OITDA規格

TP

Technical Paper

TP（技術資料）

高出力光増幅器に関する一般情報

（General information for high power optical amplifier）

OITDA/TP 26/AM：2017

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CONTENTS

INTRODUCTION

Optical amplifiers (OAs) are necessary components as booster, line and pre-amplifiers for current optical network systems. IEC TC86/SC86C, therefore, has published many standards for OAs. Recently, high optical output power amplifier is used for applications in Passive optical network (PON) system and CATV systems.

Although OAs with high optical power which has more than 500 mW are deployed in field, there are very few documents addressing high optical power.

This technical report provides a better understanding of high power amplifier, especially based on cladding pump technology as well as concerning on handling high optical power.

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OITDA/TP（技術資料）

OITDA/TP 26/AM：2017

高出力光増幅器に関する一般情報

General information for high power optical amplifier

1 Scope

This technical paper deals with high power optical amplifier. The main purpose of the report is to provide general information relating to high power optical amplifier, which has high power output over 500 mW. The report covers the following aspects:

– General information;

– Cladding pump technology;

– Test method for optical output and gain.

2 Normative references

There are no normative references in this document.

3 Terms, definitions, and abbreviated terms

3.1 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.2 Abbreviated terms

For the purposes of this document, the abbreviated terms given in IEC 61291-1 and the following apply.

ASE Amplified spontaneous emission

CO Central office

DC Double cladding

DWDM Dense wavelength division multiplexing

EDF	Erbium-doped fiber
EDFA	Erbium-doped fiber amplifier
FTTH	Fiber to the home
HP-EDFA	High power erbium-doped fiber amplifier
MLFL	Mode-locked fiber laser
MM	Multi-mode
MUX	Multiplexer
NA	Numerical aperture
OA	Optical amplifier
OFA	Optical fiber amplifier
OLT	Optical line termination
ONU	Optical network unit
OSNR	Optical signal-to-noise ratio
PCE	Power conversion efficiency
PON	Passive optical network
SM	Single-mode
TV	Television
V-OLT	Video optical line termination
V-ONU	Video optical network unit
WDM	Wavelength division multiplexing

4 Configuration

4.1 EDFAs using combined single mode pump laser diode

Figure 1 shows the example of the schematic diagram of the Erbium Doped Fiber Amplifier (EDFA) by applying multiple single mode pump laser. Amplifying erbium doped fiber by high output power radiation which is multiplexed a plurality of single mode pump lasers around 1 480 nm which is widely used allow to obtain high output power.

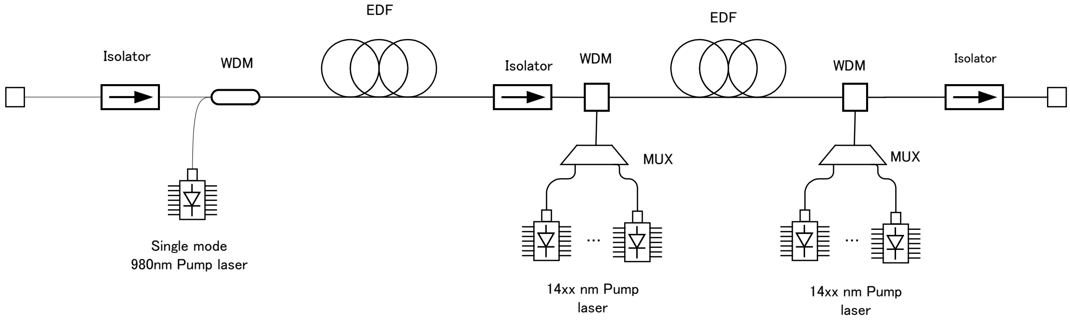

Figure 1 – Schematic diagram of the EDFA using combined single mode pump laser diode

Figure 2 shows the example of the output characteristics of high-power EDFA.

