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T/R switch development utilizing optical fiber technology

Tetsuo Hosokawa(Kyoei Optronics CO.,LTD)

Hiroo Kunimori(National Institute of Information and Communications Technology)

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Abstract

T/R switch utilizing well established optical fiber communication technology has been developed in order to use Synergy of Optical Communication and Ranging System.

The switch utilize the optical fiber circulator concept, and enlarge the clear aperture from 10μm to 2.2mm in order to handle the high power laser pulse. The switch can handle the ps to ns-pulse, 10kw peak power, 1MHz pulse repetition rate laser and operate in C-band wavelength range.

We describe the configuration, operation principle, and evaluation data such as insertion loss, and T/R isolation characteristics vs. beam size.

The switch will be used in eye-safe laser ranging and long distance optical communication.

Introduction

The National Institute of Information and Communications Technology(NICT) has been in development of optical space communication measurement control evaluation system[1]. In the system, technical synergy of optical communication and laser ranging is very important. In order to increase system reliability, operability, and also to decrease development cost

Especially applying well established optical fiber communication technology is one of the key issues. In the system we use the C-band laser oscillator(ITU grid wavelength laser diode), EDFA, mode locked 30ps fiber laser oscillator, beam combiner, high speed fiber optical switch, fiber voltage controlled attenuator, wave length selector, and so on. These devices and instruments are off the shelf products. Thy are very reliable ,cost effective ,and short delivery term.

To develop the system the T/R switch has a very important roll. But the switch can not get from the commercial products. Because of the systems power handling capability ,conventional fiber circulator has very small clear aperture (fiber core diameter is about 10μm）and limited to about a few hundred mill watts.

But the conventional fiber circulator concept is very attractive for its simplicity and does not require any electrical control circuit.

Large clear aperture sized 2.2mm circulator for open space application has been developed and evaluated the performance which satisfy the system requirements of the T/R switch .

