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TECHNICAL REPORT

Safety of laser products –
Part 17: Safety aspects for use of passive optical components and optical cables in high power optical fibre communication systems

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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SAFETY OF LASER PRODUCTS –

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FOREWORD

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IEC 60825-17, which is a technical report, has been prepared by IEC technical committee 76: Optical radiation safety and laser equipment.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
76/425/DTR	76/435/RVC

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

A list of all parts of the IEC 60825 series, published under the general title *Safety of laser products,* can be found on the IEC website.

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

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- withdrawn,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

A bilingual version of this publication may be issued at a later date.

INTRODUCTION

The rapid growth of applications such as the internet and business intranets requiring high bitrates has caused a dramatic increase in the need for high capacity data connections. This increase in capacity has resulted in a requirement for a corresponding increase in power levels used in optical fibre communications systems. There are a number of areas of concern including the use of erbium doped fibre amplifiers (EDFA), high power dense wavelength division multiplexing (DWDM) systems, and Raman amplification.

The power levels associated with these systems are typically greater than 500 mW (i.e. Class 4), but some studies have shown additional thermal effects can occur at lower powers. These additional thermal and related hazards mean that it is necessary to address a number of new issues. It should be noted that the vast majority of these systems use single mode fibre.

SAFETY OF LASER PRODUCTS –

Part 17: Safety aspects for use of passive optical components and optical cables in high power optical fibre communication systems

1 Scope

This part of IEC 60825 recommends safety measures to protect against effects caused exclusively by thermal, opto-mechanical and related effects in passive optical components and optical cables used in high optical power fibre communication systems.

This technical report does not apply to the use of high power optical systems in explosive atmospheres or the use of optical fibres in material processing machines. Throughout this part of IEC 60825, a reference to 'laser' is taken to include light-emitting diodes (LEDs) and optical amplifiers.

2 Normative references

The following referenced documents are indispensable for the application 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 60825-1:2007, *Safety of laser products – Part 1: Equipment classification and requirements*

IEC 60825-2:2005, *Safety of laser products – Part 2: Safety of optical fibre communication systems (OFCS)*

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*

IEC/TR 62547, *Guidelines for the measurement of high-power damage sensitivity of single-mode fibres to bends – Guidance for the interpretation of results*

3 Terms and definitions

3.1
automatic laser shutdown (ALS)
technique (procedure) to automatically shutdown the output power of laser transmitters and optical amplifiers to avoid exposure to hazardous levels

3.2
automatic power reduction (APR)
technique (procedure) to automatically reduce the output power of optical amplifiers to avoid exposure to hazardous levels

3.3
automatic power shutdown (APSD)
technique (procedure) to automatically shutdown the output power of optical amplifiers to avoid exposure to hazardous levels

NOTE In the context of this technical report the term APSD is equivalent to the term ALS.

3.4
optical fibre communication system (OFCS)
an engineered, end-to-end assembly for the generation, transfer and reception of optical radiation arising from lasers, LEDs or optical amplifiers, in which the transference is by means of optical fibre for communication and/or control purposes

3.5
loss of continuity (of an optical link)
any event which may cause hazardous optical power levels to be emitted from some point along the path of an optical transmission system

NOTE Common causes of loss of continuity of an optical link are a cable break, equipment failure, connector unplugging, etc.

3.6
high optical power
an optical power of 500 mW or greater (in the context of this technical report)

NOTE 1 500 mW is recommended partly as it is the breakpoint between Class 3B laser products (unlikely to cause fire) and Class 4 laser products (may cause fire).

NOTE 2 Studies have shown damage is significantly more likely at powers in excess of 1 W, but damage has also been shown to occur at powers as low as 200 mW – see references [1] [1] and [2]..

