Towards Integrated Communication and Ranging system using 1.5um wavelength fiber technology

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Table of Contents

- Why we move to synergy with laser comm. ?
    - Background and requirement
    - Wavelength/Modulation scheme
- How we designing system now.
    - Key elements
- Experiment plan using a pilot satellite
- Summary

Background(1) : Global Fiber Network

Submarine Cable MAP 2013
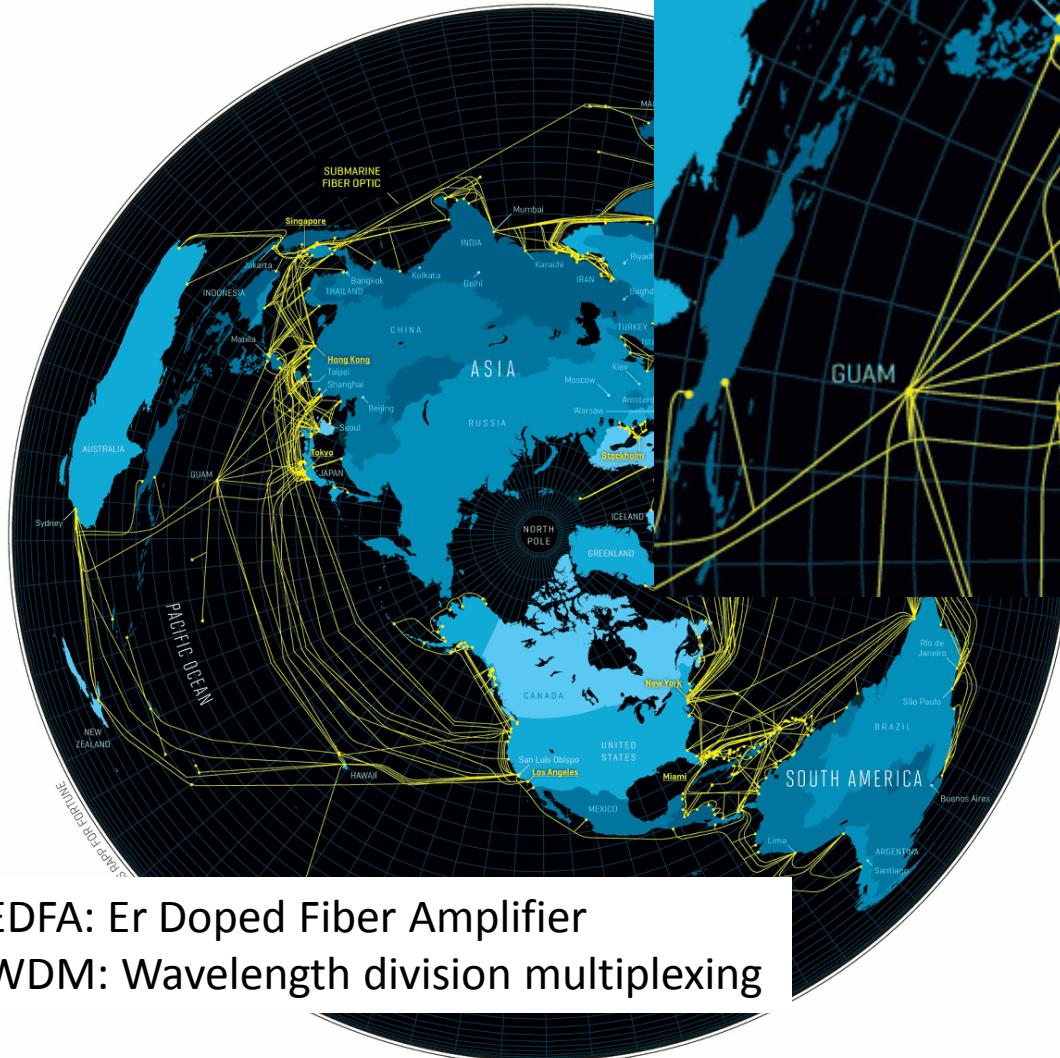
232 cables between continents as of Jan.2013, and growing ,
10G-40Gbps/wavelength, <0.8nm spacing

EDFA: Er Doped Fiber Amplifier
WDM: Wavelength division multiplexing

Background(2): Demanding Space Communication Bandwidth

Downlink is more demanding than that of Uplink

Communication Rate for Earth Observation Satellite

M. Toyoshima, "Trends in satellite communications and the role of optical free-space communications"
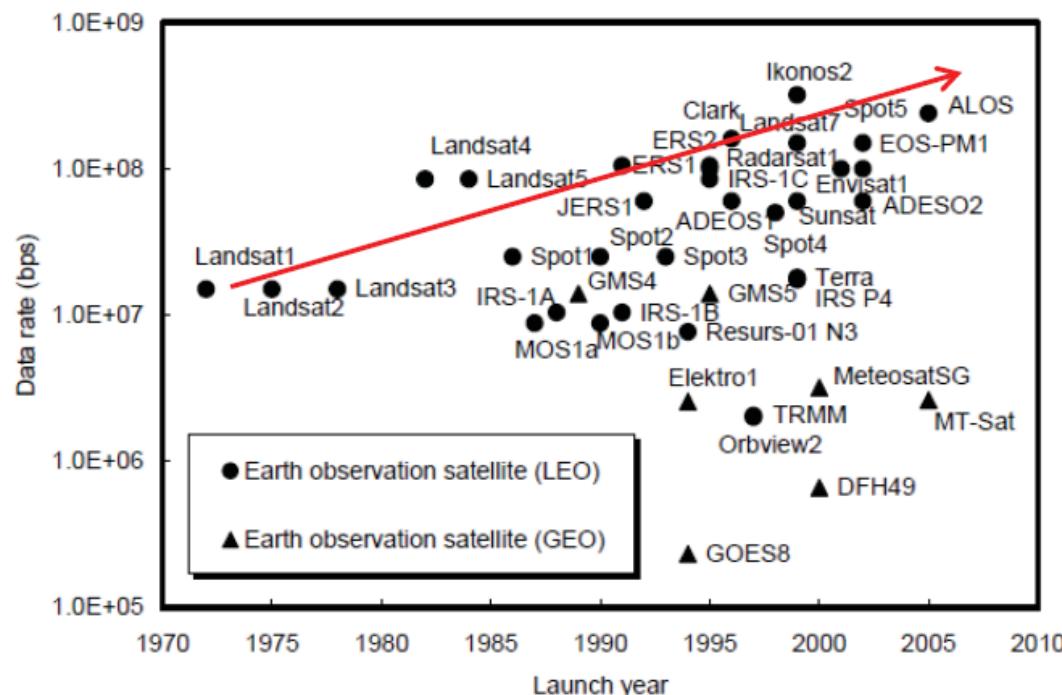
Demanding Comm. Bandwidth
RF system : Matured and Robust
against weather , however,
Up to 1Gbps per ch. (e.g. Ka band)
Limitation of Bandwidth
Subject to Radio license regulation

