Research Highlights

the Ministry of Internal Affairs and Communications (MIC), Japan (Research representative: Hitachi Kokusai Electric Inc.).

In this work, the NICT researchers developed a technology to transmit approximately 20-Gbit/s radio signals (16-QAM, carrier frequency of 7 GHz and sampling rate of 6 GHz) in the 90-GHz band from a central station to 50 remote radio stations using a switchable wavelength-division-multiplexing radio-over-fiber and mmWave wireless network. The switching of the remote radio stations in accordance with the movement of trains can be controlled from the central station, and a switching time of less than 10 µs was achieved using high-speed wavelength-tunable lasers.

"We demonstrated that the signal distribution to radio stations can be switched in less than 10 µs."

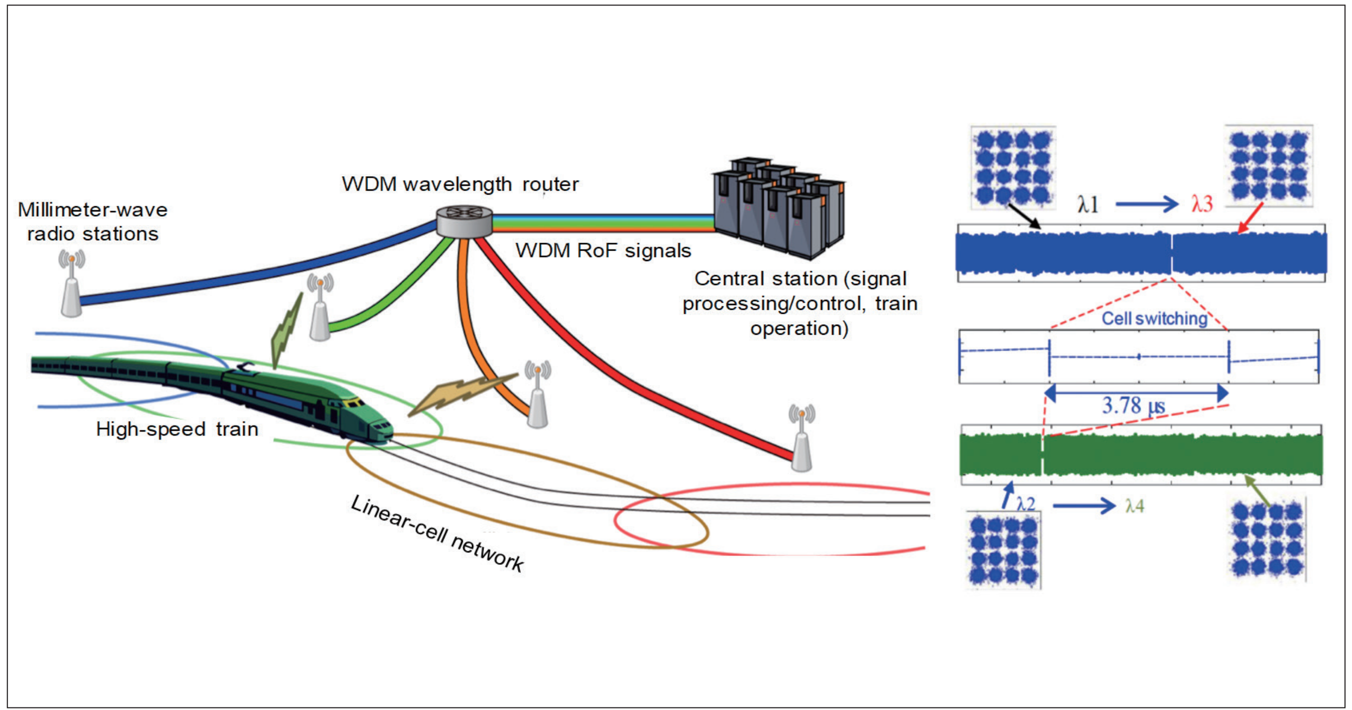
In high-speed railways, the radio stations that the trains are approaching can be precisely predicted using train information such as train location and velocity, which is available at the train operation center. Thus, appropriate signal distribution to the corresponding radio stations can be performed by means of high-speed optical switching technologies, such as high-speed wavelength-tunable lasers. Naokatsu Yamamoto, Director of the NSRI Network Science and Convergence Device Technology Laboratory, stated, "We demonstrated that the signal distribution to radio stations can be switched in less than 10 µs. This indicates that an uninterrupted communication system for high-speed railways can be constructed, even for trains moving at 500 km/h or faster."