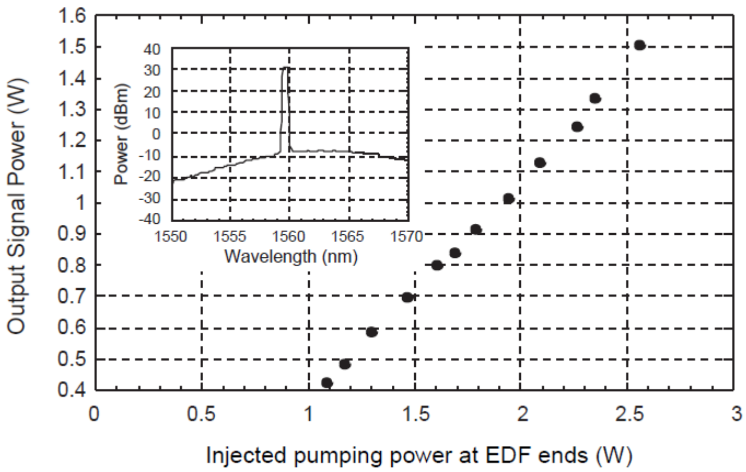

Figure 2 – Output characteristics of high-power EDFA

Polarization combine methodology is also applicable to realize more high output power.

4.2 Cladding pumped fiber amplifier

4.2.1 General

Figure 3 shows the schematic diagram of the cladding pump fiber amplifier. In this example, conventional EDFA is used as pre-amplifier because the gain of cladding pump fiber amplifier is less than that of EDFA and the relatively high input power is required to obtain the high output power.

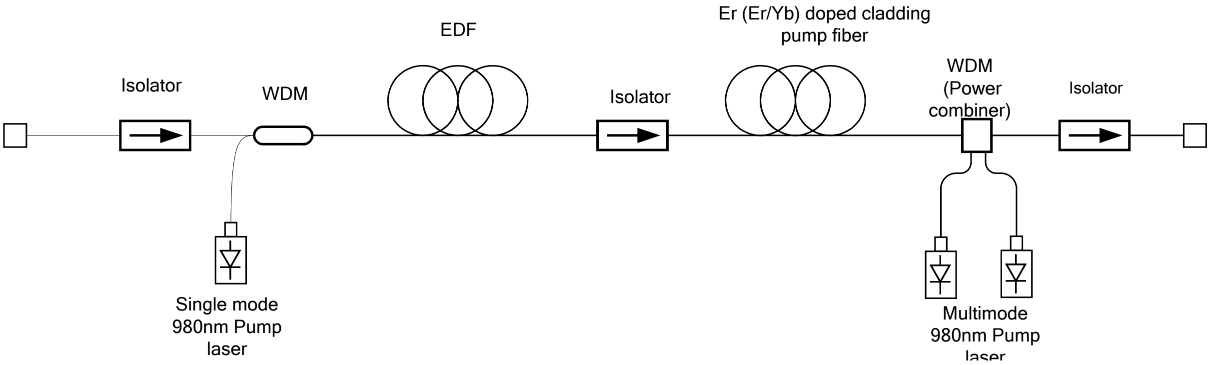

Figure 3 – Schematic diagram of the cladding pumped fiber amplifier

4.2.2 Cladding pump methodology

4.2.2.1 General

Cladding pump methodology is the pumping technology by using multi-layer fiber composed of the inner cladding around the rare earth element doped fiber core for signal transmitting, which is surrounded by an outer cladding of lower refractive index. Large area of inner cladding enables to input high power pump light from multi-mode pump laser which has higher electrical efficiency than single mode pump laser.

As Figure 4, light launched into the inner cladding also gets into the fiber core, where it can be absorbed by laser-active ions. (Note that the inner cladding is undoped, so there is no pump absorption there.) Only, the overlap of pump light with the doped core is reduced, as much of the pump power travels in the undoped inner cladding.

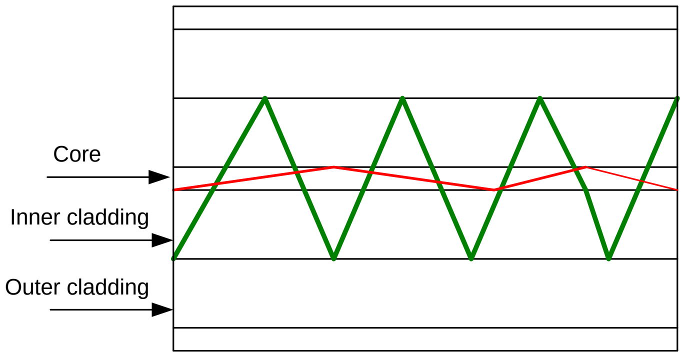

Figure 4 – Schematic of cladding pump

4.2.2.2 Pumping method

a) End-pumping

The pump light is launched into the end of the fiber as the same as EDFA using a conventional single mode EDF.

b) Fused bundled fiber pump combiner

In this method, several multi-mode fibers are bundled together, fused and drawn into a taper, fusion spliced to a double cladding (DC) fiber, and then recoated with a low index polymer. Figure 5 shows one of the examples.