OPTICAL "SPACE" Communication
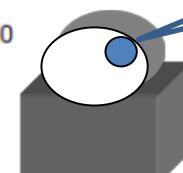
High bandwidth,
Small, Light weight
No license needed
But,
High Pointing accuracy
Subject to weather

Requirement(1) :
Global Optical Site Diversity

J.Degnan, IWLR, SanFernando, Spain,2004

Synergy of two applications SLR and Comm
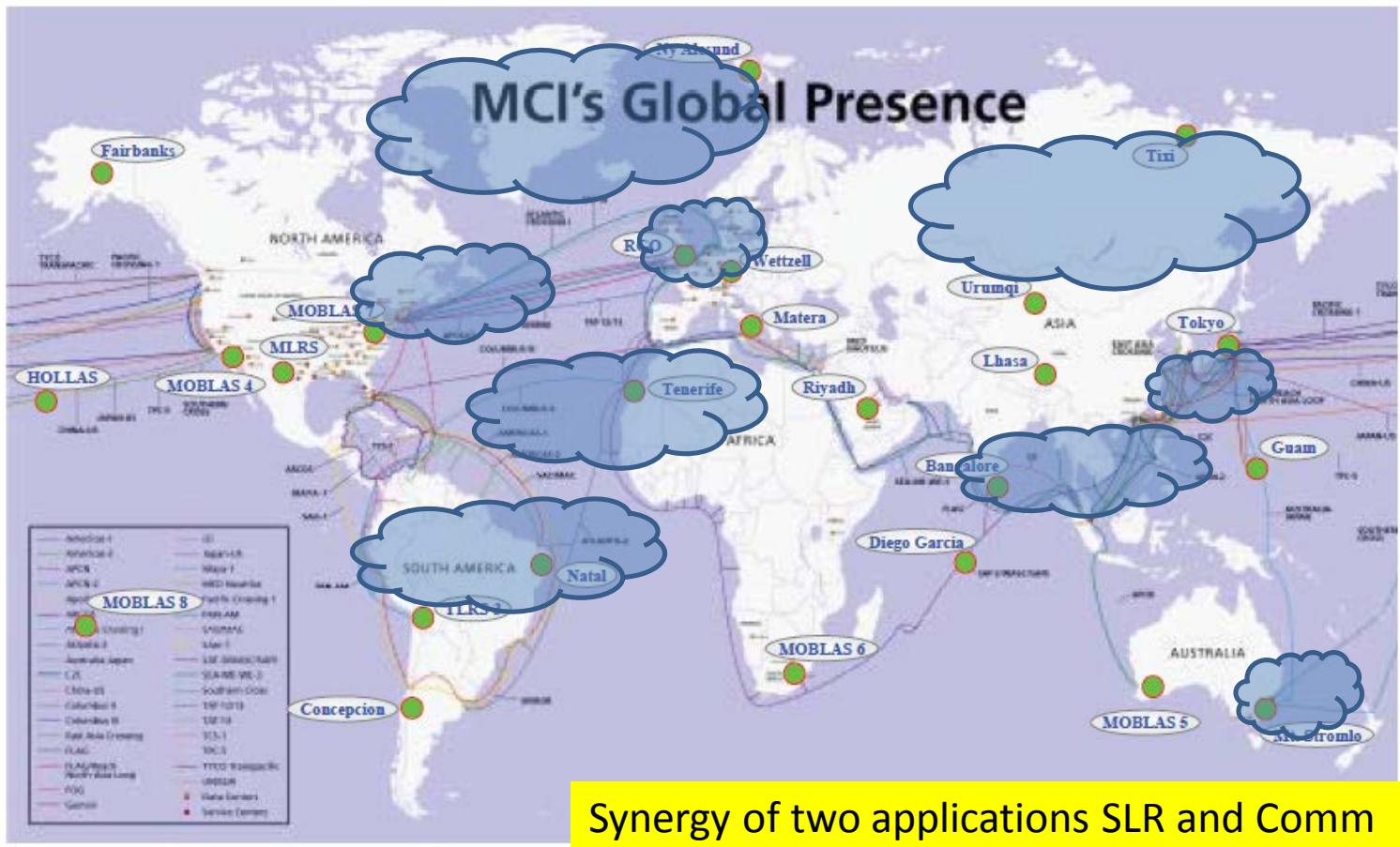
Figure 4: Candidate SLR2000C site locations relative to global MCI fiberoptic net.

