ATLAS Systems Safety Review

Introduction and General Strategy

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Topics to be Covered

- Introduction to laser safety standards
- Applicability to optical fibre systems
- Relevance of ‘Location Types’ and access restrictions to ATLAS
- Identification of appropriate Accessible Emission Limits
- Description of features common to several sub-systems
- Results of maximum power calculations
- Description of common control measures
- Testing during assembly, installation and maintenance
- Training and working practices

Primary Laser Safety Documents

IEC Standards:

- 'Safety of laser products Part 1: *Equipment classification, requirements and user's guide*', (IEC 825-1)
- 'Safety of laser products Part 2: *Safety of optical fibre communication systems*', (IEC 825-2)

CERN Safety Instruction:

- 'Rules for the Safe User of Lasers at CERN' TIS Division, CERN Safety Instruction IS-22 (January 1994)

UK Universities 'Yellow Book':

- 'Safety in Universities: Notes of Guidance. Part 2:1 Lasers'; W.T.Baker *et al.* (October 1992) – Primary reference to CERN IS-22

LASER Safety Classification Scheme According to IEC 825-1

Class 1	**Safe**	*Either* **very low power, so 'inherently safe'** *or* **totally enclosed, so 'safe by engineering design'**
Class 2	**Low power** **Visible only**	**Protected by natural aversion responses (eg blinking).** **Simple control measures are sufficient.**
Class 3A	**Low-medium power**	**Hazard from direct viewing of beam with optical aids.** **This must be controlled.**
Class 3B*	**Low-medium power** **Visible only**	**As for class 3A, but slight hazard from direct viewing of beam.** **This must be controlled.**
Class 3B**	**Medium power**	**Hazard from direct viewing & from specular reflections.** **More detailed control measures are necessary.**
Class 4	**High power**	**Not only hazard from direct viewing & from specular reflections, but possible hazard from diffuse reflections.** **Use requires extreme caution.**

Applicability to Optical Fibre Systems

- Totally enclosed under normal operation
    - Could therefore be argued to be class 1
    - Not a true reflection of the potential hazard
- Distributed system
    - Potential hazard may arise at a considerable distance from the source(s)
    - Potential hazard may vary from one location to another
    - Not under effective local operator control
- Therefore need special rules – hence IEC 825-2

IEC 825 'Location Types' and Access Restrictions

IEC 825-2 defines three location types:

- ***location with controlled access:*** 'A location where access to the protective housing (enclosure) is controlled and is accessible only to authorized persons who have received adequate training in laser safety and servicing of the system involved. Examples include optical cable ducts and switching centres.'

- ***location with restricted access:*** 'A location where access to the protective housing (enclosure) is restricted and not open to the public. Examples include industrial and commercial premises.'

- ***location with unrestricted access:*** 'A location where access to the protective housing (enclosure) is unrestricted. Examples include domestic premises and those open to the public.'

IEC 825-1 contains the following definition:

- ***laser controlled area:*** 'An area where the occupancy and activity of those within is subject to control and supervision for the purpose of protection from radiation hazards.'

Relevance of 'Location Types' to ATLAS

Most of ATLAS would appear to be a '**location with restricted access**'

However, some important exceptions

- SCT alignment lasers in the surface buildings

  '**Laser controlled area**'

- Inside of cable ducts, patch panels and electronics racks

  '**Locations with controlled access**'

Basic Strategy

For each location where there is a potential laser hazard

1. Assess Hazard Levels
2. Assess ‘Location Type’
3. Implement control measures to reduce accessible radiation to safe level
    - Engineering Controls
        - Administrative Controls
            - Personnel Protective Equipment

Accessible Emission Limits (AELs) for ATLAS Systems

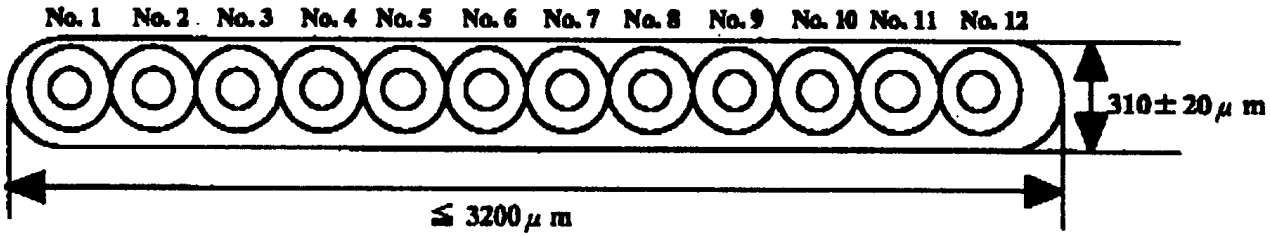
l / nm	Class 1	Class 3A		Class 3B
	t = 100s	t = 100s	t = 10s	
820	0.38 mW	1.9 mW and 9.9 Wm^{-2}	3.38 mW and 17.6 Wm^{-2}	500 mW
850	0.44 mW	2.2 mW and 11.4 Wm^{-2}	3.9 mW and 20.3 Wm^{-2}	500 mW
1310	8.85 mW	46 mW and 230 Wm^{-2}	81.8 mW and 409 Wm^{-2}	500 mW