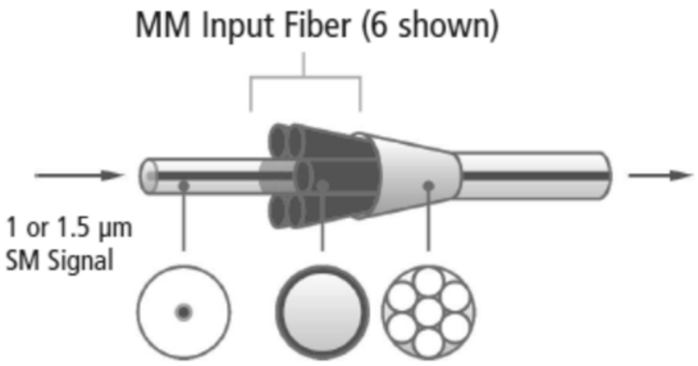

Figure 5 – Schematic structure of fiber bundle for power combiner

c) V-groove side pumping

In this approach, the double cladding fiber is stripped and bonded to a glass slide; a V-shaped notch is cut into the inner cladding, and the pump beam is launched by total internal reflection from the facet of the V-groove as Figure 6.

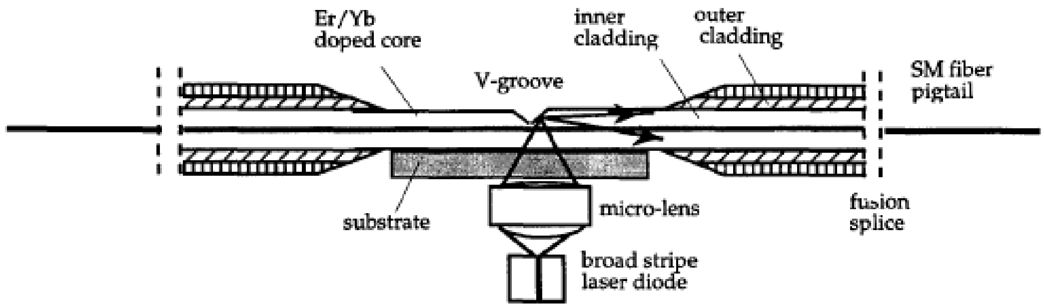

Figure 6 – V-groove side pumping arrangement

4.2.2.3 Key components

a) Active fiber

As gain medium of cladding pumped amplifier, double cladding fiber is applied. DC fiber is an optical fiber with a structure consisting of three layers of optical material instead of the usual two. Figure 7 shows the example of the DC fiber. The inner-most layer is called the core. It is surrounded by the inner cladding, which is surrounded by the outer cladding. The three layers are made of materials with different refractive indices. The core is doped with active dopant material; it both guides and amplifies the signal light. The inner cladding and core guide the pump light, which provides the energy to amplify the signal in the core. The core has the highest refractive index and the inner cladding has lower refractive index than the core and the outer cladding has the lowest. In most cases the outer cladding is made of a polymer material rather than glass.

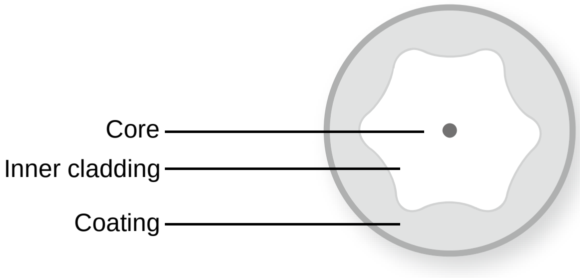

Figure 7 – Schematic diagram of the section of Double cladding fiber

Figure 8 shows another example of double cladding fiber. Here, the inner cladding for pump laser is supported by very thin struts in the air cladding, by which the pump light is captured. Such a structure can have a very high NA for the pump light, which relaxes the requirements for the pump beam quality.

