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TECHNICAL REPORT

colour inside

Optical amplifiers –
Part 8: High-power amplifiers

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OPTICAL AMPLIFIERS –

Part 8: High-power amplifiers

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IEC TR 61292-8, which is a technical report, has been prepared by subcommittee 86C: Fibre optic systems and active devices, of IEC technical committee 86: Fibre optics.

Optoelectronics Industry and Technology Development Association (OITDA), Technical Paper OITDA/TP 26/AM, *General information for high power optical amplifier* has served as the basis for the elaboration of this Technical Report.

The text of this Technical Report is based on the following documents:

Draft TR	Report on voting
86C/1534/DTR	86C/1549/RVDTR

Full information on the voting for the approval of this Technical Report can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 61292 series, published under the general title *Optical amplifiers*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

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- withdrawn,
- replaced by a revised edition, or
- amended.

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INTRODUCTION

Optical amplifiers (OAs) are necessary components as booster, line and pre-amplifiers for current optical network systems. IEC TC 86/SC 86C, therefore, has published many standards for OAs. Since the mid-2000s, high optical output power amplifiers have been used for applications in passive optical network (PON) and community access television (CATV) systems.

Although OAs with optical power greater than 500 mW are deployed in the field, there are very few documents addressing high optical power applications.

This document provides a better understanding of high-power amplifiers, especially those based on cladding pump technology, and addresses the handling of high optical power.

OPTICAL AMPLIFIERS –

Part 8: High-power amplifiers

1 Scope

This document deals with high-power optical amplifiers. It provides general information relating to high-power optical amplifiers with an output power greater than 500 mW for the fibre communication field. It covers the following aspects:

– general information;
– example of the optical amplifier's configuration realizing high optical output power;
– test method for optical output power and gain;
– considerations on high-power optical amplifiers.

Potential applications of high-power optical amplifiers are briefly reviewed in Annex A.

Informative IEC documents related to high optical power are listed in Annex B.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61291-1, *Optical amplifiers – Part 1: Generic specification*

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-clad
DWDM	dense wavelength division multiplexing
EDF	erbium-doped fibre
EDFA	erbium-doped fibre amplifier

FTTH	fibre to the home
HP-EDFA	high-power erbium-doped fibre amplifier
MLFL	mode-locked fibre laser
MM	multi-mode
MUX	multiplexer
NA	numerical aperture
OA	optical amplifier
OFA	optical fibre 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 General

This document provides typical configuration and performance of high-power optical amplifiers and guidance of test method and special consideration. Potential applications of high-power optical amplifiers are also briefly reviewed in Annex A. Informative IEC documents related to high optical power are listed in Annex B.

5 Configuration

5.1 EDFAs using combined single-mode pump laser diodes

Figure 1 is a schematic diagram of an erbium-doped fibre amplifier (EDFA) using multiple single-mode pump lasers. Multiplexing many single-mode pump lasers within the 1 4xx-nm band is commonly used to obtain high power output, since EDF has a wide absorption spectrum in the 1 480-nm band compared to the 980-nm band. The closeness of 1 480-nm pumping and signal wavelengths also benefits power conversion efficiency and thus mean 1 480-nm pumps are used for high power.