3.7
hazard level

the potential hazard at any accessible location within an OFCS. It is based on the level of optical radiation which could become accessible in a reasonably foreseeable event, e.g. a fibre cable break. It is closely related to the laser classification procedure in IEC 60825-1

[IEC 60825-2, definition 3.4]

3.8
unrestricted location
location with unrestricted access
an accessible location where there are no measures restricting access to members of the general public

[IEC 60825-2, definition 3.15]

3.9
restricted location
location with restricted access
an accessible location that is normally inaccessible by the general public by means of any administrative or engineering control measure but that is accessible to authorized personnel who may not have laser safety training

[IEC 60825-2, definition 3.14]

3.10
controlled location
location with controlled access
an accessible location where an engineering or administrative control is present to make it inaccessible, except to authorized personnel with appropriate laser safety training

[IEC 60825-2, definition 3.13]

[1] Figures in square brackets refer to the Bibliography.

3.11
class of laser product
see IEC 60825-1, sections 3.18 to 3.23 for definition of 'class of laser product'

4 Recommendations

4.1 General considerations – the background to optical fibre damage at high powers

When optical fibres are operated at high power levels (typically > 500 mW), fibres and optical connectors can be damaged. In optical communications systems the optical power is transmitted in CW mode or at high repetition rates, and therefore catastrophic damage is predominantly caused by thermal mechanisms. It has been shown that several effects can cause high optical power-induced damage of single mode fibre systems leading to fibre failures. Systems employing high optical power operation in fibres, connectors, collimators and attenuators thus carry additional safety concerns. For example, local heating in contaminated connectors/attenuators carrying high optical power can pose a potential fire hazard to surrounding materials, depending on the flammability of those materials.

IEC/TR 61292-4 provides extensive guidance on the following topics (see also [7]):

– fibre fuse and its propagation;
– loss-induced heating at connectors or splices;
– connector end-face damage induced by dust/contamination;
– fibre-coat burn/melt induced by tight fibre bending.

Studies [3] on tight fibre bending at high power show that coating ageing can occur slowly and catastrophic damage effects can occur after hundreds of hours. The main implication is that damage testing must be carried out for sufficiently long times; some early experiments were conducted over short times, possibly leading to incorrect conclusions. IEC/TR 62547 should be followed for the measurement of high power damage sensitivity at bends.

As discussed by Bigot-Astruc M et al [4] and in IEC/TR 62547, a fast method of testing for potential damage effects at high powers can use a thermal imaging camera. Equilibrium temperatures are established relatively quickly, allowing the consequences of high power to be rapidly assessed. The issues concerning high power at tight bends arise because of exposure of the fibre coating to high power at or near to the bend. Coating ageing occurs at a rate determined by bend loss, launch power, environmental conditions and coating resilience. New bend insensitive fibre designs – described by the ITU G.657 specifications – are a possible solution (see Section 2.5 in [8]). However, for extreme situations more resilient coatings may also be required.

The long-term damage effects of high power in other optical components, described for example in 4.5 and 4.9, show the need to consider the implications of high power damage research, as discussed in IEC/TR 62547.

4.2 Additional recommendations for automatic power reduction (APR)

Extra recommendations for automatic power reduction (APR) are made because APR will become more critical in systems where fire, fibre and connector damage, and other hazards are possible if fibre is mishandled. These recommendations may include additional network management and administrative controls, electrical connectivity testing for higher reliability of APR, and others. Systems employing high optical power operation in fibres may necessitate the incorporation of automatic power reduction within one section of a main optical path in the event of recovery from the loss of optical power within that particular section of the main optical path.

Automatic power reduction should be specified and shown to have a high level of reliability for systems using high optical power operation in fibres at all installed locations. IEC 60825-2 describes an 'adequate' level of reliability for APR systems (500 FITs).

NOTE IEC 60825-2 defines FITs as "an indicator of reliability defined as the number of failures per 10^9 h."