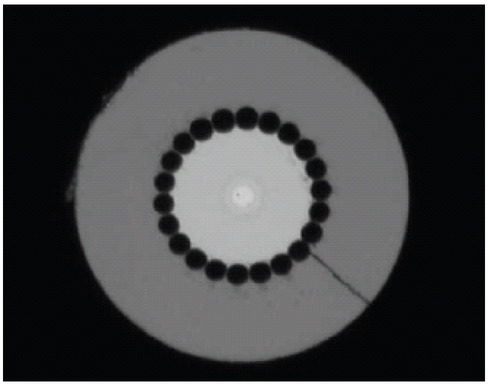

Figure 8 – Cross section of the hole assisted double cladding fiber

Co-doping ytterbium ions into an erbium-doped core is frequently used technique in an active fiber for a high-power amplifier. There are two advantages for an ytterbium co-doping. One is broadening the 980-nm absorption band, which enables using multiple 9xx-nm pump lasers with different lasing wavelengths so that the pump power is greatly increased. The other is preventing erbium ions from forming clusters, which makes high-concentration erbium doping possible and suppresses upconversion. An efficient energy transfer from ytterbium to erbium ions also makes this technique convenient.

b) Power combiner

For pumping double cladding fiber, multiplex device to combine high power pump laser light into signal light is necessary.

c) Pump laser diode

Multimode 9xx nm laser more than 6.0 W fiber pigtail output is commercial product and it is reliable for use telecommunications application. Figure 9 shows the typical performance on uncooled multimode 9xx nm laser diode.

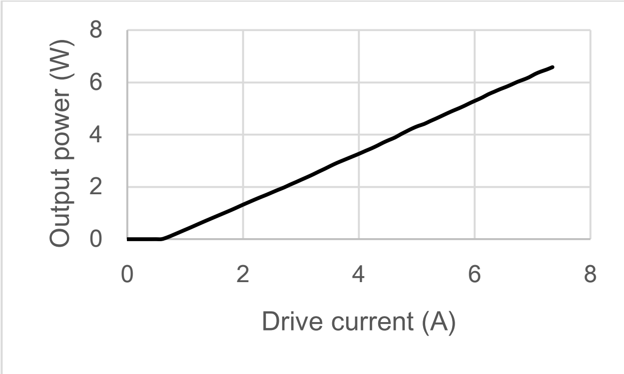

Figure 9 – Typical optical output power vs. drive current on 9xx nm multimode pump laser module.

4.2.2.4 Configuration of cladding pumped amplifier

Figure 10 shows configuration of cladding pumped fiber amplifier to evaluate the power conversion efficiency. Er and Yb co-doped double cladding fiber is utilized for gain medium and multiple multimode 980 nm band laser diode is used for pumping.

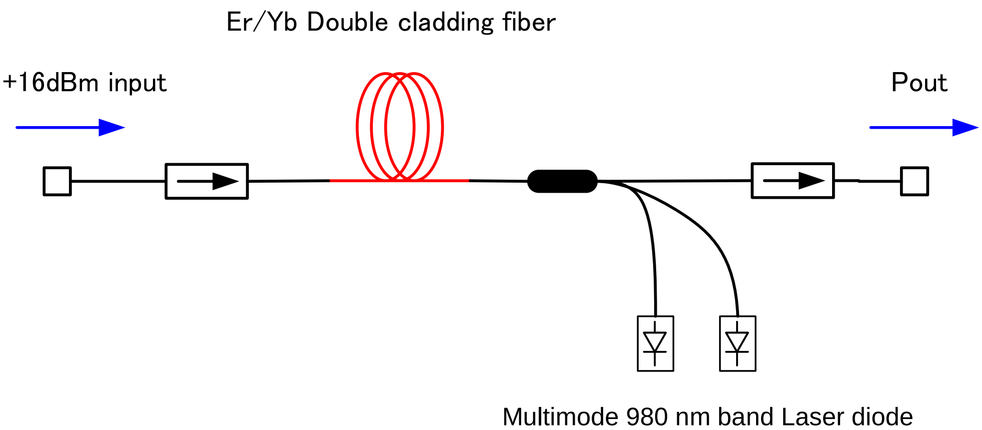

Figure 10 – Configuration of double cladding amplifier

4.2.2.5 Performance example

Figure 11 shows the power conversion efficiency of cladding pumped amplifier. Using multiple pump lasers, output power increases up to 10 W is realized in commercial and power conversion efficiency (PCE) of more than 30 % in cladding pump amplifier allow radiating more than 3 W.

