

Osaka – Austin Exchange Program Workshop

Abstracts from Osaka participants

Introduction of Exchange Program between OPU and UT

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Having financial support for Support Program for Improving Graduate School Education from MEXT (the Ministry of Education, Culture, Sports, Science & Technology, Japan), we have launched a new educational program for graduate students starting from 2008 for the period of three years, which was named as Heterogeneous Education Program for Graduate Students. Through this program, PhD students will be exposed more in international academic experiences and disciplines. The program also contains Rikyu-science lectureship*, which allows PhD students to give lectures at outside universities. Among the program, we have Graduate Student Exchange Program in which PhD students will stay at OPU and/or UT for 3 to 6 months to be disciplined. All the costs for accommodations and travel fees are fully covered by OPU. In addition to the student exchange program, we have a guest professor program in which we invite a guest professor to OPU for a month to give a series of lecture and to make the cooperation proceed. We hope that this exchange program may be a good opportunity to make a good partnership between OPU and UT, and to forward mutual understandings and reciprocal relations from the point of view of their scientific research and their teaching systems.

*This lectureship is organized for commemorating Sen no Rikyu (1522-1591) who accomplished Japanese celebrated tea ceremony that was originated from China. He was born in the merchant city of Sakai where OPU is located.

Electric-field control of THz wave from coherent LO phonon in GaAs multiple quantum well

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In our group, we investigate the optical properties of condensed matter as following subjects: syntheses of new optical materials with new functions, the interaction of light with condensed matter by optical spectroscopy, ultrafast phenomena in condensed matter, and quantum optics for quantum entanglement. Concerning the study of the ultrafast phenomena, we energetically investigate coherent phonons, coupling of coherent phonons to excitons or electrons, and THz radiation in semimetals, semiconductors, multiple quantum wells and superlattices. In this workshop, we present the characteristics of terahertz (THz) waves emitted from coherent longitudinal optical (LO) phonons in a GaAs/AlAs multiple quantum well (MQW) structure under an applied

electric field. It is found that the intensity of the THz wave from the coherent LO phonon is resonantly enhanced in comparison with the intensity in a low electric field region and its decay rate becomes faster, under the condition that an intersubband energy is tuned to the LO phonon energy of GaAs. This enhancement originates from the double resonances in the Raman scattering process. Under the resonant condition, moreover, the decay rate of the THz wave is proportional to the power density of the pump pulse. We discuss the decay process of the THz wave from the coherent LO phonon from the viewpoint of the spontaneous and stimulated emission of the coherent LO phonon at the excited state.

Some Research Results Obtained by Present Collaboration between UT and OPU:

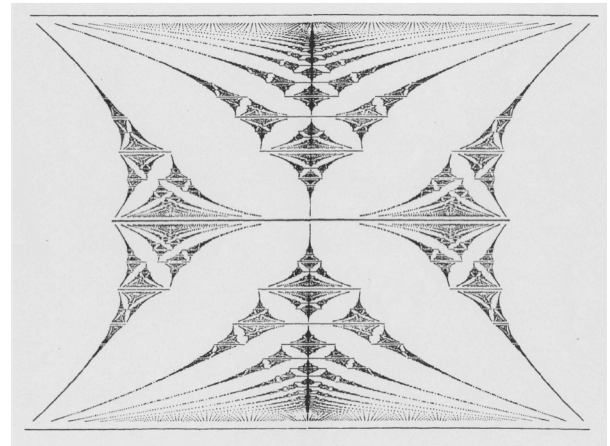
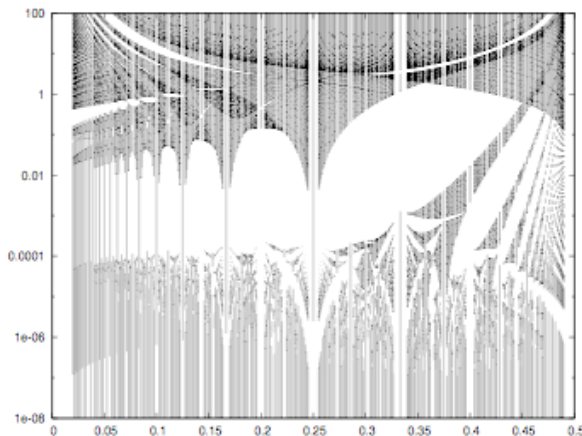
UT's longhorn Bevo vs. Hofstadter's butterfly