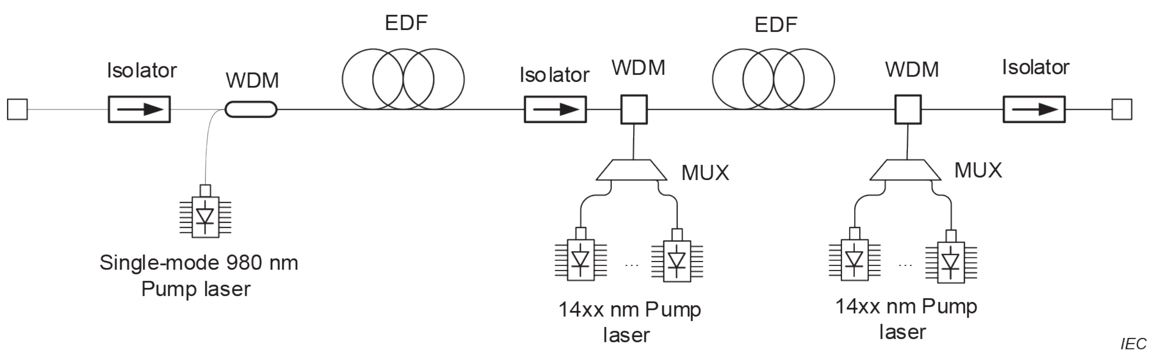

Figure 1 – Schematic diagram of EDFA using multiplexed single-mode pump lasers

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

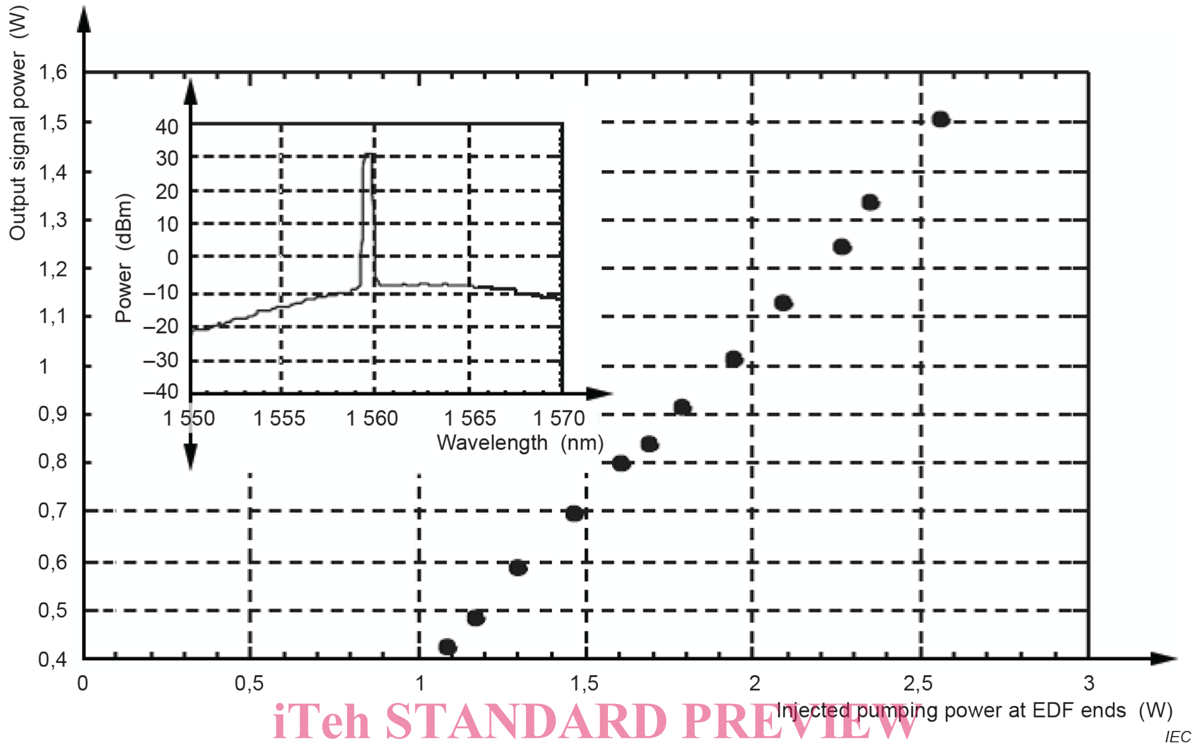

Figure 2 – Output characteristics of a high-power EDFA

In addition to the design of wavelength multiplexing, the concept of polarization multiplexing technologies, which combines two input pump light sources in orthogonal polarizations into one output, is also applicable to realize higher output power. By using a number of wavelengths in wavelength division multiplexing, it is possible to obtain high pump power although it is necessary to stabilize the wavelength. As the number of wavelengths increases, the insertion loss of the multiplexer increases. Thus, the optical power conversion efficiency gets worse. On the other hand, polarization multiplexing does not need to stabilize the wavelength, so it is useful way when there are a few pumping lasers to be multiplexed. If signals into EDF are polarized, polarization multiplexing can suffer from needing to balance the powers into the multiplexer to maintain low DOP in order to suppress the polarization dependent gain. It is also possible to utilize a combination of both multiplexing methods.

Several high-power pump sources are also utilized as a pump source, a 1 480-nm cascaded Raman resonator, for example. Figure 3 shows the schematic diagram of the EDFA by using a pump laser, which is a cascaded Raman resonator.

