Communications and Ranging Experiment using Laser terminal on satellite

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Background : Space-based Laser Comm. Program in the past and present (1)

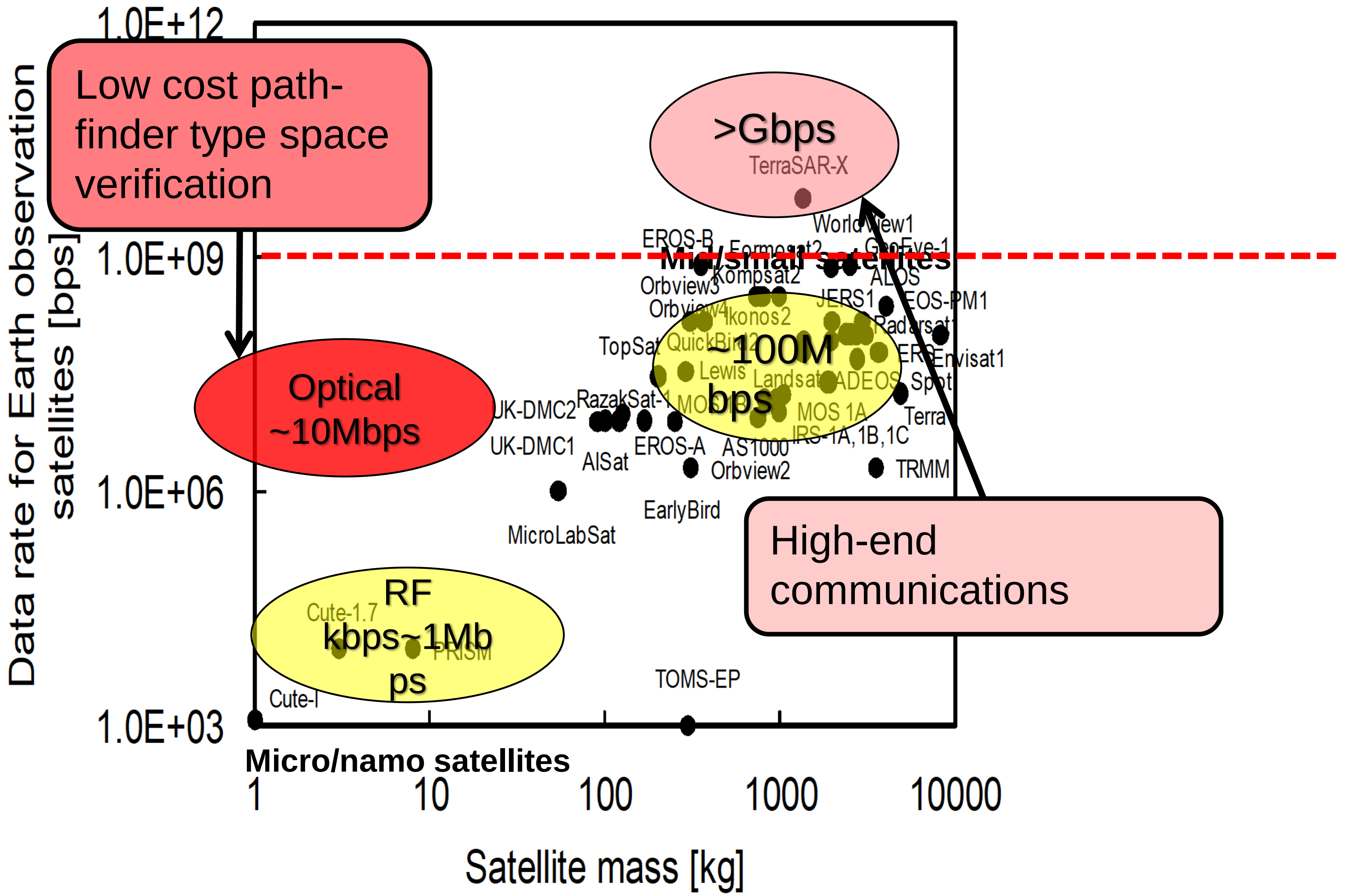
	Asia	USA	Europe
Past	- 1994: **ETS-VI** (NICT), GEO-GND, 0.8μm/0.5μm, IMDD, 1Mbps - 2006: **OICETS** (JAXA/NICT), LEO-GEO,LEO-GND, 0.8μm, IMDD, 50Mbps - 2011: **HY-2** (China), LEO-GND, 1.5μm, IMDD, 504 Mbps- - 2014: **SOCRATES/ SOTA** (NICT), LEO-GND),0.98/1.5μm, IMDD, 10Mbps -2017 **Micius** (China) , QKD international demonstration.	- 1995: **GOLD** (NASA JPL), GEO-GND, 0.8/0.5μm, IMDD, 1Mbps - - 2001: **GeoLITE** (NRO), GEO-GND - 2008: **NFIRE** (MDA), LEO-LEO, 1.06μm, homodyne BPSK, 5.6Gbps -2012 **LRO** (NASA) 532nm, PPM 300bps - 2013: **LLCD** (NASA GSFC), Lunar-GND, 1.5μm, PPM, 622Mbps - 2014: **OPALS** (NASA JPL), ISS-GND, 1.5μm, IMDD, 30~50Mbps	- 2001: **SILEX** (ESA), GEO-LEO, GEO-GND, GEO-Air, 0.8μm, IMDD, 50Mbps - 2008: **TerraSAR-X** (DLR), LEO-LEO, LEO-GND, 1.06μm, homodyne BPSK, 5.6Gbps - 2011: **BTLS** (Russia), ISS-GND, 1.55μm/0.85μm, IMDD, 125Mbps - 2014: **EDRS/Copernics** (ESA), GEO-LEO, GEO-GND, 1.06μm, homodyne BPSK, ~1.8Gbps -Sentinel-1B

