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## DEVELOPMENT OF A BREADBOARD MODEL OF SPACE LASER COMMUNICATION TERMINAL FOR OPTICAL FEEDER LINKS FROM GEO

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### I. INTRODUCTION

National Institute of Information and Communications Technology (NICT) has a long history of the R&D of space laser communications. Engineering Test Satellite VI (ETS-VI) experiments had been carried out between 1994 and 1996. The on-board equipment of 22 kg weight and 60 W power established 1 Mbps bi-directional optical links among ETS-VI and NICT's Koganei OGS (optical ground station) in Tokyo. From 2006 to 2009, we performed laser communication experiments between OICETS satellite and the OGS, on 0.8  $\mu\text{m}$  wavelength with data rate of 50 Mbps for downlink and 2 Mbps for uplink. In addition to the space-OGS links, satellite-satellite laser communication experiments were successfully carried out between OICETS and ESA's ARTEMIS with the 50Mbps link.

A microsatellite SOCRATES was built by AES (Advanced Engineering Services Co., Ltd.) and launched on H-IIA in 2014. SOCRATES carries a laser communication system SOTA (Small Optical Transponder) developed by NICT ([1], [2]), and 10 Mbps communication links whose wavelengths are 1.5  $\mu\text{m}$  and 0.98  $\mu\text{m}$  have been performed between SOTA and NICT's three OGSs (described later) for more than two years [3].

Fig. 1 shows the trend of data rate for space laser communications vs satellite launch years. Due to the appearance of large imaging sensor format etc., the data rate of the space communications is getting higher and higher in recent decades. Therefore, the realization of much higher data rate is required for the future space communications and we have to prepare for the development of ultra-high-speed space laser communication equipment.

### II. CURRENT MISSION

#### A. HICALI Project

NICT has initiated a project called HICALI (HIgh speed Communication with Advanced Laser Instrument) to facilitate the next generation space laser communication research. The aim of the project is to achieve 10 Gbps-class space communications with a 1.5  $\mu\text{m}$  laser beam from a geostationary satellite to OGS. The terminal is going to be launched on a next generation high throughput satellite (HTS) on the geostationary orbit (GEO) in 2021. In Fig. 2, we display the schematic drawing of the HTS project, which will equip not only the HICALI terminal but also radio frequency (RF) terminals.

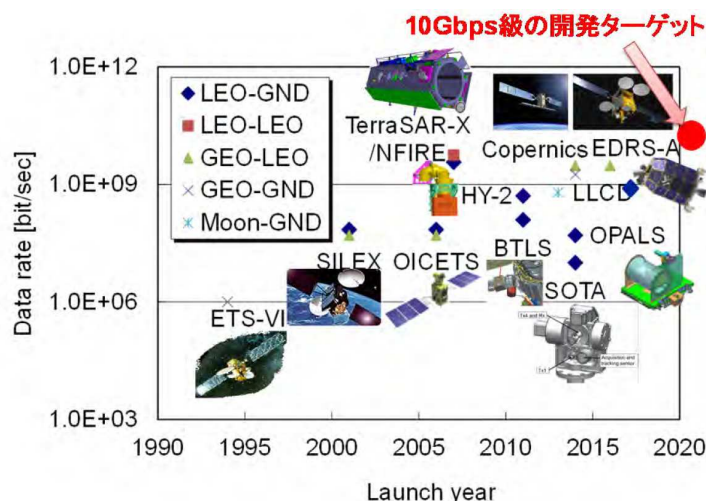


Fig. 1. Trend of data rate vs. satellite launch year for space laser communications [4]