Common Features

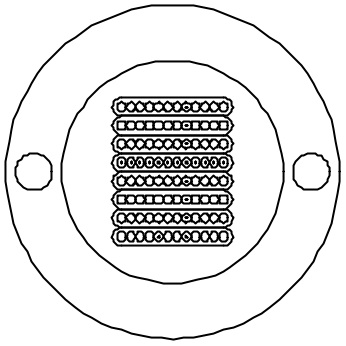
Many similar features amongst the different sub-systems

- Wavelength 820 – 850 nm (all sub-systems, at present)
- Individual fibres
- Ribbon fibres
- Multi-ribbon cables
- MT ribbon fibre connectors
- VCSELs

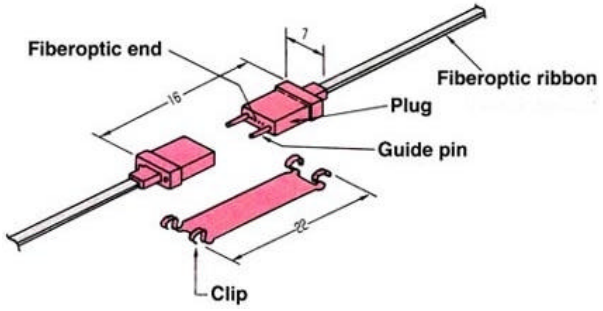
Therefore, it makes sense to use a common approach to laser safety



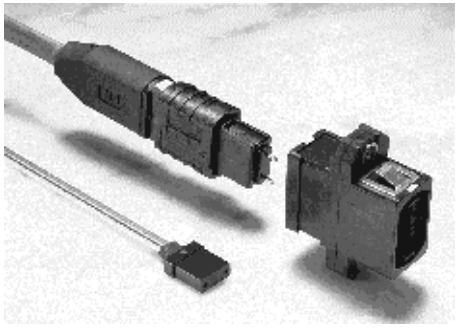
12-way Ribbon Fibre



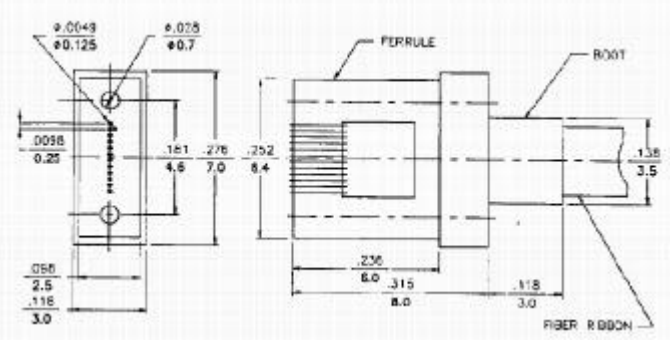
Multi-ribbon Cable



MT Connector



MT and MTP/MPO



MT Connector Ferrule

Maximum Power Calculations (1)

Assumptions made:

- Aperture sizes
  - 50 mm for radiant power condition
  - 7 mm for the irradiance condition
- Hazard level 3A
  - t = 100 s
  - z = 100 mm
- Hazard level k x 3A
  - t = 10 s
  - z = 250 mm

Maximum power calculations (2)

Source	l	Hazard Level			
		1	3A	k x 3A	3B
MM Fibre	850 nm	0.44 mW	2.2 mW	6.6 mW	500 mW
VCSEL	850 nm	0.44 mW	2.2 mW	5.7 mW	500 mW
SM Fibre	820 nm	0.38 mW	0.9 mW	3.4 mW	500 mW

Ribbon Fibre Issues

- Ribbon fibres **must** be treated as **additive** when ends are **polished** or **cleaved**
- But, can be treated as individual fibres for purposes of **broken** ribbon
- MT connectors represent greater potential hazard than random breaks
    - **Worst case:** divide maximum power equally between all fibres
    - More careful calculations give slightly greater maximum power per fibre
- Above also applies to VCSEL arrays (as used in SCT)
- Special precautions required for patch panels and electronics crates