Background : Space-based Laser Comm. Program in the past and present(2)

	Asia	USA	Europe
Present ~Near Future	- 2018: **RISESAT/ VSOTA** (NICT), LEO-GND, 0.98/1.5μm, IMDD, ~1kbps - 2019**ODRS** (JAXA), GEO-GND, 1.5μm, DPSK, 1.8Gbps - 2021 **HICALI** (NICT) , 1.5μm, 10Gbps, DPSK	- **LCRD** (NASA GSFC), GEO-LEO, GEO-GND, 1.5μm, DPSK/PPM, 2.8G/622Mbps - **DSOC** (NASA JPL), Deep space-GND PPM,	- EDRS-C, EDRS-D - **OSIRISv1-3** (DLR), LEO-GND, 1.5μm, IMDD, 20M-10Gbps - **OPTEL-μ** (RUAG), Deep space-GND, LEO-GND, 1.5μm, IMDD, 2Gbps - **OPTEL-D** (ESA), Deep space-GND
	And more, There is growing commercial based program and service using LEO/MEO constellation optical comm.		

http://icsos2017.ieee-icsos.org

Space Communication Data Rate v.s Satellite size

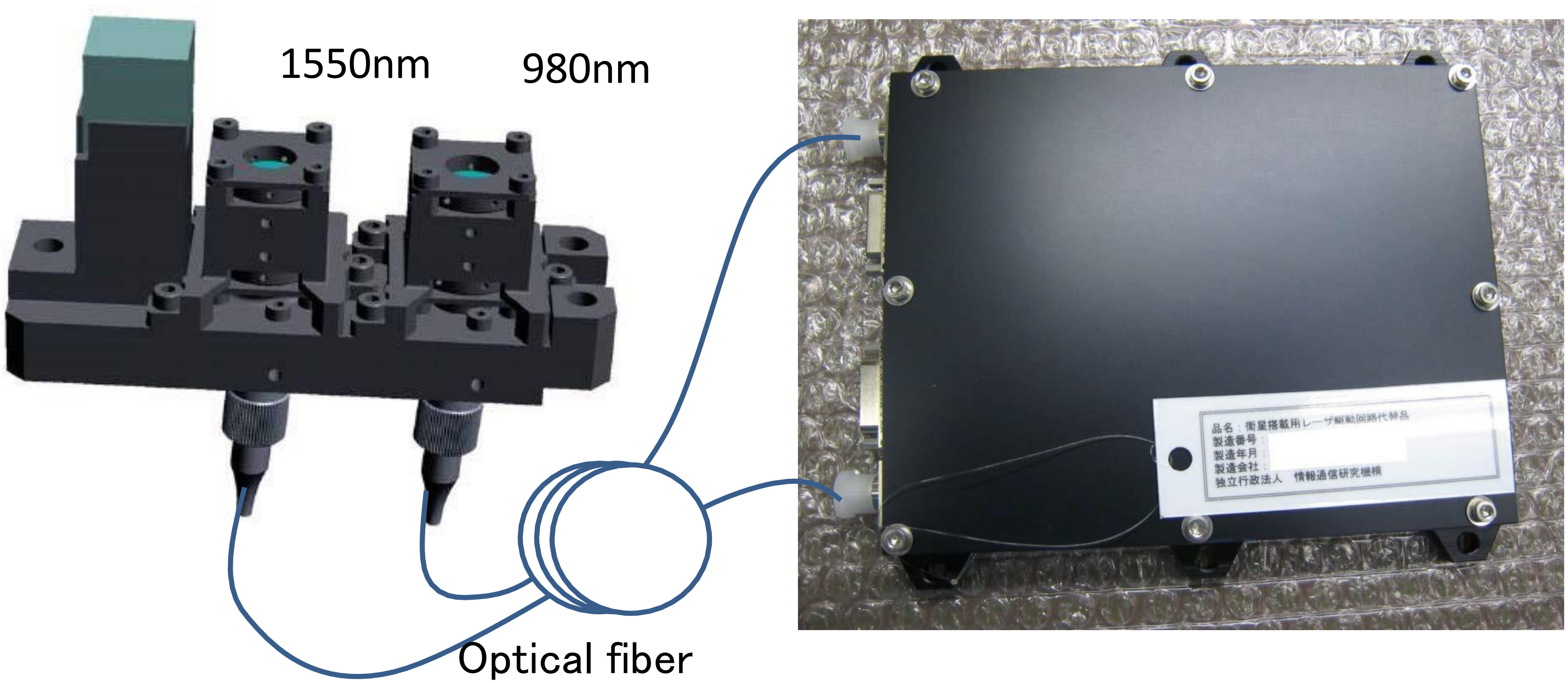


Background : **RISESAT/ VSOTA** project

2010	"Hodoyoshi" Reliability/Cost balanced micro-sats program as RISESAT defined Sateliite No.2 start
2012	Collaborative Research Agreement between NICT and Tohoku Univ.
2013	VSOTA FM completed environment test . Lost opportunity of launch at over sea site.
2014	SOTA experiment start
2016	SOTA experiment end
2016 2017	Regain the Launch Opportunity by Epsilon Rocket #4 under JAXA Innovative Satellite Technology Demonstration Program
2018	Re-start project NICT FM start integration and Test END－END system level test software refinement Preparation of Ground station Pass to Launcher place in Nov.

