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Abstract: Demonstration of an obstacle-tolerant THz wireless link established by a self-healing Bessel beam at 300 GHz is introduced.

Purpose: Proposal of fixed self-healing THz wireless for discussion in future THz standardization.

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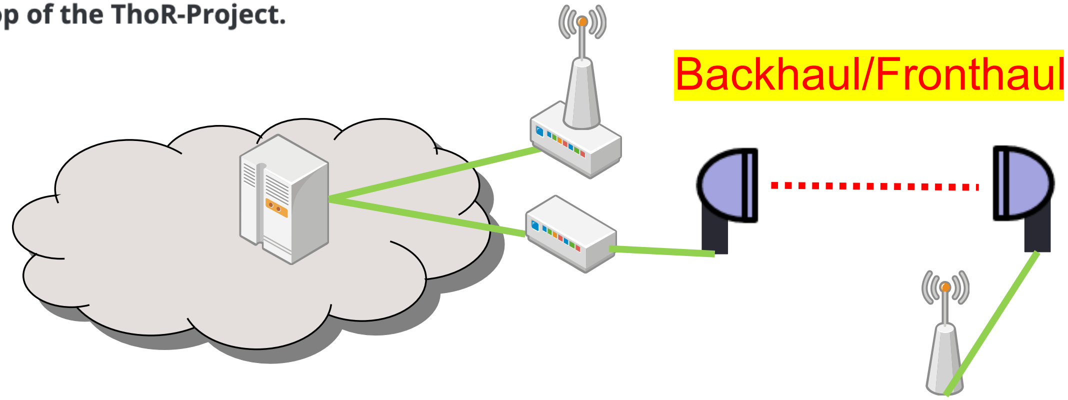
THz P2P communication

27. June 2022 | Press releases: Research

Milestone of THz communication

Bidirectional THz radio link will be presented in final workshop

Scientists from a project coordinated by Technische Universität Braunschweig in Germany and Waseda University in Japan with ten other partners from five countries have succeeded for the first time worldwide in developing a bidirectional THz radio link that can be connected as a "backhaul" to the data network of mobile radio providers. This link achieved by the Horizon Europe-funded ThoR project, can realise high data rates and thus play an important role in the network infrastructure of the future. On 29 and 30 June 2022, the THz radio link will be presented in a final workshop of the ThoR-Project.

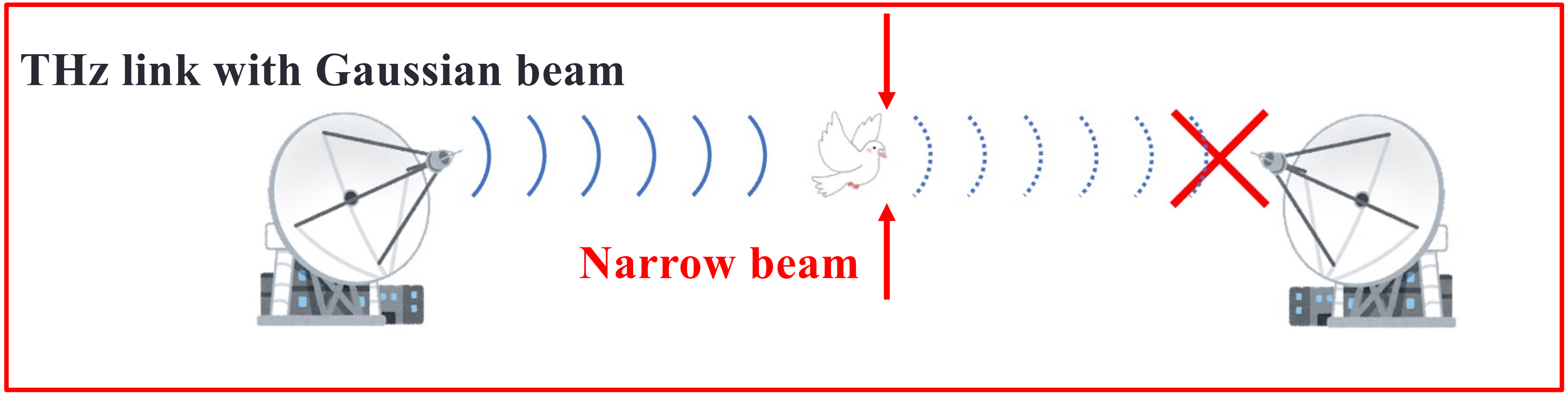


https://magazin.tu-braunschweig.de/en/pi-post/milestone-of-thz-communication/

- Real time, bi-directional @ 300 GHz
- 2X20 Gbps (2X4ch, 2.16 GHz/ch)
- Distance: 160 m
- Antenna gain > 50dBi

GIFU UNIVERSITY

Motivation

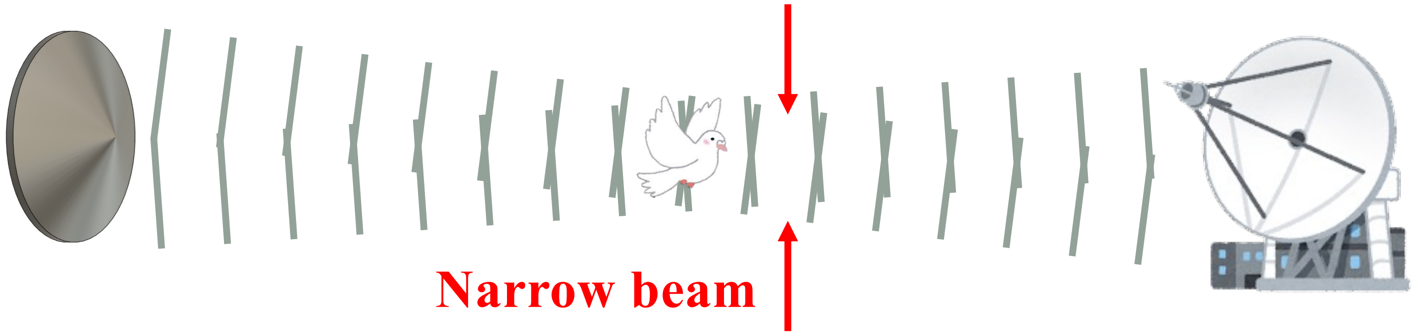


THz link is likely to be lost if an obstacle crosses the communication path (terahertz beam).

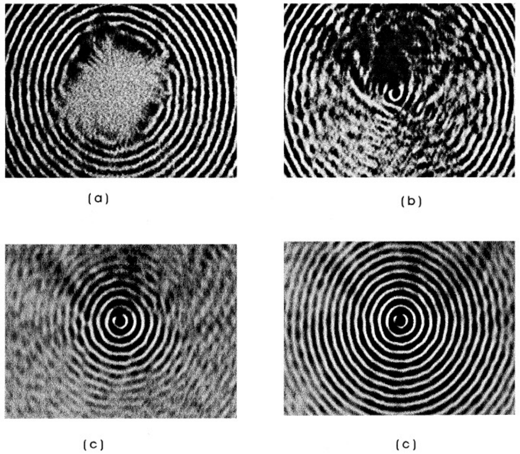
Obstacle-tolerant THz wireless link will be needed.

Approach

THZ link with Self-healing beam



Self-healing effect:



The distribution was perturbed immediately after the obstacle, but **the beam shape was reconstructed** after some distance.

