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Versatile Link Technical Specification, part 2.3.1

VERSATILE LINK PASSIVE COMPONENTS – FIBRES AND CONNECTORS

Abstract

This document describes the mechanical, electro-optical and environmental specifications of optical fibres and connectors for use as HL-LHC passive components for the Versatile Link Common Project.

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History of Changes

Rev. No.	Date	Pages	Description of Changes
0.1	27 Nov. 2008		First prototype version
1.0	14 Dec. 2009		First version for internal distribution
1.1	12 May 2010		Updated i/o specs to include electrical interface and match overall link spec.
1.2	15 Dec. 2010		Updated power levels for Tx out and Rx Sensitivity
1.3	19 Jan. 2011		Added explicit environmental test levels
1.4	13 Apr. 2011		Added EDMS document number
1.5	11 May 2011		Added pinout specification
1.6	17 May 2011		Added related documents
1.7	19 May 2011	All	Major changes in format and content in most sections. These changes are with respect to v2.1. Splitter specifications removed.
1.8	21 May 2011	5,7, 8	Changes from VL meeting on 14/03/2011 and comments from T. Weidberg.
2.0	23 June 2011		Converting the specification to this new format.
6.0	28 Sept 2011	All	Changes made throughout document in response to comments since last revision.
8.0	25 Dec 2011		Minor updates to the tables in order to make them look similar and to fix problems with labelling.
8.1	29 Aug 2012	9,10	Specification changes to 7.1 and 7.2 and changes to section 6.1.1 to be in compliance with other VL documentation.

Specification Tree

The hierarchy of the Versatile Link system specification is shown below. The position of the present specification document is highlighted in bold. Line items in italic will not result in specification documents but are shown to ease understanding of the structure.

		EDMS Document Number
Part 1	System	1140664
Part 2	*Components*	
Part 2.1	Front-end Transceiver	1140665
Part 2.1.1	Transmitter Optical Sub-Assembly (TOSA)	1141155
Part 2.1.2	Laser Driver	1141163
Part 2.2.3	Receiver Optical Sub-Assembly (ROSA)	1141157
Part 2.2.4	Trans-impedance Amplifier	1141160
Part 2.2	*Back-end Components*	
Part 2.2.1	SFP+ Transceiver	1146246
Part 2.2.2	Parallel Optics	1146248
Part 2.3	*Passive Optical Components*	
Part 2.3.1	**Optical Fibres and Connectors**	**1146253**

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1. INTRODUCTION

The Versatile Link project [1] aims to provide a multi-gigabit per second optical physical data transmission layer for the readout and control of High Luminosity LHC (HL-LHC) experiments. A point-to-point bidirectional system architecture is proposed for which components are currently being assessed and developed, as shown in Figure 1.

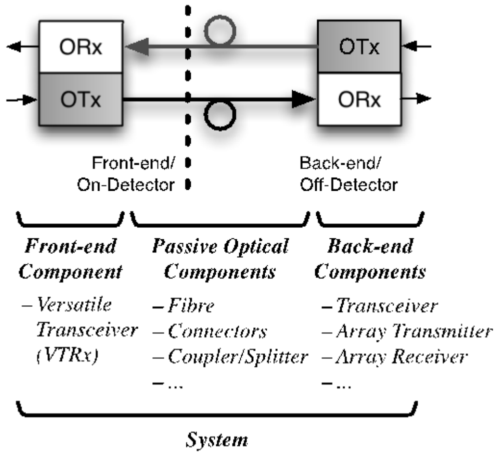

Figure 1: A point-to-point radiation hard optical link for HL-LHC

Passive optical components as shown above are the optical fibre, the cable system, and connectors needed for the P2P system. The passive components within 10m the front-end components will be in a radiation environment. Some foreseen applications involve active cooling of the front-end components to temperatures near -40^{o} C making the nearest 2m from the front-end a cold environment. The passive components near the back-end will be in a normal laboratory environment after the cables have passed through up to 150m of ducting.