Automatic power reduction should take into account all optical signals present in both directions on the optical path, as described in the following excerpt reproduced with permission from Recommendation ITU-T G.664 (1999), *Optical safety procedures and requirements for optical transport systems*):

> "APR techniques are necessary when the sum of operational power (main optical signal) and pump-laser output power at the optical interfaces exceeds the applicable Hazard Levels defined in IEC 60825-2. The total power is the sum of the power in any one direction from all optical channels, the power from all pump-lasers and the power from Optical Auxiliary Channels (OAC), if used. Within the context of this Recommendation, an Optical Supervisory Channel (OSC) is regarded as a specific case of an OAC.
>
> After power reduction, the total power level (the sum of the power from all optical channels, the remaining power from pump-lasers and power from an OAC) must be within Hazard Level 1M (or 3B in controlled locations), but reduction of the total power to Hazard Level 1 or even complete shutdown is acceptable.
>
> Optical transmission systems employing distributed Raman amplification need extra care to ensure safe optical working conditions, because high pump powers (power levels above +30 dBm are not uncommon) may be injected into optical fibre cables. Therefore, it is recommended to use APR in all systems employing distributed Raman amplification with operational power levels above Hazard Level 1M (or 3B in controlled locations). In this way hazards from laser radiation to the human eye or skin, and potential additional hazards such as temperature increase (or fire) caused by locally increased absorption due to connector contamination or damage are avoided. Further guidance is provided by IEC/TR 61292-4.
>
> Distributed Raman-based systems differ from discrete optically amplified systems due to the possible presence of pump lasers at the "receiving" side of a link, launching high optical powers backward into the fibre. In order to ensure that the power levels radiating from broken or open fibre connections are at safe levels, it is necessary to reduce the power not only from the main optical signal sources but also from all pump lasers employed, including the reverse pump lasers. Because the operating wavelength of the Raman pump lasers is usually different from the actual data signal, separate assessments at various wavelengths may need to be made both at pump laser wavelength and at main signal wavelength."

ITU-T G.664 Appendix II.3 describes automatic laser shutdown (ALS) and restart procedures for single channel synchronous digital hierarchy systems with the additional presence of optical amplification.

Operational aspects of APR should also comply with all relevant subclauses in IEC 60825-2:2005, notably 4.5 ("Automatic power reduction (APR) and restart pulses") and 4.5.4 ("Disabling of the APR").

4.3 The need for additional user information and its recommended format

Due to the potentially increased hazards arising from higher optical powers, additional user information may be needed. This subclause describes possible extra requirements that may be placed on manufacturers, operating organizations and users (including extra training, additional user manual requirements and others). Manufacturers of high optical power OFCS, turnkey end-to-end high optical power systems or subassemblies intended to be incorporated into high optical power systems should ensure that the equipment satisfies IEC 60825-2 and the applicable advice of this technical report.

The organization responsible for the installation and servicing of high optical power OFCS should follow the manufacturer's instructions for installation of equipment in a manner that will ensure that the accessible radiation satisfies the applicable requirements of IEC 60825-2 and the recommendations of this technical report, under all reasonably foreseeable conditions.

The operating organization has the ultimate responsibility for the safety of the high optical power end-to-end system. This includes the determination of the location type (defined by IEC 60825-2) at all accessible locations of the entire high optical power OFCS and ensuring that access to any location is appropriately controlled with respect to laser safety. In addition to the required markings of IEC 60825-2, it is suggested that hazard levels 2, 2M, 3R and 3B locations in a high optical power OFCS should bear the label shown in Figure 1 of IEC 60825-1.

At any location in a high optical power OFCS where access to a fibre end or a connector is foreseeable, instructions should be provided to the operator or other persons having access. These instructions should include directions to avoid direct exposure to laser radiation. It may also be necessary to consider the need for the use of appropriate laser safety eyewear.

Only persons who have received appropriate training in optical fibre and high power hazards (optical powers in excess of 500 mW is suggested) should be allowed to operate high optical power OFCS.

Those persons responsible for ensuring that all required markings, protection and safeguards are incorporated in a hazard level 3B location of a high optical power OFCS should have received appropriate training in laser safety.

