6 Other Space Laser Experiments

6-1 Other Demonstrations on Space Laser Communication

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Successful in-orbit demonstrations on space laser communications are introduced.

Keywords
Space laser communications, Inter-satellite, Satellite-to-ground, In-orbit demonstration

1 Introduction

Laser communication experiments with the use of satellites started from an experimental proof in 1994 and still continue today. OICETS is one example of success in the field of space laser communications. This paper presents the on-orbit experiments that have been performed so far, and introduces some examples of space laser communications.

2 Examples of on-orbit experiments

Figure 1 shows successful examples of on-orbit space laser communications. In the figure, GEO denotes geostationary earth orbit, LEO low earth orbit, GND ground, and OGS optical ground station. The satellite names and the launch years are shown in the frames of GEO and LEO. The abbreviated names of the institutes having optical ground stations are

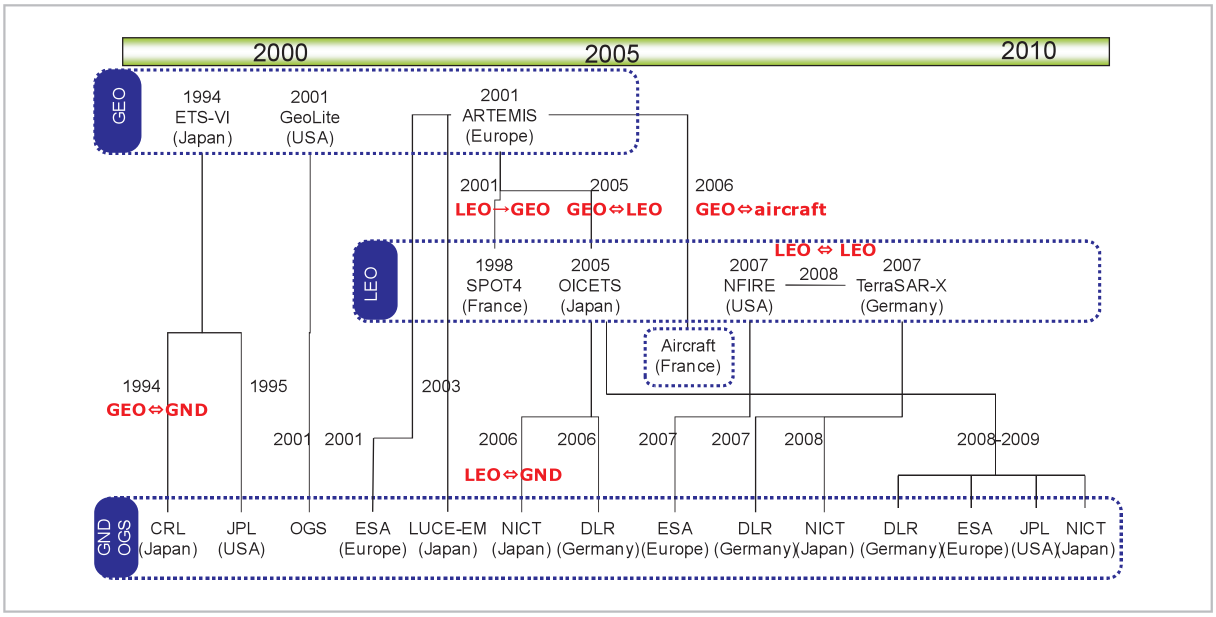

Fig.1 *Successful examples of on-orbit space laser experiments*

given in the frame of OGS. The solid lines represent the combinations of the laser communications experiments. By the line of each combination, the year of the first experiment is given.

The first successful laser communication with the use of a satellite was demonstrated in an experiment conducted by Japan. A laser communication device developed by CRL (currently, NICT) was mounted on the satellite ETS-Ⅵ (Japanese name; KIKU 6) of NASDA (currently, JAXA), which was launched in 1994. CRL conducted bidirectional optical communications experiments between the ETS-Ⅵ and the optical ground station in Koganei, Tokyo [1]. In 1995, a laser communication between this satellite and the JPL ground station was established in collaboration with JPL of NASA [2]. In this experiment, a laser beam with a wavelength of 0.515 μm was transmitted from the ground to the satellite and a wavelength of 0.83 μm was transmitted from the satellite to the ground. The data transmission speed was 1 Mbps using an intensity-modulation direct detection (IMDD) technique.