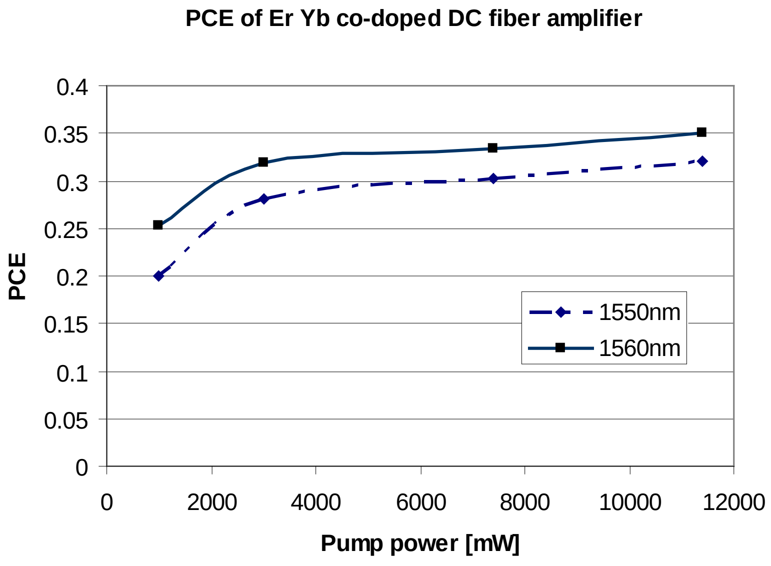

Figure 11 – Typical power conversion efficiency of double cladding amplifier

4.3 EDFA by using cascaded Raman resonator

Figure 12 shows the schematic diagram of the EDFA by using the pump laser which is cascaded Raman resonator. Multi-mode pump laser which is easy to realize high output power can be utilized for high power pump laser into Er-doped fiber.

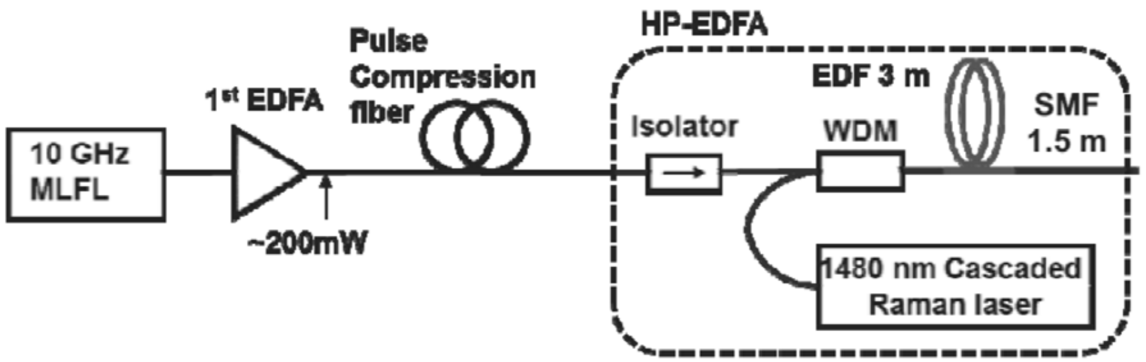

Figure 12 –Schematic diagram of the EDFA by using cascaded Raman resonator

5 Test method

Figure 13 shows the example of test setup for high power amplifier to measure optical output and gain. Most of the high power optical amplifiers are designed power amplifier (booster amplifier), therefore an optical input power is also required high power level (e.g. more than +13 dBm) to measure an amplifier parameter (Output power, Gain, Noise figure and so on). Since the optical output power for optical source in commercial is limited, manufacturers use amplified signal optical source by additional OA. To keep high accuracy of measurement, good OSNR (at least 35dB) in input signal is recommended because the amplified spontaneous emission (ASE) from optional OA is also amplified by OA under test. An Optical spectrum analyzer also should be applicable for measurement equipment.

