INTERNATIONAL STANDARD

ISO 20780

First edition
2018-06

Space systems — Fiber optic components — Design and verification requirements

Systèmes spatiaux — Composants à fibres optiques — Exigences de conception et de vérification

Reference number
ISO 20780:2018(E)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html

This document was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

Introduction

Fibre optic sub-systems are finding increasingly wide utilizations in space systems. In these fibre optic sub-systems, fibre optic components are the significant elements. Hence, the reliability of fibre optic components is essential to the system lifetime, performance and safety. For space applications in particular, the environmental adaptability of fibre optic components can be a critical factor in the mission schedule and success.

This document is a directive document for fibre optic components, which are sorted as a specific category used in space systems. In this document, the design and verification requirements for fibre optic components focus on the space environmental adaptability and reliability, the pertinent procedures and concerns are described in order to provide safe and reliable hardware and operation.

NOTE Each manufacturer could suggest to the customer that tailoring is possible for any part of the standard that seems difficult to apply because of a manufacturing process that is being used.

Space systems — Fiber optic components — Design and verification requirements

1 Scope

This document specifies requirements for the design and verification of fibre optic components used in space fibre optic sub-systems. In this document, the requirements are established to assure the reliability and environmental adaptability of fibre optic components in space environmental conditions. These are in a range of applications such as ground systems, unmanned applications and manned systems. This document suggests a set of requirements to be applied to the selection of space fibre optic components.

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.

ISO 14302, *Space systems — Electromagnetic compatibility requirements*

ISO 14621-1, *Space systems — Electrical, electronic, and electromagnetic (EEE) parts — Parts management*

ISO 14621-2, *Space systems — Electrical, electronic, and electromagnetic (EEE) parts — Control program requirements*

3 Terms, definitions, abbreviated terms and symbols

For the purposes of this document, the following terms and definitions apply.

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 https://www.iso.org/obp

3.1 Terms and definitions

3.1.1
optical fibre
filament shaped optical waveguide made of dielectric materials

[SOURCE: IEC 60050]

3.1.2
optical fibre cable
assembly comprising one or more optical fibres or fibre bundles inside a common covering designed to protect them against mechanical stresses and other environmental influences while retaining the transmission quality of the fibres

[SOURCE: IEC 60050]

3.1.3
optical fibre pigtail
short length of optical fibre, usually permanently attached to a component and intended to facilitate jointing between that component and another optical fibre or component

Note 1 to entry: "Launching fibre" is synonymous with optical fibre pigtail only when the latter is connected to an optical source.

[SOURCE: IEC 60050]

3.1.4
fibre optic component
components that are based on optical fibre properties or components that are coupled with optical fibres that cannot be disassembled, including passive fibre optic components and active fibre optic components

3.1.5
passive fibre optic component
fibre optic components that could realize certain photoelectric functions with no need for external energy, including fibre optic connectors, optical fibre couplers, wavelength division multiplexers, fibre optic attenuators, fibre optic filters, fibre optic isolators, circulators, polarization controllers, fibre delay lines and fibre optic gratings

3.1.6
active fibre optic component
fibre optic components that require a source of energy for their operation to realize the function of electro-optical/optical-electro conversion, including semiconductor sources (LD, LED, DFB, QW, SQW, VCSEL), semiconductor detectors (PD, PIN, APD), fibre lasers, optical amplifiers, wavelength transducers, optical modulators and optical switches

3.1.7
space fibre optic sub-system
assembly of interconnected basic fibre optic subsystems

Note 1 to entry: The assembly is specified at defined interfaces within the fibre optic system.

[SOURCE: IEC 61281-1:1999, modified]

3.1.8
coupling efficiency
efficiency of optical power transfer between an optical component and its fibre pigtail

3.1.9
fibre alignment dislocation
misalignment between the fibre tip and optic chip (or crystal) facet