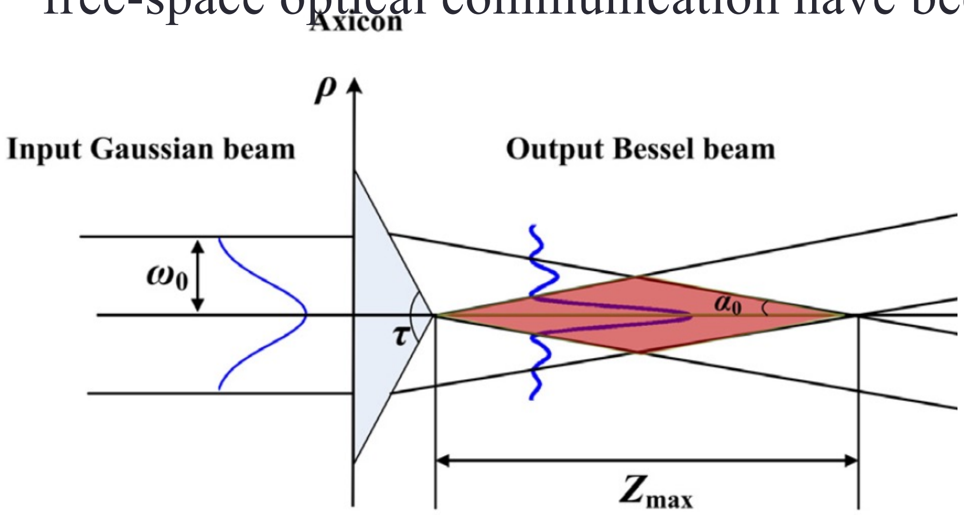
Distribution behind the obstacle.
(a)Z=0, (b)Z=Zmin/2,
(c)Z=Zmin , (d)Z=4Zmin.
Zmin : the length of the shadow zone behind the obstacle.

Z Bouchal, J Wagner, M Chlup, "Self-reconstruction of a distorted nondiffracting beam," Optics Communications, Volume 151, Issues 4–6, (1998).

Bessel beam

The nondiffracting effect was experimentally demonstrated at λ=632.8 nm with the Bessel beam in 1987.

Applications of the optical Bessel beam such as optical imaging, optical tweezers, and free-space optical communication have been extensively studied.



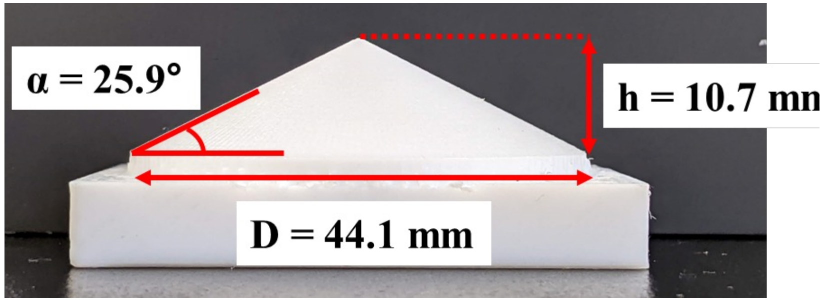
- The transverse intensity profile remains unchanged in free-space propagation.
- The transverse intensity profile of this beam can be described by the Bessel functions.

→**Usually called Bessel beam.**

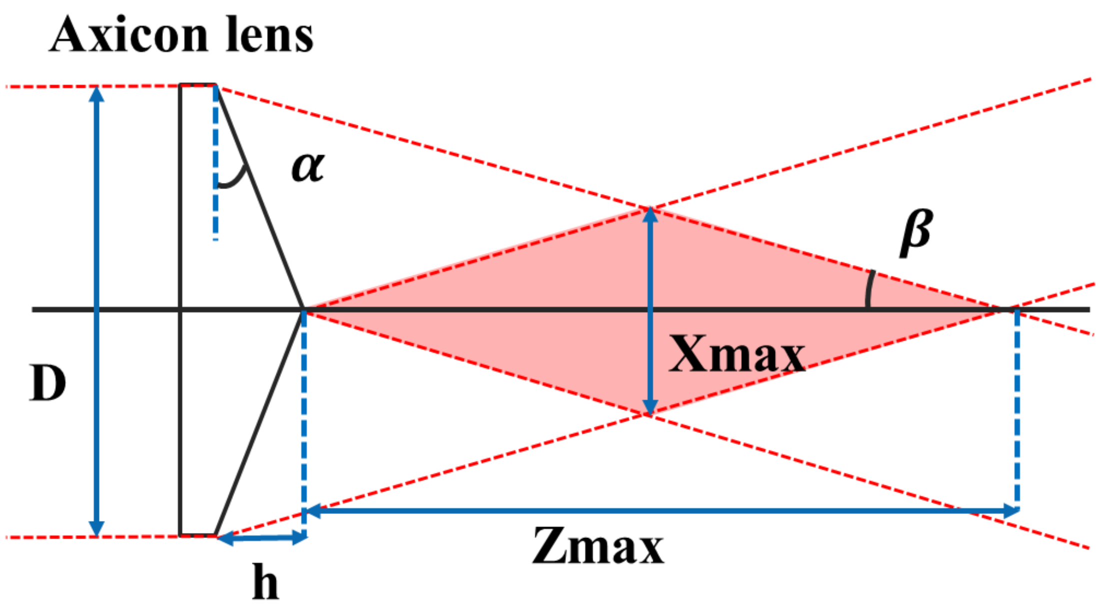
D. Wang et al, " Extended depth of field in continuous-wave terahertz computed tomography based on Bessel beam", Optics Communications, Volume 432, 2019.

Generation of the Bessel beam using Axicon lens

Dielectric axicon lens



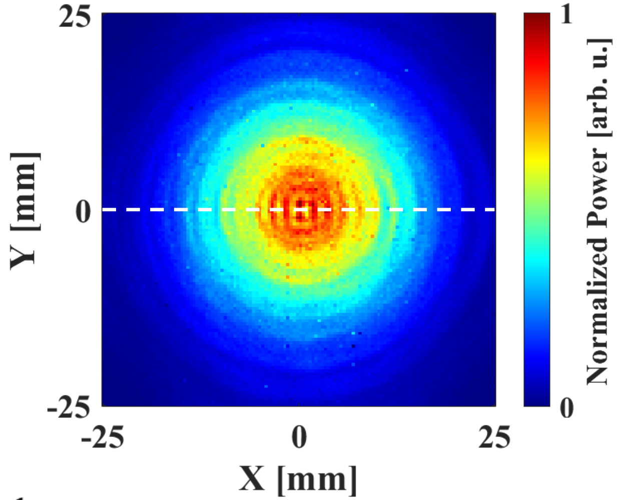
Polytetrafluoroethylene (PTFE)
with a relative permittivity ε_r of 2.0
and a loss tangent $tan\delta$ of 0.001 at 300 GHz.

