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CMS Tracker optical links laser safety manual

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Abstract

Laser safety concerns are addressed for the CMS Tracker analogue and digital optical link systems. These systems operate with low-power 1310nm light that is normally confined to optical fibre channels. The system and its components are classified according to the International Electrotechnical Commission (IEC) Laser Safety guidelines, for periods of test and development, assembly and installation, as well as for final operation and subsequent maintenance. Recommendations for labelling, access requirements, safe-working practices and eye protection are also derived from the IEC standards. The general issue of laser safety training is also addressed.

The contents of this document will be reviewed if there are any changes in the Standards or system specifications. The most up-to-date information will be available at http://edms.cern.ch/document/338505/1.

Document history

Version 1:	Initial report based on existing IEC 60825-1 and IEC 60825-2 Standards. Released as CMS Internal Note March 01,2002.
Version 2:	Modifications made based on new release of IEC 60825-1, Edition 1.2. FEC optical interface is specified and now digital control links fully included. Application to other CMS sub-systems using these systems or components.

Preamble

The information provided in this document focused originally on safety requirements related only to the optical link systems based on those using the systems originally developed for the CMS Tracker[1], operating at 1310nm wavelength using single-mode fibre channels. These links include the ECAL, Preshower, and Pixel readout and control links. The classification cannot be applied or transferred directly to other optical links, or laser systems. In principle, every group involved in using lasers, optical links, or other potentially hazardous optoelectronic equipment must address individually the specific concerns related to laser safety in their particular systems.

The laser safety requirements and recommendations in this document are derived from the the latest IEC standards[2,3] 60825-1, 60825-2 concerning safety of laser products and safety of optical fibre communication systems respectively. The use of the latest version of 60825-1 means that the hazard classifications of the system and its components have changed significantly since the first version of this report, following a relaxation of various numerical factors involved in the calculation of the accessible exposure limits (AEL), which are particularly important for systems using a wavelength of 1310nm.

The publication of the first version of this report followed extensive discussions with the CERN/TIS/RP Laser Safety Officer on how to interpret the CERN Rules document IS-22. It was recognized that the CERN rules have not followed the evolution of the IEC standards and are inappropriate for assessments of large and distributed fibre-based communication systems such as those in the CMS Tracker and related systems.

The laser safety issues presented here were therefore examined separately by TIS/RP and accepted on the condition that they are kept fully informed of the implementation of laser safety practices within the project.

The laser safety issues in these optical link systems will be periodically reviewed and modified as and when required.

The layout of this document is as follows: In Section 1 Hazard classification is outlined and then in Section 2 the CMS Tracker optical link systems and their components are described briefly. In Section 3 the hazard classification is determined for the components and for the full optical link system and in Section 4 the laser safety requirements for the final CMS optical link systems are outlined.

The latest version of the document will be available at: http://edms.cern.ch/document/338505/1

1 Overview of laser hazard classification

Laser safety is usually categorized in terms of a hazard level classification, related to the potential of the laser source to cause harm. The hazard level is determined by the optical power level that is potentially accessible, under all reasonably foreseeable circumstances. The classification is strongly dependent upon the wavelength of the radiation and various other factors such as the nature of the radiation source, its size, whether it is collimated or divergent, as well as the time-dependence of the radiation. It should be emphasized that the potential damage to the eye or skin tissue varies enormously depending upon these factors. In addition, the classification is also affected by the potential exposure times and the type of tissue exposed.

The different hazard classes are listed below[2]. Each is limited according to an accessible emission limit (AEL). For eye-safe lasers the AEL is related directly to the maximum permissible exposure (MPE), which is a conservative estimate of the threshold for permanent eye or skin tissue damage. For more powerful lasers or systems, the AEL is related to the potential to cause eye or tissue damage by reflection of the radiation, and to the potential of the source to cause a fire.