3.2 Abbreviated terms

AFOC active fibre optic component

AIT assembly, integration, test

APD avalanche photodiode

COTS commercial off-the-shelf

DFB distributed feedback

DLAT destructive lot acceptance test

DPA destructive physical analysis

EEE electrical, electronic, and electromagnetic

ESD electrostatic discharge

FBG fibre Bragg grating

FMEA failure mode and effect analysis

FOC fibre optic component

LAT lot acceptance test

LD laser diode

LED light emitting diode

MRL manufacturing readiness level

MTTF mean time to failure

NA numerical aperture

PD photodiode

PDL polarization dependent loss

PFOC passive fibre optic component

PID process identified document

QW quantum well

RHA radiation hardness assurance

SQW single quantum well

TEC thermal-electric cooler

TRL technology readiness level

VCSEL vertical cavity surface emitting laser

WDM wavelength division multiplexing

3.3 Symbols

V volt

MΩ mega ohm

°C degree Celsius

Hz hertz

m/s^2 gravitational acceleration

ms millisecond

µm micrometre

N newton

cm^3 cubic centimetre

Pa pascal

4 General requirements

4.1 Design criterion

— Design and verification of FOC shall meet related requirements in ISO 14621-1, ISO 14621-2 and ISO 14302.

— Mature technologies and operating principles, COTS are preferred (TRL 6 (refer to ISO 16290) shall be demonstrated for any selected technology and associated COTS).

— The design shall satisfy the requirements of environmental adaptability and reliability.

— The design parameters could be optimized by validated software simulations and corrected by process tests.

— New materials and technologies shall be fully proven before application, verified materials and technologies for space environment are preferred, TRL 6 (refer to ISO 16290) will be demonstrated for technology and associated COTS.

— Apply derating design to FOC, the stress exerted on FOC during usage should be lower than the rated value in order to slow degradation, decrease failure rate and improve reliability of FOC.

— Balance the design of FOC by overall consideration of the function, reliability, risk, and economic efficiency.

4.2 Design input

— Specific requirements from customer, user and prime contractor.

— Requirements based on the space environment and system application, including mission profile in order to calculate a consistent MTTF according to dedicated methodology.

— Standards and criteria approved by customer and industry.

— New technology that helps to improve FOC performance in space environment.

— Safety requirements from space systems.

— Safety regarding health regulations.

4.3 Design output

The following output files shall be documented during the design and verification processes, which are in accordance with the design flow chart shown in Figure 1:

— document for design plans and strategies;

— document for justification (e.g.: design report);

— document for manufacturing process (e.g.: technical document, data record);

— document for verification (e.g.: specifications, reliability report, application verification report);

— document for safety demonstration (e.g.: health, safeguard, operations, transportation, and storage);

— document for users (e.g.: operation guides and precautions).

4.4 Design flow

— The design flow chart is shown in Figure 1.

— Conduct failure mode and effect analysis (FMEA) during the design process (IEC 60812:2006) to identify weak links, safety issues and key items of the design, so as to improve the design iteratively.

— When the design is modified, in principle, verification tests shall be completely conducted again in accordance with the whole verification process. Conducting effect analysis only on the modified part with related verification items is allowable. The verification results shall be added to the original verification report and demonstrate that the modified part does not have unwanted transverse system effect.