Handover-free communication has faced a significant challenge in terms of avoiding significant degradation of the throughput of high-mobility users, which includes users on high-speed trains, due to the frequently interrupted connections with radio stations. With this network configuration, the development of an uninterrupted network for high-mobility users can be implemented in an easier way than in standard cellular networks because the necessary control signals are available at central stations.

Dr. Yamamoto further said, "In the future, in collaboration with Hitachi Kokusai Electric Inc., the Railway Technology Research Institute, the Electronic Navigation Research Institute (part of the National Institute of Maritime, Port and Aviation Technology Institute), and other related parties in the aforementioned MIC-funded project, we will implement field test demonstrations on actual railway lines."

Reference

Pham Tien Dat, Atsushi Kanno, Keizo Inagaki, Toshimasa Umezawa, Fançoir Rottenberg, Jérome Louveaux, Naokatsu Yamamoto, and Tetsuya Kawanishi, "High-Speed and Handover-Free Communications for High-Speed Trains Using Switched WDM Fiber–Wireless System," in Proc. 41st Optical Fiber Communication Conference and Exhibition (OFC), March 2018, paper Th4D. 2.



Conceptual diagram of the proposed communication system for high-speed railways (left) and radio station switching and performance of 16-QAM signals (right).

DEVELOP

Enhancing the energy controllability using strong interaction with photons

Observed huge Lamb shift shows potential of utilizing vacuum fluctuation in designing quantum circuit

The physics of extremely strong interaction between light and matter has not been well understood due to the lack of suitable experimental means. To find and understand new phenomena in this unexplored regime, a research group comprising Senior Researcher Fumiki Yoshihara, Senior Researcher Tomoko Fuse, and Executive Researcher Kouichi Semba of the NICT Advanced ICT Research Institute has been working on superconducting artificial atoms[*1] that can interact very strongly with an electromagnetic field mode in a resonator circuit. In 2016, they successfully implemented a new regime of very strong interactions between light and matter (deep-strong-coupling (DSC) regime), and became the first to demonstrate the existence of stable states molecule-like consisting of photons and artificial atoms.

In the DSC regime, interactions with just a single photon can cause tremendous changes in the energy levels of an artificial atom. Until now, there have been no reports of systematic experiments to explore phenomena (Lamb shift, Stark effect) in this regime.

In collaboration with NTT Corporation, Qatar Environment & Energy Research Institute, Tokyo Medical and Dental University, and Waseda University, this research group has become the first to successfully generate a very large energy change (optical shift) in artificial atoms interacting with photons. This experiment was conducted using the superconducting circuit shown in Fig.1. The superconducting artificial atoms (outlined in red) were prepared using microfabrication techniques. Artificial atoms have quantum properties equivalent to atoms, and can confine photons in the superconducting resonator circuit. New experiments using double resonance spectroscopy showed that the observable energy range became wider, and the team succeeded in observing a huge relative light shift about 100 times larger than in conventional experiments (Fig.2).

"The relative shift we observed is 6 orders of magnitude larger than that initially observed in the hydrogen atom."

The Lamb shift is caused by interactions with the vacuum electromagnetic field in resonator circuits. The effect was first discovered as a difference in the fine energy levels of hydrogen atoms. Since then, it has brought dramatic developments in quantum electrodynamics, and plays a key role in the sophisticated electronics technology supporting modern society. In the words of Kouichi Semba (Executive Researcher at the Frontier Research Laboratory), "The huge Lamb shift we observed this time is 6 orders of magnitude larger than the energy shift initially observed in the hydrogen atom, due to the effect of the zero point fluctuation current in the superconducting circuit. In this way, quantum technology using superconducting artificial atoms has lead to an era when it is necessary to change the idea in circuit design, to make use of the quantum fluctuation which was only a very small correction term in the past in a leading role"