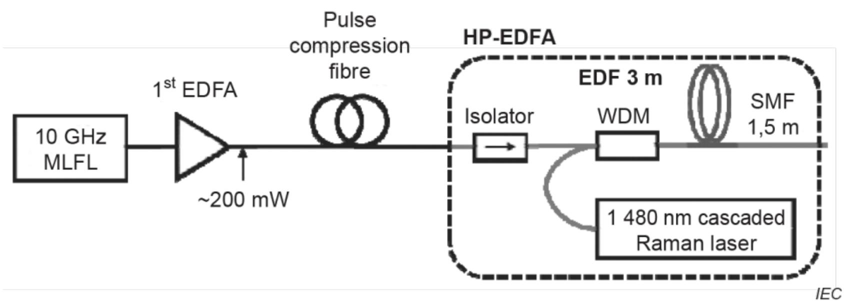

Figure 3 – Schematic diagram of an EDFA using a cascaded Raman resonator

5.2 Cladding pumped fibre amplifier

5.2.1 General

Figure 4 is a schematic diagram of a cladding-pumped fibre amplifier. In this example, an EDFA using a single-mode pump laser diode is used as pre-amplifier because the pre-amplifier stage needs high gain to achieve a low noise figure and thus requires a longer active fibre with higher absorption, but the length of cladding fibre is limited by the absorption of pump light. Also there is a parasitic effect, such as 1-µm ASE in erbium–ytterbium co-doped fibre. Therefore, the gain achieved in a cladding-pumped fibre amplifier is less than that of the conventional EDFA, and higher input power is required to obtain higher output power.

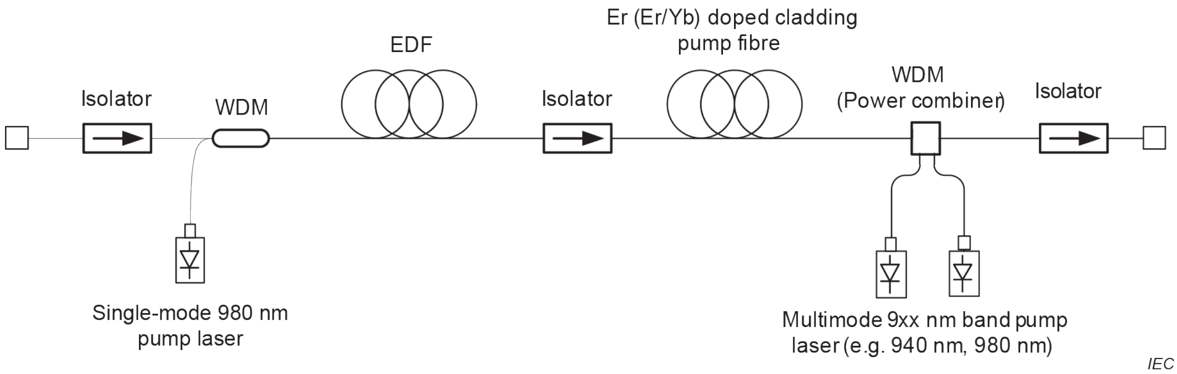

Figure 4 – Schematic diagram of a cladding-pumped fibre amplifier

5.2.2 Cladding-pumped methodology

5.2.2.1 General

Cladding-pumped technology utilizes a multi-layer fibre composed of an inner cladding around the rare-earth-element-doped fibre core for signal transmission that is surrounded by an outer cladding of a lower refractive index. The large area of the inner cladding with a large numerical aperture enables coupling of the high-power pump light from the multi-mode pump laser, which has higher electrical efficiency than a single-mode pump laser. Though the optical conversion efficiency of the cladding-pump method is generally worse than that of the core-pump method, the two approaches complement each other to achieve the highest output power.

In Figure 5, a signal light, shown by the red line, is launched into the core while the pump light, expressed as the green line, launched into the inner cladding also propagates into the fibre core, where it can be absorbed by laser-active ions. Note that the inner cladding is un-doped, so there is no pump absorption in this region. Only the overlap of pump light with the doped core is reduced, as much of the pump power travels in the un-doped inner cladding.

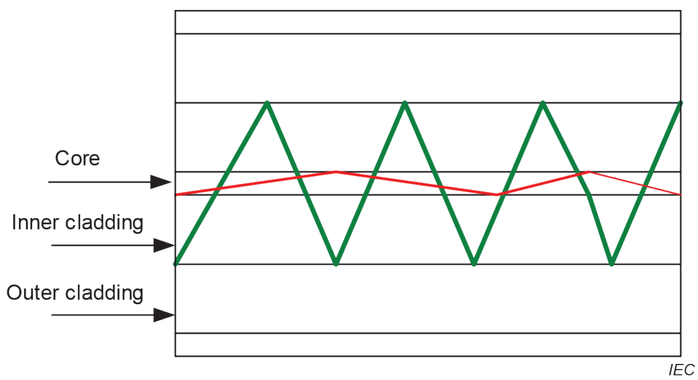

Figure 5 – Schematic of cladding pumping