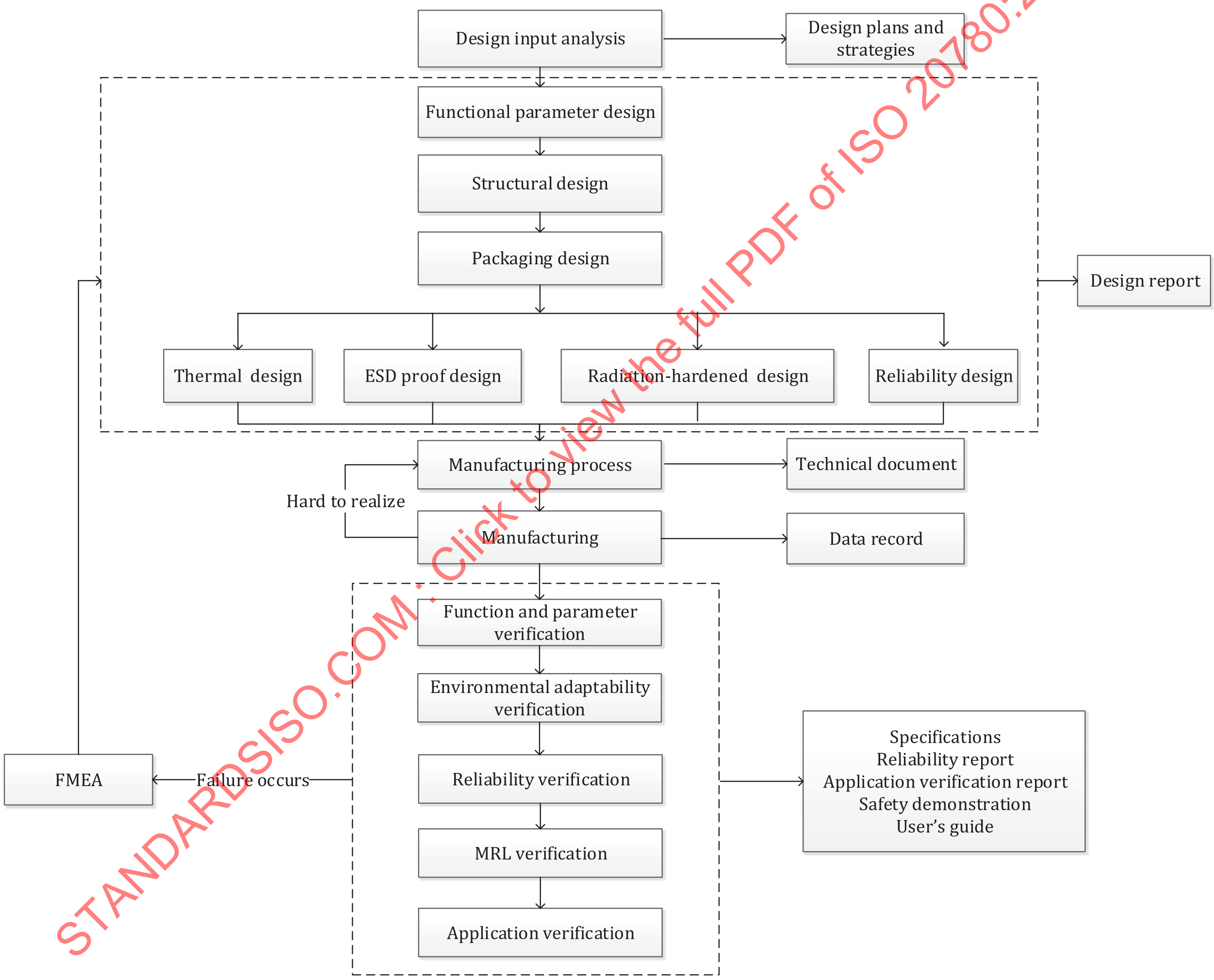

Figure 1 — Design flow chart for fibre optic components

5 Design requirements

5.1 Functional parameter design

5.1.1 Overall design

Employ an optimal overall design scheme according to the FOC function and required specifications:

— Operating principles: for the same function, the FOC could be fabricated by different operating principles. For example, for non-wavelength selective branching components (such as optical fibre couplers), fibre fused and tapered structure, fibre polished structure or optical waveguide structure are all usable; for fibre filters, etalon, FBG or thin film filter technologies are both adoptable; and for semiconductor light sources, different resonant cavities structures could be used. Hence, the operating principle shall be first determined according to the required specifications and applications.

— Packaging: determine the packaging type, external structure and fibre bending radius inside the FOC according to the application environment and dimension requirements; determine the type of connector and the interface structure of the fibre connectors, such as FC, SC, ST, etc.

— Operating conditions: determine the operating conditions of the FOC according to the application requirements (e.g.: long life-time application, severe environment application). The FOC shall not be used out of the range of their qualified characteristics.

— Raw materials and accessories: determine the key parameters of raw materials and accessories according to the operating conditions. Especially, many kinds of polymeric compounds are used in FOC, including adhesive, sealant, pouring sealant, etc. Besides the functional requirements, space environmental adaptabilities shall be considered for polymeric compounds, such as decomposition under high temperature and irradiation environments, volatilization under vacuum environment.

— TRL 6 (refer to ISO 16290) shall be preferred as a minimum for any choice of technology.

5.1.2 Optical design

The optical parameter design of FOC includes:

— By determining the design of active light-emitting devices, determine the parameters of active light luminescent devices, such as beam mode field, divergence angle, output power, wavelength, spectral bandwidth, polarization, side-mode suppression ratio, pulse width and so on.

— By determining the design of active light-receiving devices, determine the parameters of active optical receivers, such as operating wavelength, responsivity, sensitivity, polarization sensitivity and so on.

— Design the parameters of passive FOC, such as operating wavelength range, insertion loss, return loss, PDL, extinction ratio, isolation (e.g. for fibre optic isolators and fibre WDM), split-ratio (optical fibre coupler, fibre WDM), reflectivity (fibre reflector, fibre grating) and set up the overall optical loss for the system.