> **Class 1** is considered as safe to use without restrictions.
>
> **Class 2** is related to visible wavelengths where 'blink-aversion' protects the user from significant danger.
>
> **Class 1M (and 2M for visible radiation)** refers to laser sources that are naked-eye safe, i.e. safe provided that optical instruments are not used.
>
> **Class 3R** refers to laser sources that are low risk, where the total accessible power is limited to at most five times the MPE.
>
> **Class 3B** and **Class 4** are for components and systems that can expose users to radiation well above the thresholds for physical injury. The main difference is that Class 3B lasers will cause retinal damage through direct intrabeam exposure, or specular reflections, whereas Class 4 can cause retinal damage even through diffuse reflections and may also present a fire hazard.
>
> **Hazard Levels 1, 2, 1M, 2M, 3R, 3B and 4** are the corresponding classifications for *fibre-optic systems*, as opposed to laser or LED sources. This different nomenclature reflects the fact that the laser source may be far distant from an accessible element of the fibre-optic system where there may exist a potential risk.

The hazard classification of a laser, LED, or fibre-optic system system, is made by, first of all, measuring or calculating the accessible power that passes through an aperture placed a certain distance from the light source, fibre-end or connector face. The diameter of the aperture and its distance from the source are given in the IEC standards and there is a nominal exposure time used in the calculation.

For the CMS Tracker optical link systems operating with single-mode fibres at 1310nm (with divergent laser radiation emitted from the fibre-ends), the relevant aperture size is 7mm, representing a fully dilated eye-pupil, at a distance of between 14mm and 100mm from the light source, with the precise distance depending upon the angular subtense of the radiation source. The angular subtense α is determined at a distance of 100mm and the value is then limited (by truncation) to the range $\alpha_{min}<\alpha<\alpha_{max}$, where α_{min}=1.5mrad and α_{max}=100mrad.[1] A relaxation factor of α/α_{max} is applied in the AEL calculation to increase the AEL in proportion to the increase in size of the source, which represents the spread of the image size and diminution of the thermal energy density incident upon the retina. This relaxation is important in the calculation of the AEL for fibre ribbons and ribbon connectors in the optical link system.

The exposure time used in the calculation for AEL for the CMS Tracker system is 100s, as there is no intention in the final system to expose users to laser light for longer timescales.

The CMS Tracker optical link components are detailed in the following Section and then in Section 3, the hazard classification is given for these components.

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[1] In earlier versions of IEC 60825-1 the factor α_{min} was 11mrad.

2 CMS Tracker optical link systems

Approximately 40000 uni-directional analogue optical links, and ~2600 bi-directional[2] digital optical links will be used to readout and control the CMS Tracker[1]. The basic elements of the optical link system are illustrated in Fig. 1 and the architecture of the (analogue) system is outlined in Fig. 2.

Both analogue and digital optical links for the CMS Tracker share the same basic components, namely 1310nm edge-emitting lasers coupled to p-i-n photodiodes via single-mode optical fibre. To enable installation and facilitate testing there are three break-points in the optical links at three patch-panels: the distributed patch-panel, located at, or close to, the detector modules inside the Tracker, the in-line patch-panel in the HCAL crack, and the back-end patch-panel at the FED and FEC crates in the counting room.

The optical fibre is in the form of buffered single-way fibre inside the Tracker volume, between the laser (or photodiode) and the distributed patch-panel, ruggedized 12-way ribbon between the distributed and in-line patch-panels, and then dense 96-way multi-ribbon cable from the in-line patch-panels to the FED (or FEC) patch panels. The single-way fibre connections at the distributed patch-panel will be MU to SMU, and the fibre-ribbon connections will use 12-way MFS connectors in the in-line patch-panel and 12-way MPO connectors in the back-end patch-panel.