VSOTA
(Very Small Optical Transmitter)

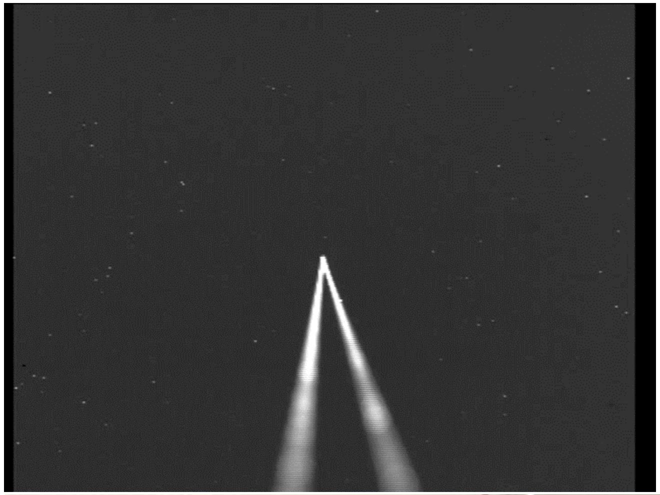
VSOTA–Collimator



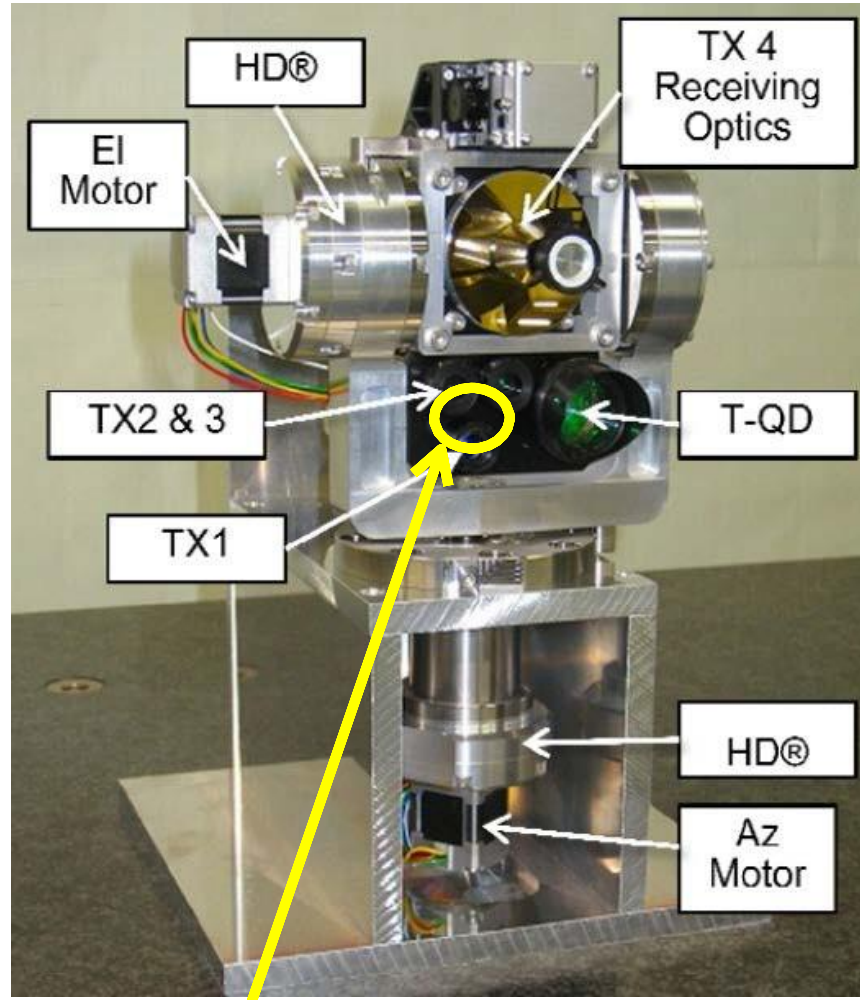
LD Driver (VSOTA-E)

VSOTA　SOTA Heritage

SOTA:　Small Optical TrAnsponder　(in orbit 2014～2016)



Electric Part



Optical on Gimbal Mechanics

LD and driver board and Collimator→VSOTA Compoonent

VSOTA Specification

	VSOTA	SOTA
Mass	<1kg	6.2 kg
Power Consumtion	<10W	40W
Link distance	2000km max	←=
Wavelength (Divergence)	980nm(TX1), 1550nm(TX4) **Div.（3.3mrad/ 1.2mrad）**	980nm（TX1), 1550nm(TX4) **Div. (200µrad)** 800nm(TX2,3) 1064nm(RX)
Optical Power	980nm:540mW(max) 1550nm:80mW(max)	←=
偏光	980nm:Arbitrary 1550nm: Linear	←=
Modulation Format	100kbps nominal (10kbps~6Mbps Variable)	1Mbps or 10Mbps

Microsatellite RISESAT

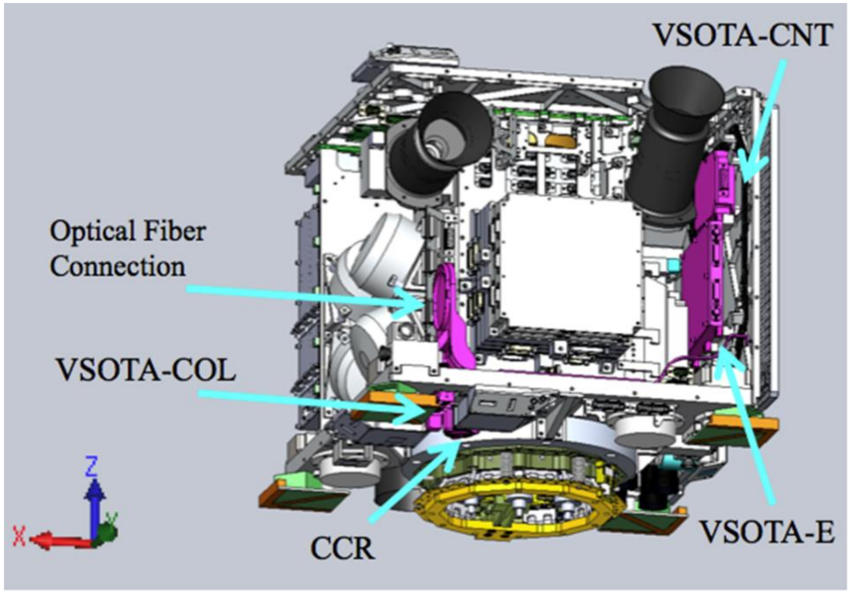
Mission Instruments includes:

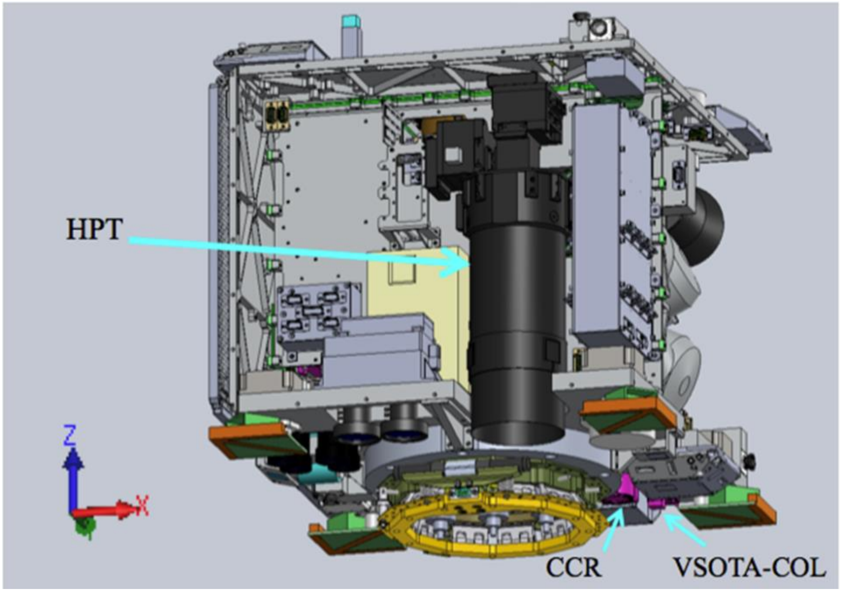
- High Precision Telescope (HPT)
- Dual-band Optical Transient Camera (DOTCam)
- Ocean Observation Camera (OOC)
- Space Radiation micro-Tracker (Timepix)
- Micro Monitor Camera (MMC)
- Other engineering missions
- **Very Small Optical Transmitter (VSOTA)**

Satellite Size & Mass
50x50x50cm，55kg
<u>Orbit</u>：500-700km (nominal 500㎞), Sun-Synchronous LTDN nominal 9:30

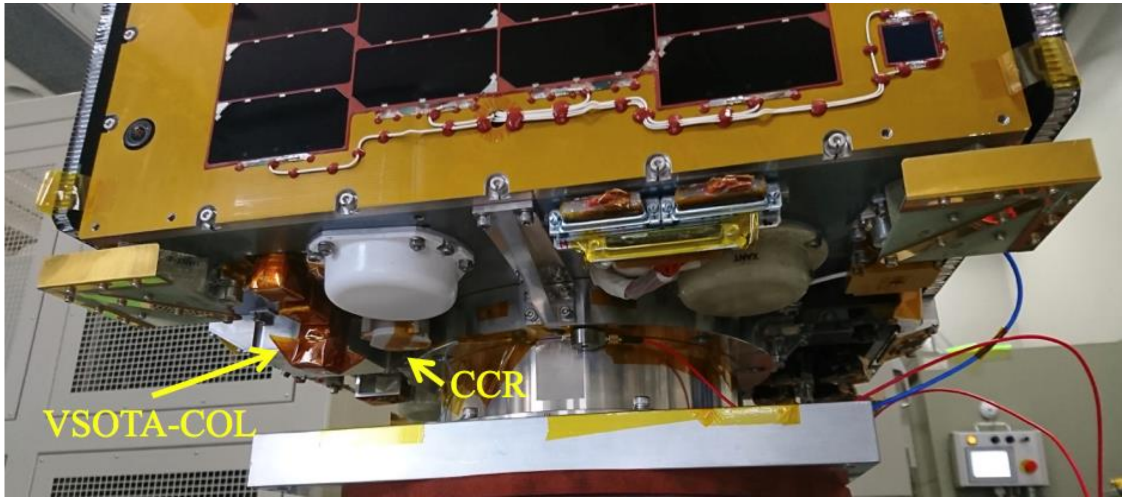
Pointing Accuracy:
0.1degree or 1.7mrad（3σ）: Requirement／
0.04 degree or 0.7mrad（3σ） Goal