— Analyze compatibility of monitoring optical signal (wavelength, continuous or pulsed signal, power or energy delivered) with optical detector.

5.1.3 Electrical design

The electrical parameter design of FOC includes:

— Design amplifying circuits for detectors with amplification function, including parameters such as bias voltage, frequency bandwidth, gain, noise, etc.

- Design driving circuits for lasers, including parameters such as operating current range, current modulation frequency, current modulation duty cycle, etc.
- Design thermal control circuits for components with thermal control function, including parameters such as heating/cooling current, thermistor, cooling efficiency, etc.
- Design modulation characteristics for waveguide modulation components, including parameters such as half wave voltage, modulation bandwidth, etc.
- The designer shall provide the electrical parameters such as threshold current, power conversion ratio, operating current/voltage, and reverse voltage for FOC, such as laser source.
- Operating and responding time (with the required rise time) (minimum/maximum) shall be expressed for the design and component selection.

5.1.4 Low power consumption design

Meanwhile, low power consumption design shall also be considered for FOC with the aim of reducing system power consumption, on the premise that the performance and reliability requirements of FOC could be satisfied, which includes:

- Use low power consumption internal components.
- For light-emitting components, design semiconductor chips with high luminous efficiency to reduce the required drive current. For example, employ a multi-quantum well structure for the active region of the chip.
- For thermal control components, choose a high efficiency TEC to reduce the thermal control current required to maintain the operating temperature range.

5.2 Structural design

5.2.1 External structure design

- The structural design shall satisfy the user's requirements on the dimension, weight, installation, interfaces, tightness and decomposition (gas, etc.).
- Appropriate tolerance shall be defined for measured dimensions.
- Besides the seal welding area, the outside surface of the metal shell should be mildew proof with metal plating (such as gold, nickel, etc.); the outside lead or material shall meet the requirements of anti-corrosion and solderability with environmental friendly solutions.
- For a tubular passive FOC sealed with sealant or compound (such as a fused and tapered optical fibre coupler, WDM, isolator, etc.), metal tubes with anti-extrusion, anti-corrosion and anti-contamination properties shall be applied. The anti-corrosion property, stability and volatility of the organic sealant applied at the end of fibre-tail shall satisfy the requirements for space application. No bubbles shall be observed for the sealant under 50X microscopic visual inspection.
- Under the precondition of ensuring the function and installation requirements, the dimension of FOC shall be as compact as possible.
- Appropriate fixture shall be set up to clamp the optical fibre.

5.2.2 Internal structure design

- According to the function and dimension requirements, choose a suitable size for the internal elements.
- Design the internal element layout by overall consideration of the specifications of the FOC.

— The internal conductors and wires shall not be damaged when the maximum allowable operating current is input.

— Eutectic soldering is the priority for electronic chip bonding of hermetically sealed components. Organic materials such as conductive sealants could also be used if it is difficult to apply eutectic soldering because of large chip area or complex structure, but the seal tightness and internal gas composition should meet the requirements.

— Design internal optical crystals according to the function parameter requirements. Consider parameters such as the crystal refractive index, overall dimension, crystal orientation, waveguide structure, surface coating, etc.

— If an organic adhesive is needed for bonding optical crystals, then the adhesive with high hardness (shore D hardness higher than 70 is recommended), high glass transition temperature (higher than 125 °C is recommended), low expansion coefficient ($< 100 \times 10^{-6}$ K^{-1} is recommended), and wide operating temperature range (−50 °C ~ 125 °C is recommended) shall be applied.

— For a passive FOC with fibre fusing and tapering technology (i.e. optical fibre coupler, WDM, etc.), the dimension of the fused tapering zone shall be designed (5.2.4) and the packaging size shall be optimized.

— The optical fibre inside the FOC shall be designed and processed to satisfy the performance requirements (5.2.5).

— The internal fibre coupling design shall assure the coupling stability (5.2.3) and the packaging tightness (5.3).

— Thermal design shall be applied for internal structures (5.4).

5.2.3 Fibre coupling design

For FOC, the optical fibre is often coupled with a semiconductor chip or optical crystal. Fibre coupling design shall be undertaken in order to assure the required beam transmission properties and coupling efficiency. The coupling structure shall be stable under the appropriate temperature, humidity, mechanical and shock environmental conditions.

