THz-driven quantum phase transition

Chih-Wei Luo[1,2,3*]

[1]*Department of Electrophysics, National Yang Ming Chiao Tung University, Hsinchu, Taiwan*
[2]*Institute of Physics and Center for Emergent Functional Matter Science, National Yang Ming Chiao Tung University, Hsinchu, Taiwan*
[3]*National Synchrotron Radiation Research Center, Hsinchu, Taiwan*

* Presenter:Chih-Wei Luo, email:cwluoep@nycu.edu.tw

The intense THz sources with electric fields strength up to MV/cm-level have been developed and used to drive the quantum phases and collective excitation, such as phonons, magnons (collective spin excitations), etc., in materials due to the resonant frequencies of these excitations in the THz region. The dynamics induced by the intense THz pulses can be further monitored by various spectroscopic (e.g., THz-TDS, ARPES, etc.) and microscopic (e.g., AFM, STM, TEM, etc.) techniques. In this talk, I will first introduce the mechanism of quantum phases in materials driven by THz fields. Then, some examples will demonstrate the THz-driven quantum phase transition. For instance, one can use an intense circularly polarized THz electric field to resonantly drive the infrared-active soft phonon mode in $SrTiO3$ and provide experimental evidence of room-temperature magnetization [M. Basini et al., Nature 628, 534 (2024)], which show a new avenue for ultrafast controlling magnetism by coherently manipulating the phonons with the THz fields.

Keywords: Intense THz, Quantum phase transition, THz-driven, Coherent manipulation

THz Spectroscopy, a tool for exploring electrical and structural properties of materials

HYE YOUNG AHN[1*]

[1]*Department of Photonics, National Yang Ming Chiao Tung University, Hsinchu, Taiwan*

* Presenter:HYE YOUNG AHN, email:hyahn@mail.nctu.edu.tw

Terahertz time-domain spectroscopy (THz-TDS) is a phase sensitive analysis technique for characterization of optical and electrical properties of nearly any type of materials and their nanostructures. Owing to the low photon energy compared to optical light sources, THz waves can also be used to investigate the intermolecular bonding and crystalline nature of materials. In this talk, I will review our group's recent work and demonstrate the practical applications of THz spectroscopy. Through the THz spectroscopic analysis, we found that environmental and chemical instabilities in perovskites can be greatly improved when coupled with ultrathin transparent conductive electrodes such as graphene and two-dimensional transition metal dichalcogenide layers. We also utilized THz-TDS to investigate the conducting-insulating transition near percolation threshold of nanostructured materials and the crystalline quality of ultrathin metal films.

Keywords: nanostructured fabrications and characterizations, homogeneous and heterogeneous materials, low-dimensional semiconductors

Developments and applications of ESR apparatus using a millimeter-wave band high power light source gyrotron

Ishikawa Yuya[1*], Ohmichi Eiji[2], Ito Takero[1], Keisuke Kawagita[1], Takahashi Hideyuki[3], Ohta Hitoshi[1,4], Yoshinori Tatematsu[1], Fujii Yutaka[1]

[1] *Research Center for Development of Far-Infrared Region, University of Fukui, Fukui, Japan*
[2] *Graduate School of Science, Kobe University, Kobe, Japan*
[3] *Technoassist Co. Ltd., Technoassist Co. Ltd, Ishinomaki, Japan*
[4] *Molecular Photoscience Research Center, Kobe University, Kobe, Japan*

* Presenter:Ishikawa Yuya, email:ishikawa@fir.u-fukui.ac.jp

We have developed an Electron Spin Resonance (ESR) system using a millimeter-wave band high power light source gyrotron. The frequency range in which ESR apparatus is possible to 108-394 GHz. Using a mechanism with a Force Detection (FD) system, we succeeded in detecting the ESR signal of DPPH, which is known as a stable radical, at 108-206 GHz at 293 K and 295-394 GHz at 13 K. This system is applicable to condensed matter physics, and practical examples of its use in spintronics and other fields will be presented.

Keywords: Electron Spin Resonance, Spintronics, Low temperature, High magnetic field

Advances in High-power Terahertz Radiation Source Gyrotron and Its Potential Applications

Masafumi Fukunari[1*], Yoshinori Tatematsu[1], Yuusuke Yamaguchi[1]

[1] *Research Center for Development of Far-Infrared Region, University of Fukui, Fukui, Japan*