In 2001 it was reported that the United States had launched the stationary satellite GeoLite and succeeded in an experiment of laser communications between the satellite and a ground station [3]. In the same year, a laser communication between ESA's stationary satellite ARTEMIS and an optical ground station in Tenerife Island, Canary Islands was established [4]. ARTEMIS also succeeded in receiving, by laser communications, data from the low earth orbit satellite SPOT4 of CNES in France. It was the first successful one-way laser communication from LEO to GEO [5]. In 2003 an engineering model of the laser communication equipment mounted in JAXA's low earth orbit satellite OICETS (Japanese name: Kirari) was transferred to Tenerife Island and laser communication experiments were conducted with ARTEMIS [6]. In these experiments, an IMMD scheme with a wavelength of 0.8 μm was employed. The data transmission speed of the downlink from ARTEMIS was 2 Mbps and the speed of the uplink was 50 Mbps.

In December 2005, Europe and Japan collaboratively made bidirectional laser communications between satellites. The communication experiment between OICETS and ARTEMIS was the first successful bidirectional laser communication between LEO and GEO [7][8]. In March 2006, a bidirectional laser communication between OICETS and the NICT optical ground station was conducted. It was also the first successful communication between a low earth orbit satellite and an optical ground station [9]. In the successful experiment of laser communications between ETS-Ⅵ and a ground station in 1994, the distance between the communication units was large and the direction of the satellite from the ground station did not change considerably. However, the direction in which OICETS on the low earth orbit and the ground station see each other changes greatly, and it is therefore much more difficult to capture the laser communication target and maintain communication.

Following the laser communication experiment between the satellite and NICT's optical ground station, DLR of Germany succeeded in a one-way laser communication in which a transportable optical ground station received data transmitted from OICETS [10]. After that, optical inter-orbit communications between OICETS and ARTEMIS were performed repeatedly and the experiments finished in September 2006. On the other hand, ARTEMIS made a bidirectional laser communication with French aircraft in December 2006, which was the first successful laser communication between a stationary satellite and an aircraft [11].

In 2007, the low earth orbit satellite NFIRE of the Missile Defense Agency (MDA) in the United States and the low earth orbit satellite TerraSAR-X of DLR were launched one after another. Each of these satellites was equipped with communication equipment that could send and receive data in the form of a 1 μm wavelength at a speed of 5.6 Gbps, using the coherent binary phase shift keying (BPSK) stations [12]. During this period, DLR, ESA, and NICT collaborated to perform the international experiments with TerraSAR-X and their optical ground stations. During the collaborative period, NICT conducted the experiment in December 2008. The photograph taken in the experiment is shown in Fig. 2.

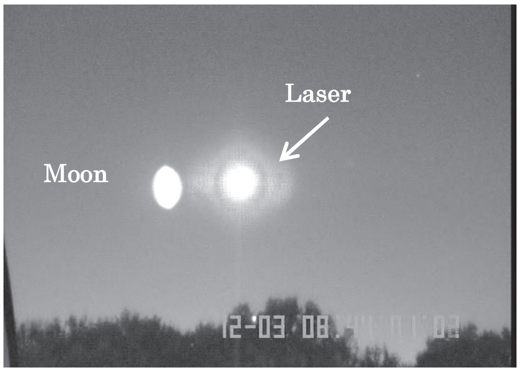

Fig.2 *Laser light from TerraSAR-X (at the center of the photograph)*
Shot on December 3, 2008.

The experiments using the OICETS satellite finished in September 2006 and were restarted in October 2008. The joint international experiments using the satellite then started in April 2009 and continued until September 2009 [13].

3 Conclusions

This paper introduced and explained examples of past successes in on-orbit space laser experiments, to show some examples of optical communication experiments.

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