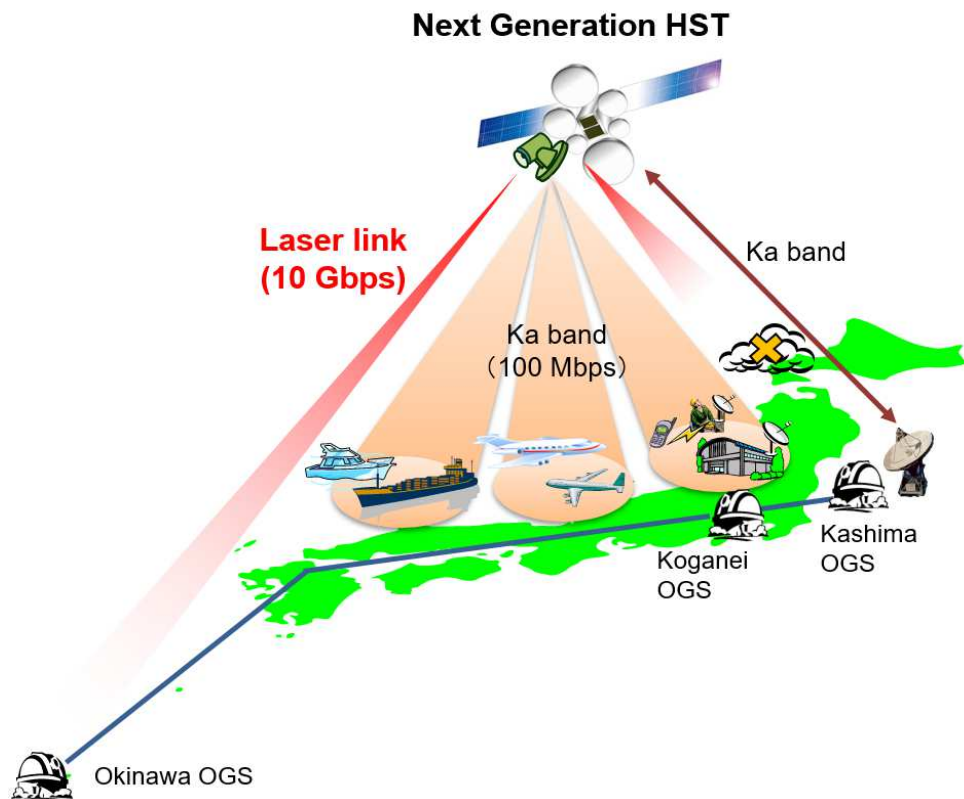


Fig. 2. Schematic drawing of the next generation HTS

The main objectives of the HICALI project are as follows:

- (1) in-orbit verifications of the first 10 Gbps-class laser communication from GEO to OGS,
- (2) in-orbit verifications of novel optical modulation/demodulation methods,
- (3) in-orbit verifications of novel high speed optical devices,
- (4) acquisition of laser beam propagation data and in-orbit experience.

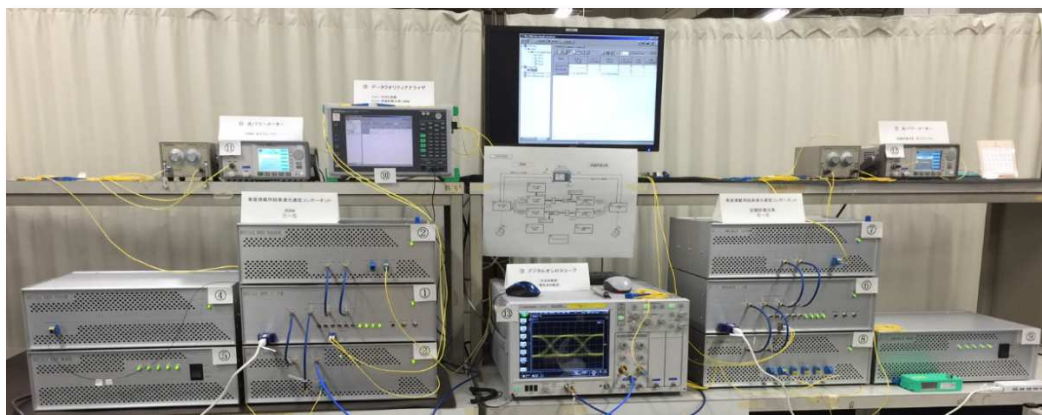
In addition to the objectives, it is expected that NICT and Japanese manufactures will be able to have knowledge of development of space laser communication components and also explore new users who have potential to use laser communications through the HICALI project.

#### B. Partial Trial Manufacture for HICALI

A feasibility study for the HICALI was conducted in 2014, and a number of critical parts for the project were identified. These include devices employing wavelength division multiplexing (WDM) techniques, optical delay line interferometers, integrable tunable laser assemblies (ITLAs), and high speed digital processing devices.



Fig. 3. Partial trial manufacture for the HICALI terminal



**Fig. 4.** Bread board model for the HICALI terminal

Several devices have been developed on a partial trial manufacturing basis (Fig. 3) and evaluated for space use such as an optical transmitter, an optical receiver, a data procession unit, and a WDM unit.

#### C. Bread Board Model for HICALI

The device performances were assessed during the partial trial manufacturing stage, and a breadboard model (BBM, Fig. 4) was developed in 2015. We are currently evaluating the BBM as follows:

- (1) Bit Error Rate (BER): Measuring BER through LNA (Low Noise Amplifier), the communication performance is evaluated.
- (2) Dynamic Range: Measuring the dynamic range through LNA, the communication performance is evaluated.
- (3) Temperature Characteristics: Evaluating the temperature characteristics, the specifications for on-board equipment are organized.

#### D. Optical Ground Stations of NICT

NICT currently manages three OGSs at Koganei HQ in Tokyo, Kashima Space Technology Center in Ibaraki Pref. and Okinawa Electromagnetic Technology Center in Okinawa Pref. (Fig. 2), and each facility has a 1m optical telescope. Through regular operation the HICALI terminal on the HTS, we plan to conduct site diversity propagation experiments using these OGSs. We now push ahead the conceptual designs of transmitting and receiving optics at the OGSs.

### III. REFERENCES

- [1] M. Toyoshima, et. al., "Small Optical Transponder for Small Satellites", International Symposium on Communication Systems, Networks and Digital Signal Processing, 2nd Colloquium in Optical Wireless Communications at the IEEE International Conference (CSNDSP10), OWC-10, Northumbria University, UK, 2010.
- [2] Y. Koyama et el, "Completion of The Small Optical Transponder Development for Satellite-ground Laser Communication Demonstrations", 19th Ka and BroadBand Communications Conference, 2013.
- [3] H. Takenaka et al., "In-orbit verification of small optical transponder (SOTA): evaluation of satellite-to-ground laser communication links", Proc. of SPIE, Vol. 9739, 973903, 2016.
- [4] Study Group on Next Engineering Test Satellite, "Study Report on Next Engineering Test Satellite (in Japanese)", <http://www8.cao.go.jp/space/committee/27-kiban/kiban-dai20/gijisidai.html>, 2016.