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Theoretical groups in statistical mechanics at UT and OPU have collaborated on an individual level in the last several years. This collaboration has led to several interesting results in transport properties in 1D protein chains as well as nano-devices. In this workshop we report an unexpected discovery in the spectrum of the collision operator for the quantum Boltzmann equation. Despite the fact that one deals with the 1D system and an irreversible process in the Boltzmann equation, its spectrum has quite a similar structure to the well-known Hofstadter's butterfly in the spectrum of the Hamiltonian for an electron in a 2D tight-binding model under a magnetic field in a reversible system. Indeed, the spectrum of the collision operator is completely different if the dimensionless width of the band energy of a vibron in the chain is a rational number or an irrational number. However, there appears a series of self-similar shapes of UT's longhorn Bevo (Fig.1) in the spectrum instead of Hofstadter's butterfly (Fig.2). The discovery reveals the fact that the entropy production in a protein chain is very complicated and rich as compared with the kinetic process in simple molecular systems.



Entangled photons from biexcitons in a semiconductor

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We investigate the entanglement between photon pairs generated from a biexciton in a semiconductor via resonant hyper-parametric scattering (RHPS) [1, 2]. The entanglement of photon pairs are created by exchange interaction between excitons which form biexciton (excitonic molecule). In other words, the entangled photons hold information of biexciton. Therefore, the entangled photons can be “probe” of excitons which have experienced interaction between each other. We also investigate exciton-photon coupling phenomena in a semiconductor microcavity. Large Rabi splitting was realized and the controllability of Rabi splitting was shown with a bulk CuCl microcavity [3]. The semiconductor microcavities are promising candidate for enhancement device of entangled photon generation.

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[3] G. Oohata, T. Nishioka, D. Kim, H. Ishihara, and M. Nakayama, *Phys. Rev. B* **78**, 233304/1-4 (2008)

Quantum Spin Magnetism in Organic Radical Crystals

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Organic radicals consisting only of light elements show the isotropic nature of electron spins because of the quenching of spin-orbit couplings. Such spin systems are expected to show novel quantum states. We have developed low-dimensional quantum spin systems using rational design of organic polyradicals. Both the sign and magnitude of magnetic exchange interactions are controllable in π -conjugated organic radical crystals. Our current interests are single-component ferrimagnets, spin ladders with various spin quantum numbers, frustrated spin systems and so on. For the ‘soft’ organic materials, pressure is also a powerful tool to control the magnetism. In this workshop, I present the magnetic properties of a quasi-two-dimensional $S = 1$ antiferromagnets F_2PNNNO . In applied magnetic fields, magnetization can have discrete values due to quantization of magnetization. The neutron diffraction measurements have revealed the spin redistribution by entanglement. A field-induced antiferromagnetic transition has been detected by NMR measurements in the field range 9.5 - 15.4 T, where the magnetization varies continuously. The staggered moment perpendicular to the field and the power-law

temperature dependence of the critical field indicate that the phase transition can be described as the Bose-Einstein condensation of triplet magnons.

Direct observation of gas molecules adsorbed on metal-organic framework by synchrotron powder diffraction and MEM/Rietveld method

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In our structural materials science group, we are doing crystal structure analysis of novel functional materials including accurate charge density analysis by synchrotron powder diffraction, in order to investigate their physical and chemical properties.

In this workshop, I present one of the topics on direct observation of gas molecules adsorbed in the nanochannels of metal-organic framework (MOF). MOF materials have perfectly ordered nanochannel structures and have very high gas adsorption property. To develop these materials as functional materials, structural information of gas molecules is indispensable. But they have not been revealed yet. We have succeeded in observation of adsorbed gas molecules by an *in-situ* powder diffraction experiment of gas adsorption using high brilliance synchrotron light source at SPring-8 and MEM (Maximum Entropy Method) /Rietveld charge density analysis. In oxygen adsorption on a MOF called CPL-1, molecular oxygen was found to be adsorbed in the nanochannels forming O₂-O₂ dimers with one-dimensional ladder structure ¹. They were considered to have an antiferromagnetic ground state from the magnetic susceptibility. The slightly higher Raman shift of O₂ stretching mode showed their state at ambient pressure compatible with that of solid phase at 2 GPa. The confinement effect and restricted geometry resulted specific molecular alignment. In the case of acetylene adsorption, acetylene molecules were found to be trapped by double hydrogen bonds with oxygen on the pore wall. Stable storage of acetylene with very high density is understood from the atomic level and electron density level structure ².

References

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