Optical communication and laser ranging system block diagram

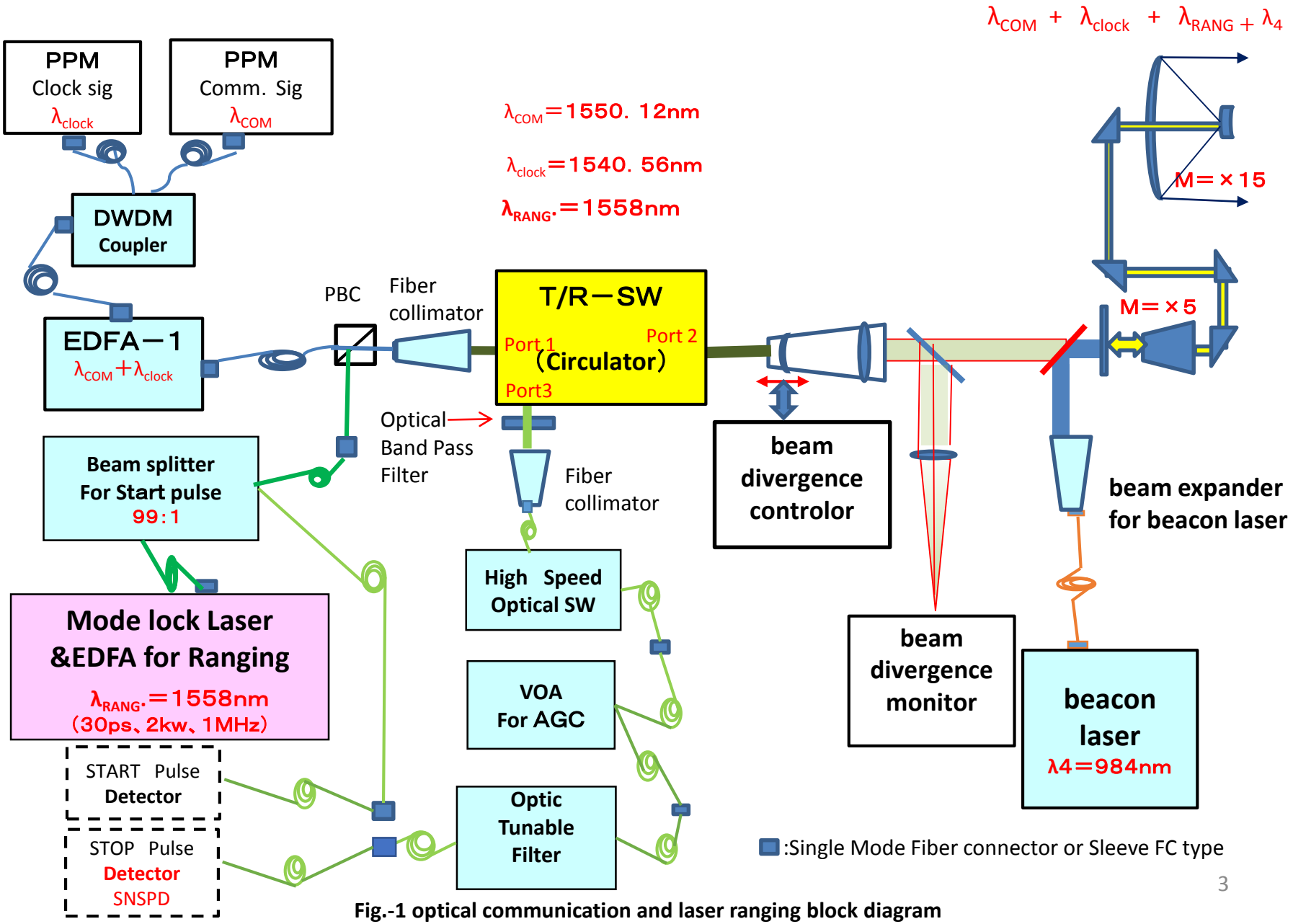


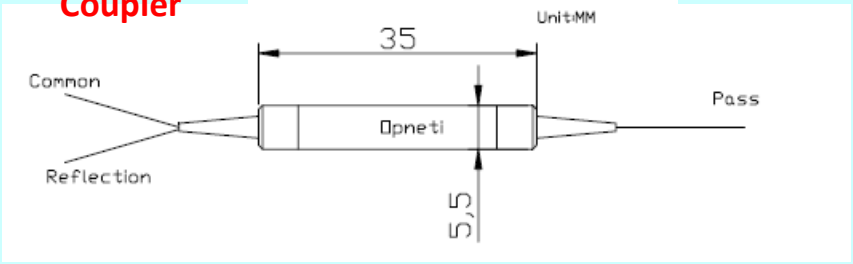
Fig.-1 optical communication and laser ranging block diagram

Optical fiber communication devices and instrument

In the system we use the optical communication devises and instruments as shown below. Most of these devices and instruments are off the shelf items.

1,DWDM Coupler

PM Fiber DWDM [2]



Features
Low Insertion Loss
High Extinction Ratio & Isolation
High stability and reliability
Application
DWDM System
Sensor
Fiber optical testing equipment

2,EDFA—1

$\lambda_{COM} + \lambda_{clock}$

PMFA Series [3]

POLARIZATION MAINTAINING OPTICAL FIBER AMPLIFIERS

	PMFA-15	PMFA-24
Saturated output power	15 dBm	24 dBm
Signal gain	30 dB @ -20 dBm	35 dB @ -20 dBm
Optical noise figure	< 3 dB @ -20 dBm	< 4.5 dB @ -20 dBm
Input power range	-30 to +10 dBm	-20 to +20 dBm
Wavelength range	1527-1565 nm	1527-1565 nm
Spectral gain flatness (single channel input)	0.5 dB typical	0.5 dB typical
Minimum distortion-free pulse width (standard)	1.0 ps	1.0 ps
Dimensions	10 cm x 26 cm x 28 cm	10 cm x 26 cm x 28 cm

3,High Speed Optical SW

Nano Speed™ 1x1 Fiberoptic Switch / On-Off Modulator

(Bidirectional)

Product Description

The NS 1x1 fiber optic switch/on-off modulator is a fast shutter device featuring very low loss, fast response, and high optical power handling. This is achieved using patented non-mechanical configurations with solid-state all-crystal designs, which eliminates the need for mechanical movement and organic materials. The NS fiberoptic switch is designed to meet the most demanding switching requirements of ultra-high reliability, fast response time, and continuous switching operation. The switch is bidirectional.