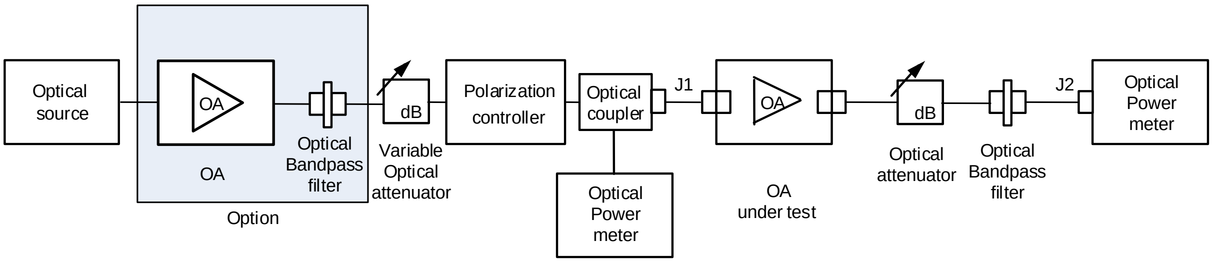

Figure 13 –Test setup to measure optical output and gain

6 Considerations on a high power optical amplifiers

6.1 Designing consideration

a) Component selection

Insertion loss of component in a high power amplifier should be as lower as possible to avoid unexpected damage or degradation by transmitting high optical power. In addition, it is important to reduce reflection at the connection points and components to avoid unexpected oscillation leads to fiber fuse phenomena.

b) Heat dissipation

As components transmitting a high optical power, the insertion loss causes fever leads to deterioration and damage, even if it is slight. It is necessary to consider enough heat dissipation because it has been reported that the degradation of coating with light leaked from the part of bended optical fiber.

c) Reliability qualification criteria

There is still no distinct standard document which defines the reliability of an amplifier and its components transmitting high optical power and under discussion in IEC.

6.2 Handling consideration

Laser product which has high power optical output over 500 mW is categorized as Class 4 laser product in IEC 60825-1 and safety to human eye and skin is concerned. Manufactures and users should take safe into account.

Annex A
(informative)

Application of high power OAs

A.1 General

In fact, high power OAs, especially OFAs are widely deployed in commercial optical network systems. In this annex, current applications of high power OFAs are briefly introduced.

A.2 Power amplifier for FTTH PON systems

Recently, FTTH has been deployed by PON system. A PON system utilizes a passive splitter that splits input one signal to broadcast signals to many users. This system reduces the cost of the system substantially by sharing one set of electronics.

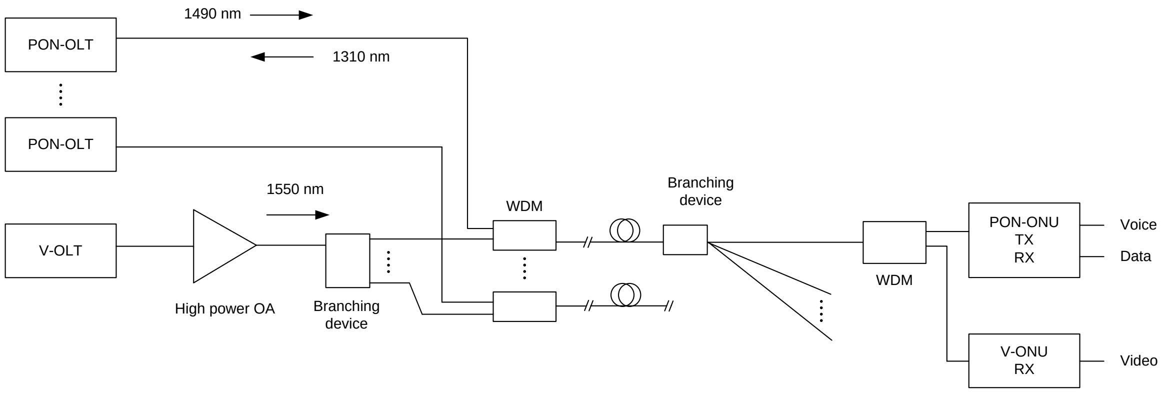

Figure A.1 – Schematic diagram of the FTTH system adapted high power OA

Figure A.1 shows the schematic diagram of the FTTH system adapted high power OA. Most FTTH systems are so-called "triple play" systems providing voice (telephone), video (TV) and data (Internet access.) To provide all three services over one fiber, signals are sent bi-directionally over a single fiber using several wavelengths of light. Downstream digital signals from the CO through the splitter to the home are sent at 1 490 nm. This signal carries both voice and data to the home. Video signal broadcast separately using a 1 550 nm laser which amplified by OFA to supply enough signal strength to overcome the loss of the optical splitter. Usage of high power OA allows the system to reduce the number of amplifier and controller in CO and reduce the equipment cost. Upstream digital signals for voice and data are sent back to the CO from the home using an inexpensive 1 310 nm laser. WDM couplers separate the signals at both the home and the CO.