In high optical power systems, losses due to high power absorption can produce elevated temperatures which cause damage and possible ignition. Therefore, those persons dealing with optical components intended for use in high optical power systems, i.e. connectors, attenuators, collimators, splices, etc., should have received appropriate laser safety training according to IEC 60825-2 and IEC/TR 61292-4.

Instructions should be provided to personnel handling connectors in high optical power systems. The following are examples:

Connector end-face:	Do not touch connector end face, and clean each connection with appropriate cleaning techniques.
Connection:	Caution; note any anti-rotation keys or similar locating features.
Dust cap:	It is recommended that dust caps be removed only during operation (to protect connectors from contamination).
Bending and twisting:	Exercise care when handling cables – avoid all unnecessary bending and twisting. Take extra care when (e.g.) unwinding cables from drums
Test/Check:	Checks should be made for any contamination or damage to connectors or fibre ends. A high magnifying power viewing microscope (with approved attenuating filters to eliminate the possibility of eye exposure to unsafe levels of optical radiation) or an indirect viewing instrument should be used. Use only approved attenuating direct viewing magnifying instruments.

IEC 61300-3-35 provides guidance on end-face inspection, and IEC/TR 62627-01 on cleaning.

NOTE It is the responsibility of the user, his or her employer, the Laser Safety Officer or the manufacturer to determine an appropriate level of attenuation.

Personal safety:	It is recommended that high power lasers be powered down before opening connectors or commencing splicing procedures. The recommendations of this document do not supersede those in IEC 60825-1 or IEC 60825-2.
Front face of cable & connector protection:	Where practical, power the laser off. Exercise care when cleaning.

When optical instruments or viewing optics are not used, devices classified as 1M are considered safe under the conditions indicated in IEC 60825-1. However, they may be hazardous if the user employs non-attenuating optical instruments or viewing optics within the beam. It is recommended to use indirect viewing instruments in all cases.

The laser radiation hazards present in high optical power systems and detailed safety precautions necessary to prevent exposure to hazardous laser radiation should be contained in the user manual and installation instructions.

4.4 Fibre and connector damage induced by high optical powers

4.4.1 Fibre fuse and other effects

Optical connectors can fail in high optical power transmission systems as the end surface of the glass core of the optical fibre can be destroyed due the very high optical power density. Exposure to high temperatures (potentially in excess of 1 000 °C) can cause a tension crack and destroy the connector. Destruction of the fibre can also be caused by a rapid vaporization of contaminants, leading to a micro-explosion/laser-induced melting of fibre core.

The high power density can also initiate a catastrophic failure in the core area of the connector, causing a 'fibre fuse' effect along the cable. This process may reach temperatures sufficient to vaporize glass and induce bubbles and voids in the fibre core and may make further optical transmission impossible. In the 'fibre fuse', the optical fibre can be destroyed at a velocity of 1 m/s over a length of several hundred metres (depending on the laser power present). In the event of fibre melting, the high temperatures reached also pose a risk of fire in the fibre coating, any matching or other fluid or gel filling, isolation material, and any surrounding flammable materials.

The transmission of high optical power through single and multi-mode fibres raises new issues for fibre manufacturers and manufacturers of in-line components. Reliable connectors provide minimum attenuation of the transmitted signal but minor losses can be caused by mismatch of the fibre core parameters (e.g. numerical aperture/diameter) or lateral/angular misalignment. Energy lost due to fibre misalignment may not necessarily reduce connector reliability, as the energy is dissipated through fibre cladding – however this dissipated energy may cause heating in the adhesives and/or the ferrule.

If shuttered connectors are used, then the temperature rise on the surface of the shutter, flammability, and exposure time of the shutter to high optical power on the shutter material must be considered and the shutter must be made of an appropriately robust material such as metal.

4.4.2 Contamination particles

Cleanliness of the connectors is very important. Contamination particles at the connector interface can absorb energy and convert it to heat, thus causing the temperature of the fibre to rise above the melting point of silica and failure of the connection. The most harmful contaminants are solids such as those produced by wear of alignment sleeves, and also dust and similar particles from the environment. It is suggested that zirconia sleeves are used for higher powers as these generate a lower level of contamination than metal sleeves.