The device can be driven by a cost effective circuit with 12V input voltage and a 0-5 V control signal.

4,VOA For AGC

MEMS Variable Optical Attenuator

Product Description

The MM Series VOA is based on a proprietary micro-electro-mechanical mechanism featuring compact design, simple construction, easy direct drive, and excellent optical performance. The MM series VOA is compliant with the Telcordia 1209 and 1221 reliability standards. The MM series VOA is available in either normally-open or normally-closed configurations and with an integrated tap option. The VOA is driven by applying an electrical voltage.

5,Optical Tunable Filter

Manual Etalon Based Fiber Optic Tunable Filter

Product Description

Based on a proprietary thin film cavity filter technology, Agiltron offers Fiber Optic Tunable Filter with central wavelengths ranging from 450 nm to 2000 nm. It is tunable continuously over a wide spectral range up to 80 nm. Agiltron further offers high optical power handling up to 10 W(CW) while maintaining the transmission spectral shape polarization-insensitive over the whole tuning range. Agiltron's unique high reliability and low insertion loss design presents a most cost-effective solution for OEM applications from fiber optic networks to fiber sensing interrogation.

6,Beam splitter For Start pulse

99:1

1x2 (2x2) Fused PM Fiber Standard Coupler

5

Features
Low Excess Loss & Low Insertion Loss High Extinction Ratio High Stability and Reliability
Application
Optical Amplifier Power Monitoring Coherent Communication Fiber Gyroscope Fiber Sensor

Specification

Parameter		P grade	A grade
Central Wavelength (nm)		1310, 1550	
Bandwidth (nm)			
Excess Loss (dB)		≤0.3	≤0.4
ER (dB)		≥20	≥18
Insertion Loss(dB)	1/99	≤21.5/0.3	≤22/0.4

7,Mode lock Laser & EDFA for Ranging

$\lambda_{RANG.}$=1558nm

※Frequency and PRF are customized

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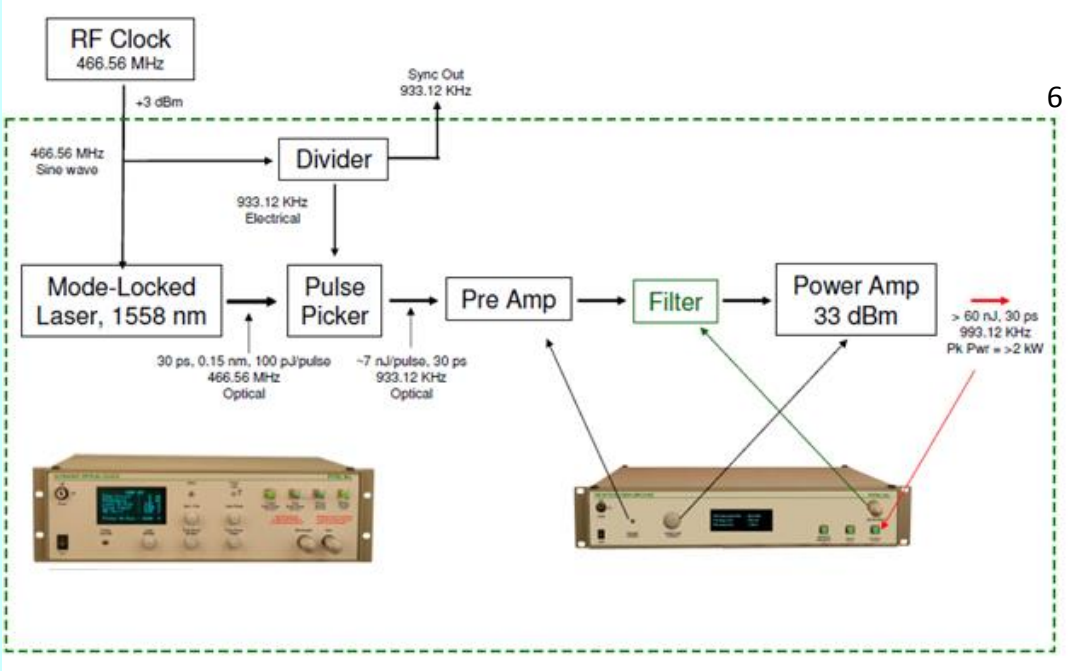
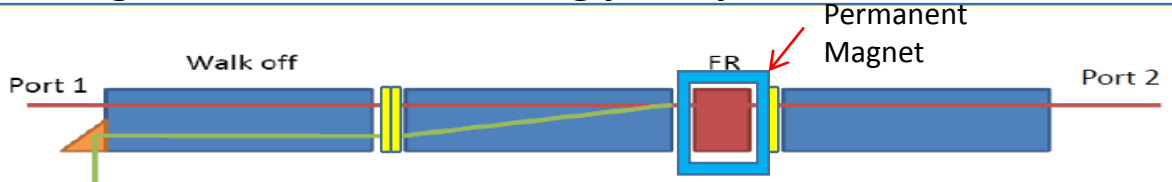


