Optical Link Connections

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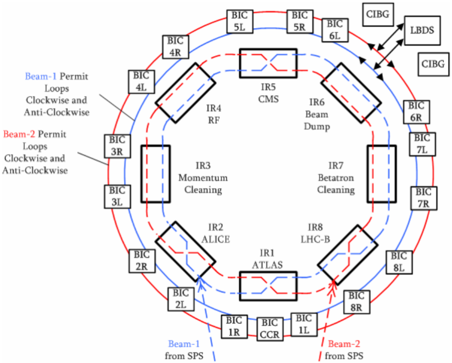
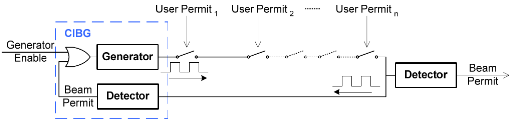
Contents

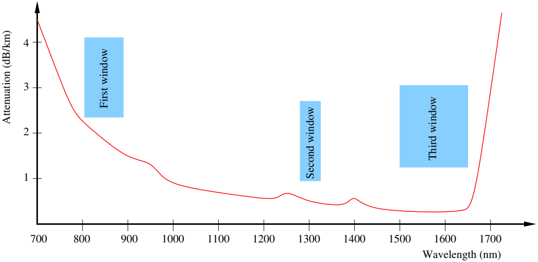
- Beam Permit Loop signal travelling along the LHC.
- Two per LHC beam: loop A and loop B, in opposite directions.
- Each Beam Interlock Controller (BIC) has users inputs, any user can disable the beam permit.



Closed beam permit loop:



- **Advantages** of optical transmission:
  - **EMI immunity**.
  - Long **distance** links, thanks to low attenuation in single-mode fibre.

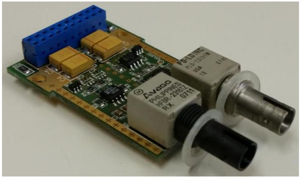


  - High available **bandwidth**.
- **Disadvantages**:
  - Optical fibre is more **fragile** than copper cable.
  - More **costly** than electrical connections.

Optical Transmission in the Current BIS

Optical connections for the Beam Interlock System:

- **Beam Permit Loops**: CIBO transceiver, single-mode ELED transmitter.
  - Sent along the 27 km of the LHC, 6 km of the SPS, PSB and transfer lines.
  - $\approx$ 10 MHz square signal, frequency is measured at the receiver side.
  - User permits generate local permit at each location, re-transmit the signal if true.



- **Optical interface for the users** (CIBF): CIBL transceiver, single-mode laser transmitter.
  - Transmits data using RS-485/RS-422.
  - Low speed: 62.5 kbps.
  - Only links longer than 1.2 km.

Optical Transmission in the Current BIS

Why?

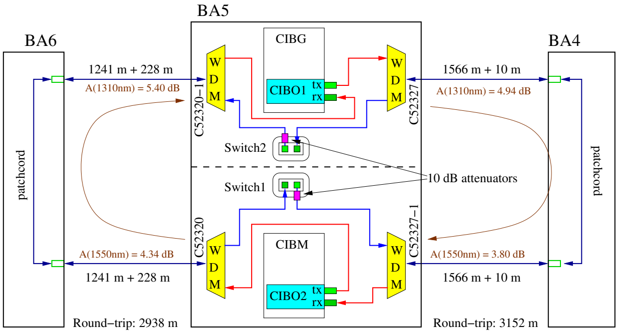
- Long links (in most cases).
- Immune to electromagnetic interference.

How?

- Single-mode fibre, 1310 nm window: low attenuation, zero dispersion.
- **Ad-hoc designs**:
  - CIBO for the Beam Permit Loops: ELED transmitter, PIN diode receiver.
    - Sends and receives a ≈ 10 MHz square signal.
    - Interface signals are 5 V TTL.
  - CIBL for the User Interface: laser transmitter, PIN diode receiver.
- Issues:
  - Tight **power margin** on some of the CIBOs.
  - Low **flexibility** to change output power.
  - No possibility of measuring received power, hence no fibre **monitoring** is available.

Monitoring Optical Fibres

- Track **radiation damage** or fibre **failure** by checking attenuation.
- Not feasible with current devices.
- **Small Form-factor Pluggable** transceivers (SFP):
  - Industry **standard** (Multi-Source Agreement).
  - Common electrical interface.
  - **Diagnostics** interface: temperature, received and transmitted power.
- **Wavelength Division Multiplexing** to separate signals: 1310 nm for BPL, 1550 nm for monitoring signal.



Looking Towards the Future

SFP transceivers

- The good:
  - **Availability**, future-proof.
  - Easy **insertion** and removal.
  - Easy fibre **connection**.
  - Digital Diagnostics **Monitoring** interface.
  - Small **footprint**.
  - **Protocol** agnostic.

- The bad:
  - Sometimes incompatible optical signals between different **manufacturers**.
- The ugly:
  - Needs **DC-balanced** signals.
  - **Needs testing** with the current 10 MHz BPL signal . . .
    - SFPs tested with a pure 10 MHz signal, works OK.
  - . . . or develop a **new BPL signal**.

Looking Towards the Future

Beam Permit Loop upgrades:

- **Keep the signals**, change the transceivers to SFPs.
  - It is possible to send signals down to 1 MHz using SFPs without much degradation.
  - A **first upgrade**: replace the CIBOs with SFPs
    - Requires signal translation: CIBO takes TTL, SFP takes LVDS.
    - Requires voltage regulation: 5 $\mathrm{V} \rightarrow$ 3.3 V.
- **Rethink** the Beam Permit Loop signals?
  - Sending **messages** instead of an analogue frequency.
  - For low **latency**, messages must be short.
  - **Ethernet** is ruled out (64 bytes/frame minimum).
    - The SFP will take any protocol we want.
    - As long as the signals are DC balanced.
  - We need to find a replacement for the current CPLDs anyway.
- **VersatileLink**: CERN project for an optical transceiver at the LHC experiments.
  - Back-end transceiver: commercial SFPs are acceptable.
  - Front-end transceiver: rad-hard SFP-like transceiver, tracker grade (500 kGy).
  - Bit-rates $\approx$ 5 Gbps.

Conclusions

- **Optical links** are good for:
  - Long **distances**.
  - High **data rates**.
  - Low **EMI**.
- In scenarios where distances are short and data rate is low:
  - EMI immunity may trample the few disadvantages.
  - Ease of monitoring is another good asset.
  - Flexibility in the transceivers choice.