To avoid these problems, a connector carrying high optical power signals should be as clean as possible. A visual inspection of the ferrule's end-faces before every mating is recommended. When the connectors are demated, a protection cap should be fitted to the ferrules to avoid any contamination. The mating adapter or bulkhead connector should also have a protection cap. The protection caps should be kept clean at all times to prevent cross contamination.

4.5 Splicing, polishing, and cleaning of connectors and fibre, and fibre preparation

4.5.1 General

As in 4.4, the high optical power density present at unterminated fibres (e.g. when they are prepared for splicing) may cause damage, and as the optical power increases above 500 mW, this becomes increasingly likely. APR techniques may be applied to reduce optical power if systems are to be worked on live for splicing, or alternatively, administrative controls may be appropriate (to ensure power is shut down before work commences). Fibre preparation issues must be considered including cleaning with solvents (and the potential fire hazard of these cleaning solvents). Fibre polishing techniques may give rise to damage. It is generally recommended that fibres carrying high powers not be worked on live.

Any dirt, grease or imperfections can present a high risk of causing damage to or burning of connectors. For a reliable optical connection, it is important that the connector end face is accurately aligned to the fibre axis and is clean. One method of achieving a low loss connection is a mechanical press to ensure exact alignment of the fibre cores. Optical connectors may also be sensitive to extraneous influences such as ambient pollution or mechanical stress. However, fusion splicing is generally the most reliable and effective method of joining fibres carrying high powers.

For all high optical power systems such as those using Raman amplification, connectors should be rigorously cleaned. It is recommended that cleaning only be carried out on connectors when the laser is switched off or the laser power in the fibre has been reduced to an appropriately low level. Care should also be taken since the vapour of a cleansing agent or dust can potentially damage the fibre or core end. Signal loss from splices or bends should be reduced in all locations of the system.

4.5.2 Fibre in a splice tray

See also IEC 60825-2.

When using high optical powers, it may be necessary to carry out a hazard assessment for polishing, cleaning, and fibre preparation. Appropriate APR, shuttering and splicing controls should be considered and implemented with respect to the potentially increased hazard level and the location of the OFCS using high optical powers.

These controls may include:

- mandatory depowering of fibres when work is carried out;
- mandatory depowering of fibres during splicing;
- access controls (such as restricting access to specified persons);

- segregation of fibres carrying optical high powers from standard fibres;
- extra mandatory fibre and cable handling precautions.

4.6 Other fibre core damage, coating or cladding damage and damage to adjacent services

Damage to optical fibres can also be caused by excessive bending or other mishandling, including possible melting of the core (potentially even resulting in risk of fire and explosion). In OFCS using high optical powers it has been shown that fibre bends (where the bend radius becomes tighter from 30 mm to 3 mm) causes an increasing risk of fibre damage and catastrophic failure, both in the long term (over hundreds of hours) and – when fibre is bent at the smallest bend radius – almost instantaneously.

As well as 'acute' damage issues, 'chronic' damage caused by slow degradation of the fibre over many hundreds of hours is of concern, with the optical loss in the fibre slowly increasing and fibre routes of many kilometres potentially becoming unusable. The 'fibre fuse' effect can destroy fibre, and monitoring of fibre loss may be needed over the whole fibre lifetime. Fibres are expected to age over time with possible increases in loss and a possible increased potential for triggering the fibre fuse effect.

Fire hazards due to build-up of flammable gasses in inspection chambers and other zones below ground may also be a serious issue. It may be necessary to undertake gas testing in chambers through which fibres carry high powers, prior to work being carried out in these chambers, and when work is to be carried out on the high power fibres (or near the high power fibres and when there is significant risk of touching or moving these fibres).

See also IEC/TR 61292-4 and IEC/TR 62547.