T/R Switch configuration and its working principle



BD: Beam Splitter, Refractive Index no=1.945, ne=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

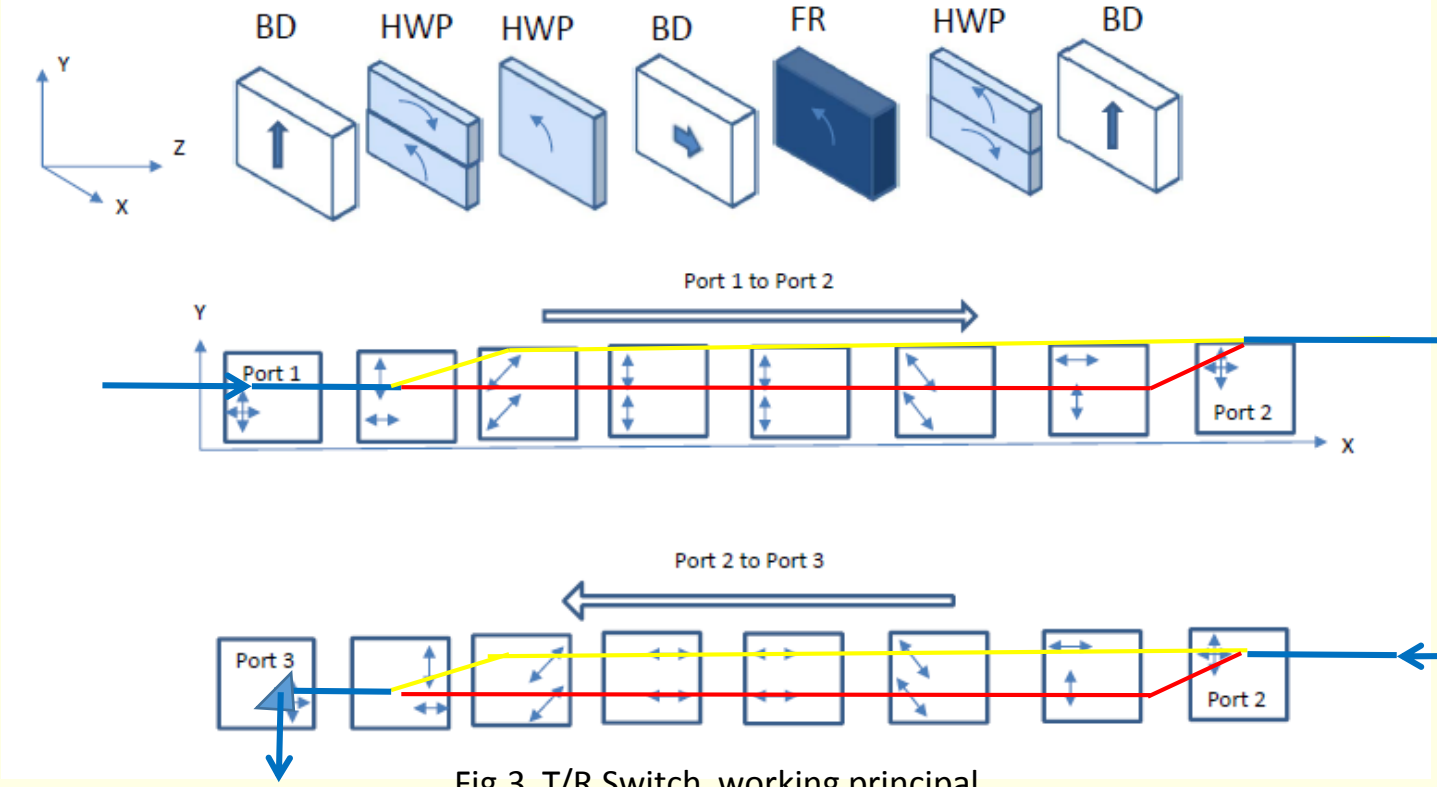


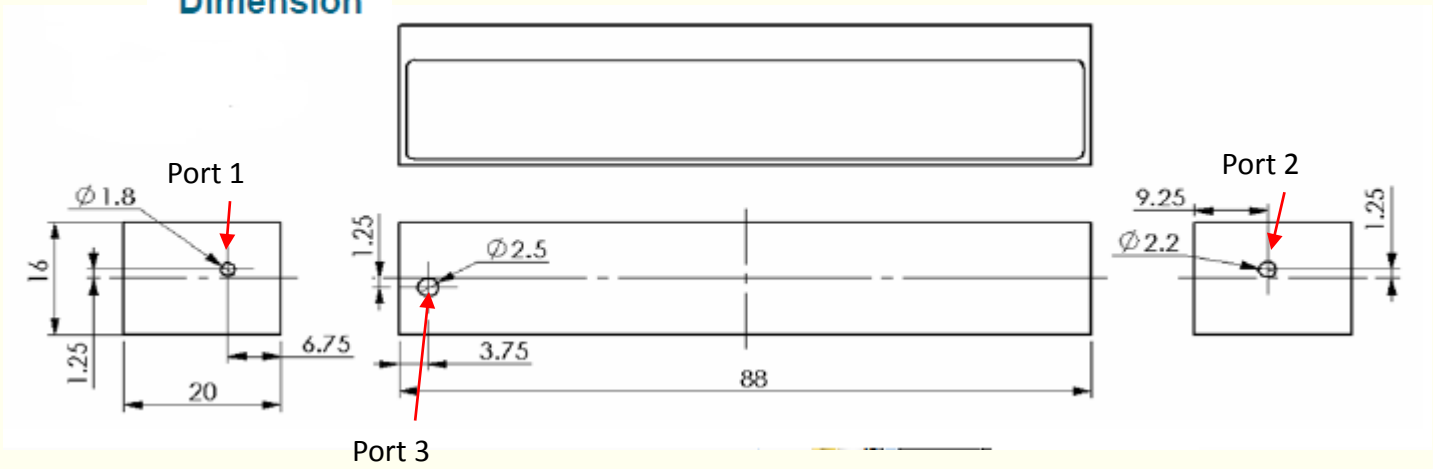
Fig.3 T/R Switch working principal

T/R Switch specifications and dimensions [7]

Specifications

Parameters	Unit	Values
Center Wavelength (λ_C)	nm	1550
Operating Wavelength Range	nm	C-band
Clear Aperture	mm	2.25
Typ. Peak Isolation	dB	35
Min. Isolation, λ_C, 23°C, all polarization states	dB	Min. 25, >30 (target)
Typ. Insertion Loss, 23°C	dB	0.4
Max. Insertion Loss, 23°C	dB	0.6
Max. Polarization Dependent Loss	dB	0.5
Max. Optical Average Power	W	3
Max. Peak Power for ns pulse	kW	10

Dimension



T/R Switch evaluation setup

① Inersertion loss mearsurement setup

When measuring the Port 1 ⇒ Port 2 Insertion loss, w1(w) and w2(w) are measured by the power meter shown in fig-4.
When measuring the port 1 ⇒ Port 2 ⇒ Port 3 Insertion loss, w1(w) and w3(w) by the power meter shown in fig-5.