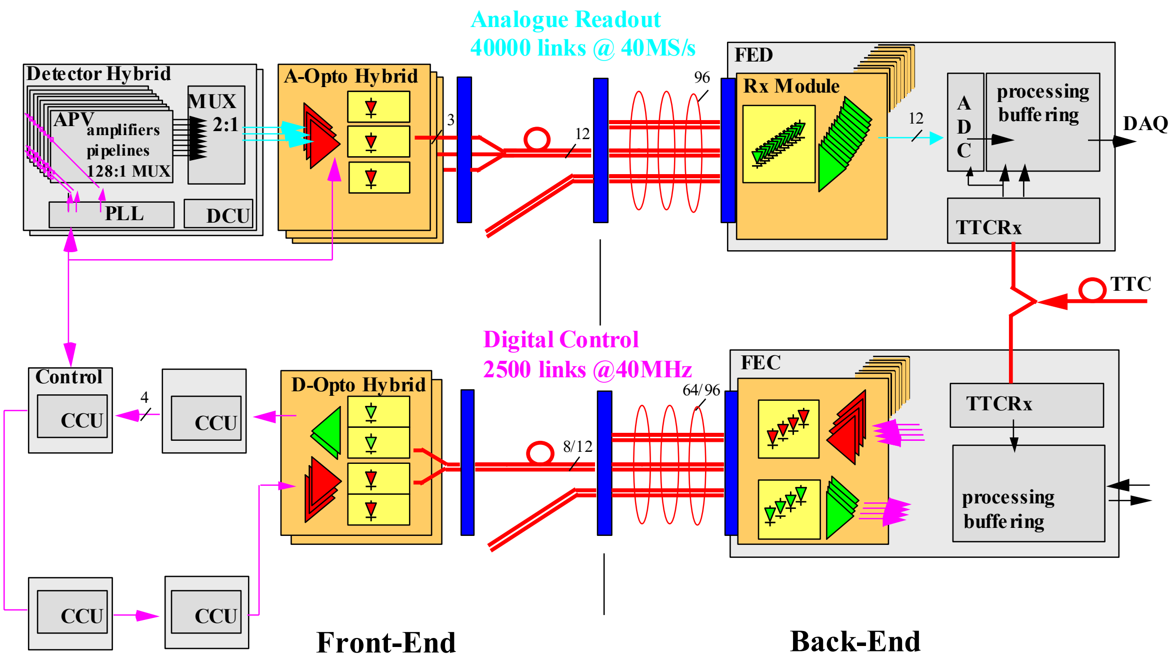

Fig. 1: Schematic outline of analogue and digital optical link systems for the CMS Tracker.

[2] Although the digital links are considered bi-directional, there will be only a one-way transmission of light in any given fibre and separate fibre channels carry the signals to and from the Tracker.

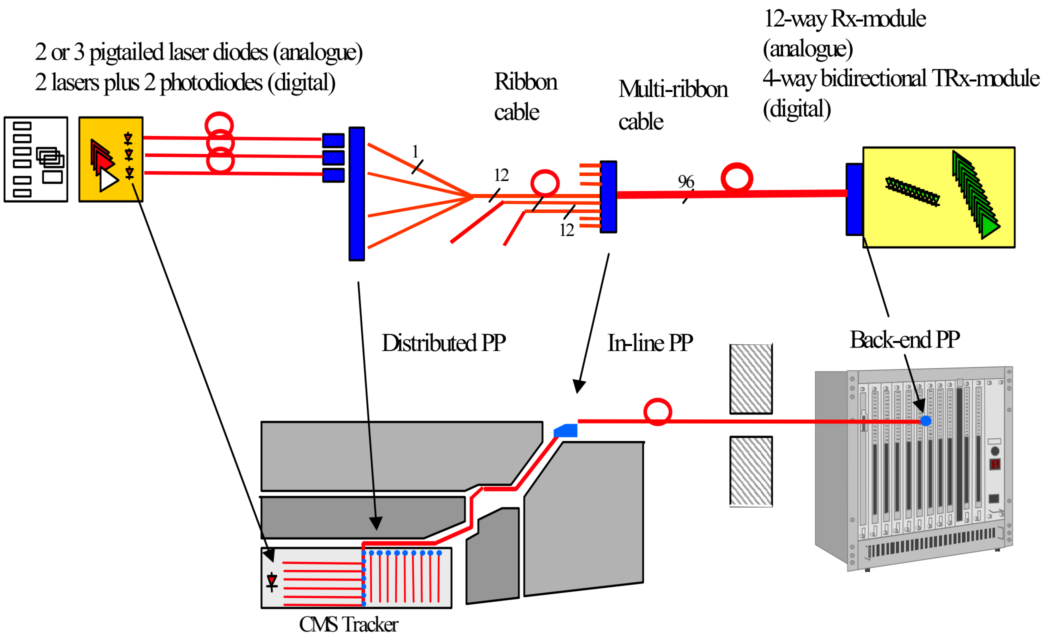

Figure 2: Schematic optical link implementation, highlighting the common and different components in the analogue and digital systems.