2. GENERAL SPECIFICATIONS

This specification is based upon the measurement results as well as the specific system level requirements of the Versatile Link. This document will be in three main parts. Because the versatile link project is seeking both a 1310 nm single mode optical link and also an 850 nm multimode link, specifications for each type of link will be covered. The Electro-Optical section will cover the fibre specification of the 850 nm multimode solution and the fibre specification of the 1310 nm single mode solution. The connector specification, which will apply to both solutions, appears under "Interface specifications". The mechanical requirements and information on the expected environment are common to both fibre solutions and appear in the final sections.

Our interest is in providing these solutions together and severally so 850 and 1310 nm solutions need not come from the same vendor.

Table 1: Versatile Link Specifications which are common to MM and SM optical fibres.

#	Specification	Min	Typ	Max	Unit	Notes
1.1	Data-rate		4.8	5	Gb/s	From VL spec.
1.2	Data transmission distance			150	m	From VL spec.

3. ELECTRO-OPTICAL SPECIFICATIONS

3.1 MULTIMODE FIBRE (MM) SPECIFICATIONS

The minimum standard the fibre cable must follow is the IEC 60793-2-10 or OM3 standard for graded index optical fibre at 850 nm wavelength. In the case of the IEC standard this means A1a.2 and A1a.3 fibre types. A summary of the relevant parameters for A1a.2 and A1a.3 fibres extracted from IEC 60793-2-10 are given below.

Table 2: Versatile Link Mulit-mode specifications which impact optical fibres.

#	Specification	Min	Typ	Max	Unit	Notes
2.1	Wavelength	840	850	860	nm	From IEC 60793-2-10
2.2	Core dia.	47.5	50	52.5	μm	From IEC 60793-2-10
2.3	Cladding dia	123	125	127	μm	From IEC 60793-2-10
2.4	Primary coating dia.	240	250	260	μm	From IEC 60793-2-10

A future upgrade path is also identified where transmission speeds are specified up to 10Gbits/s.

Table 3 Transmission requirements specific to A1a optical fibres. Reproduced from [1][3].

#	Attribute	Unit	Limit	Notes
3.1	Max. attenuation coefficient at 850 nm	dB/km	3.5	
3.2	Min. modal bandwidth-length product for overfilled launch at 850 nm	MHz·km	1500	Baseline spec. 5Gbps

3.2.1	Min. modal bandwidth-length product for overfilled launch at 850 nm			MHz·km	3000	Upgrade spec.10Gbps. See [1][4] and appendix for requirements
3.4	Numerical aperture				0.20±0.015	
3.5	Maximum Macrobending loss	Radius	Number of turns	dB	at 850 nm	
		37.5 mm	100		0.5	
		15 mm	2		1.0 [a]	
	a. The launch condition for the macrobending loss measurement shall fulfill that described in IEC 61280-4-1.					

3.2 SINGLE MODE (SM) FIBRE SPECIFICATIONS

The minimum standards with which the SM fibre must comply are given in IEC 60793-2-50 ed. 4.0 [1][4]. Alternate standards are the ITU G.652a or ITU G.652b standard for step-index single-mode optical fibre at 1310 nm wavelength operation.

The relevant fibre type given in [1][4] is B1.1 step index single mode fibres as listed in Appendix A of that reference. A summary of the most relevant parameters is given below and in appendix A of that document.

Table 4: SM fibre specifications: User requirements and specifications extracted from IEC 60793-2-50 ed. 4.0

#	Specification	Min	Typ	Max	Unit	Notes
4.1	Attenuation			0.40	dB/km	
4.2	Wavelength	1260	1310	1355	nm	To be compatible with VL TOSA
4.3	Cut off Wavelength			1260	nm	From IEC 60793-2-50 ed. 4.0 [1][4]
4.4	Nom. Modal Field Dia.	8.6		9.5	μm	See ref. [1][4]
4.5	Core Concentricity error			0.6	μm	See ref. [1][4]
4.6	MFD tolerance		±0.6		μm	See ‘a’ below
4.7	Cladding dia	124	125	126	μm	See ref. [1][4]
4.8	Primary coating	235		255	μm	See ref.

	dia. - uncoloured					[1][4]
4.9	Zero dispersion wavelength λ_0	1300		1324	nm	
4.10	Zero dispersion slope			≤0.092	$ps/nm^2 \cdot km$	
4.11	Maximum Macrobending loss	Radius 30mm rad. mandrel	Number of turns 30	<0.1 dB	at 1310 nm	Standard loss spec is at 1625 nm
a. The value of the nominal MFD shall be agreed between supplier and customer from within the range given. The tolerance shown is then applied around that nominal value.						