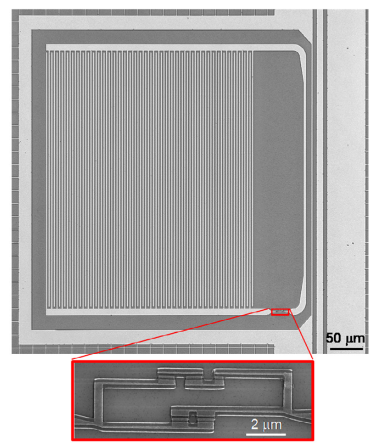


Fig.1 : The deep-strong-coupling circuit used in the experiments, consisting of an aluminum superconducting artificial atom (outlined in red) and an LC resonator circuit

It is expected that DSC physics could be exploited to control artificial atoms at high speed and to minimize the back action of quantum measurements, thus contributing to the progress of quantum technology.

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Footnote

***1 Superconducting artificial atom:** A quantum circuit made from a superconductor with discrete energy levels that resemble the line spectrum of a natural atom.

Reference

Physical Review Letters
DOI: https://doi.org/10.1103/PhysRevLett.120.183601
URL: https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.120.183601
Inversion of qubit energy levels in qubit-oscillator circuits in the deep-strong-coupling regime
F. Yoshihara, T. Fuse, Z. Ao, S. Ashhab, K. Kakuyanagi, S. Saito, T. Aoki, K. Koshino, and K. Semba

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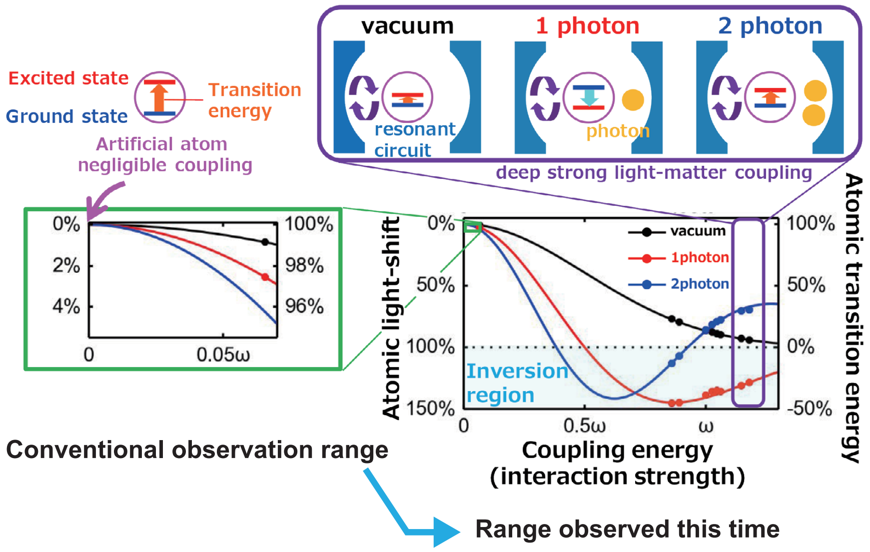