2.1 System Components

2.1.1 Front-end laser transmitters (analogue and digital readout and control systems)

Individual 1310nm InGaAsP lasers used as front-end transmitters in both the Tracker analogue and digital control links. The lasers are supplied by ST Microelectronics, assembled in a compact package that includes a single-mode fibre pigtail and MU connector.

In this type of packaging, the laser output efficiency is specified to be 40µW/mA for the analogue links and 16µW/mA for the digital links, each of these values having a tolerance of ±20%. The laser threshold currents are typically 5mA – this is the current required to stimulate the laser to output a coherent light beam.

When mounted on optohybrids, these lasers are driven via a linear laser driver (LLD) ASIC at low levels of electric current. The LLD is specified to deliver up to 55mA dc bias and up to +/- 6.25mA modulation around the dc bias point. Each of these values having a tolerance of ±20%. The maximum laser current is therefore limited at ~80mA. The output power should therefore be limited to 3.6mW in the final analogue system.

In the digital control links system, the input electrical signal at the front-end digital optohybrid is expected to be at most 400mV differential swing, generating a modulation current of +/- 5mA around a maximum bias current of 55mA. If a 20% increase in each of these numbers is included for the component gain tolerances, the (average) optical power output should therefore be at most 1.3mW. The average power is used, rather than peak power, since the transmitted digital signal is balanced in terms of the number of ‘1’s and ‘0’s.

2.1.2 Back-end transceivers (in digital control system)

4-way 1310nm InGaAsP laser arrays are embedded in the back-end transceiver modules that are mounted on the FEC in the digital control link systems. The optical interface is 12-way MPO with the four innermost fibre channels being unused.

The average launched optical power from the transceivers is specified to be at most –3dBm or 500µW. The output is again a balanced-code signal therefore the average power figure is used for the subsequent calculations.

On the receiver channels light will be received that was emitted at the front-end laser (described above).

2.1.3 Photodiodes (digital control system)

Single-channel InGaAs photodiodes are mounted on the front-end digital optohybrids in the digital control links. They are packaged with a single-mode fibre pigtail having an MU-connectors. On these receiver channels light will be received that was emitted at the back-end transceiver (described above).

2.1.4 Fibre and fibre-ribbon

One-way tight-buffered single-mode optical fibre is used between the front-end optohyrids and the distributed patch-panel. The light levels concerned are therefore up to 3.6mW in the analogue link laser pigtails, 1.3mW in the digital link laser pigtails and 0.5mW in the photodiode pigtails.

The one-way fibres emerging from the sMU connectors are fanned into 12-way ribbon, that is ruggedized over most of its length between the distributed and in-line patch-panels.

12-way ribbons, bundled into a ruggedized 96-way cable, are then used between the in-line and back-end patch-panels. The fibre pitch is 250μm.

The 12-way fibre-ribbons used in the analogue optical link system transmit up to 3.6mW on each channel. The 12-way ribbons in the digital control system are utilised such that the first four fibre channels of the twelve transmit light from the back-end transceivers, therefore up to 0.5mW per channel, and the last four fibres, transmit light emitted at the front-end lasers, therefore up to 1.3mW each.

It should be noted that a broken fibre ribbon is considered to be only as hazardous as a single fibre channel, likewise a 96-way cable made of eight 12-way ribbons also presents the same risk as a single broken fibre in terms of danger from the laser radiation.

In contrast, a cleaved fibre ribbon will act as a single extended (linear) light source, as in the case of the ribbon connectors below.

2.1.5 Patch-panels and connectors

The distributed patch-panel is based upon an MU-sMU connection, the MU side being attached to the front-end laser or photodiode pigtails. Both sides of the connector are attached to individual single-way fibres.