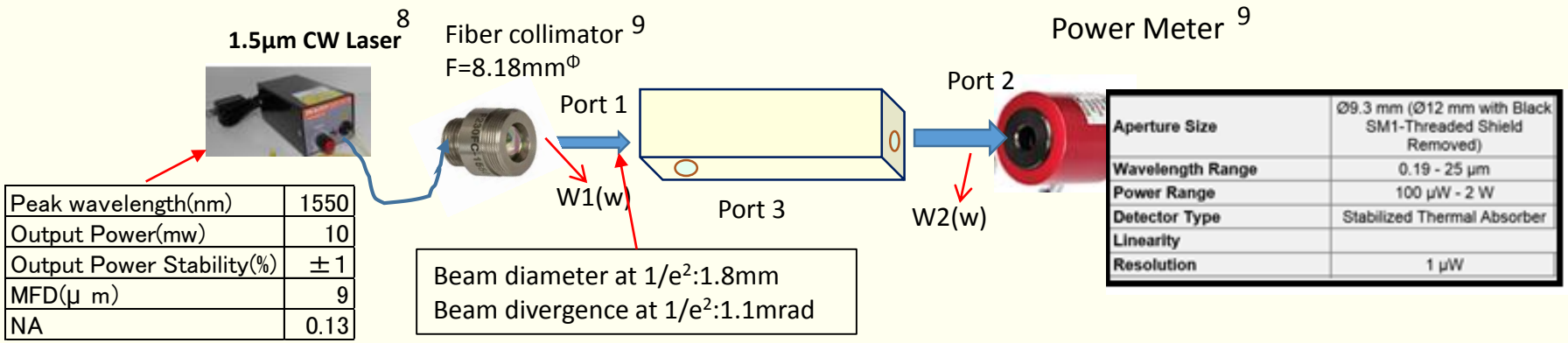


Fig-4 Port 1 ⇒ Port 2 Insertion loss measurement setup

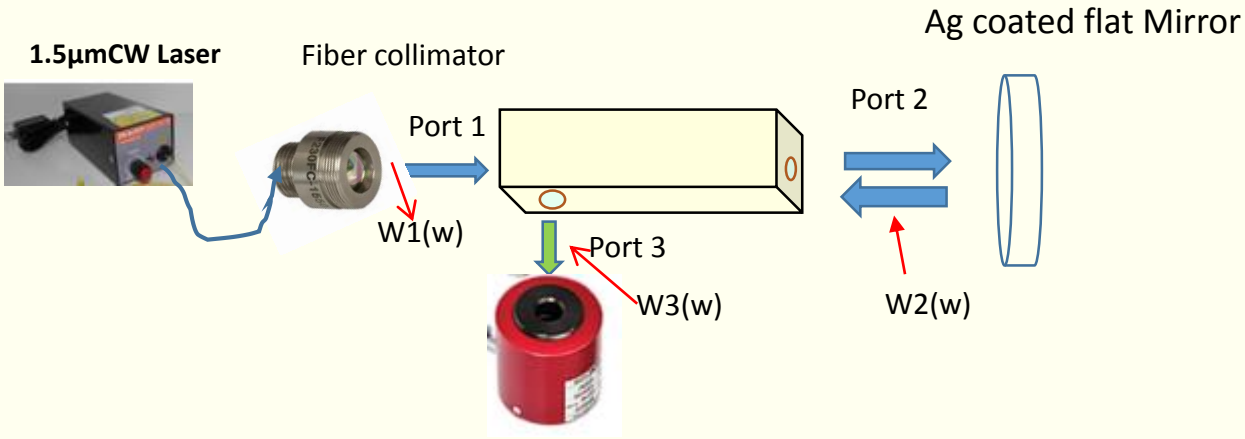


Fig-5 Port 1 ⇒ Port 2 ⇒Port 3 Insertion loss measurement setup

T/R Switch evaluation setup

② Isolation mearsurement setup