A.3 Ultra-long haul DWDM transport system

Increasing the number of channels on the transport system requires higher power OAs in recent years. Especially, the high power OAs are deployed as booster to long span repeater-less links, for instance, island to island, desert area, and oil platform.

Annex B
(informative)

IEC documents on high optical power

IEC/TR 62547, Guideline document for the measurement of high power damage sensitivity of single mode fibre to bends and guidance for interpretation of results

IEC 61300-2-14, Fibre optic interconnecting devices and passive components - Basic test and measurement procedures - Part 2-14: Tests - Optical power handling and damage threshold characterization

IEC/TR 62005-10, Fibre optic interconnecting devices and passive components - Reliability - Part 10: High Power Transmission Test of Passive Optical Components

IEC/TR 62627, Fibre optic interconnecting devices and passive components - Fibre optic connector cleaning methods

IEC 60869-1, Fibre optic passive power control devices - Part 1: Generic specification

IEC 61753-056-2, Fibre optic interconnecting devices and passive components performance standard - Part 056-2: Single mode fibre pigtailed style optical fuse for category C - Controlled environment

IEC 61753-057-2, Fibre optic interconnecting devices and passive components performance standard - Part 057-2: Single mode fibre plug style optical fuse for category C - Controlled environment

IEC 61753-058-2, Fibre optic interconnecting devices and passive components performance standard - Part 058-2: Single mode fibre pigtailed style optical limiter for category C - Controlled environment

IEC/TR 61292-4, Optical amplifiers - Part 4: Maximum permissible optical power for the damage-free and safe use of optical amplifiers, including Raman amplifiers

Bibliography

IEC 60825-1, Safety of laser products - Part 1: Equipment classification and requirements

IEC 61292-3, Part 3: Classification, characteristics, and applications of optical amplifiers.

Furukawa Review, No. 19. 2000

IEEE JOURNAL OF QUANTUM ELECTRONICS, VOL. 39, NO. 4, APRIL 2003 529 A New Method for Side Pumping of Double-Clad Fiber Sources Jeffrey P. Koplow, Sean W. Moore, and Dahv A. V. Kliner

D. J. DiGiovanni and A. J. Stentz, Tapered fiber bundles for coupling light into and out of cladding-pumped fiber devices, U.S. Patent 5 864 644, Jan. 26, 1999.

Goldberg, L.; Koplow, J., "High power side-pumped Er/Yb doped fiber amplifier," Optical Fiber Communication Conference, 1999, and the International Conference on Integrated Optics and Optical Fiber Communication. OFC/IOOC '99. Technical Digest, vol.2, no., pp.19,21 vol.2, 21-26 Feb. 1999

Frank Koch1, Bera Pálsdóttir, 30dBm Wideband Air-Clad EDFA Using Two Pump Lasers OFC 2008

A. Fujisaki, M. Yoshida, T. Hirooka and M. Nakazawa, "Generation of 10 W, 100 fs, 10 GHz pulse train using high power EDFA-MOPA system with cascaded Raman pumping," 2015 Conference on Lasers and Electro-Optics (CLEO), San Jose, CA, 2015, pp. 1-2.

Pump and signal combiners for fiber laser and amplifier design [pdf] OFS FITEL, LLC.
Available at:
< http://fiber-optic-catalog.ofsoptics.com/asset/pump-signal-combiners.pdf > [Accessed 21 Feb 2017].

OITDA/TP 26/AM：2017

高出力光増幅器に関する一般情報
解　説

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光増幅器は光ファイバ伝送システムにおいて不可欠な部品である。近年、PON システムならびに CATV システムにおいて高光出力光増幅器が用いられている。実際に 500 mW を超える光出力の光増幅器が実用化されているが、高出力に関して規定する標準がほとんど存在していない。本技術資料は、高出力光増幅器、特にクラッド励起技術に関する一般情報のほかに、通常の光増幅器との差異を明確にし、高光出力を取り扱う上での注意事項について、光増幅器だけでなくその周辺技術についても高出力に対応する標準化を活性化する手助けとなるよう記載内容を配慮した。

2　原案作成部会

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