— Design the structure of coupling fibre end according to the light beam properties (5.2.5).

— In order to assure the coupling efficiency, the distance and alignment angle between the fibre end face and chip (or optical crystal) end face shall be designed precisely.

— After the fibre is aligned with the chip (or crystal), in order to assure the alignment stability, it is recommended that the fibre is fixed at two points at least.

— Metalized fibre is recommended to use for hermetically sealed components. The metalized fibre is soldered with the shell with metal, glass or ceramic soldering paste according to different packaging types; for non-hermetic components, the fibre is bonded with the shell with sealant (5.2.1).

5.2.4 Fibre fusing and tapering design

— For fibre fusing and tapering parameters such as fibre arrangement, heating type, flame type, gas composition and proportion, gas flow, flame temperature and height, tapering speed and length shall be designed. The fast and slow axes of polarization maintaining fibre need to be aligned first before tapering.

— In order to assure the performance and reliability of the FOC, the fused tapering region shall be protected to prevent the FOC from being contaminated by dust or other impurities. The protection material should have high rigidity and match with the tapered fibre material, for example a silica tube.

— If the cavity of the fused tapering region needs to be protected by filling pouring sealants, then the pouring sealant with low hardness (shore A hardness < 50 is recommended), low glass transition temperature (< −50 °C is recommended), higher elasticity and lower refractive index than that of the fibre shall be applied.

5.2.5 Fibre pigtail design

The fibre pigtail design includes fibre type selection and fibre end face design:

— Fibre type selection: Multimode fibre, single mode fibre, polarization maintaining fibre and other special fibres (such as photonic crystal fibre, high temperature resistance fibre, radiation-hardened fibre, etc., refer to IEC 60793-2 series).

— Determine the fibre parameters: cut-off wavelength, fibre diameter and mode field diameter, numerical aperture, mechanical tension and bending radius, etc.

— Determine the fibre protection types: bare fibre, hytrel sheath layer (tight or loose tubes), and fibre cable (armour, anti-flaming, thermo-stability, anti-extrusion, etc., refer to IEC 60794-2 series).

— Design the shape of the fibre end face (flat, spherical, quadric surface, cylindrical, cone, wedge-shaped, etc.) and parameters (radius of curvature, cone angle, bevel angle, etc.) according to the coupling beam properties (light emitting area, divergence angle, spectrum, polarization); determine the type of contact (if any) at the end of fibre face (FC, PC, etc.).

— Design the coating film material and coating thickness at the fibre end face according to wavelength and reflectivity requirements; provide its mechanical and thermal characteristics (amount of layers, thermal insulation, etc.).

— According to the reflectivity requirements of the application, e.g. formation of a laser cavity, fabricate the FBG and design the reflection wavelength and reflectivity. However, the influence of radiation and temperature environments on FBG parameters must be taken into account, and radiation insensitive fibre is recommended to use to fabricate the FBG.

5.3 Packaging design

5.3.1 Objective

— Take into account the mechanical, electrical, thermal and optical connections between the FOC and external structure, circuits and optical components.

— Take into account that the lifetime of internal components and processed fibres (such as fused, tapered, etched and polished fibres) are not affected by mechanical, temperature, humidity, corrosion and radiation environments.

— Take into account the mechanical stability of interconnections among internal fibres, optoelectronic chips and optical crystals of the FOC, and reduce the alignment dislocation.

— Facilitate the testing, installation and transportation of the FOC.

5.3.2 Packaging requirements

— Hermetic packaging shall be used if the internal components are vulnerable to gas corrosion or oxidization. Hermetic packaged components shall be sealed with metal, glass or ceramic (or the combination of these materials). For the components that will not experience gas corrosion or oxidization failure, and for components that could not be hermetically packaged due to limitation of manufacture technology, evidence must be supplied to prove that the long-term reliability of the component will not be affected due to the use of a non-hermetic package. The evidence shall be approved by both authenticate organization and user.

— The fibre of a hermetically packaged component shall be metalized and coated with shell by metal solder (metalized fibre is generally welded with metal tube, then the metal tube and the shell are welded together), the air tightness and coupling stability shall be guaranteed under environmental conditions of life profile (such as temperature, humidity, vacuum, radiation, mechanical shock, vibration, etc.).