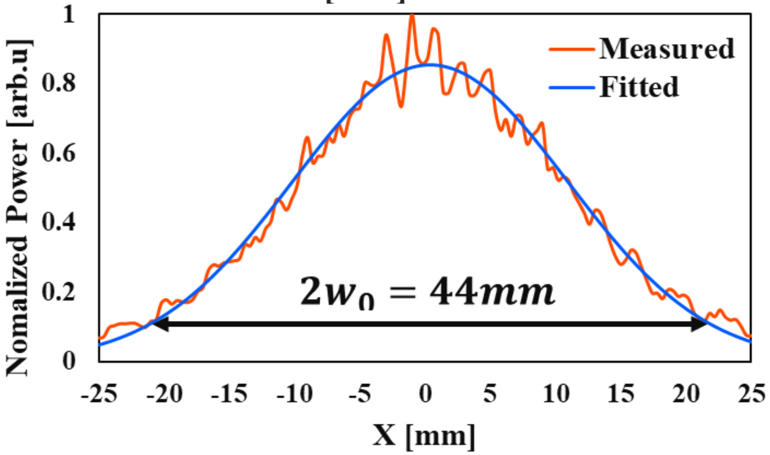


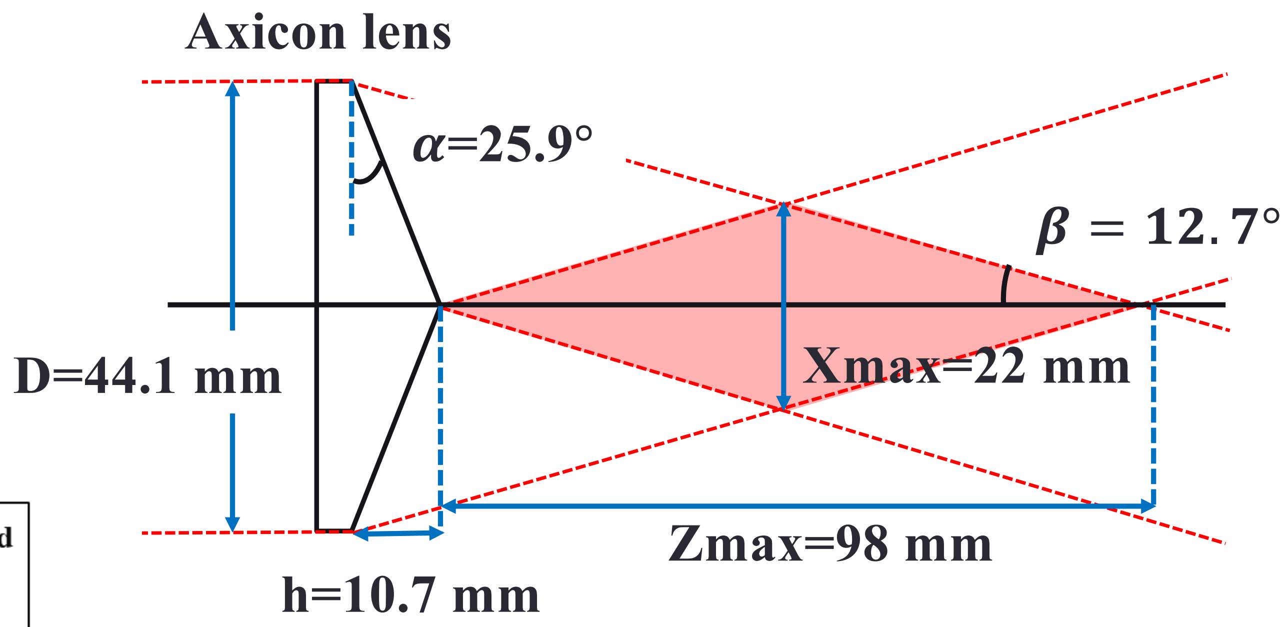
D：waist diameter of the incident Gaussian beam
α：inclination angle, β：semi-apex angle
Zmax：non-diffraction range, Xmax : non-diffraction width