The in-line patch-panel is based upon groups of 12-way MFS (fibre-ribbon) connectors.

The back-end patch-panel consists of 12-way MPO (fibre-ribbon) connections at the FED and FEC boards.

The light levels transmitted are the same as those outlined above for the single fibres and ribbon-fibres.

A ribbon connector is considered as an extended linear light source in terms of the laser safety classification.

3 Hazard classification

All of the components involve output of light from a single-mode fibre end (or linear array of ends) therefore the hazard classification can be generalized to that of a single set of calculations for single-fibres and one for an array of fibres in a ribbon or ribbon connector.

An example of a calculation for single-mode fibre is given in the 60825-1 Standard[4]. The following calculations follow from that example.

3.1 Using individual single-mode fibre channels

For Class 1 and Class 1M, the AEL calculation starts with a comparison of the exposure duration with the breakpoint T_2 [5]

$$T_2 = 10 \times 10^{(\alpha - 1.5mrad)/98.5} \text{ (seconds)} \tag{1}$$

where α is the angular subtense of the source.

For a single fibre, the angular subtense is smaller than 1.5mrad and it is therefore limited to the minimum value, $\alpha = \alpha_{min} = 1.5$mrad [6].

T_2 is therefore 10s.

At 1310nm, the time-base for the hazard calculation appropriate for the CMS Tracker links systems is t=100s[7]. Since t > T_2, according to [8], the accessible emission limit, AEL is given by,

$$AEL = 3.9x10^{-4} C_4 C_7 \qquad \text{(units of W)} \qquad (2)$$

where the correction factors C_4=5 and C_7=8 [5].

Therefore AEL = 15.6mW.

An individual single-mode fibre is considered to be a special case of a point-source of light, where the diameter of the beam at some distance r from the fibre end is given by d_{63}:

$$d_{63} = \frac{2\sqrt{2}r\lambda}{\pi w_0} \qquad (3)$$

where λ is the wavelength and w_0 is the mode-field diameter in the fibre. At r=100mm, with λ =1310nm and w_0 =9µm (as is the case for our Ericsson fibre), this gives d_{63}=13.1mm. For single-mode fibre the beam-diameter is considered to be the width of the beam where the intensity is 1/e times the peak.

The fraction of light power coupled into an aperture of diameter d_a is then

$$\eta = 1 - \exp\left[-\left(\frac{d_a}{d_{63}}\right)^2\right] \qquad (4)$$

For the classification of a divergent beam, such as that from a fibre end, we consider the condition where the light is coupled into a 7mm aperture at a distance 14mm from the source [9]. In the case of a single fibre end, 100% of the light will be coupled into the aperture, therefore the Class 1 AEL is 15.6mW.

The next hazard class, Class 1M, considers the case where the emitted power might be greater than the AEL of Class 1, but less than 3B. To satisfy the Class 1M limit the light into an aperture of 7mm at 100mm distance must be less than the AEL of Class 1 for this condition. This is calculated again following the example in the IEC Standard [4]. For a 7mm aperture at 100mm distance η=25.2%.

The AEL for the power emitted from the fibre tip, or connector end-face is P_{MAX} given by

$$P_{MAX} = \frac{P_{AEL}}{\eta} \qquad (5)$$

giving P_{MAX} =15.6/0.252=61.9mW.

This value is lower than the Class 3B limit of 500mW therefore the Class 1M AEL is meaningful and is 62.9mW for a single-mode fibre in our system.

It should be noted also that Class 3R also exists for the use of this fibre, in the case where power levels exceed Class 1M, but are less than five times the MPE (5x16mW = 80mW), therefore Class 3R covers the output power range 61.9mW<P_{3R}<80mW.

In summary, for the CMS Tracker system, and other CMS systems based on this optical link technology, the optical power levels are at most 3.6mW per fibre channel therefore the hazard remains well within the Class 1 limit. Consequently, the lasers mounted on optohybrids are Class 1, the fibre-pigtails are Hazard Level 1, and the distributed patch-panels of MU-sMU connectors are also Hazard Level 1.