Location of VSOTA Sub-Components and HPT (High Precision Telescope) in RISESAT

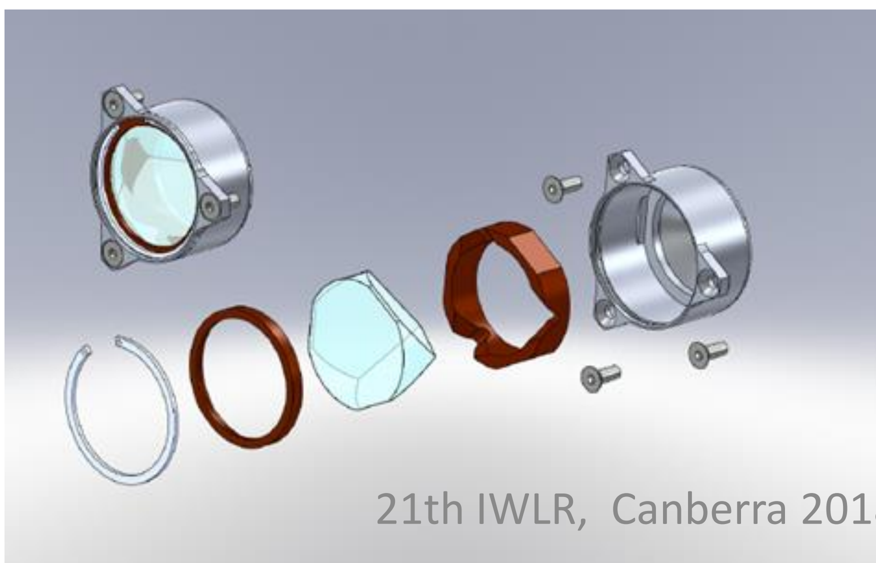




CCR on Nadir Panel



VSOTA-COL and CCR shown on the flight model of RISESAT

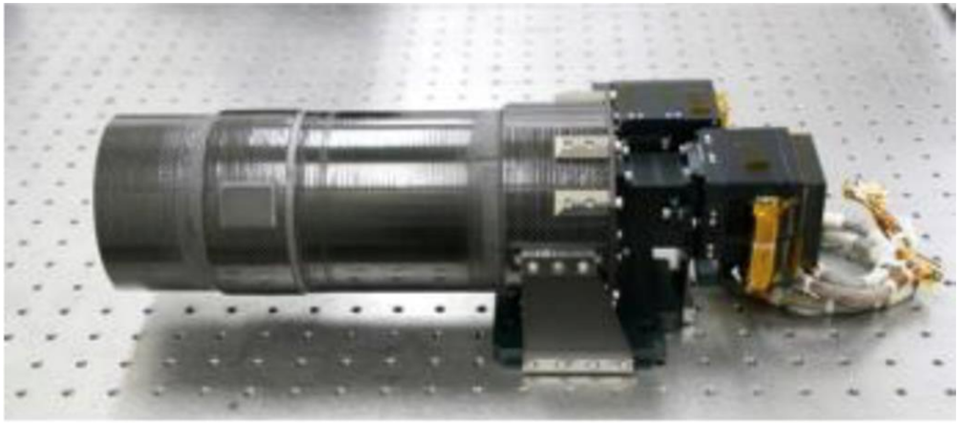


CubeDiameter: CA 28mm
Uncoated
Dihedral angle = 2.4 arcseconds +-0.4

Heritage of cancelled project (Astro-G) in 2013

Specification of HPT

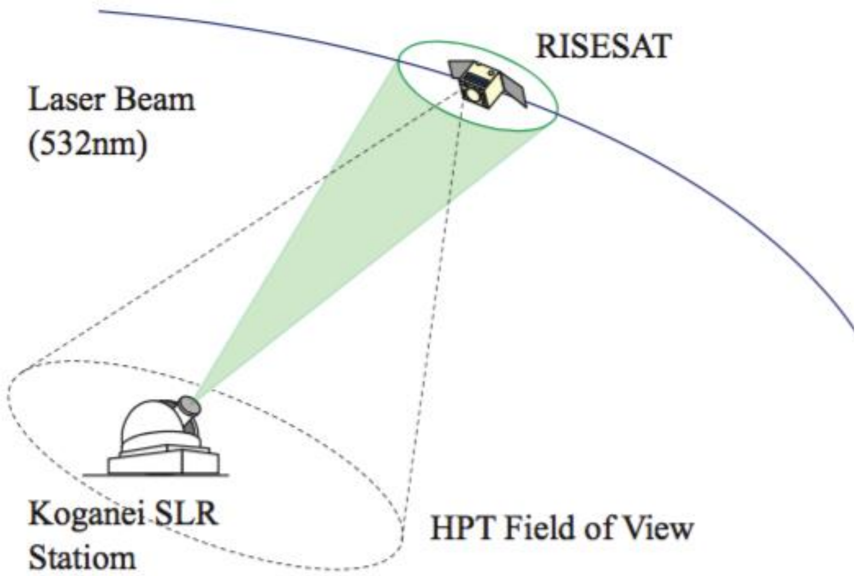
Parameter	Value
Observation Band	630 bands (420 nm – 1050 nm)
Ground resolution	5 m (at 700 km LEO)
Field of View	0.2°
Data update frequency	10 Hz
CCD Area	659 x 494 pixels
Diameter	100 mm
Focal Length	1000 mm