4.7 Degradation or burn-through of protection cap and/or shutter

Current working practises often recommend using a cap on all live fibres when they are unterminated. With the use of high optical powers the resistance of the cap to burn-through and its potential flammability may become an issue.

Protective caps, shutters and similar mechanisms used on connectors should have adequate resistance to burn-through by high power beams. They should be made of material not likely to catch fire, such as an inert metal (for example, aluminium may not be a suitable shutter material).

4.8 Potentially collimated beam profile resulting in an increased optical hazard

4.8.1 General

In OFCS using higher optical powers, the beam emerging from the fibre may be expanded and/or collimated. Traditionally, the beam emerging from a fibre is a divergent cone, normally resulting in the eye intercepting considerably less power than the total power emerging from the fibre (however, it should still be noted the power may be sufficient to cause injury). One technique for mitigating the hazards to connectors and fibre arising from high optical power densities is to expand and then collimate the beam, thus reducing power density. If the emerging high power beam is collimated in this manner, the protection to people (afforded by diverging beams) may be reduced or even totally lost. This subclause addresses issues arising from the use of connectors with inbuilt lenses which produce such a collimated beam.

Other risks may include the use of direct viewing fibre microscopes, which might present a hazard even if an attenuating filter is used in the microscope. However, recent studies have shown that in most cases the use of high magnifying power viewing aids does not increase the hazard. Nevertheless, it is recommended that indirect viewing aids (IVAs) be used to examine high power fibres and components.

4.8.2 High power expanded beam connectors

Even after cleaning, small particles may be overlooked with an inspection microscope, and these could cause the connector to fail. The only way to eliminate this risk is to reduce the power density at the connector interface by enlarging the beam diameter (as discussed above). Typically, expanded beam connectors that use collimating lenses are constructed with rugged bodies suitable for use in harsh environments, and provide high insertion loss values. One method is to use a piece of gradient index fibre (GRIN fibre) instead of an external lens to collimate the beam. This method allows the expanded beam system to be integrated in a standard 2,5 mm or even a 1,25 mm ferrule. The lens will collimate the mode field diameter from e.g. 11 μm to 44 μm (and the beam may be angled at 2° from the fibre axis following angled polishing). If these connectors are opened during operation, the emitted laser beams are often hazardous for a longer distance and over a larger area than those emerging from a normal optical connector with conventional single mode fibre. It is also possible the hazard at or near this connector is higher than that of the rest of the system.

For example, a calculation of hazard level (HL) 1M for one of these GRIN connectors operating at 1 550 nm results in a HL 1M limit of 14 mW, compared with a limit of 136 mW for the beam emerging from a conventional connector. If the power in the fibre is less than 136 mW and it is fitted with a conventional connector, then it is HL1M. But if it is fitted with a GRIN connector then for such a system to be HL1M the power in the fibre would have to be below 14 mW. Also, the beam continues to be dangerous for a much longer distance than is generally expected by telecoms operators used to conventional fibre-to-fibre connectors.

NOTE See also Note 1 in Table D.1 of IEC 60825-2 “Some high power connectors use enlarged mode field diameter (MFD) and the far field divergence is lower. These connectors can result in a higher hazard level and determination of the hazard level when using these connectors is strongly recommended”.

4.8.3 Secondary hazards – fire hazard

All components and materials in contact with and/or adjacent to fibres and/or connectors in a high optical power system should have an appropriate flammability rating, if the optical power carried by the fibre is sufficiently high (>500 mW is suggested) to result in an increased fire risk to the optical fibre (and hence to surrounding materials or equipment). This applies throughout the system and it is necessary that hazards from high powered optical communications cables in ducts carrying other utilities are taken into account.

4.9 Increases in the temperatures of attenuators, collimators, splitters and other passive components

Care should be taken that the cleanliness of optical components for use in a high optical power system is not compromised at any time from manufacture to installation. The polished end face of the connector should not be touched or handled, and should be cleaned only with appropriate techniques according to recommended instructions.