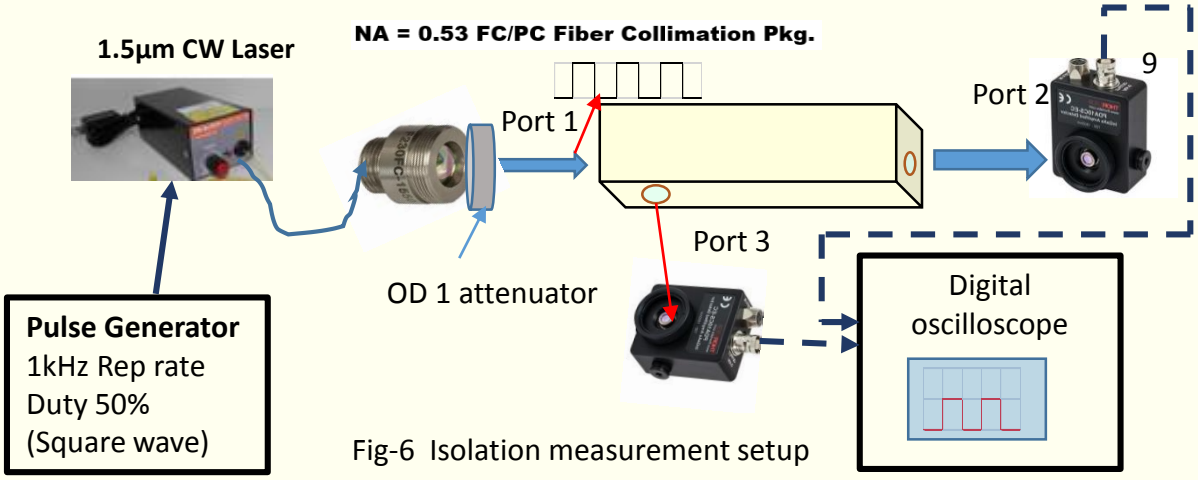
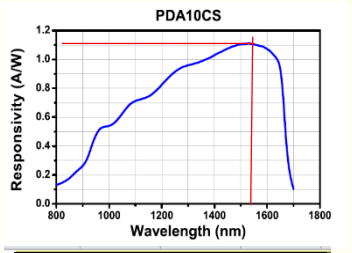


Fig-6 Isolation measurement setup



0 dB Setting	
Gain[3] (Hi-Z)	1.51 x 10^3 V/A ±2%
Gain[1] (50 Ω)	0.75 x 10^3 V/A ±2%
Bandwidth	17 MHz
Noise (RMS)	600 μV
NEP (@ λ_p)	6.0 x 10^{-11} W/√Hz
Offset	5 mV (10 mV max)