Generation of the Bessel beam using Axicon lens

The incident Gaussian beam





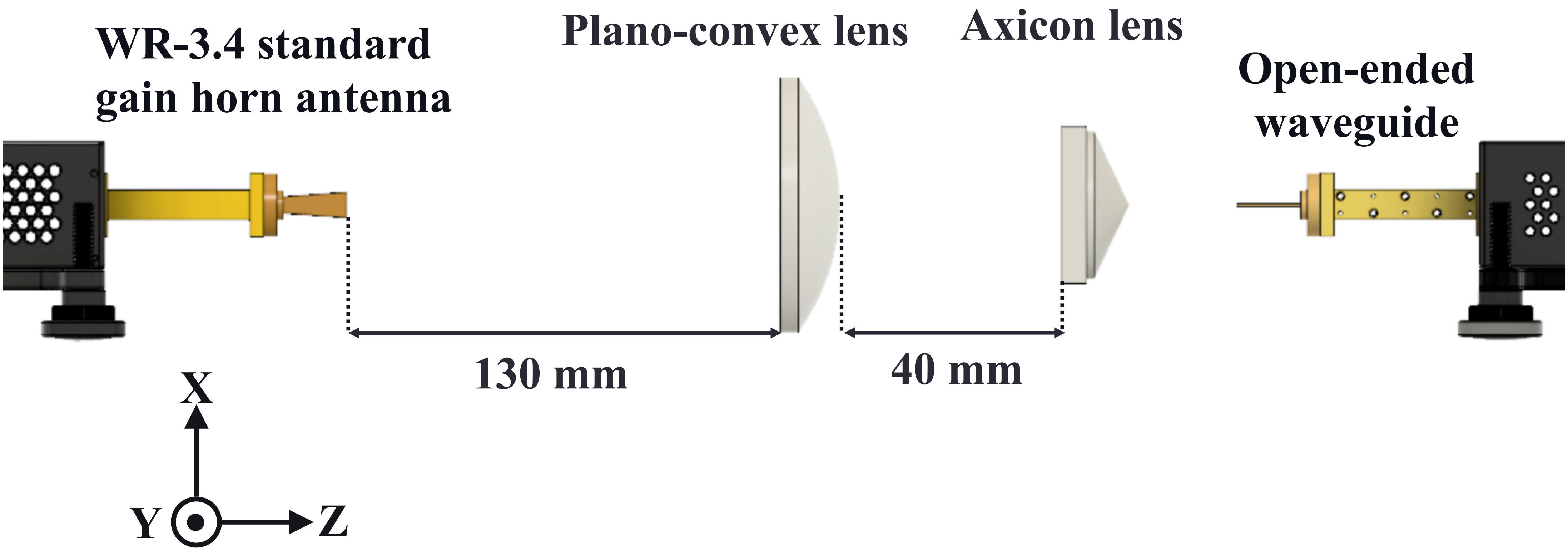


$$\beta = \sin^{-1}(\sqrt{\varepsilon_r}\sin\alpha) - \alpha$$

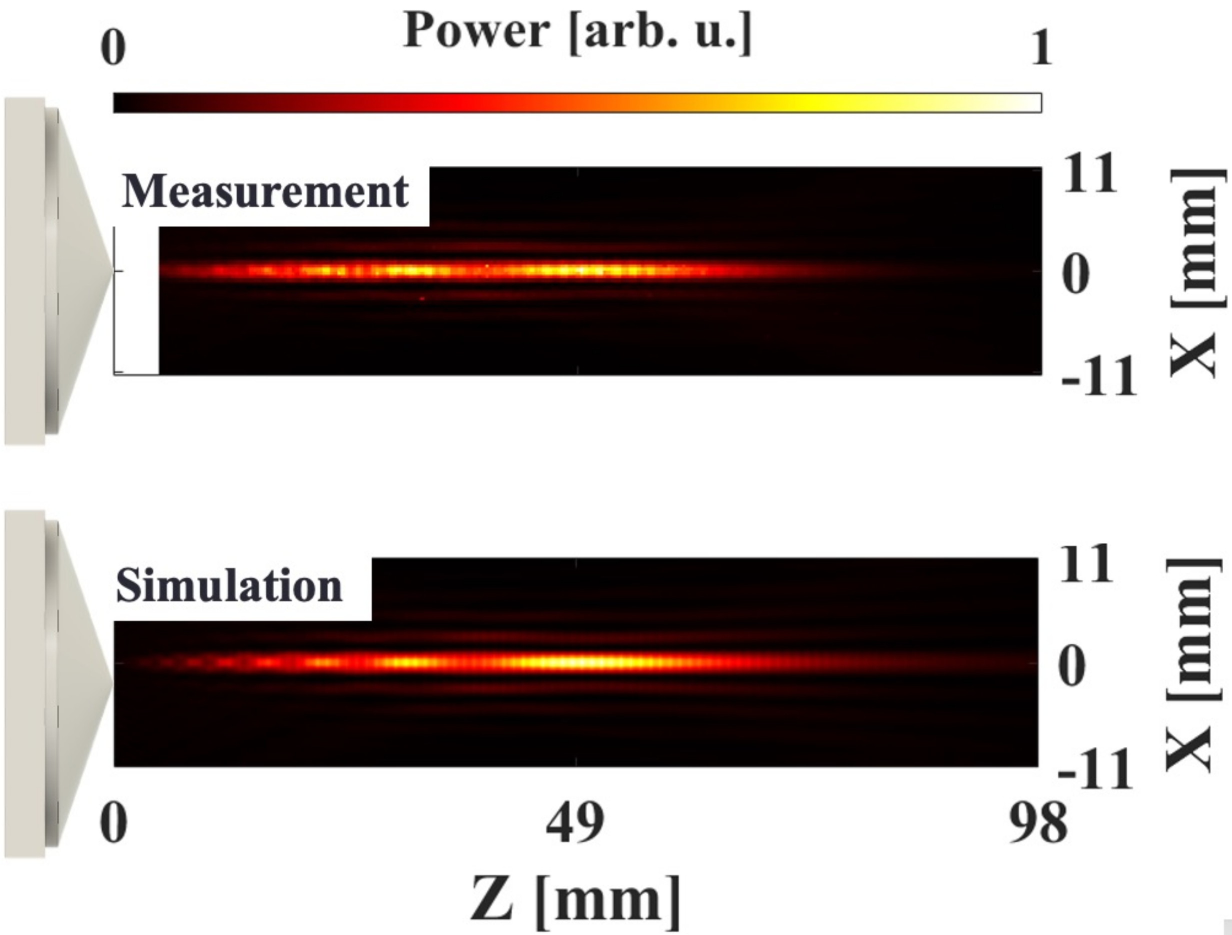
$$Zmax = w_0 \cdot \frac{1}{\tan\beta}$$

Non-diffraction region
Zmax：98 mm
Xmax：22 mm

Experimental setup



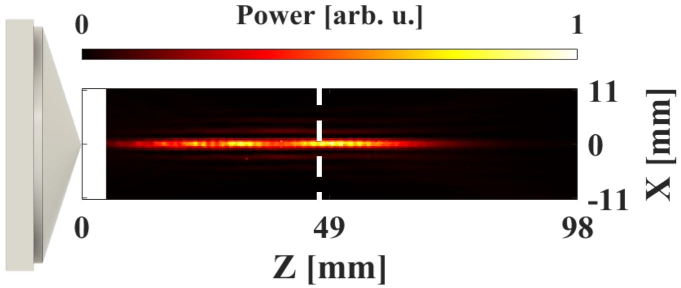
Generated Bessel beam



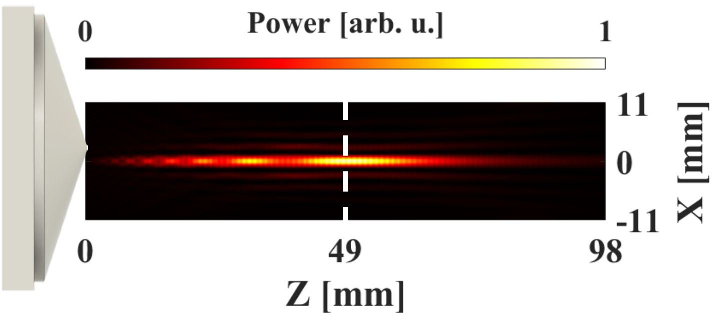
Measurement parameters	
Frequency	300 GHz
Measurement plane	XZ plane
Measurement area	22 mm x 98 mm
Resolution	0.4 mm

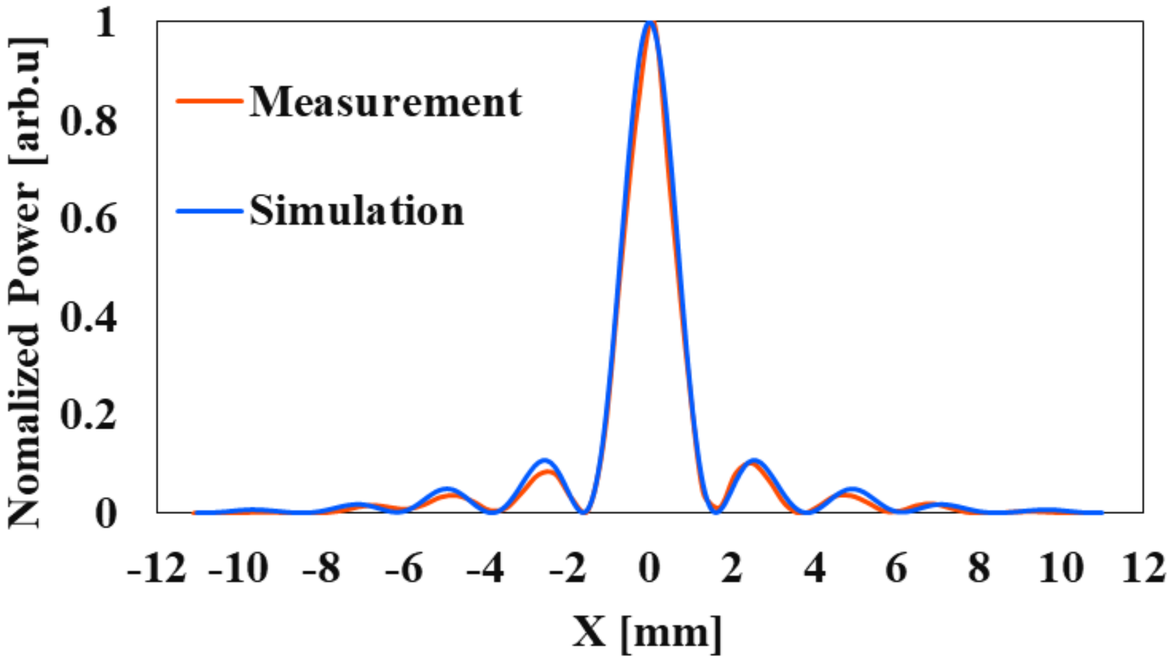
Evaluation of the generated Bessel beam

Measurement



Simulation





The distribution of the experimentally generated Bessel beam **agreed** well with the simulation result.