Requirement(2): Eye safety Consideration on Wavelength

Science Experiment had been less care about safety will be eventually over,
Consider about hundreds or more application to comm. expanding to infrastructure

IEC 60825

$t=10^{-9}\,sec$

MPE:Maximum Permission Explosure
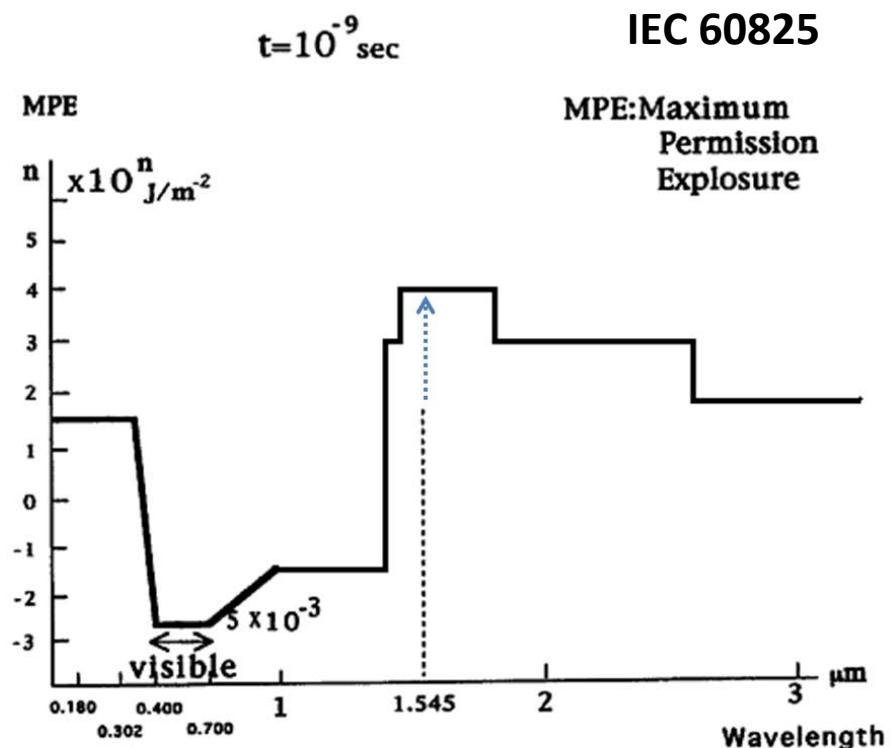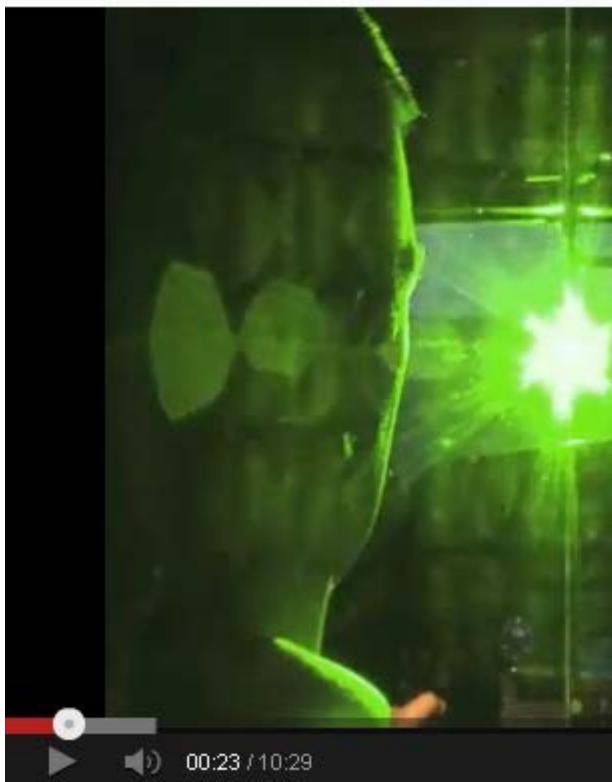
"Aircraft Laser Illumination" edited version of FAA & Air Force video

2011.2. 10 YouTube

Consideration on Modulation
What is Pulse Position Modulation (PPM) among others
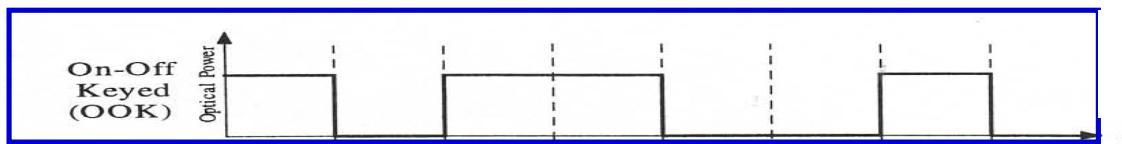

M-ary
PPM
M=4
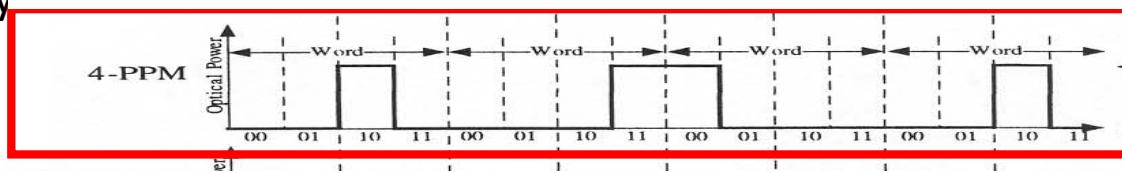
One pulse per Symbol with High PeakPower→Benefit when lossy channel.

Other
Modu
-lation
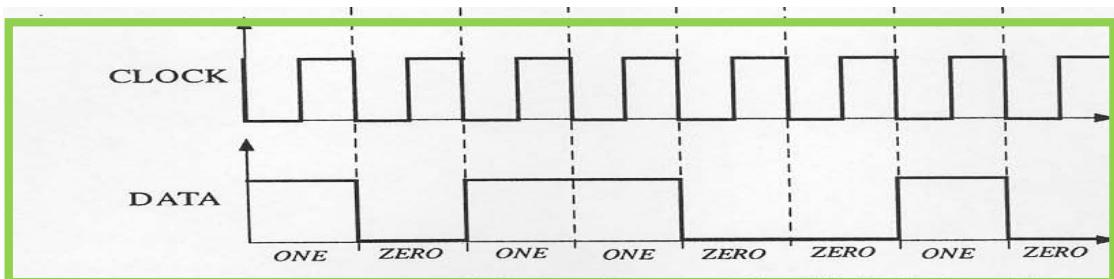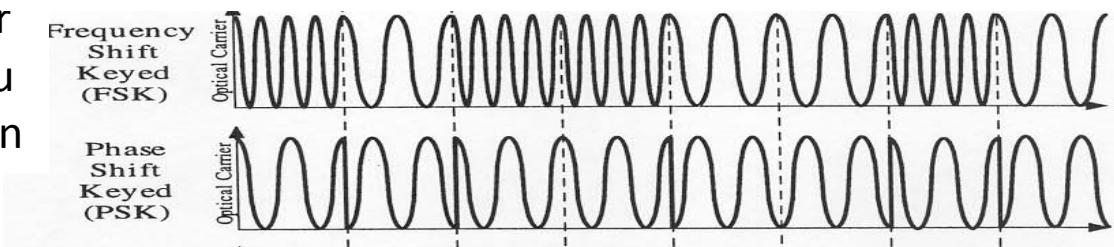
Consideration on Modulation:
Theoretical Transmission rate v.s. power for various modulation in comparison to PPM at distance of 1AU.

