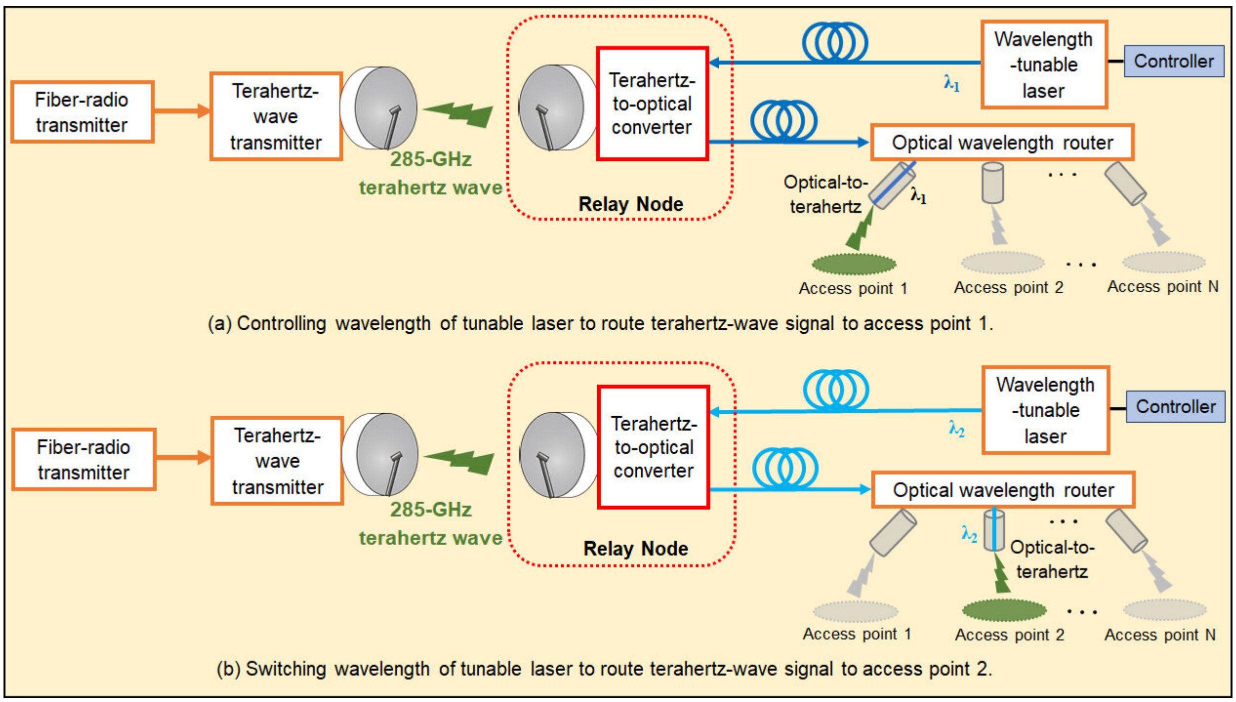
World's first demonstration of terahertz signal transparent relay and switching

June 6 2023



Concept of transparent relay and switching of terahertz-wave signals using direct terahertz–optical conversion and optical wavelength control. Credit: National Institute of Information and Communications Technology (NICT), Sumitomo Osaka Cement Co., Ltd., Nagoya Institute of Technology, and Waseda University

A team including researchers from the National Institute of Information and Communications Technology; Sumitomo Osaka Cement Co., Ltd.;

Nagoya Institute of Technology; and Waseda University has jointly developed the world's first system for the transparent relay, routing, and switching of high-speed terahertz-wave signals to different locations.

Direct conversion of a 32-Gb/s terahertz-wave signal in the 285-GHz band to an optical fiber and its transparent relay and switching to different access points in ultrashort time periods were successfully demonstrated.

The key technologies include a newly developed low-loss optical modulator for the direct conversion of terahertz-wave signals to optical signals and an adaptive fiber-wireless technology for the ultrafast switching of terahertz signals. The developed system overcomes the disadvantages of radio communications in the terahertz band, such as high free-space loss, weak penetration, and limited communication coverage, paving the way for the deployment of terahertz communications in beyond 5G and 6G networks.