Obstacles

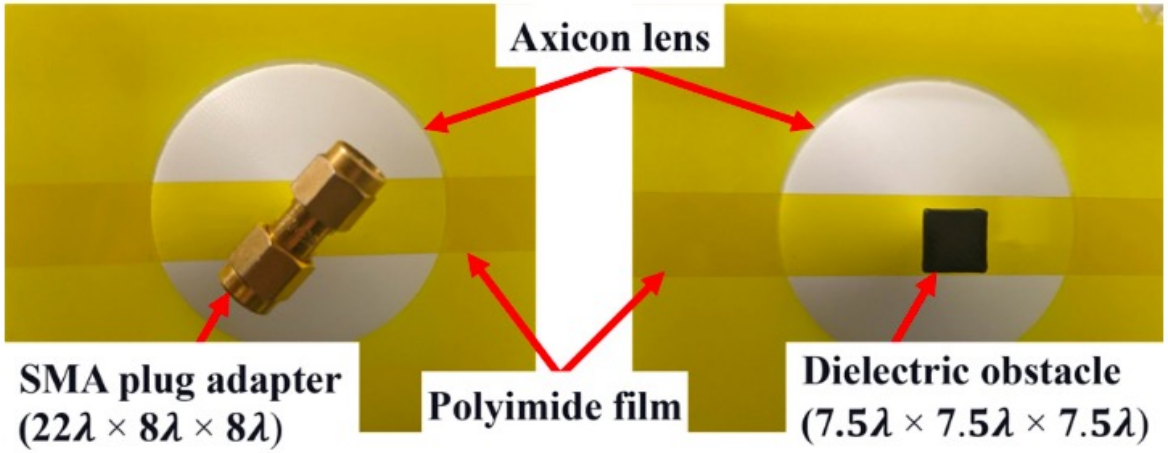
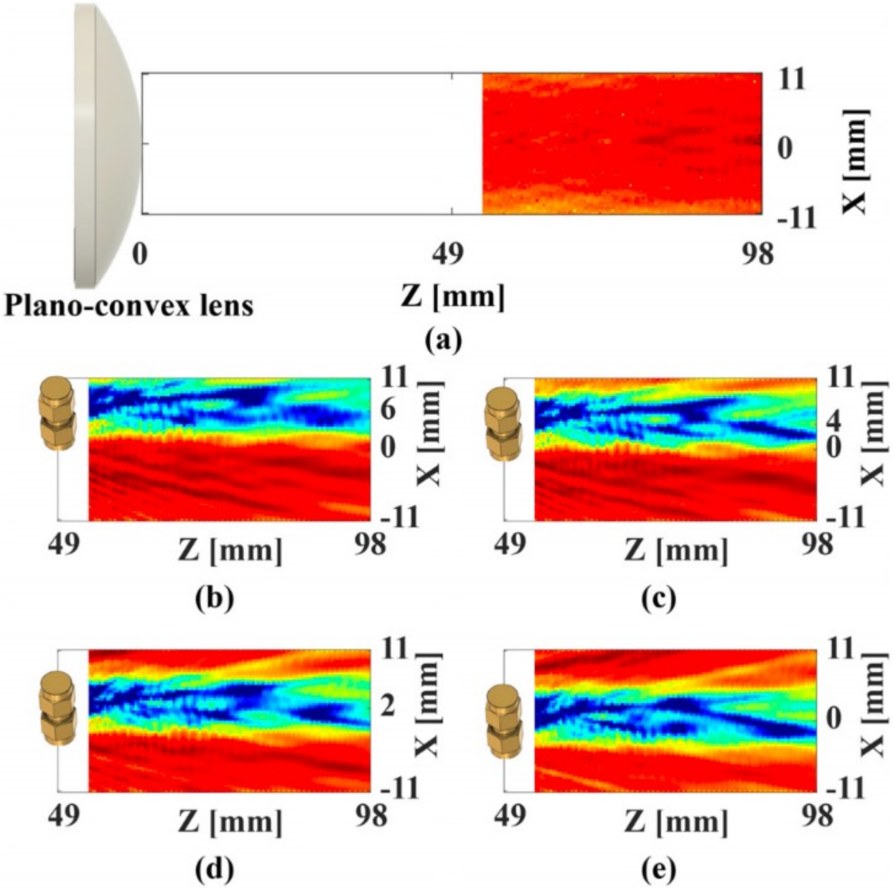


FIG. 4. Photograph of obstacles attached to polyimide film.

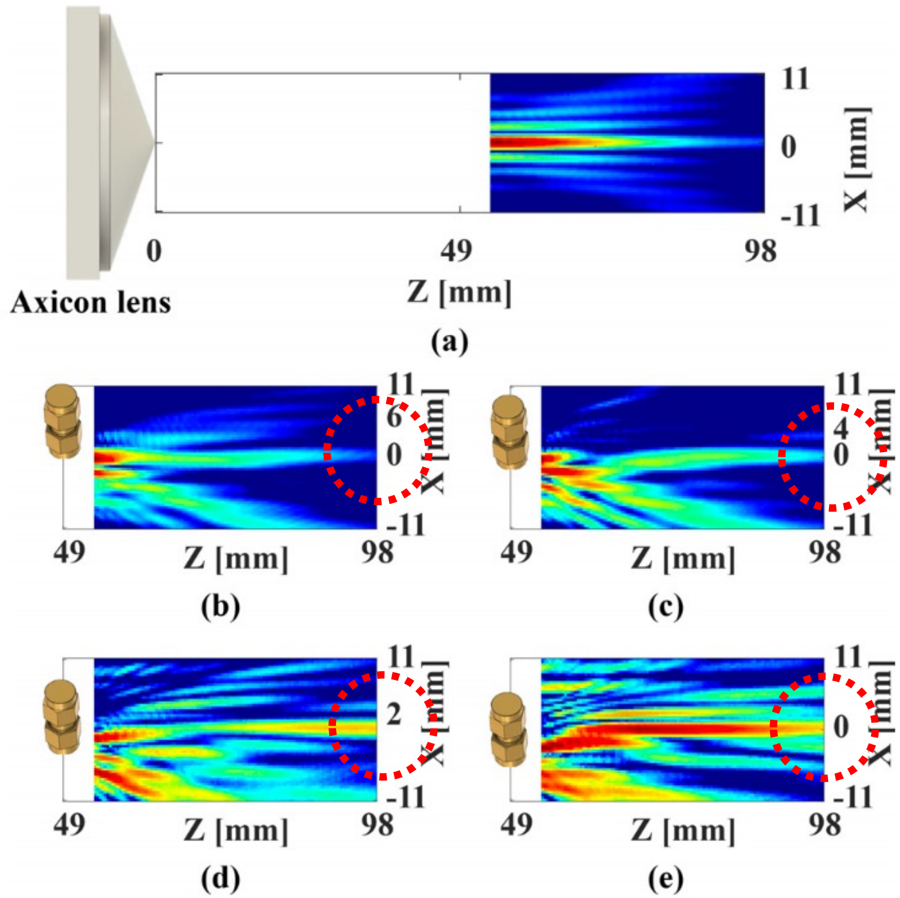
A SMA plug adapter (22λ 8λ 8λ) made of metal and a dielectric cube (7.5λ 7.5λ 7.5λ) made of poly-lactic acid were used as the obstacles. The obstacles were placed 49 mm from the PCXL and axicon lens for the Gaussian beam and Bessel beam, respectively.