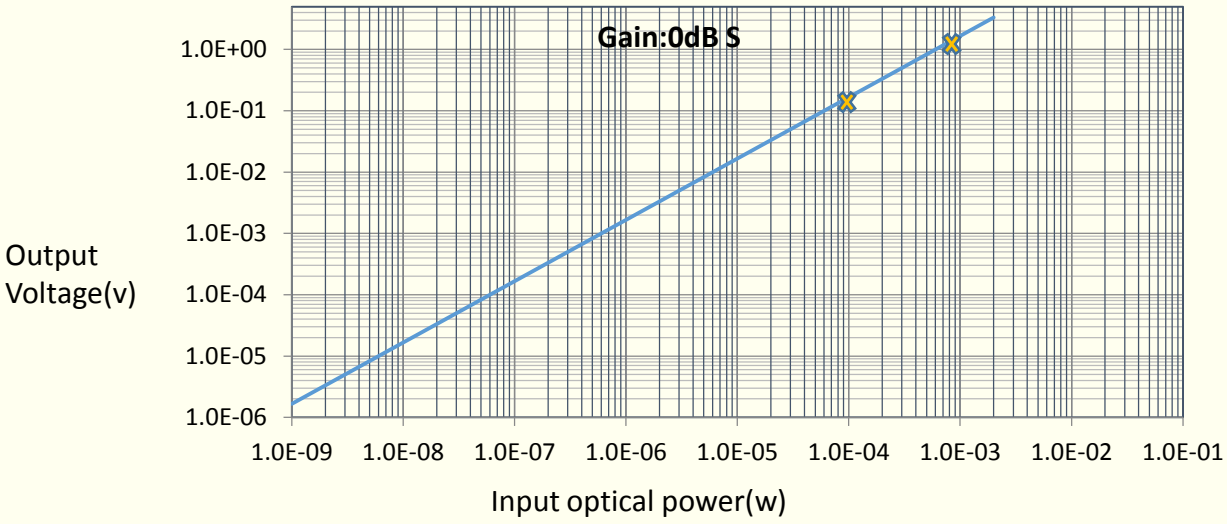


Fig-7 InGaAs detector calibration chart

T/R Switch evaluation result

We have evaluated two T/R Switch. Evaluated performances are insertion loss from Port 1 to Port 2 , Port 2 to Port 3 , and Port 3 isolation from Port 1 to Port 2 path. Result is shown table-1.

Table-1 Insertion Loss and Isolation Result

Sample 1	Port 1 Input W1(mw)	Port 2 Output W2(mw)	Insertion Loss(dB)	Port 3 Output voltage(mv)	Port 2 Output voltage(mv)	Isolation(dB)
	10.05	9.08	0.44	2	3000	31.8
	Port 2 Input W2(mw)	Port 3 Output W3(mw)	Insertion Loss(dB)			
	7.87	7.14	0.4			
Sample 2	Port 1 Input W1(mw)	Port 2 Output W2(mw)	Insertion Loss(dB)	Port 3 Output voltage(mv)	Port 2 Output voltage(mv)	Isolation(dB)
	10.05	9.04	0.46	1	3000	34.8
	Port 2 Input W2(mw)	Port 3 Output W3(mw)	Insertion Loss(dB)			
	8.17	7.42	0.4			

Conclusion

Optical communication and laser ranging system under development by the National Institute of Information and Communication Technology has bee descried as the back ground of the T/R switch development.

Technical synergy of optical fiber communication and laser ranging has been shown such as optical fiber , well established optical fiber devices, optical Amplifiers.

The large diameter telescope was used for transmitting the communication signals and laser ranging. Even though they are all c-band wave lengths, we will be distinguish the signals by the highly established DWDM technology. We will verify this point using the system which are now under developing.

As the best example of the synergy, we reported T/R Switch configuration, working principle, specifications, and evaluation results. Working principle is the very similar to that of optical fiber circulator, but we developed open space circulator (T/R Switch) which has 2.2mm clear aperture which is about 200 times larger than that of Optical fiber circulator. It means the newly developed T/R Switch can handle more than 40 thousand times higher laser power than that of fiber circulator.

The newly developed T/R Switch will be used in the various eye safe laser ranging application such as satellite laser ranging, security and defense fields because of its simplicity , reliable ,and cost effective.

acknowledgement

This work has bee supported to the many of optical fiber engineers and manufacturing companies. Especially I appreciate DR.Reddy who is the president of PriTel,INC. he gave a good advice to customize the 30ps mode lock laser.
I also express my great thanks to the people of OKAMOTO OPTICS WORK,INC. they discussed the optics with a great professional knowledge and experience.

Reference

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[4] AGILTRON,INC. brochure
[5] Opneti Communication,Co. brochure
[6] PriTel ,Inc. semi-customized Products
[7] Boston Applied Technologies,Inc. customized Product
[8] Craft Center SAWAKI Inc. brochure
[9] Thorlabs,Inc brochure