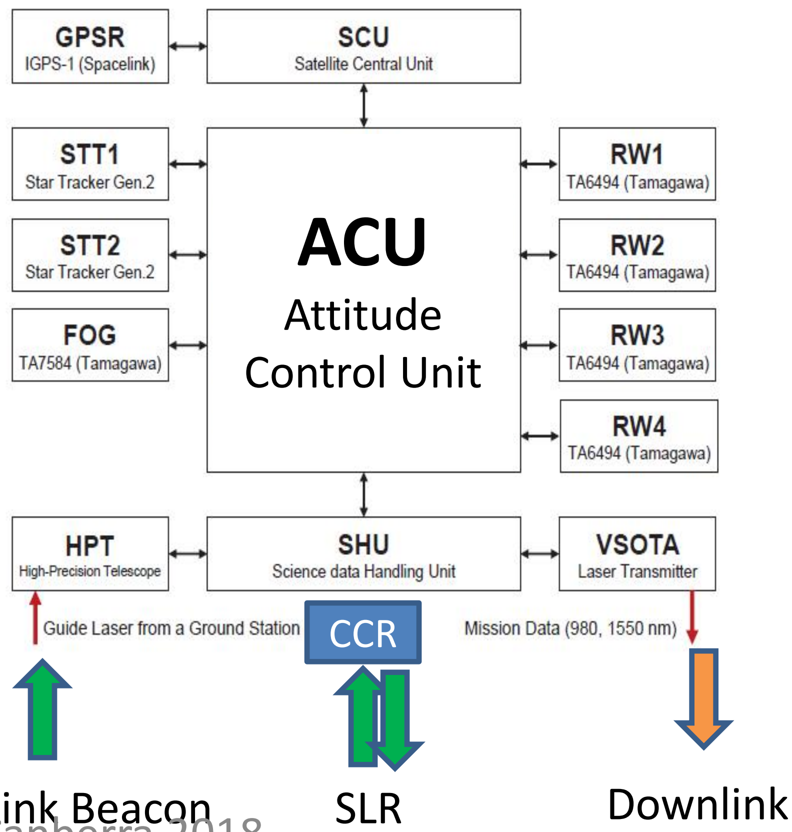


Experiment scheme

Attitude Control System with combination to SLR and High Precision Telescope during Comm.

S.Fujita et al., IEEE_SICE (2017)

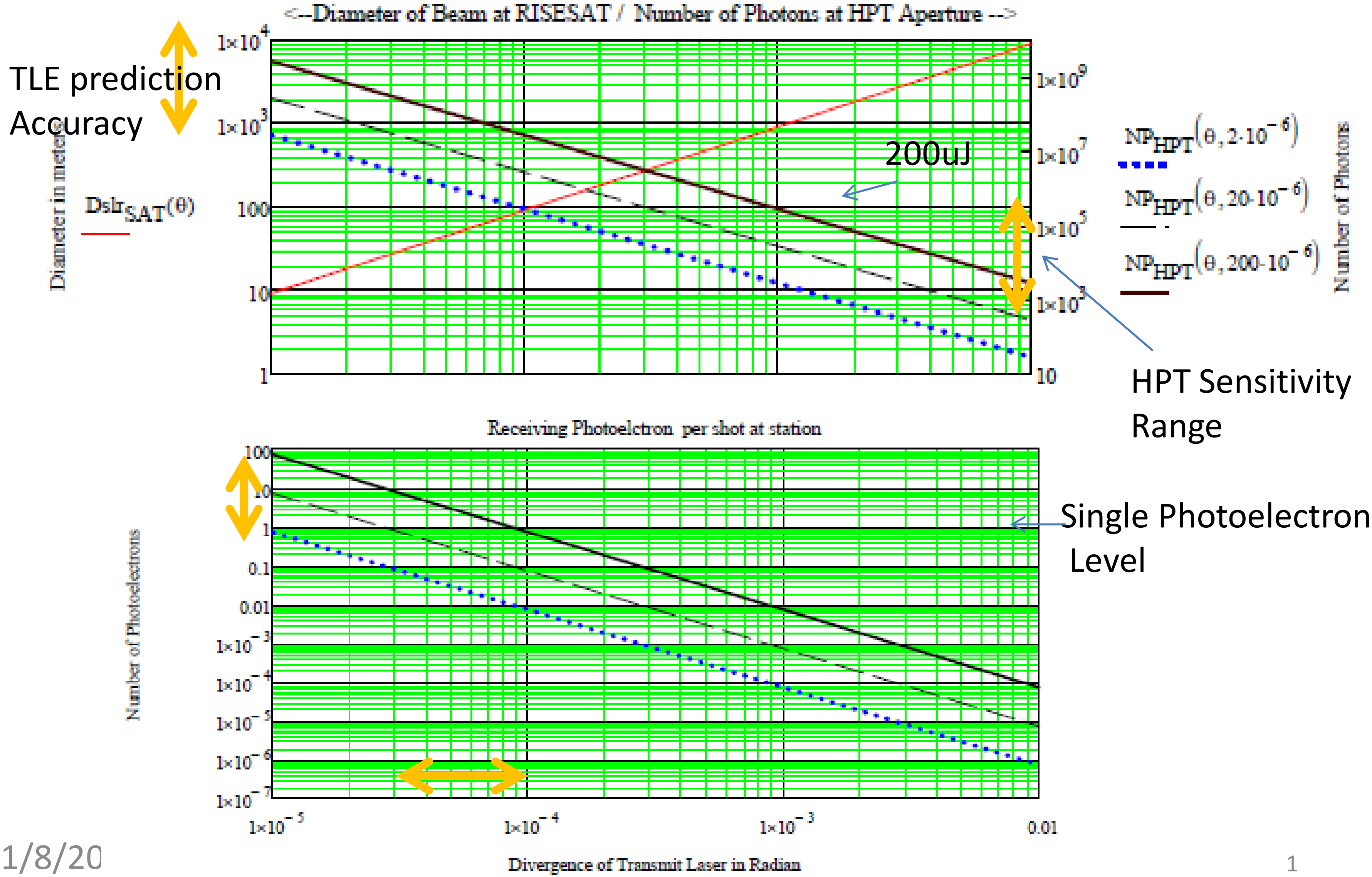




Link for Communication
（VSOTA λ=980nm 100kbps, BER=10^{-5}）

Items/ Size of Telescope→	1.5m	1m	35cm	20cm	unit
Power	270	=	=	=	mW
Wavelength	980	=	=	=	nm
Beam Divergence (Full width)	3.3	=	=	=	mrad
Optical Loss(TX))	-2	=	=	=	dB
Strehl ratio	0.4	=	=	=	dB
Pointing Loss	0.9	=	=	=	dB
Satellite Pointing Loss （3σ）	1.7	=	=	=	mrad
Space Loss	261	=	=	=	dB
Range(oneway)	900	=	=	=	km
Aperture SIze	1.5	1.0	0.35	0.2	mφ
Receive Gain	134	130	121	116	dB
Optical Loss(RX)	-2	=	=	=	dB
Atm.Turblulance Loss	-7	=	=	=	dB
Atm.Transmission	-4	=	=	=	dB
Receiving Power	-54.7	-58.2	-67.3	-72.2	dBm
Receiver Sensitivity	-60	-60	-70	-70	dB
Margin	5.3	1.8	2.7	-2.2	dB