Self-healing effect

Gaussian beam

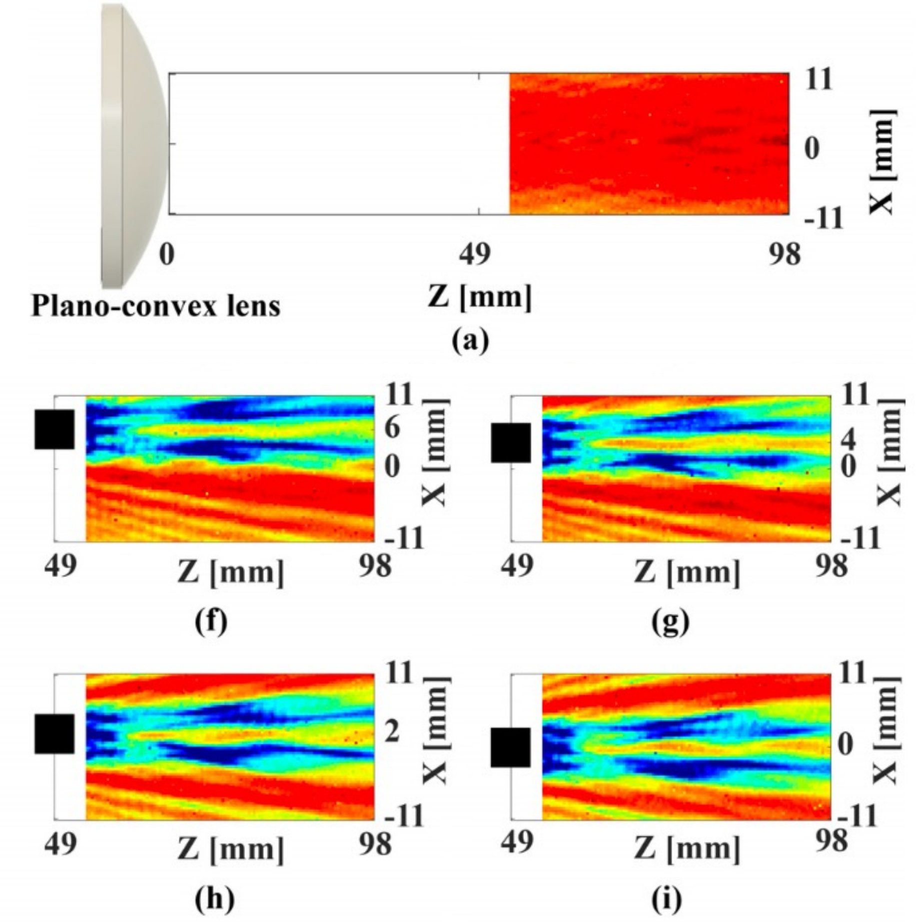


Bessel beam

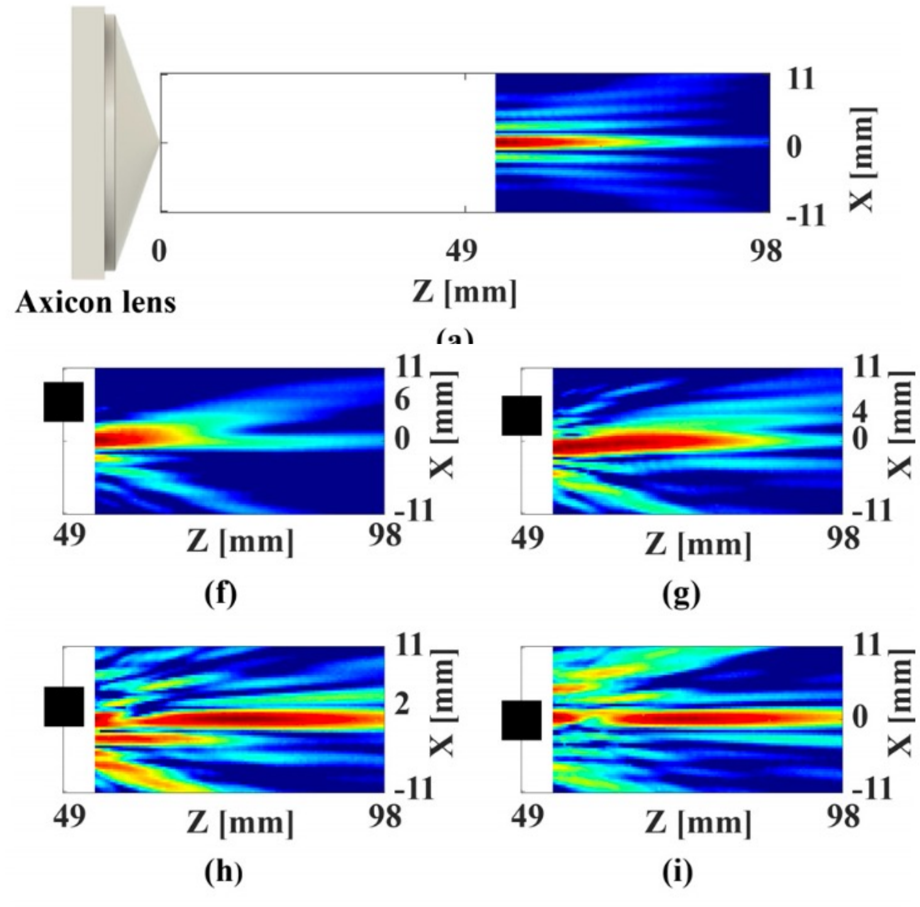


Self-healing effect

Gaussian beam



Bessel beam



Received THz power

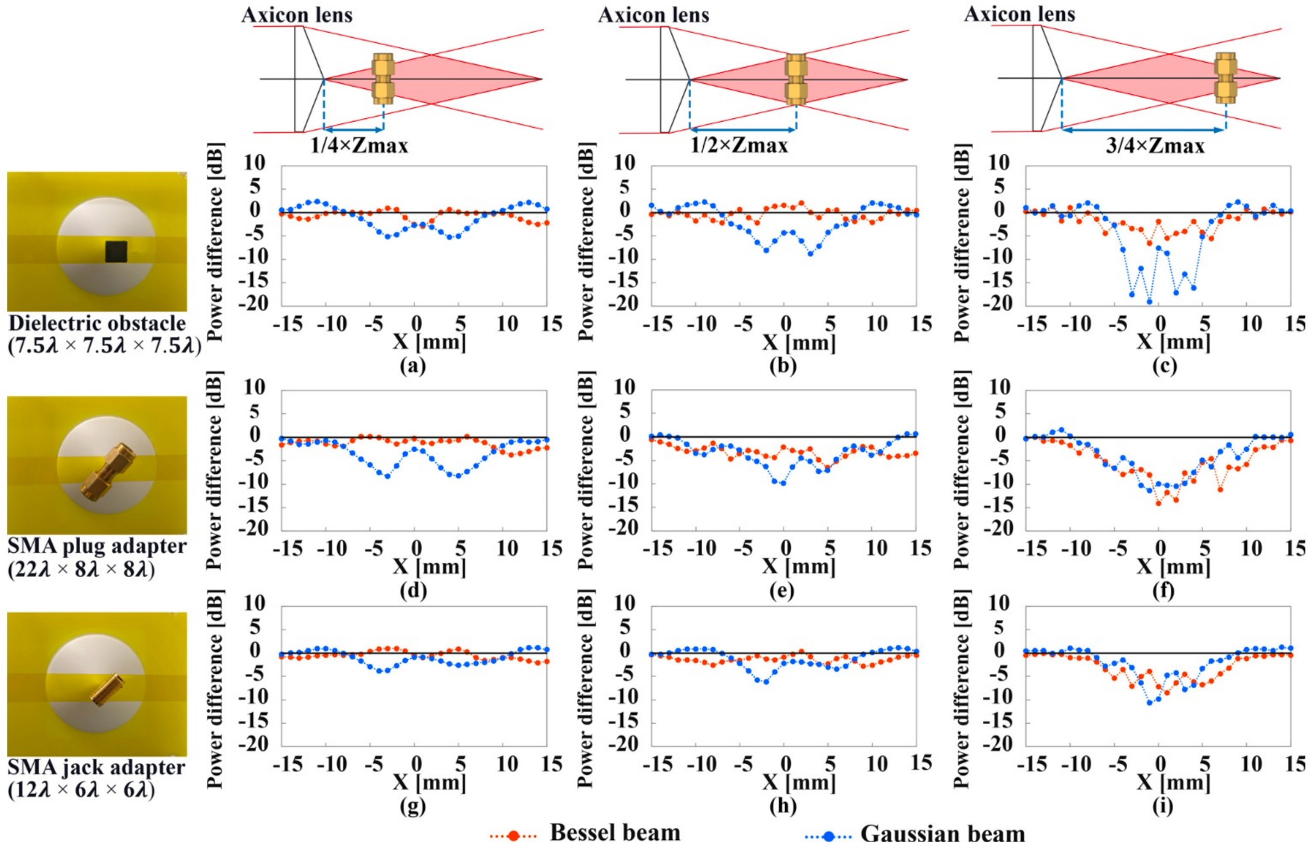


FIG. 7. Received power difference between with and without obstacles as a function of obstacle position on the X-axis when the dielectric obstacle was placed at (a) $Z = \frac{1}{4} \times Z_{max}$, (b) $Z = \frac{1}{2} \times Z_{max}$, and (c) $Z = \frac{3}{4} \times Z_{max}$; the SMA plug adapter was placed at (d) $Z = \frac{1}{4} \times