt, M. Schuh, M. Schwarz, M. Weber, A.-S. Müller, Fast mapping of terahertz bursting thresholds and characteristics at synchrotron light sources, Phys. Rev. Accel. Beams 19, 110701 (2016). DOI: 10.1103/PhysRevAccelBeams.19.110701, Editors' Suggestion at Phys. Rev. Accel. Beams

(4) P. Balzerowski, E. Bründermann*, M. Havenith, Fabry-Pérot cavities for the terahertz spectral range based on high reflectivity multilayer mirrors, IEEE Trans. THz Sci. Technol. 6(4), 563-567(2016). DOI: 10.1109/TTHZ.2016.2572361

(5) B. Kehrer, E. Blomley, M. Brosi, E. Bründermann*, N. Hiller, A.-S. Müller, M. Nasse, M. Schedler, M. Schuh, P. Schönfeldt, P. Schütze, N. Smale, J. Steinmann, Simultaneous Detection of Longitudinal and Transverse Bunch Signals at ANKA, Int. Particle Accelerator Conf. (IPAC2016), 109-111 (2016).

(6) M. Brosi, E. Blomley, E. Bründermann*, N. Hiller, B. Kehrer, A.-S. Müller, M. Schedler, M. Schuh, P. Schönfeldt, J.L. Steinmann, Systematic Studies of Short Bunch-Length Bursting at ANKA, Int. Particle Accelerator Conf. (IPAC2016), 1662-1665 (2016).

(7) J. L. Steinmann, E. Blomley, M. Brosi, E. Bründermann*, M. Caselle, N. Hiller, B. Kehrer,

A.-S. Müller, M. Schedler, P. Schönfeldt, M. Schuh, M. Schwarz, M. Siegel, Influence of Filling Pattern Structure on Synchrotron Radiation Spectrum at ANKA, Int. Particle Accelerator Conf. (IPAC2016), 2855-2857 (2016).
(8) A. Schmid, M. Brosi, E. Bründermann*, K. Ilin, B. Kehrer, A. Kuzmin, S. Kuznetsov, A.-S. Müller, J. Raasch, M. Schuh, P. Schönfeldt, M. Siegel, J. L. Steinmann, S. Wünsch, Single-Shot Spectral Analysis of Synchrotron Radiation in THz Regime at ANKA, Int. Particle Accelerator Conf. (IPAC2016), 115-117 (2016).
(9) T. Q. Luong, Y. Xu, E. Bründermann*, D. M. Leitner, M. Havenith, Hydrophobic collapse induces changes in the collective protein and hydration low frequency modes, Chemical Physics Letters 651, 1-7 (2016). DOI: 10.1016/j.cplett.2016.02.036
(10) N. Hiromoto, K. Mori and J. Sato, "Study on Material-Classification of Objects Detected by the THz Passive Body Scanner for Security Screening," 41st Int'l Conf. Infrared, Millimeter and Terahertz Waves (IRMMW-THz 2016), (Bella Center, Copenhagen), T5P.03.01 (September 2016).
(11) A. Banerjee, H. Satoh, A. Tiwari, C. Apriono, E.T. Rahardjo, N. Hiromoto, H. Inokawa, Width Dependence of Platinum and Titanium Thermistor Characteristics for Application in Room-Temperature Antenna-Coupled Terahertz Microbolometer, 2016 Int. Conf. on Solid State Devices and Materials, PS-2-12, Tsukuba, September 2016