Uplink for HPT and SLR Link budget v.s. Beam Divergence (λ=532nm Slant range=900km)



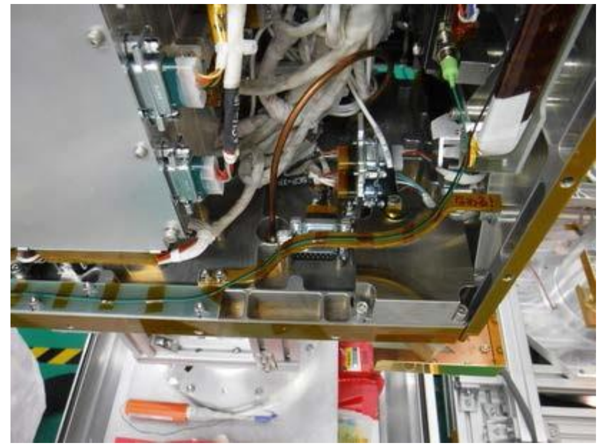
Mission Success Level

Mission Success Level	Item	Objective
Minimum Success	M1	Demonstrate the capability of lightweight, compact optical communication on a scientific microsatellite.
	M2	Acquire data on the effect of atmospheric scintillation noise on the laser communications link.
Full Success	F1	Evaluate the HPT image of the SLR guide laser from ground
	F2	Evaluate the downlink beam divergence and ACU accuracy using the primary ground station and feed back to ACU.
Extra Success	E1	Evaluate the downlink beam divergence and ACU accuracy simultaneously using the primary ground station and mobile ground stations to consider the beam spread.
	E2	Be used as a reference source for verifying the adaptive optics of the optical ground stations intended for future high-throughput satellites, etc.
	E3	Be used as a reference source for verifying the superconducting nanowire single-photon detector (SSPD) to be used for a PPM-based deep space communication.

Current Status: Test Activities

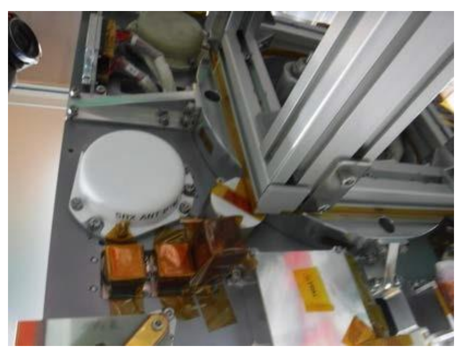
VSOTA-COL additional Vibe. test (Feb **2018)**

Integration of VSOTA on RISESAT (Jun. 2018)

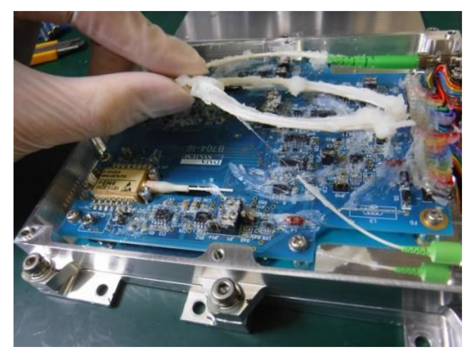


VSOTA-E baking (May2018)

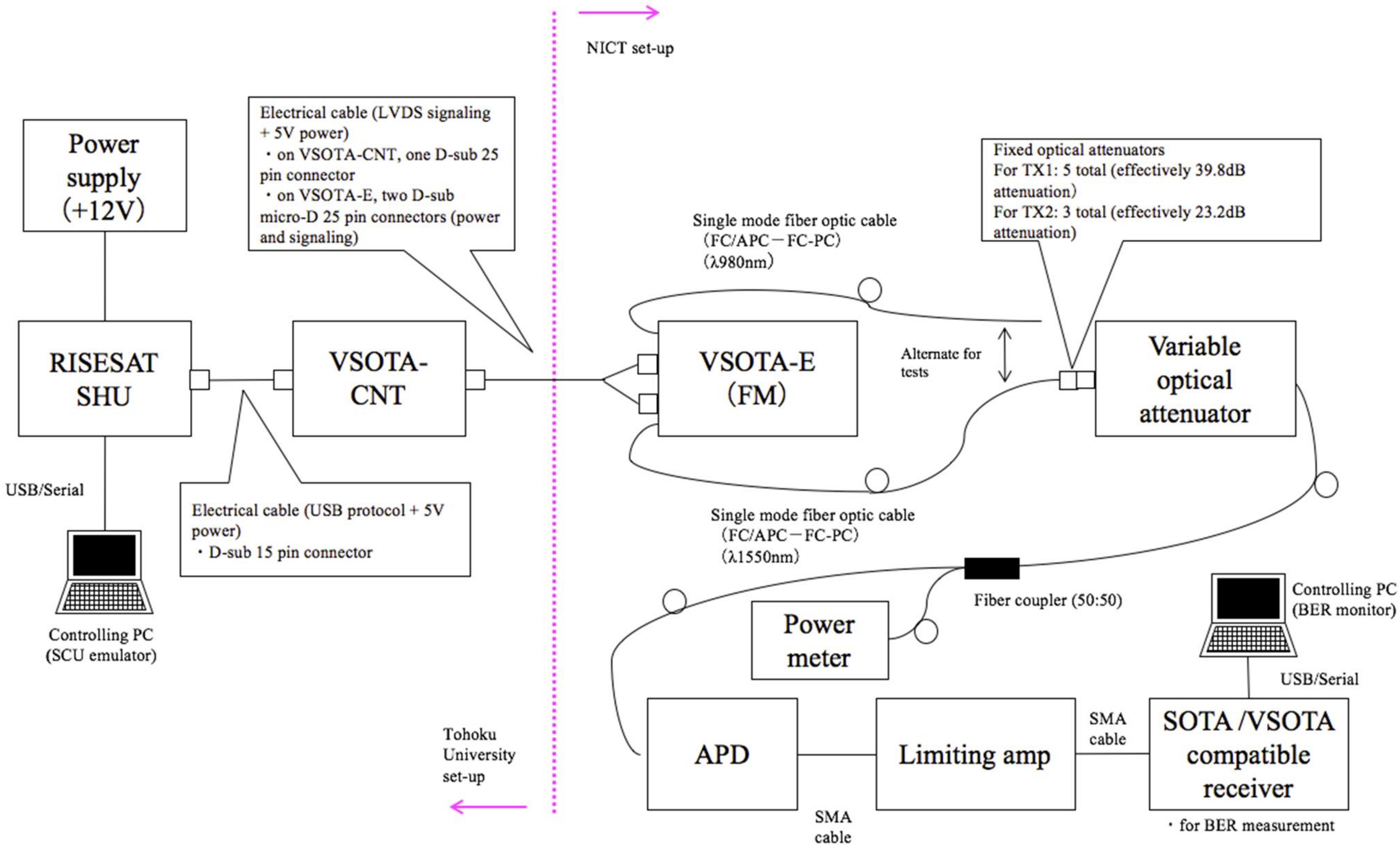
VSOTA-COL Safety Cover set (Mar. 2018)