Z_{max}$, (e) $Z = \frac{1}{2} \times Z_{max}$, and (f) $Z = \frac{3}{4} \times Z_{max}$; and the SMA jack adapter was placed at (g) $Z = \frac{1}{4} \times Z_{max}$, (h) $Z = \frac{1}{2} \times Z_{max}$, and (i) $Z = \frac{3}{4} \times Z_{max}$.

THz wireless transmission

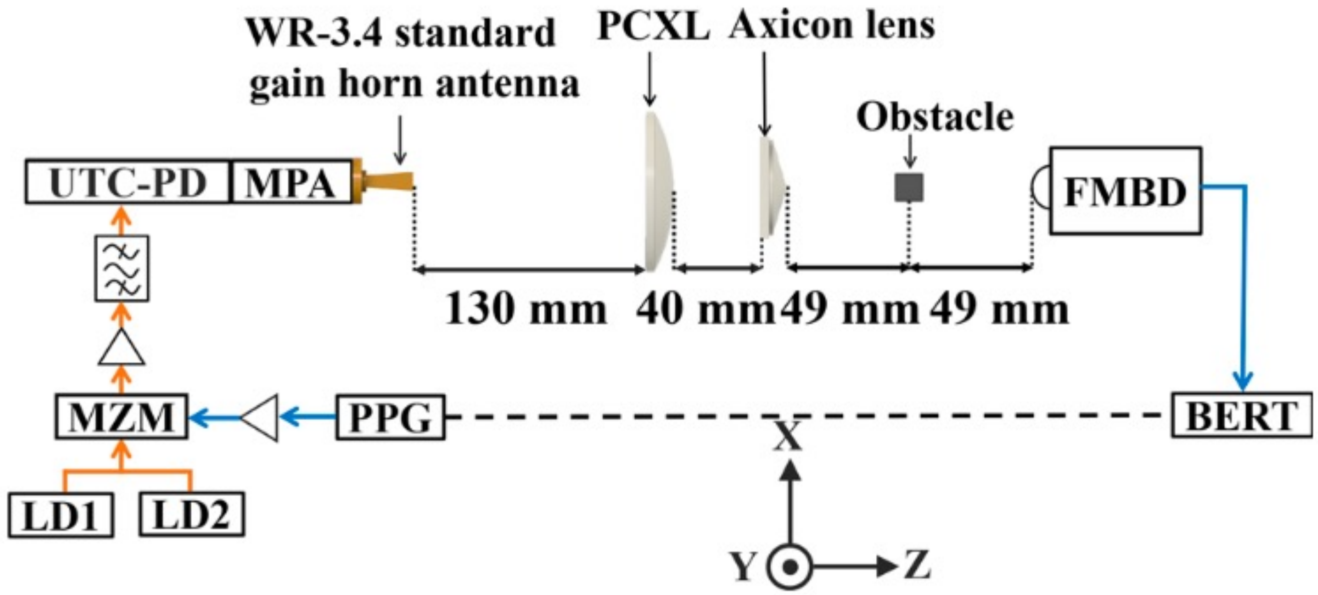


FIG. 8. Experimental setup for THz wireless transmission. LD: Laser Diode; MZM: Mach–Zehnder modulator; UTC-PD: uni-traveling-carrier photodiode; MPA: medium-power amplifier; FMBD: Fermi-level managed barrier diode; BERT: bit error rate tester; PPG: pulse pattern generator.