Distance:1AU
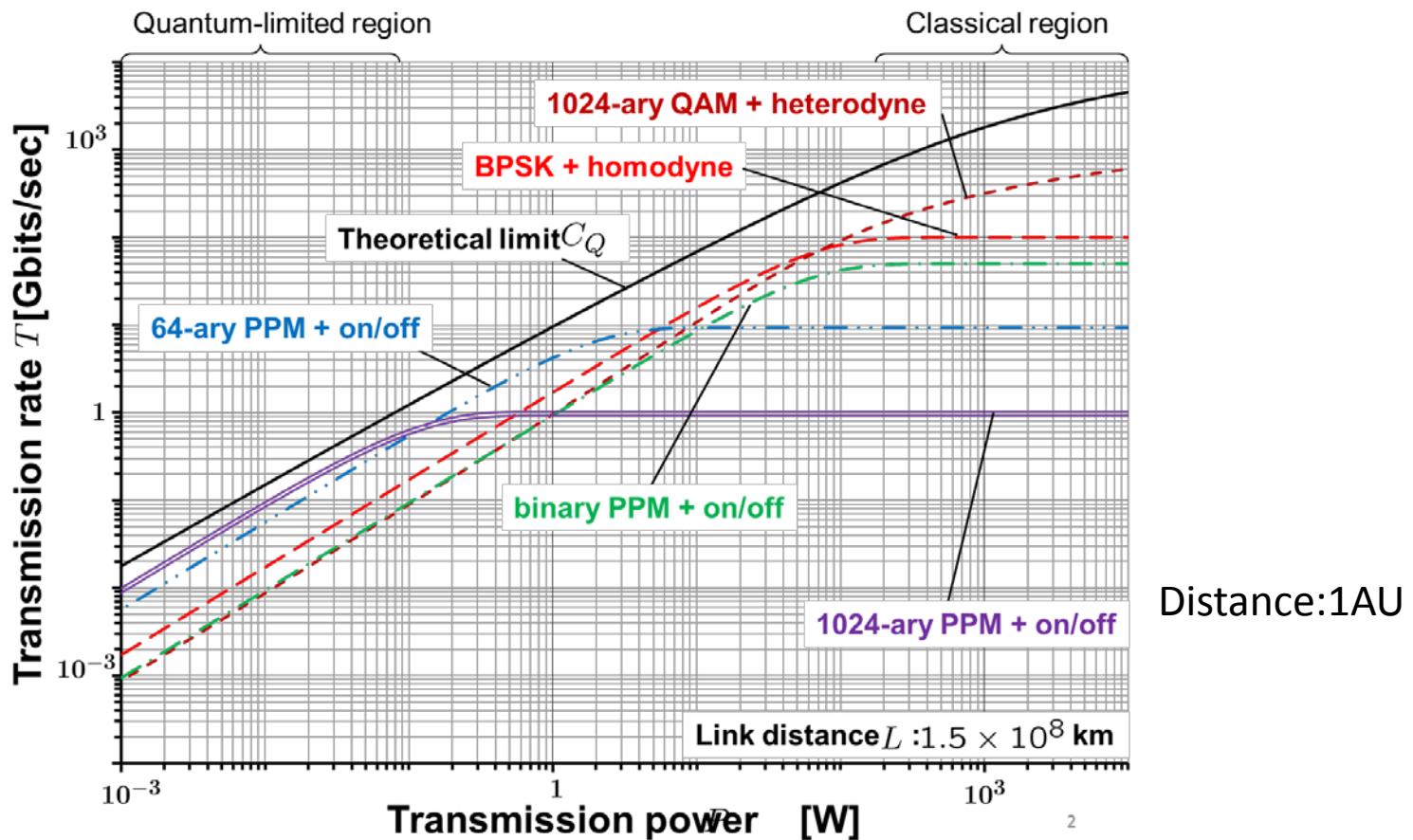
Waseda, et. al, J. Opt Commun. Netw. 3(6) 514 , 2011.

How we are designing(1)
-WDM wavelength allocation-

	Wavelength
PPM Comm.	λcomm=1550.12nm
Ranging (Beacon）	λrange=1558.17nm
Ref. Clock (Freq. Standard)	λclock=1540.56nm

Use C-Band EDFA amplifier in which separation of wavelength must care
To avoid contamination due to Non linear effect between WDM channel

Freq. Standard   Communication   Ranging

1530   1540   1550   1560   1570

S-Band   C-Band   L-Band

Block diagram of Whole System

PPM Transmitter and Ranging station

OUT

PD / → To TIA

PPM Transmitter

WDM Coppler → EDFA Main−AMP → T/R Switch → Space Optics → Telescope Interface

λ₁ / BS → PD

Ranging Laser

Start Disc.

λ₃

折り返しλ2

Beacon

CLK（fo/N）
DATA

RGG/ET PRN Hz

CLK

UTC-NICT Ref signal

LNA Disc.

Two way Range Ch

Online Rangin data

SSPD1
Cryostat1

1.5um Ranging/Beanon

PPM Comm.

BD: Beam Splitter, Refractive Index n=1.945, n=2.146, length=12.5mm
Prism: Refractive Index n=1.517, length=3mm;
HWP: quartz; refractive index n=1.545;
Faraday Rotator: refractive index n=2.370, length: 0.36mm

Fig.2 T/R Switch configuration

SSPD Chip （Manufactured by NICT）

Block diagram of Whole System

PPM Transmitter and Ranging station

OUT

PD → To TIA

PPM Transmitter

WDM Coppler → **EDFA Main−AMP** → **T/R Switch** → **Space Optics** → **Telescope Interface**

Beacon

BS

λ₁ → **PD** → **Start Disc.**

λ₃

折り返しλ2

Ranging Laser

RGG/ET PRN Hz

CLK（fo/N）
DATA
CLK

UTC-NICT Ref signal

Start Disc.