It should be noted that prototype lasers, driven by a different current source, other than the LLD ASIC, might be able to emit in excess of 3.6mW and the corresponding hazard level should be calculated for the given situation. However, it is considered extremely unlikely, under all reasonably foreseeable circumstances, even in the development laboratory, that the lasers used for the CMS Tracker optical link system would be driven with sufficient current for them to output more than 15.6mW into the fibre. This would require a very large electrical current (>390mA). Therefore, used in the development lab, these lasers are Class 1.

3.2 Using fibre-ribbon connectors at the in-line and back-end patch-panels

In the worst-case of opening an energized 12-way ribbon connector there could be 12 fibres each transmitting 3.6mW. The 12 fibre channels in the ribbon are arranged with a pitch of 250µm and the classification is done taking into account the actual spatial distribution of the light sources in the connector, and their optical divergence, in order to avoid being overly conservative.

This procedure is essentially the same as the classification procedure for an extended source[6], such as an array of lasers, requiring a calculation for each possible α value of the distributed radiation sources, effectively checking for any 'hot-spots' at particular angular subtenses across the ribbon.

For the fibre ribbon classification a separate calculation is therefore made for the individual fibre channels, then groups of two neighbouring fibres, groups of three, and so on up to 12 fibres in a 12-way connector. First of all the average angular subtense is calculated. For a ribbon of single-mode fibres the angular subtense orthogonal to the plane of the ribbon is limited to $\alpha_x=\alpha_{min}$ =1.5mrad since the individual fibres subtend less than 1.5mrad. In the plane of the ribbon (i.e. along the row of fibre ends) the angular subtense of a group of *n* fibres (n>1) is given by,

$$\alpha_Y = \frac{(n-1)\times 250\mu m}{100mm} \qquad (6)$$

The average angular subtense is then,

$$\overline{\alpha}_Y = \frac{\alpha_Y + \alpha_x}{2} = \frac{\alpha_Y + \alpha_{\min}}{2} = \frac{\alpha_Y + 1.5mrad}{2} \qquad (7)$$

Then the breakpoint T_2 can be calculated according to equation (1). Also the distance at which the 7mm aperture should be placed can also be calculated according to [9],

$$r = 100 \times \sqrt{\frac{\overline{\alpha} + 0.46mrad}{\alpha_{\max}}} \qquad (8)$$

where α_{max} =100 mrad, or

r = 14mm if $\overline{\alpha} < \alpha_{min}$ (9)

or

r = 100mm if $\overline{\alpha} > \alpha_{max}$ (10)

The diameter of the beam at this distance and the coupling of the light into the aperture can then also be calculated according to equations (3) and (4).

If $\overline{\alpha} > \alpha_{min}$ (1.5mrad) then the AEL for Class 1 (and Class 1M, but with different positioning of the aperture) is given by [8],

$$AEL = 7x10^{-4} C_4 C_6 C_7 T_2^{-0.25} \quad \text{(W)} \qquad (11)$$

where the correction factor C_6 [5] takes into account the increased angular subtense,

$$C_6 = \alpha / \alpha_{\min} \quad \text{for} \quad \alpha_{min} < \alpha < \alpha_{max} \qquad (12)$$

Table 1 summarizes these steps of the calculations to arrive at the AEL values for different sized groups of fibres, from one to a group containing all twelve fibres.

In the case of a 12-way connector, the group of 2 fibre-channels is the most restrictive in terms of AEL, having a limit of 10mW/fibre for Hazard Level 1 and 41mW/fibre for Hazard Level 1M.

In summary, since the maximum power in any fibre is limited to 3.6mW, Hazard Level 1 is the therefore appropriate classification for all the 12-way connectors, both at the in-line patch-panels and at the back-end (FED and FEC) patch-panels, as well as being appropriate classification for any cleaved fibre ribbons in the system.

Table 1: Calculations for AEL Class 1 (Hazard Level 1) and Class 1M (Hazard Level 1M) for a 12-way array of fibres in a cleaved ribbon or ribbon connector.