Every connection should be checked for cleanliness and/or damage with a high power viewing microscope (with an attenuator to reduce optical power to a safe level for eye viewing in case the fibre is accidentally powered up) or an equivalent indirect viewing aid. It is recommended that connectors, fibre ends prepared for splicing and similar be checked for cleanliness before making a connection or splicing. It is also recommended that these be checked before high power is applied to the system. Materials used for optical components intended for use in high optical power systems, i.e. connectors, attenuators, collimators, shutters, etc. should also have the appropriate flammability rating.

Some optical passive components – for example, plug style optical attenuators using metal-doped fibres, containing optical power absorbing materials – are poorly resistant to high optical powers. According to high power evaluations and thermal simulation, the allowable maximum power to maintain long term reliability for SC type (IEC 61754-4) plug style fixed optical attenuators (5 dB attenuation), is around 300 mW. That maximum power depends on the attenuation value and care should be taken when using high optical powers. TC 86 is currently discussing the issue of temperature rise over a range of powers and plans to issue technical reports on this subject in the near future.

Note that damage testing of passive components (e.g. fibre splitters) may be necessary over quite long times at high powers to ensure that the packaging materials (and coatings) do not fail under high power operation. Well documented experiences of the ageing of coatings of fibres in tight bends under high power have shown that catastrophic effects can occur after hundreds of hours [3]. Coating ageing has been seen to be the trigger for catastrophic failure; the use of thermal imaging cameras as described by Bigot-Astruc M et al [4] and in IEC/TR 62547 has shown that equilibrium temperatures can be a good indicator of lifetime and such cameras can be used to reduce the time required for high power evaluation and damage testing. Also, note that the rate of fibre coating ageing is usually temperature dependent, thus ambient environmental conditions may affect component resilience – see Sikora et al [5].

4.10 Additional labelling

The possible extra hazard due to increased optical powers may result in a need to provide extra labelling and more user information over and above that specified in IEC 60825-2.

It may be necessary to use additional labelling to draw attention to the high optical powers present in the fibre and thus the potential for fibre or connector damage, or damage to the cladding (or even damage to adjacent low power fibres). Extra labelling about potential fire hazards is recommended if the optical power in the fibre exceeds ~500 mW. Alternatively, rigorous administrative controls (such as key controlled access to locations where high powers are present) may be used. Additionally, a hazard assessment may be needed to determine if optical components intended for use in high optical power systems should be labelled separately according to the applicable hazard level defined by IEC 60825-2.

4.11 Potential problems arising from incompatibly between fibre types

To reduce potential damage to optical fibres due to incompatibility of core/cladding size or problems with connecting fibres together, several solutions have been suggested. These include the use of damage resistant fibres using novel construction (so-called 'holey' fibres), or fibres with different and novel core/cladding refractive index ratios. One design uses a low refractive index fibre coating to contain leaky radiation within the fibre cladding. This proved to be an effective solution, eliminating coating ageing at bends under high power. However, downstream fibres or components may be compromised (see IEC/TR 62547).

There may be additional issues arising from the use of these new fibre types such as difficulties in splicing to existing conventional fibre and the failure of light to propagate effectively between different fibre types. Documentation or user guidance should be supplied with these novel fibres, explaining the improved damage resistance of the fibre, and any potential difficulty in interfacing with conventional fibre types.

4.12 Identification of non-standard damage-resistant fibres

It may be necessary to require additional identification of new or non-standard fibres so that manufacturers, users and operators are aware of the issues of splicing these fibres and connection of them to conventional OFCS. Changes in the beam divergence of open fibres and other features which can affect the hazard from opened or fractured optical fibres should also be considered.

Optical fibre cables carrying high power provided as part of an OFCS should comply with IEC 60794-1-1. They should not present a hazard in the context of this technical report, whether they are detachable or not and including the hazard from fibre fracture. For optical fibre cables intended for high power use and supplied as stand-alone cables, the recommendations of this subclause are optional and may be met at the discretion of the manufacturer.