LNA Disc.

Two way Range Ch

SSPD1
Cryostat1

λ₃

Optical/Timing System

Cryostat SSPD

1.5um Ranging/Beanon

PPM Comm.

Online Rangin data

PPM Receive Station

TIA Interface

TIA → Offline One way Ranging Data

PPM λ₁

LNA Disc ← **SSPD2/ APD_Array** / **Cryostat2** ← **FPM** ← **Telescope Interface**

Beacon

INPUT

Spectral BP Filter

PPM Receiver

DATA

CLK（f0）

Optical antenna (35 mm) · Fast steering mirror (FSM) · CCD camera · QPD tracking sensor · Fiber coupler · PID servo controller · DC-DC converter · Beacon LD

11

PPM Parameters:
Slot rate, M,N,T$_{interval}$

M=16 , N=2 PPM Format

1 symbol WORD

1symbol

T$_{slot}$

DATAin の 伝送rate

Tinterval

インターバル(Ti),10ns ～ 10us

M=16

N=2

DATA in $\times$ 0000b $\times$ Ti $\times$ 0111b $\times$ Ti $\times$

PPM data
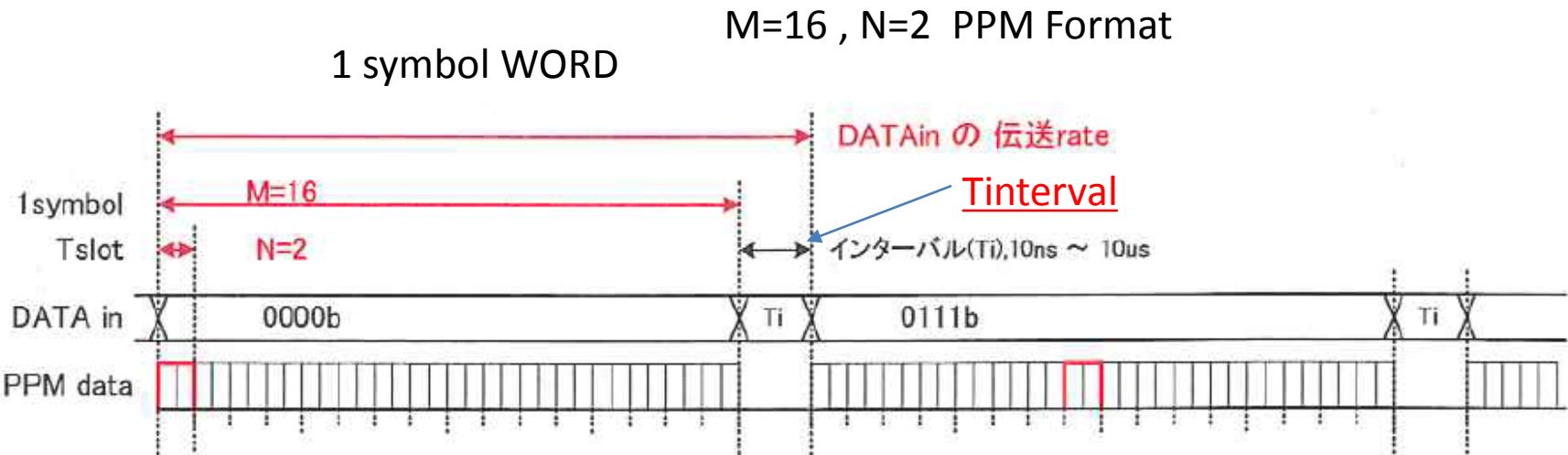
$$Rate_{comm} = EF_{codding} * ((T_{slot} * N) * M + T_{interval})^{-1} *$$

$$log_2 M$$

M: M-ary PPMのM 1 Symbol=log$_2$M bits

T$_{slot}$:   Baseslot width(N=1)

Base Slot rate: 10GHz（width:100ps）

N :   Natural number to slow effective slot rate by 1/N

T$_{interval}$:Dead Time for the next PPM symbol

EF$_{coding}$:Channel Coding Efficiency

PPM Comm. Rate v.s. M
N=1,Tinterval(10ns)

M-ary PPM Communication rate vs M

PPM COMM Rate (bps)

M.ary(LOGM)

M-ary (2,4,8....1024)