Basic Hazard Level Assessments

It is proposed to use the following ‘basic’ hazard level assessments (i.e. in the absence of further control measures) for the detailed design phase

- Hazard level **k x 3A** for all fibres and ribbons on the detectors
- Hazard level **k x 3A** for all multi-ribbon cables linking the detectors to their associated electronics racks in USA-15
- Hazard level **3B** for the inside of all MT patch panels and electronics crates
- Hazard level **3B** for the FSI power delivery fibres, which connect the splitter-tree crate in USA-15 to the lasers in the surface buildings
- Hazard level **4** for the FSI laser system in the surface buildings

Automatic Power Reduction (APR)

- IEC 825-2 appears to make APR mandatory in restricted (or unrestricted) locations where hazard level k x 3A (or 3A) could be exceeded?
- APR will presumably be needed for the patch panels and electronics crates where MT ribbon fibre connectors are employed?
- APR will presumably also be necessary for the hazard level 3B, FSI power delivery fibres?
- APR systems must be ‘fail-safe’
- APR systems must be very reliable, so as not to disrupt ATLAS data taking
- Administrative controls will be necessary in the event of an over-ride due to failure of APR system

Control Measures for Single Fibres of Hazard Level k x 3A or less

- ***All single optical fibre cables***
  - Will carry appropriate markings to distinguish them from other services, such as electricity.
- ***All single optical fibre cables not installed in a controlled location***
  - Will have mechanical characteristics of not less than those required by IEC 794-2
  - With a hazard level in excess of 3A, will have 'further and adequate mechanical protection', in addition to the requirements of IEC 794-2
  - In which connectors will be accessible in an unrestricted location, will require the use of a tool to disconnect them, if hazard level 1 can be exceeded
  - In which connectors will be accessible in a restricted location, will require the use of a tool to disconnect them, if hazard level 3A can be exceeded
- ***All single optical fibre cables not enclosed within a patch panel or electronics crate***
  - All connectors will be labelled in accordance with IEC 825-2, if hazard level 1 can be exceeded.

Control Measures for Single Fibres of Hazard Level 3B

In addition to the measures shown on the previous slide

- When inside the enclosure of a patch panel or electronics rack, the fibres will be run in miniature flexible stainless steel conduit;
- When not in a controlled area or not inside the enclosure of a patch panel or electronics rack, the cables will be fully enclosed along their entire length, within conduits, ducts or trunking;
- Any such conduits, ducts or trunking will be manufactured from either metal or an impact resistant plastic and will require the use of a tool to remove any covers;
- Appropriate laser warning labels will be attached to the outside of all such conduits, ducts and trunking at intervals of approximately 1 m, wherever they are accessible;
- A fail-safe APR system which will shut down the high power input to the fibre whenever the integrity of the cable is breached;
- No other services, such as electricity, will share these conduits, ducts or trunking, except low voltage interlock cables which form part of the APR system.

Individual Ribbon Fibres

- Individual ribbon fibres do not meet IEC 794-2
- Must therefore be installed in a controlled location

Multi-Ribbon Cables

- All multi-ribbon cables will carry appropriate markings to distinguish them from other services, such as electricity
- All multi-ribbon cables will be constructed so as to comply with mechanical characteristics not less than those required by IEC 794-2
- To satisfy the additional engineering requirements for hazard level k x 3A, all multi-ribbon cables will be fully enclosed along their entire length, either within conduits, ducts or trunking, or within the enclosures of the patch panels or electronics racks
- Any such conduits, ducts or trunking will be manufactured from either a non-magnetic metal or an impact resistant plastic and will require the use of a tool to remove any covers
- Appropriate laser warning labels will be attached to the outside of all such conduits, ducts and trunking and other enclosures containing the multi-ribbon cables at intervals of approximately 1 m, wherever they are accessible
- No other services, such as electricity, will share these conduits, ducts or trunking, except (possibly) low voltage interlock cables which form part of the APR systems

MT Ribbon Fibre Connectors

- Hazard level 3B

- Therefore, patch panels and electronics crates must comply with the following
    - Fully enclosed during normal operation
    - Require APR when covers are removed and radiation becomes accessible
- Patch panels and electronics crates
    - Do not need individual labels for every connector
    - Can be labelled as complete units (inside and outside)

Testing during Assembly, Installation and Maintenance

- Special measures required for assembly, installation and maintenance
  - Too early for full details
    - But will follow same general approach

Training and Working Practices

- Training will be required
  - General laser safety training
  - Specific training for each sub-system
- Will TIS assist with this?