No. fibres in group	$\overline{\alpha}$ (mrad)	T_2 (s)	r (mm)	C_6	d_{63} (mm)	η (%)	AEL $_{Class\ 1}$ (mW per fibre)	η (r=100mm) (%)	AEL $_{Class\ 1M}$ (mW)
1	1.5	10	14	1	1.8	100	16		62
2	2.0	10.1	15.6	1.3	2.0	100	10		41
3	3.3	10.4	18.6	2.2	2.4	100	11		45
4	4.5	10.7	22.2	3.0	2.9	100	12		46
5	5.8	11.0	24.9	3.9	3.2	99.1	12		47
6	7.0	11.4	27.3	4.7	3.5	98.0	12	25.2	47
7	8.3	11.7	29.5	5.5	3.8	96.5	12		47
8	9.5	12.1	31.5	6.3	4.1	94.6	12		47
9	10.8	12.4	33.4	7.2	4.3	92.6	13		47
10	12.0	12.8	35.2	8.0	4.6	90.3	13		47
11	13.3	13.2	37.0	8.9	4.8	88.0	13		47
12	14.5	13.6	38.6	9.7	5.0	86.0	14		47

4 Laser safety requirements

4.1 Labelling of hardware and locations

The IEC Standards state exactly where and which type of labels must be used throughout a fibre optic system.

All parts of the system being developed are Class 1 or Hazard Level 1, and as such, are only required to be labelled by the appropriate Class 1, or Hazard Level 1 labels.

According to the older versions of the IEC 60825-1 standard (combined with IEC 60825-2), the CMS Tracker system had some parts that were Class/Hazard 3A and some parts under test in the lab that were Hazard Level Kx3A which required some particular access requirements and additional labelling.

As has been shown in the previous Section, under the latest IEC 60825-1 standard the parameters involved in the classification have relaxed to the extent that the optical power levels in the CMS Tracker system, and in the development lab, using the same lasers, do not exceed Class 1 or Hazard Level 1.

However, if the development labs, or any part of the final system contain optical link or optoelectronic parts or instruments with a hazard level greater than Class 1 or Hazard Level 1, then appropriate labelling and access controls must be in place.

During installation, commissioning and maintenance of the final system, areas where the laser hazard exceeds Class 1M, because of the use of higher power optical instruments for example, work-areas will become temporarily designated as zones of Restricted Access, if they were not already restricted. At all times during work on potentially live fibres, the Hazard Level will be limited, during test or maintenance to 3R. Appropriate eye-protection will be made available for any work in an area where the accessible power is in excess of the MPE or if the hazard is Class 3B or Hazard Level 3B.

4.2 Laser safety training

Laser safety should be considered as an integral part of the training for personnel working with the optical link systems, or other optoelectronic systems within CMS. Untrained workers present not only a risk to themselves but they are also a risk to other personnel.

The IEC standards contain all appropriate general safety recommendations. Some basic good-practice notes are listed in Table 2 for work on optical fibre systems, taken from 60825-2[3]. Similar laser safety guidelines must be available for reference in all laboratories and locations housing optical link systems. However, it should be noted that referring to those guidelines alone does not represent an acceptable substitute to proper Laser Safety training.

Training must be sufficient to minimize all risks associated with the given class of hazard that is accessible. In the case of the CMS Tracker optical links the worst-case hazards in the final system are Class 1, Hazard Level 1, which does not require any special laser safety training for link users. However, those people working in the optical link development labs, with instruments that have a hazard level in excess of Class 1 should be properly trained.

The responsibility for ensuring adequate Laser Safety training of users lies fundamentally with the users themselves and with their supervisors. Training courses are widely available and it is *not* considered to be the responsibility of the CMS Tracker optical link development team to train other users in Laser Safety, or to accompany unauthorized or untrained personnel in Restricted or Controlled Areas.