VSOTA-E LD replacement (Jun. 2018)



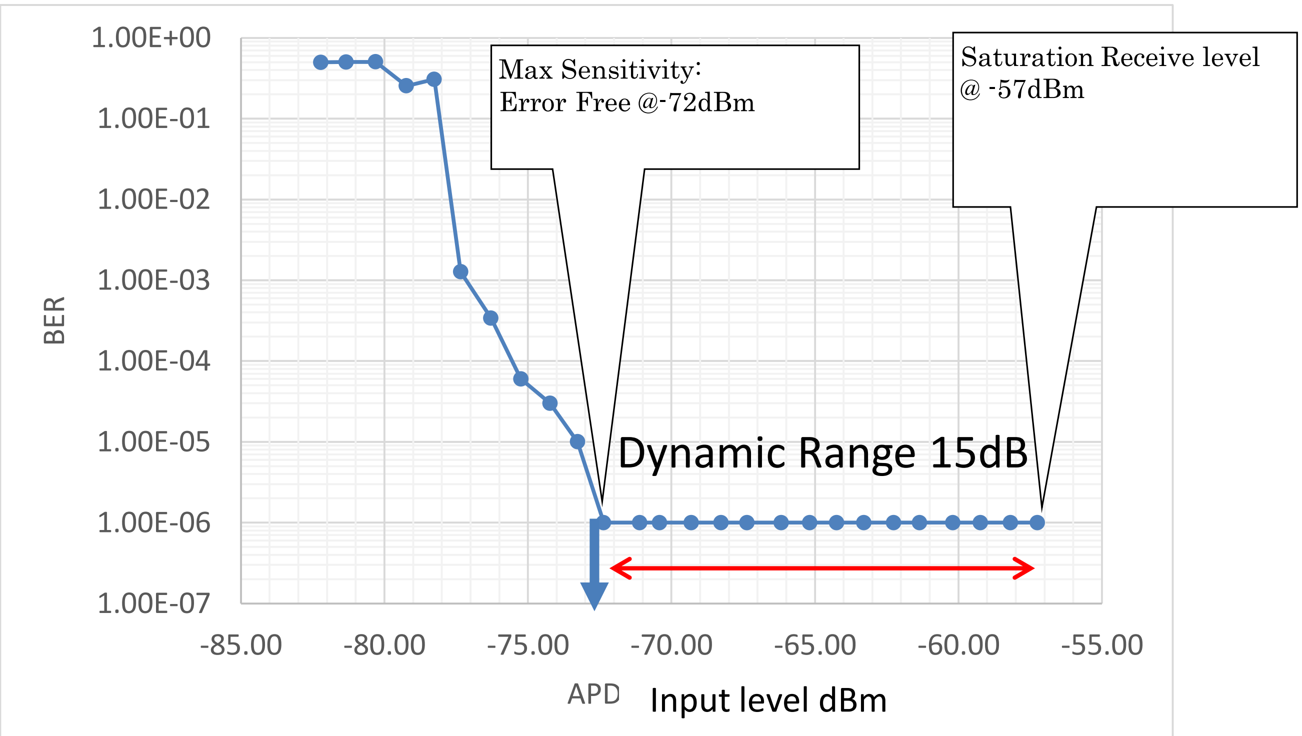
Configuration of End-to-end electrical and communication tests



H.Tomio, et al. (ICSO 2018)

End to END test : Detector Sensitivity on Ground

Input level of APD detector and BER



APD detector（Hamamatsu C5460-1864）

（Tx1 980nm, Data rate: 100kbps with HPF 2kHz）

Conclusion

- We described background and features of VSOTA, experimental plan and status.
- It is in the final stage of the End to End test.
- It is not only communication but test laser source in sky, reference for Adaptive Optics light source, and it gives you to check beam Irradiance on the camera.
- In future work we will prepare for the equipments installation and operation software in ground stations, before launch when it will around the end of this year or the early next year and start the experiment after check out of satellite phase.

Thanks