The results of this demonstration were published as a post-deadline paper at the 2023 International Conference on Optical Fiber Communications (OFC 2023).

Terahertz background

Radio frequencies in the terahertz band are promising candidates for ultrahigh-data-rate communications in beyond 5G and 6G networks. A 160-GHz slot in the 275–450 GHz band was recently opened for mobile and fixed services. However, high free-space loss and weak penetration remain as bottlenecks, making it difficult to transmit signals over long distances, such as from outdoors to indoors or in environments with obstacles.

Transparent relay and routing of terahertz signals between different locations are crucial to overcoming these disadvantages and expanding communication coverage. However, these functions cannot be realized using current electronic technologies. In addition, the narrow beamwidth of terahertz signals makes it difficult to achieve uninterrupted communication when users are moving. Terahertz-signal switching between different directions and locations is crucial for maintaining communication with end users.

However, this critical issue has not yet been addressed using electronic or photonic technologies. It is also important to turn on and off the emission of terahertz signals at appropriate intervals to save energy and reduce interference.

Study achievements

In this study, the team demonstrated the first system for the transparent relay, routing, and switching of terahertz signals in the 285-GHz band utilizing two key technologies: (i) a newly developed low-loss optical modulator and (ii) an adaptive fiber–wireless technology using an ultrafast wavelength-tunable laser. In the system, terahertz signals are received and directly converted into optical signals using terahertz–optical conversion devices with low-loss optical modulators.

Lightwave signals from tunable lasers are input to the modulators, and wavelength routers are used to route the signals to different access points where specific wavelengths are assigned. At the access points, the modulated optical signals are converted back into terahertz signals using optical-terahertz converters. Terahertz signals can be switched to different access points by switching the wavelengths of the tunable lasers.

The tunable lasers can be independently controlled, and the number of access points that can simultaneously generate terahertz signals equals the number of active tunable lasers. Using the technologies developed in this study, the team successfully demonstrated the transparent relay and switching of terahertz signals in the 285-GHz band for the first time and achieved a transmission capacity of 32 Gb/s using a 4-quadrature amplitude modulation (QAM) orthogonal frequency division multiplexing (OFDM) signal.

The possibility of switching the terahertz-wave signals in less than 10 μs was evaluated, confirming that uninterrupted communication can be attained in the terahertz band.

The system consists of the following key element technologies:

- Direct conversion of terahertz signals to optical signals using a newly developed low-loss optical modulator. The team achieved this by performing Ti diffusion on the x-cut lithium niobate ($LiNbO_3$ thickness: ≤ 100 μm) in the low dielectric constant layer for operation up to 330 GHz.
- Ultrafast terahertz-signal switching by controlling the wavelengths of tunable lasers to route and distribute terahertz signals to different locations
- 4-QAM OFDM signal transmission

By transparently relaying and distributing terahertz signals to different locations, high free-space and penetration losses of radio signals in the terahertz band can be overcome, and communication coverage can be significantly extended. In addition, by promptly routing and switching the signals to different directions/locations, communication can be maintained even when obstacles occur and/or users are moving.

Furthermore, by turning on and off the emission of terahertz-wave signals from access points at appropriate intervals, energy savings and interference reduction can be achieved. These features render the proposed system a promising solution for overcoming the bottlenecks of terahertz-wave communications and paving the way for its deployment in beyond 5G and 6G networks.

In the future, the researchers will study the terahertz-optical conversion device and fiber-wireless technology developed in this study to further increase the radio frequency and transmission capacity. In addition, they will promote international standardization and social implementation activities related to fiber-wireless and terahertz-wave communication systems.

Provided by National Institute of Information and Communications Technology (NICT)

Citation: World's first demonstration of terahertz signal transparent relay and switching (2023, June 6) retrieved 19 April 2024 from
https://techxplore.com/news/2023-06-world-terahertz-transparent-relay.html