— Slot rate= 2.5Gbps Red SOLID
•••• Slot rate=10 Gbps   Blue DOT

PPM Comm. Rate vs. T$_{interval}$ （N=1，M=16）
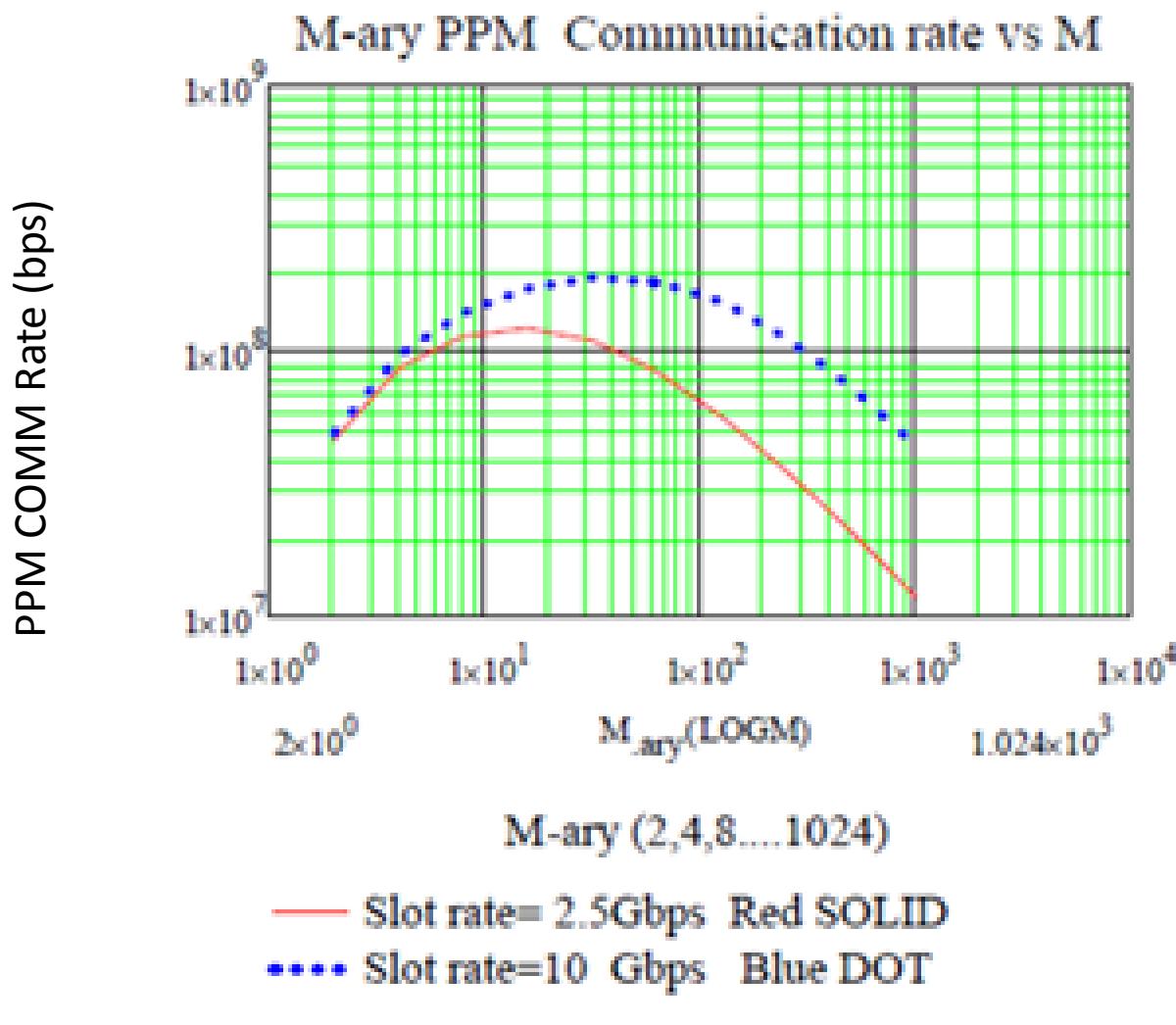
PPM Comm. Rate vs Tinterval at 16-ary PPM
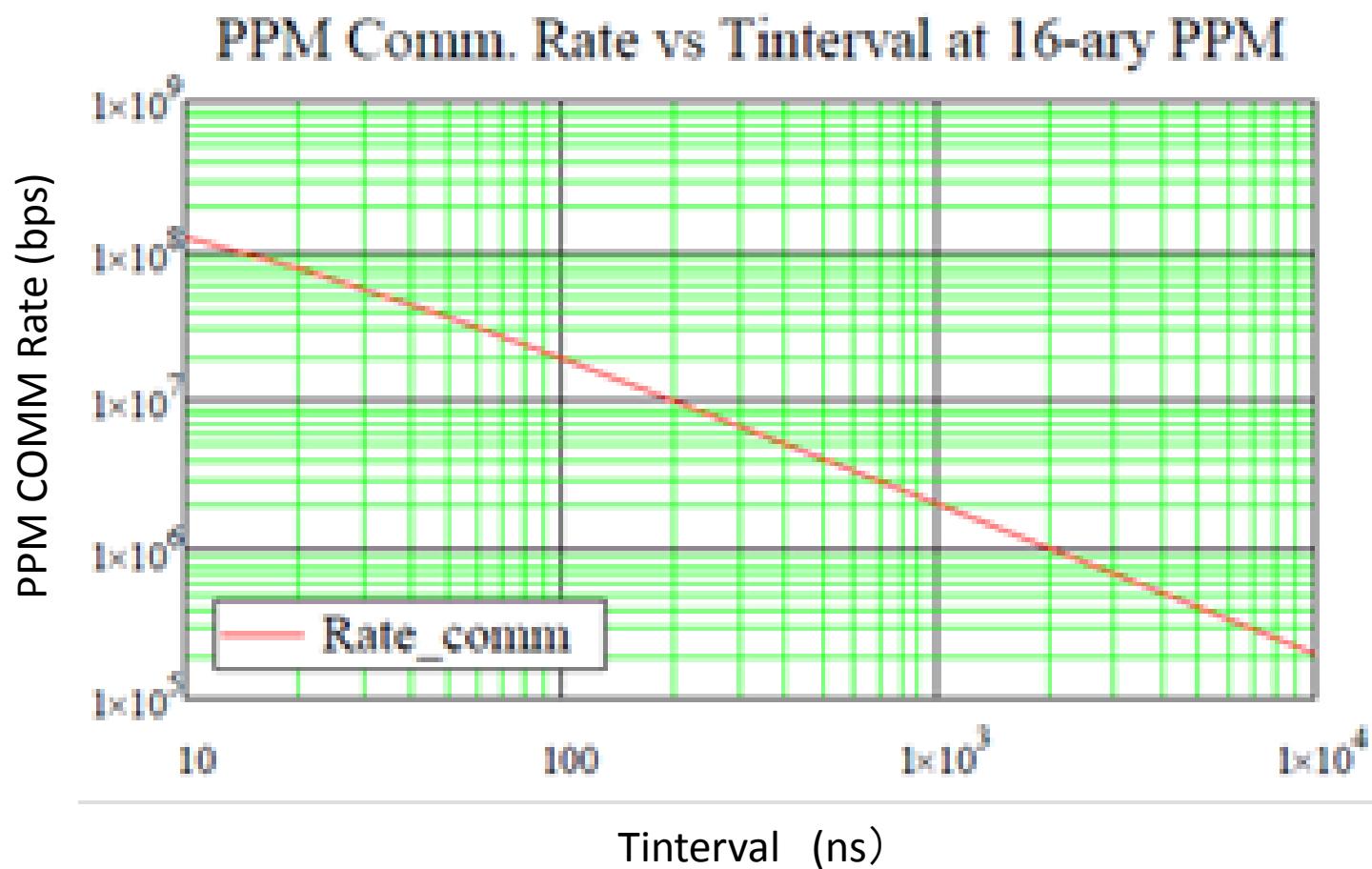
Experiment Plan: Evaluation of 1.5um Comm.&Range system using targets