BER characterization

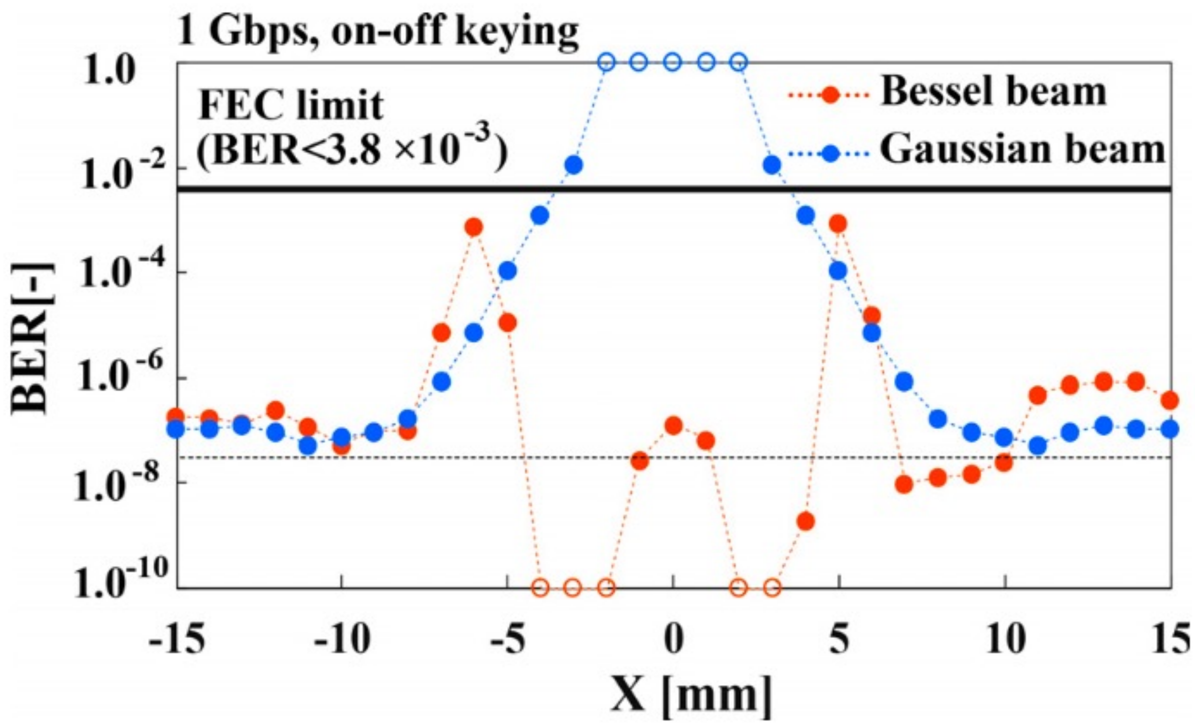
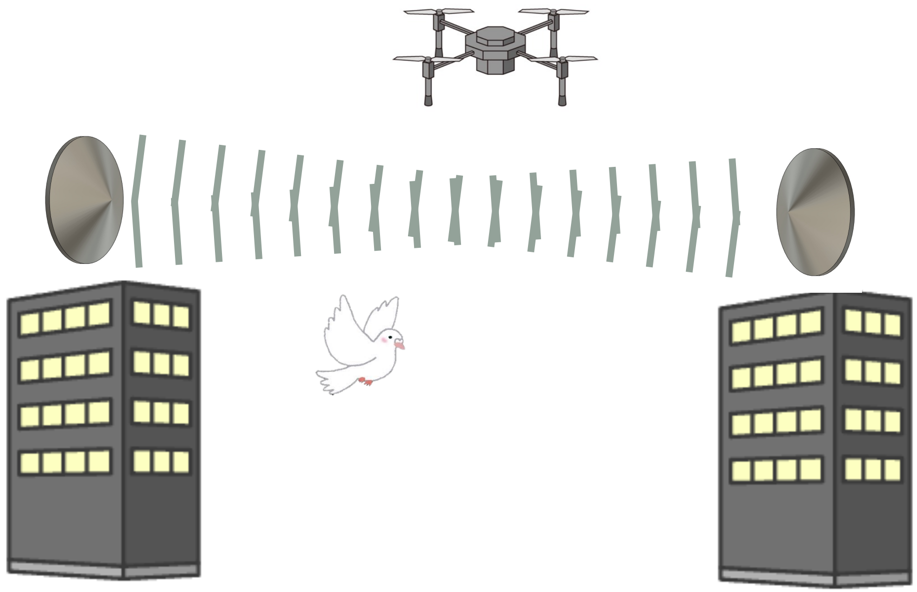
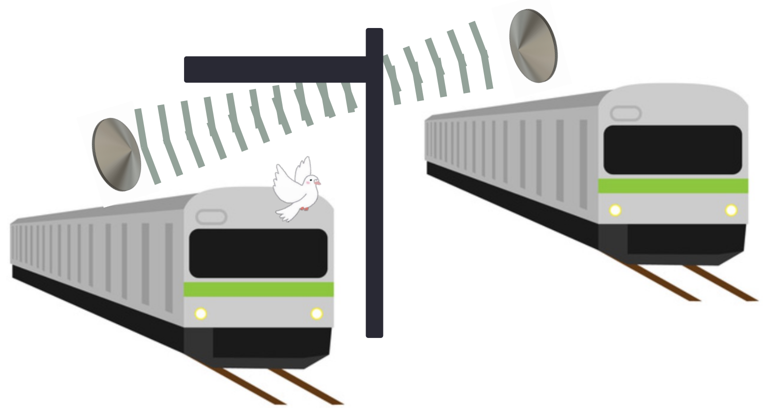


FIG. 9. Bit error rate characteristics upon varying the obstacle position across the beam cross section in the X direction.

Potential applications



Backhaul/fronthaul



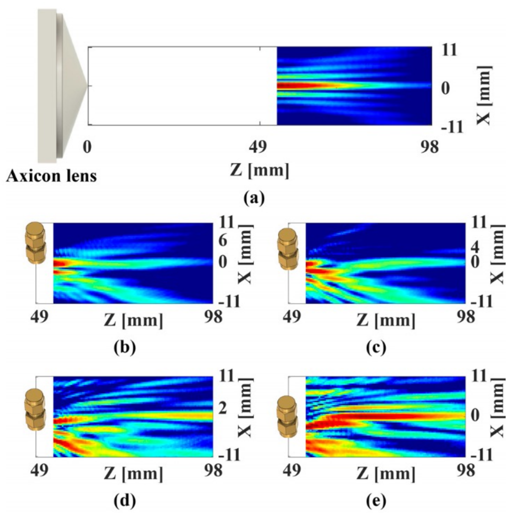
Train to train

ETSI GR THz 001 V1.1.1 (2024-01)
TeraHertz modeling (THz);
Identification of use cases for THz communication systems

Fixed point-to-point link where the obstacles may across.

Summary

- Since the THz beam is narrower compared to microwaves, it is essential to establish a wireless link that is resilient to obstacles.
- It was experimentally demonstrated that a THz radio with Bessel beam could be a potential candidate for establishing such a resilient link.
- We are currently evaluating resistance to rain, as well as extending the link distance.



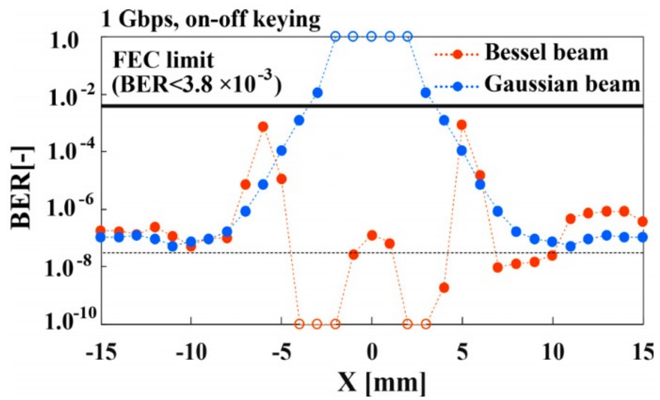
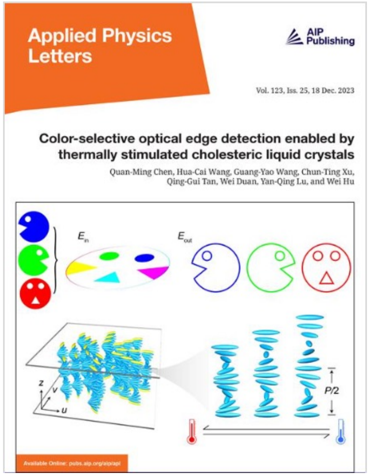


FIG. 9. Bit error rate characteristics upon varying the obstacle position across the beam cross section in the X direction.

More information



Detailed information can be found in APL.

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