4. INTERFACE SPECIFICATIONS (FIBRE CONNECTORS)

We are interested in both SM and MM fibre connectors for single fibres and fibre ribbons, typically 12 way ribbons. The material used should be flame retardant and be halogen-free. Ideally the materials used will be non-magnetic and the mass and profile of the connector should be minimized. If magnetic materials are within the connectors the mass and magnetic suseptability (μ_r) must be specific. The pre-irradiation specifications are given in Table 5. Relevant test standards are given in [1][5]

Table 5 Specifications for fibre connectors

#	Description	Single Mode	Multi Mode	Notes
5.1	Maximum insertion loss (dB)	0.5	0.3	Single fibre, random mate
5.2	Maximum insertion loss (dB)	0.65	0.5	Ribbon fibre, random mate
5.3	Minimum return loss (dB)	45	30	

The connector type will be determined by the user. LC connectors (single fibre and duplex) and MT/MPO connectors (ribbon cables) are currently under consideration for this project.

4.1 RADIATION TESTS

The users will perform radiation tests to verify that the degradation due to the connector alone after a dose of 500 kGy(Si) is negligible. Mechanical integrity of the connectors is the greatest concern and so the users and project testers will use make-and-break tests to help determine connector viability after radiation exposure. The radiation exposure conditions are explained in Section 6.1.1.

5. MECHANICAL SPECIFICATIONS

Table 6 shows the minimum mechanical specifications required of both types of optical fibre. The specification of the full cable will be common between single mode and multimode variants and will appear in a separate specification document.

The minimum bend radius for our application is 20 mm for static long-term operation.

Table 6 The minimum mechanical properties required of MM and SM fibres. These requirements are consistent with IEC 60793-2-10.

#	Attributes	Unit	Limits
6.1	Proof stress level	GPa	≥ 0,69 a
6.2	Strip force (average)b	N	1,0 ≤ Fave.strip ≤ 5,0
6.3	Strip force (peak)b	N	1,0 ≤ Fpeak.strip ≤ 8,9
6.4	Tensile strength (median) for 0,5m specimen length	GPa	≥ 3,8
6.5	Stress corrosion susceptibility constant	nd	≥ 18
A The proof test value of 0,69 GPa equals about 1 % strain or about 8,8 N force, for A1a and A1b fibres. For the relation between these different units, see 7.4 of IEC TR 62048. b Either average strip force or peak strip force, which are defined in the test procedure, may be specified by agreement between supplier and customer.			

6. ENVIRONMENTAL SPECIFICATIONS

The normal environmental specifications for the multimode and singlemode fibre types are given in Table 7.

As stated in the introduction portions the fibre will run through a radiation environment. **The user will assume responsibility for the radiation testing and radiation qualification of candidate fibres.**

Table 7 Environmental Specifications for MM and SM fibres

#	Specification	Min	Typ	Max	Unit	Notes
7.1	Operating Temperature	-30		+70	^{o}C	
7.2	Storage Temperature	-30	+25	+70	^{o}C	
7.3	Relative Humidity	0	50	60	%	Non-condensing

In general product should be halogen free and flame retartdant as per CERN IS41. Minute quantities of flourine dopant may be present in some fibres. In such a case an exemption will be requested.

6.1 INFORMATION ON THE RADIATION ENVIRONMENT REQUIREMENTS:

We are interested in radiation tolerant GRIN MM fibre and radiation tolerant step-index single-mode (SM) fibre (among other requirements, this implies there should be no phosphorous (P) in the fibre core).