* Presenter:Masafumi Fukunari, email:fukunari@fir.u-fukui.ac.jp

Gyrotrons are high-power and coherent radiation sources in the millimeter-wave to terahertz (THz) frequency range. The development of gyrotrons has diverged into two main directions. One direction focuses on the development of megawatt-class high-power gyrotrons for nuclear-fusion plasma heating. The other direction involves the development of medium-power, high-frequency gyrotrons. The high-frequency gyrotrons operating in the THz region are expected to have a wide range of potential applications, particularly in spectroscopic applications, such as electron spin resonance (ESR) and nuclear magnetic resonance with a signal enhancement through dynamic nuclear polarization (DNP-NMR). The Research Center for Development of Far-Infrared Region at the University of Fukui (FIR-UF) has developed high-frequency gyrotrons with innovative features, such as second harmonic oscillation, multi-frequency oscillation, Gaussian beam output, and continuous frequency tuning. In Gyrotron FU CW XA, continuous frequency tuning over 1 GHz was achieved in different operation modes. This gyrotron is a demountable axial output gyrotron developed for testing cavity resonators. Gyrotron FU CW GV is a multi-frequency gyrotron with Gaussian beam output, capable of stepwise frequency modulation from 162 GHz to 265 GHz in increments of approximately 10 GHz. The output power reaches 1 kW for each mode in pulse operation. Gyrotron FU CW GVII is a multi-frequency gyrotron with second harmonic oscillations. We successfully observed 20 different mode oscillations in Gyrotron FU CW GVII, including fundamental oscillations from 115 GHz to 422 GHz. In addition, we have conducted high-power THz beam shaping using a phase correction mirror. We recently achieved one kW-class optical vortex generation at 0.265 THz by using Gyrotron FU CW GV as a radiation source.

Keywords: Gyrotron, Vacuum tube, Terahertz, DNP-NMR, ESR

Development of coherent THz sources at NSRRC

Ming-Chang Chou[1*], An-Ping Lee[1], Wei-Yuan Chiang[1], Hsin-Pai Hsueh[1], Yi-Chien Chang[1], Nuan-Ya Huang[2], Wai-Keung Lau[1]

[1]*Linac group, NSRRC, Hsinchu, Taiwan*
[2]*Beam Dynamics group, NSRRC, Hsinchu, Taiwan*

* Presenter:Ming-Chang Chou, email:chou.mc@nsrrc.org.tw

Development of accelerator-based coherent THz radiation sources has been studied with the use of the high brightness photo-injector installed in the Accelerator Test Area at NSRRC. Based on the velocity bunching technique the ultrashort electron beams can be produced from the photo-injector which is composed of a laser-driven photocathode rf gun and a s-band traveling-wave linac. THz coherent transition radiation (CTR) generated by passing the ultrashort electron beam through a metallic foil is used for bunch length measurement by autocorrelation technique. Currently the bunch length of the electron beam with beam energy of 27 MeV and bunch charge of 280 pC is measured to be 240 fs with linac field of 12.5 MV/m. Intense narrow-band superradiant THz radiation with pulse energy of 20 μJ/pulse and tunable central frequency from 0.6 to 1.4 THz can be obtained by injecting such ultrashort beam into a U100 gap tunable planar undulator. The detail of the photo-injector system and generation of coherent THz sources i

Keywords: THz source, coherent transition radiation, superradiant, free electron laser, photo-injector

Probing the chemical pressure-induced topological order in $SrCd_2(As_{1-x}Sb_x)_2$ by terahertz emission spectroscopy

Ying-Kuan Ko[1], Xin-Yun Chang[1], Hung-Viet Khuc[2], Yu-Sheng Kuo[2], Yen-Chieh Lee[2], Yue Shi[3], Jiun-Haw Chu[3], Cheng-Chien Chen[4], Chih-Wei Luo[1], Jiunn-Yuan Lin[2], Chien-Ming Tu[1,5,6*]

[1]*Department of Electrophysics, National Yang Ming Chiao Tung University, Hsinchu, Taiwan*
[2]*Institute of Physics, National Yang Ming Chiao Tung University, Hsinchu, Taiwan*
[3]*Department of Physics, University of Washington, Seattle, WA, USA*
[4]*Department of Physics, University of Alabama at Birmingham, Birmingham, AL, USA*
[5]*Undergraduate Degree Program of Systems Engineering and Technology, National Yang Ming Chiao Tung University, Hsinchu, Taiwan*
[6]*Chung Cheng Institute of Technology, National Defense University, Taoyuan, Taiwan*

* Presenter:Chien-Ming Tu, email:cmtu@nycu.edu.tw

Topological materials exhibiting symmetry-protected surface states have recently attracted attention due to its unique physical properties and potential novel applications in optoelectronics, spintronics and quantum computing. $SrCd_2As_2$ is one kind of Zintl compounds and shows a narrow band gap under ambient conditions. Recently, with density function theory calculations, $SrCd_2As_2$ has been predicted to show band inversion and a pair of Dirac points under negative pressure. Introducing chemical pressure is alternative way to realize negative pressure in lattice by substitution of arsenic atoms with larger size atoms. On the other hand, terahertz emission spectroscopy has been demonstrated to study topological states by circular photogalvanic effect in topological insulators and Wely semimetals. In the study, we report helicity-dependent THz emission measurements on $SrCd_2(As_{1-x}Sb_x)_2$ single crystals. This technique provides a contact-free method to study spin-polarized photocurrent from topological surface states by changing the helicity/polarization of optical pulses. Our results agree with theoretical calculations and indicate a chemical pressure-induced topological phase existing in $SrCd_2(As_{1-x}Sb_x)_2$. Besides, we also perform two-color optical pump-optical probe (OPOP) measurements on $SrCd_2(As_{1-x}Sb_x)_2$ single crystals at various temperatures. The details of the OPOP results will be discussed in this talk.

Keywords: Novel quantum material , Terahertz emission spectroscopy, Light-matter coupling