Table 1: Examples of general good working practices essential to fibre-optic systems

Viewing fibre	Do not stare at fibre-ends or connectors without appropriate eye protection, or point the light source at other people. Do not use any unapproved viewing aid or instrument.
Fibre ends	Fibre-tips should be covered with tape, or another suitable material to avoid sharp ends, and avoid direct exposure to radiation if energized.
Connector ends	Unterminated connector ends should be covered with the appropriate dust-cap.
Test Equipment	The power supply to the optical source should be the last thing connected and the first thing disconnected. Use test equipment of the lowest class necessary.
Ribbon fibres	Do not cleave fibre ribbons unless authorized to do so.
Fibre cut-offs	Dispose of all cut-offs in a suitable container.
Safety Labels	Report all instances of damaged safety labels.
Signs	Area warning signs required for locations exceeding hazard level 3R. Signs may also be displayed in locations of lower classification.

4.3 Eye protection

In any case where the hazard level is 3B or more, and/or if the MPE is exceeded, the use of eye-protection such as safety glasses or goggles is mandatory and such equipment must be made available in these areas.

Eye-protection is not required for work with the CMS Tracker optical link system, unless high-power (Class 3B or above) test instruments are being used.

Manufacturers can be consulted directly in order to gather information on these safety products. Essentially, the selection procedure for protective eye-wear involves, first of all, a calculation of the level of protection required. This value is given by $\log_{10}(H_0/MPE)$, where H_0 is the level of accessible power at the given wavelength, and MPE is the maximum permissible exposure for that wavelength. The optical density of the safety glasses (or filter) should then be *greater* than the level of required protection at the appropriate wavelength.

DIN and Euronorm (EN) standards[7] specify a label for the protection level as ***X*** **L** ***Y*** where *X* is up to 4 letters relating to the code for type of laser: D = continuous wave, i.e. constant power, I = pulsed (~µs to ms), R = Q-switched (~ns), and M = very short pulse(~ps). Then **L** ***Y*** is the optical density, such that L 5 represents for example a transmittance of 10^{-5}.

4.4 Summary of laser safety requirements

The components and locations of hardware must have labels and access controls according to their hazard level classification.

The components and parts of the CMS Tracker optical links system are Class 1 or Hazard Level 1 and as such do not require any special engineering controls, or individual laser safety labels on each part. It is sufficient to add a Class 1 label or Hazard Level 1 label at an appropriate location on a part of the system assembly that contains a Hazard Level 1 component. There are also no access limitations from the point of view of laser safety, to test-areas or parts of the final Tracker system containing Class 1 or Hazard Level 1 components.

From the point of view of good-practice it is nonetheless preferable if all workers that will access these parts of the system are trained how to handle properly the fibre-optic and optoelectronic components in the system.

To operate any components or instruments with higher classification (1M, 2M or more) appropriate labelling and access controls, as well as operator training should be in place, in accordance with local rules and IEC Standards.

Protective eyewear is mandatory for use of instruments or parts of Class 3B or Hazard Level 3B and above.

5. Conclusion

The CMS Tracker optical link system has been classified in terms of laser safety under reasonably foreseeable circumstances, consistent with guidelines in the current IEC Standards for laser safety and laser safety in optical fibre systems. The corresponding recommendations for labelling, access controls, eye-protection and laser safety training have also been outlined.

In conclusion, the final CMS Tracker Optical link system uses low power levels and the relatively safe wavelength of 1310nm. All parts of the system and the system as a whole are Class 1 or Hazard Level 1. They require no additional engineering, access or labelling requirements apart from a Class 1 or Hazard Level 1 label as appropriate. In the case of CMS Tracker optical links, these labels can be located at a point in the Tracker where space is available. The optical fibres, ribbon, ribbon cables, and multi-ribbon cables in the system are also Hazard Level 1 and a Hazard Level 1 label should be attached to the cable duct at one or more visible points.

In the labs developing and assembling the optical links, where the Hazard Levels may exceed Class 1, appropriate controls and best-practices must be established.

It is the individual responsibility of all people in the project to have followed sufficient laser safety training. Only trained personnel will be allowed to work on parts of the system where the access is limited.

This document, its contents and recommendations will be periodically reviewed to reflect any future changes in the IEC standards and/or CERN rules concerning Laser Safety. The updated versions will be archived on EDMS at: http://edms.cern.ch/document/338505/1

Acknowledgments

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