様式C-19

科学研究費補助金研究成果報告書

平成２１年５月１９日現在

研究種目：基盤研究（C）
研究期間：2005-2008
課題番号：１７５４０３５６
研究課題名（和文）アンダーソン局在とランダム系におけるレーザー発振の数値的研究

研究課題名（英文）Numerical simulations of Anderson localization and lazing in random systems

研究代表者
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研究成果の概要：Numerical simulations of the Anderson transition and Anderson localization in 3D, 2D and fractal systems were performed. We confirmed that the lower critical dimension of the Anderson transition for Hamiltonians with symplectic symmetry is less than two. We obtained a precise estimate of the critical exponent for the Anderson transition in the integer Quantum Hall Effect.

交付額

（金額単位：円）

	直接経費	間接経費	合　計
２００５年度	1,300,000	0	1,300,000
２００６年度	700,000	0	910,000
２００７年度	700,000	210,000	910,000
２００８年度	700,000	210,000	910,000
総　計	3,400,000	630,000	4,030,000

研究分野：数物系科学
科研費の分科・細目：物理学・数理物理・物性基礎
キーワード：Anderson Localisation

１．研究開始当初の背景

Transport in macroscopic conductors at room temperature is usually well described by the Boltzmann theory that treats the electrons as particles. However, at very low temperatures of the order of several Kelvin and below the electrical transport properties of disordered systems such as doped semiconductors and metallic glasses can no longer be explained within this framework. Under such conditions, the scale on which the motion of the electron is quantum mechanically coherent becomes longer than the length scales, such as the mean free path, that are important for classical transport and the wave-particle duality of the electron manifests itself in transport phenomena such as mesoscopic conductance fluctuations, weak localization, the solid state Aharonov-Bohm effect, Anderson localization and the Anderson transition. The effects of disorder can also be observed in disordered dielectrics. In particular, the phenomenon of random lazing is thought to result from the existence of anomalously localized states in these materials.

２．研究の目的

Our objective was to perform a theoretical investigation of interference phenomena in disordered materials. In particular, we wanted to investigate by numerical simulation the Anderson transition and Anderson localization in 3D, 2D and fractal systems. One particular focus of our research was the effects of the spin-orbit interaction on Anderson localization and the Anderson transition. Another focus was the simulation of the random lazing phenomena in disordered dielectrics.

３．研究の方法

Numerical simulations of Anderson localisation in 2D systems either with strong spin orbit interactions or subject to strong perpendicular magnetic fields were performed.

Numerical simulations of Anderson localisation in fractals (with spectral dimension slightly below 2) with strong spin orbit interaction were performed.

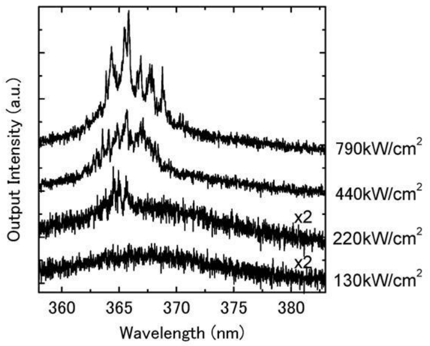
Numerical simulations of random lazing in GaN dielectrics were performed using the FDTD method.

４．研究成果

We simulated Anderson localization and the Anderson transition on the Sierpinski carpet. We performed a finite size scaling analysis of the statistics of both the Landauer two terminal conductance and the energy level spacings. We confirmed the occurrence of an Anderson transition on the SC(5,1) Sierpinski carpet and also estimated the critical exponent for the divergence of the localization length at the critical point. An exactly similar analysis for SC(3,1) did not reveal a transition. These studies confirmed that the lower critical dimension of the Anderson transition for Hamiltonians with symplectic symmetry is less than two.

We performed a very high precision numerical simulation of the Chalker-Coddington network model. Using a finite size scaling analysis, a precise estimate of the critical exponent for the Anderson transition in the Quantum Hall Effect was obtained. The same data were also used to check the scaling relation derived from the assumption of conformal invariance at the QHE critical point.

Tomi Ohtsuki collaborated with an experimental group at Sophia University. The group has grown columns of GaN, the diameter of which is a few micrometers. Irradiating the ensemble of columns with light, the group has found that some of the ensemble exhibit random lasing. We have calculated the propagation of light waves in random media, and determined the condition for random lasing. Below is the intensity of the light emission from GaN nanocolumns. When the input power is low ($130kW/cm^2$, $220kW/cm^2$), we do not observe strongly peaked emission. When the input power is strong enough ($440kW/cm^2$, $790kW/cm^2$), we observe strongly peaked emission at certain wavelengths, which can be attributed to random lasing.



５．主な発表論文等
（研究代表者、研究分担者及び連携研究者には下線）

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