UAV （1-4km）

Beacon and/or

Ranging/Comm Beams

MicroSat. （600-1000km）

SOTA/VSOTA： TX1,TX4
SOTA TX2/TX3

Optical Ground Station

Fixed station （ 0.5-4km） ＊
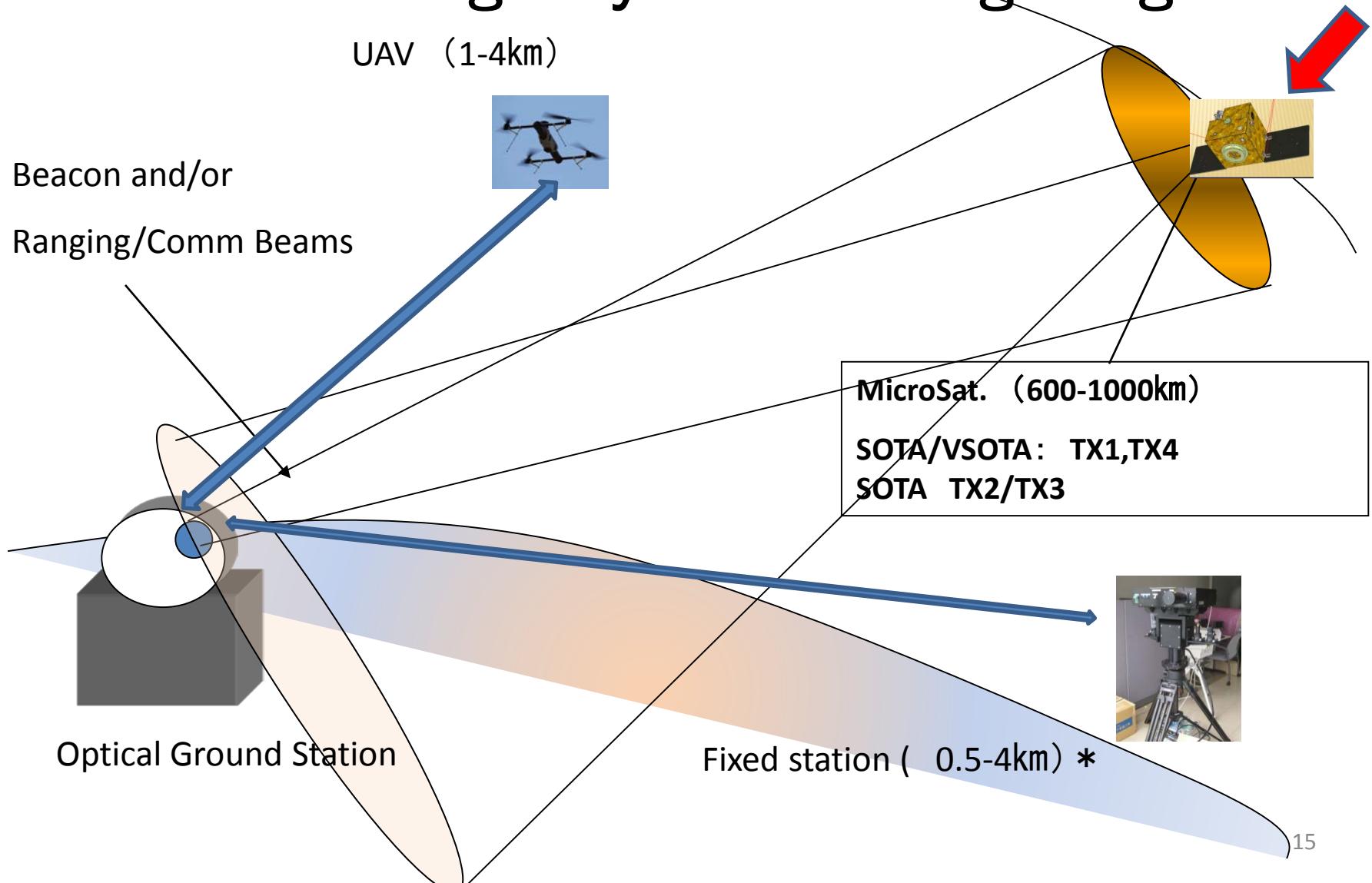
HOST Satellite :RISESAT