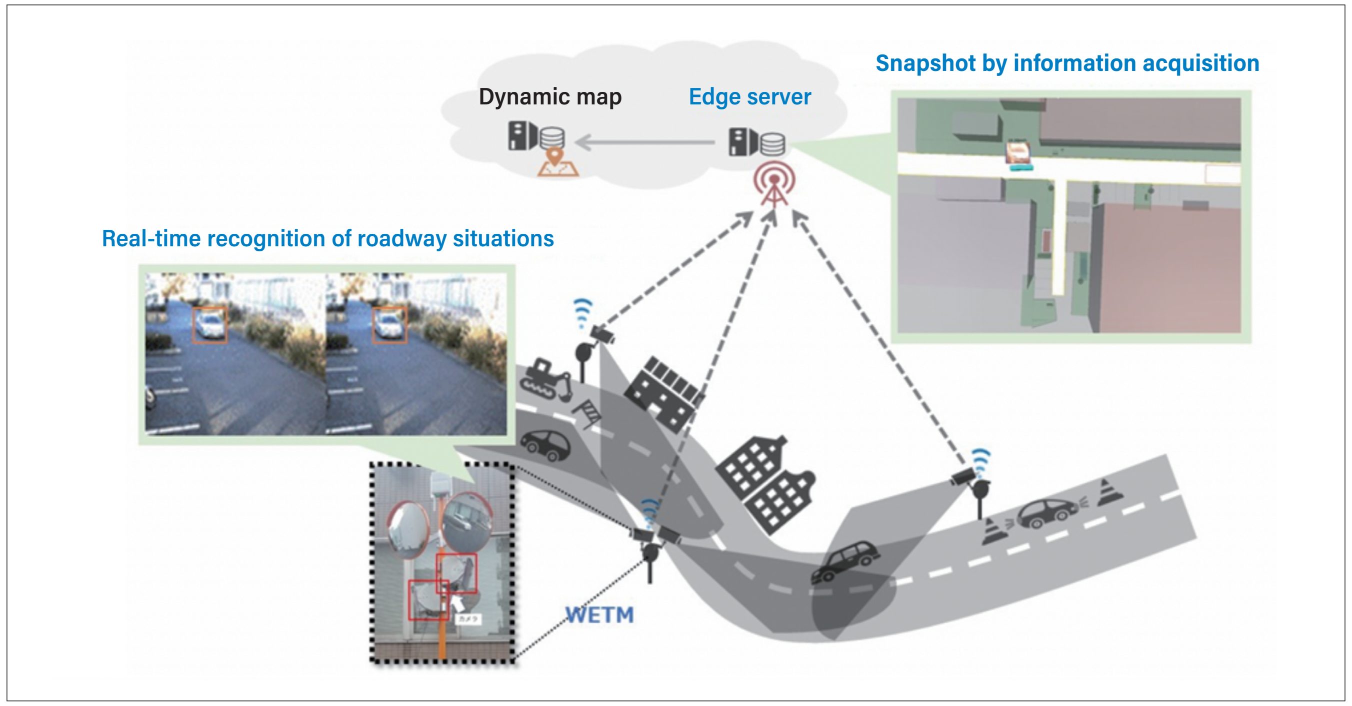
Fig.2 : Transition energy of an artificial atom with 0, 1, or 2 photons in the LC resonator circuit

CONNECT

Toward autonomous transport infrastructure utilizing 5G ultra-low latency

Real-time recognition of roadway situations by Wireless Electronic Traffic Mirror (WETM) built-in sensors

In the near future, the diverse autonomous mobilities of vehicles, drones, tractors, etc. are expected to become more popular, and a highly reliable intelligent transport infrastructure will be required to support safe autonomous movement. In addition, various mobilities may autonomously move in different road situations with combinations of congestion, construction, potential collisions, and so on. In order to achieve an autonomous transport system, the roadway situations need to be accurately grasped in real time. This necessitates the establishment of a roadway acquisition technology by which a large number of sensors with wireless communications can collect the road information and place it on a dynamic map to maintain the road information.



An overview of intelligent transport infrastructure.

For the establishment of a roadway acquisition technology, NICT Wireless System Research Center (WSRC) researchers built a test-bed intelligent transport infrastructure in Yokosuka Research Park (YRP) utilizing the 5th generation wireless communication system (5G) ultra-low latency to support autonomous mobility in the roadway environment as in the intersections.

"Under the test-bed infrastructure, we have confirmed that it is possible to grasp the roadway situations in real time."

In addition, they developed a Wireless Electronic Traffic Mirror (WETM) built-in camera and location measuring sensors that enable the collection of information on a variety of roadway situations such as road construction and vehicle congestion. This information is then reflected on a dynamic map (DM), which is a database maintaining the roadway information, and is transmitted to the autonomously moving vehicles, pedestrians, and so on.

Kentaro Ishizu, research manager of the WSRC Wireless System Laboratory, stated, "Under the test-bed infrastructure, we have confirmed that it is possible to grasp the roadway situations in real time, especially an area in the vicinity of an intersection with poor visibility. From these achievements, we expect to construct an intelligent transport infrastructure to avoid mobility collisions and to predict movement."

In the future, they will implement the 5G wireless communication system on the test-bed infrastructure and evaluate its performance with various wireless systems in different roadway conditions such as when a large number of moving objects is located on a roadway and the moving speed of each is different or the area is wide. Dr. Ishizu also said, "We will confirm the functional requirements to be aimed at establishing the technology to realize a more advanced autonomous transport system."

An apprerance of WETM