Radiation compliance of the fibre will be tested by the Versatile Link group either in partnership with, or on behalf of, the user.(find Annie’s table of “rad hard” and “rad Tolerant” requirements and put it here with kGy(si).)

Table 8: The expected radiation levels for different variants of this application.

#	Radiation level	Eq. Radius	spare
8.1	1MGy , 6e15n/cm2 20MeV	>20 cm	
8.2	500kGy, 2e15n/cm2, 1MeV	>30 cm	
8.3	10kGy, 5e14n/cm2, 1MeV	>150 cm	

6.1.1 RADIATION INDUCED ABSORPTION TESTS

User tests will verify the induced attenuation for a total dose of 500 kGy(Si). All optical fibres must have a total radiation induced absorption (RIA) <1.0 dB for MM fibres and <1.0 dB for SM fibres. We require perform traceability.

The dose rate in the final environment will not exceed 25 Gy(Si)/hour. As a result the radiation testing by the user will be performed at higher dose rates (up to 25 kGy(Si)/hour) and the effects of any annealing will be evaluated. The data at different dose rates will be used to give an upper limit on RIA for a given user's cable routing.

6.1.2 POST-RADIATION FIBRE BANDWIDTH TESTS

For MM fibre, the fibre bandwidth should be measured after the full SLHC dose and the fibre should still have sufficient bandwidth to satisfy the data rate requirement in Table 2. The bandwidth measurement should be performed by the manufacturer upon a length of fibre agreed between the manufacturer and the VL project group. From this measurement and using a model of the cable routing and radiation damage environment the bandwidth can degrade up to 10% and still meet our requirements.[1]

6.1.3 POST-RADIATION FIBRE MECHANICAL PROPERTIES

The fibre mechanical properties should be evaluated after irradiation to the full SLHC dose. This will require pull testing of samples at different speeds to allow for a reliability analysis. These tests will be performed by the user.

The quality of the primary coating after irradiation should be evaluated after irradaiton to compare with the pre-radiation results. This should be done using the test method B of IEC TR 62221 which uses an OTDR to measure the change in attenuation as the fibre is spooled onto a drum which has a specified quality of sandpaper on the surface. These tests should be performed by the manufacturer. The total additional attenuation due to microbending should not exceed 0.5dB over 500 m.[2]

[1] There is no equivalent requirement needed for SM fibre.
[2] This is to be reviewed after radiation induced increases in micro-bending loss has been studied for Multimode fibres.

7. GLOSSARY

8. REFERENCES

[1] “THE VERSATILE LINK, A COMMON PROJECT FOR SUPER-LHC”, L. AMARAL ET AL., JINST 4 P12003, JOURNAL OF INSTRUMENTATION, VOLUME 4, DECEMBER 2009

[2] “SFF-8431 SPECIFICATIONS FOR ENHANCED SMALL FORM FACTOR PLUGGABLE MODULE SFP+ REVISION 4.1”, THE SFF COMMITTEE, 6TH OF JULY 2009

[3] IEC 86A-60793-2-10 ED5_MMF PRODUCT SPECIFICATION.

[4] IEC 60793-2-50 ED. 4.0: OPTICAL FIBRES – PART 2-50: PRODUCT SPECIFICATIONS – SECTIONAL SPECIFICATION FOR CLASS B SINGLE-MODE FIBRES.

[5] IEC 61754-20. AND IEC 61300-3-45 ED. 1: FIBRE OPTIC INTERCONNECTING DEVICES AND PASSIVE COMPONENTS – BASIC TEST AND MEASUREMENT PROCEDURES. ALSO IEC 61300-1.

[6] “FIBRE OPTIC CONNECTOR INTERFACES – PART 20: TYPE LC CONNECTOR FAMILY”, IEC 61754-20, INTERNATIONAL ELECTROTECHNICAL COMMISSION, AUG. 1, 2002.

[7] “VERSATILE LINK SYSTEM SPECIFICATION, PART 1”, EDMS DOCUMENT NO 1140664, AVAILABLE FROM HTTPS://CERN.CH/PROJECT-VERSATILE-LINK/PUBLIC/