— For non-hermetically sealed components, the fibre pigtail is bonded with the shell by sealant. The coupling stability shall be guaranteed under environmental conditions of life profile (such as temperature, humidity, vacuum, radiation, mechanical shock, vibration, etc.), at least assuring water tightness.

— The packaging stability and air tightness shall not be affected by expansion coefficient mismatch of the packaging material caused by temperature variation.

— The secondary seal encapsulation of the FOC is prohibited.

— The desiccant is prohibited inside hermetically sealed components.

5.3.3 Marking

— The container shall be legibly and indelibly marked in order that the marking shall not become damaged when the container is operated.

— The following information shall be provided on the marking:

1) lot number;

2) part number;

3) part name;

4) manufacturer; and

5) manufacturing country.

5.4 Thermal design

Thermal design shall be considered for electrical heating components and thermal sensitive components:

— Internal components with excellent thermal stability, wide operating temperature range and low power consumption shall be the priorities. The junction temperature of semiconductor component shall satisfy the derating design requirements according to the type of use.

— The melting temperatures of solder material and organic bonding material inside the component shall be higher than the component operating temperature and storage temperature.

— For active FOC with thermal control circuits (5.1.3), the thickness and composition of the internal heat sink, heat resistance of internal structure, thermistor parameters, TEC parameters, contact area, and internal component arrangement shall be designed.

— Design the thermal dissipation path, which includes the heat conduction path and heat radiation path. Design a special thermal dissipation path for components operating in vacuum environment.

— Thermal design software may be applied for the structural design and simulation analysis of FOC.

— Simple structures, mature materials and active heat dissipation designs shall be employed on the premise that the thermal design requirements could be satisfied, and provide a thermal margin between maximum temperature and operating temperature for system.

— Apply low power consumption thermal design for FOC.

5.5 ESD proof design

ESD proof design shall be adopted for FOC. The ESD sensitive grade shall be suited with the ESD model considered and justified.

— Identify the electrostatic sensitive voltage of the internal components. Components with high electrostatic damage threshold shall be applied. For example, for laser chips, buried hetero structure designs have a higher antistatic voltage when compared with ridge waveguide structures.

— The electrostatic sensitive components shall be isolated and protected. Assemble the components far away from the shell or increase the gap distance inside the shell.

— Design an electrostatic discharge channel and the shell shall be well connected with ground.

— The insulation resistance between the shell and the insulated pins shall be > 1 000 MΩ.

— The package shall meet anti-static requirements. Label the package with the electrostatic sensitivity grade and with an antistatic warning sign.

— In case of static charge unexpected during operation, analyze the compliance of optical harness jacket regarding electrical continuity required between equipment of the systems.

5.6 Radiation-hardened design

Carry out radiation-hardened design for space application ensuring that the RHA shall satisfy the user's requirements.

— Choose internal components with higher RHA.

— Adopt radiation-hardened fibre for the fibre pigtail, such as pure silica core fibre with fluorine-doped cladding.

— Materials with higher RHA shall be applied for the optoelectronic semiconductor chip of an active FOC, such as wide band gap semiconductor materials. Also, the RHA could be improved by optimizing the chip structure design, such as designing a multi-layer buried hetero structure for the laser chip.

— Employ a thin oxide layer and isolation region design for semiconductor components.

— Apply temperature control design for FOC to reduce performance degradation or damage caused by radiation induced heating effects.

— High molecular materials will degrade in radiation environments, try to avoid using high molecular materials in FOC.

— If the RHA of the FOC could not be improved by design, shield protection could be applied. Lead and tantalum are common shield materials. The increased weight and size should be approved by the user.

— The radiation sensitivity of the FOC could be reduced by conducting pre-radiation treatment on the internal components and fibre pigtail before packaging. The permission of the user shall be gained to undertake the pre-radiation treatment, and the performance of the FOC shall be verified after radiation treatment.

5.7 Reliability design

— Reliability design shall be considered during the whole design process of FOC. To meet the functional requirements, all factors that affect component reliability should be considered at every step of the design.

— Apply thermal design (5.4) for component reliability.

— Apply derating design for FOC. Identify the derating parameters and derating factor, the operating stress shall be less than the designed rated value. The derating parameters include temperature, power, operating voltage/current, etc.

— Design specific reliability indexes, including time dependent parameter degradation, environmental stress adaptability, lifetime and failure rate.