Rapid International Scientific Experiment SATellite
One of "HODOYOSHI" Small Satellite Series
Under development by Tohoku University
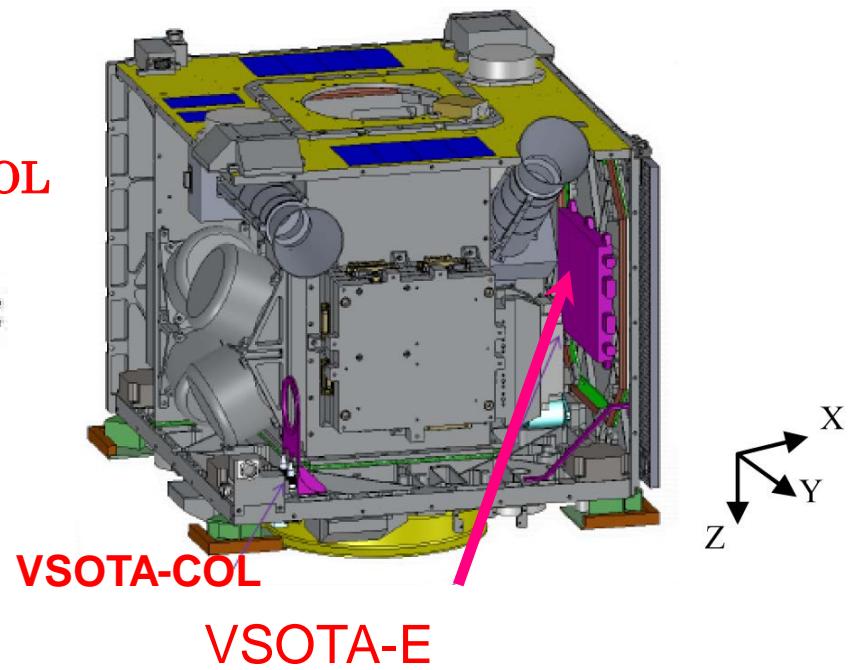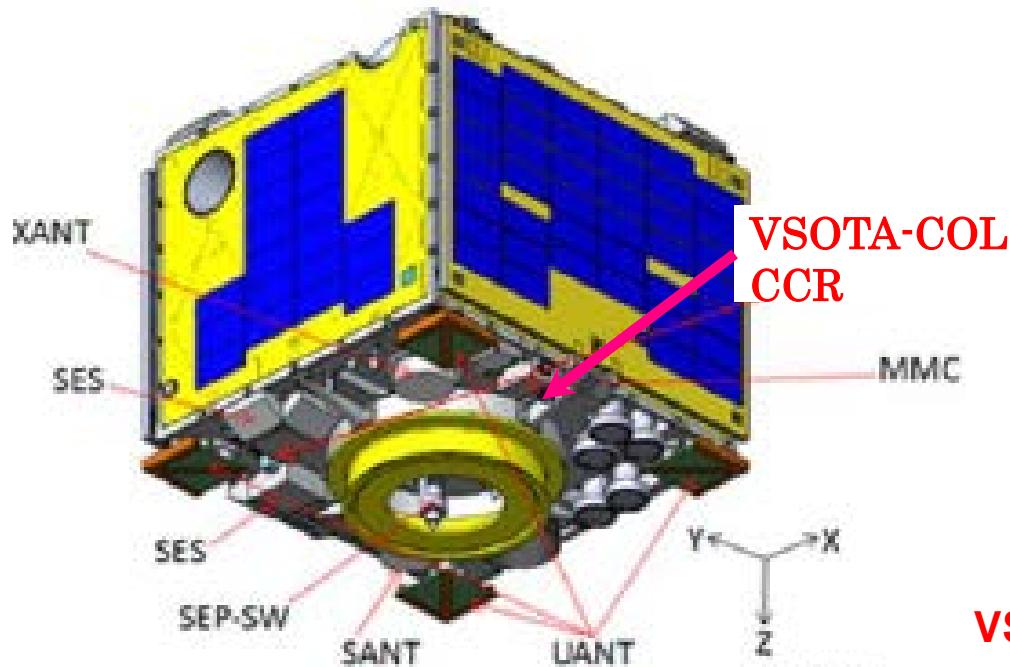
# VSOTA Component look-out

Alignment Cube

1550nm 980nm

VSOTA-COL
(Collimator unit)

Optical Fiber

VSOTA-E (Electric unit)
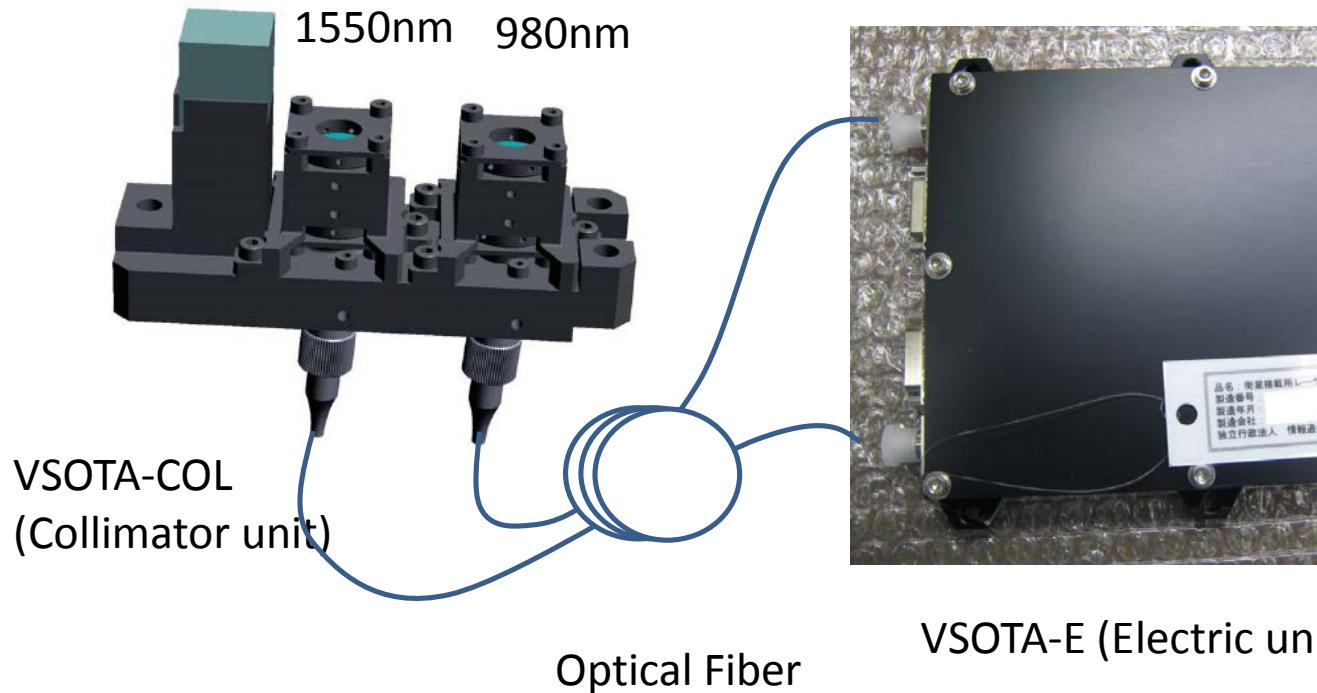
Summary

- New Optical Comm. Integrated SLR system using PPM is under development.

- The data rate (1Mbps) expansion to ranging engine as well as up to Multi 100Mbps data rate

- Evaluation in this fiscal year through next FY.
  - Fiber only
  - 10~100m on ground
  - LEO(Ajisai) ranging and comm.
  - Small satellite downlink experiment