— Identify failure modes and failure causes of FOC (refer to IEC 62005-3:2001 and IEC/TR 62572-2:2008). Failure mode and effects analysis (FMEA) (refer to IEC 60812:2006) for the FOC is recommended to be applied by manufacturer and designer in order to avoid product failure during usage and to meet the reliability requirements.

— Conduct failure analysis for the failure occurrences encountered during the design, verification and usage process. Determine the failure modes and failure causes. Measures shall be taken to solve the failures encountered during design or manufacturing process.

5.8 Safety requirements

— Each end of the optical connector facet shall be covered by a safety cap after use to avoid any optical accident or hazard caused by intense light.

— An optical safety file shall be issued in order to demonstrate the compliance with health regulations from manufacturer and end user facilities. This safety file shall be established based on the safety analysis regarding normal, abnormal and accidental environments.

— The safety optical distance shall be calculated regarding the laser source class operated in the FOC.

— The maximum input optical power or energy of the FOC shall be calculated for the whole system design.

— Safety test shall be designed to demonstrate the environmental adaptability of the FOC.

5.9 Manufacturing process requirements

Determine the manufacturing process according to the design requirements, the process shall guarantee the reliability for space application. Besides the above mentioned requirements on process technology, there are additional requirements as follows:

— All the design functions shall be practicable with current process technology. Otherwise, the design shall be revised.

— Material selection shall be compliant with radiation requirements.

— Gold wire bonding shall be applied for components with internal electrical connections. The wire diameter shall be no less than 18 µm and adhesive shall not be applied at the bonding point.

— Semiconductor chips without beam lead structures are preferred.

— Non-volatile materials are preferred inside and outside the component, in case of using pouring sealants for potting, stability demonstration shall be provided regarding the whole range of environment conditions (vacuum, temperature, etc.).

— All materials shall be compatible with each other.

— For hermeticity components filled with inert gas (such as helium, argon), nitrogen or dry air are preferred. In case of solution with vacuum packaging, the efficiency shall be justified.

— A gold coating is recommended for the interior of the shell welding hole and the outside wall of the fibre metal tube. Use soldering materials with long-term welding reliability. Apply appropriate heating temperature and heating time to assure the flowability of the soldering. Accurately control the quantity of solder.

— The sealant for non-hermetic components shall have the properties of anti-shock, damp proof, dust proof, anti-corrosion, low glass transition temperature, etc.

— Avoid using stannum (Tin) as the lead or final coating of the shell.

— Avoid potential damage to the fibre during fibre polishing and processing.

— MRL 6 shall be preferred as a minimum for any choice of process.

— AIT and operation process shall be set up to demonstrate the immunity of FOC against the pollutions met during AIT.

— Dedicated container shall be designed for the FOC transportation in order to guarantee the performance and lifetime.

— Authorized solvent shall be selected for end users.

6 Verification requirements

6.1 Function and parameter verification

— Verify the functions and parameters of the FOC according to the customer's requirements and industry standards.

— For function and parameter verification, evaluate and analyse the function of the FOC under different conditions to determine the variation tendency of the FOC performance with temperature and electrical stress conditions.

— Define the sensitive parameters in order to demonstrate and justify performance at specified environments.

— Verify the functional performance within the service life expected and the environment requirements.

— Acceptance test is recommended to be designed for the FOC acceptance.

6.2 Environmental adaptability verification

Test items and conditions are listed as follows for the environmental adaptability verification. The practical verification for space application could be carried out according to the user's requirements. However, the following verifications should be conducted in principle:

— High temperature storage: ensure that no permanent damage will be caused by storage in a high temperature environment. If there is no recommendation from the customer, in order to meet the space application requirements the recommended temperature and test time are 85 °C and 2 000 hours, respectively. Measure the key parameters (which reflect the failure mode under high temperature conditions) after the test.

— Low temperature storage: ensure that no permanent damage will be caused by a low temperature environment. If there is no recommendation from customer, in order to meet the space application requirements the recommended temperature and test time are −55 °C and 1 000 hours, respectively. Measure the key parameters (which reflect the failure mode under low temperature condition) after the test.

— High-low temperature cycle: ensure that no permanent damage will be caused by cycling the temperature between high and low values. If there is no recommendation from customer, in order to meet the space application requirements the recommended test conditions are: temperature range −55 °C ~ 85 °C, temperature gradient 10 °C/min, and 100 cycle times. Measure the key parameters (which reflect the failure mode under high-low temperature cycle) after the test.

