Open Standard for Optical Module Radiated Emission Evaluation

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Contents

1. Evaluation Platform Design

The test platform acts as a host system for the optical module during the radiated emission test. Figure 1 shows the design of test platform functional diagram. The platform consists of the following parts:

- Main loopback board designed for optical module to run functionally.
- RF source module that has a defined radiation level to verify the EMI test chamber or mode stirred chamber setup prior to the measurement of an optical module.
- Control modules that control variables such as the supplied voltage and the temperature through the USB hub.
- Power supply modules.
- A shielding enclosure with thermal management part and absorptive material.

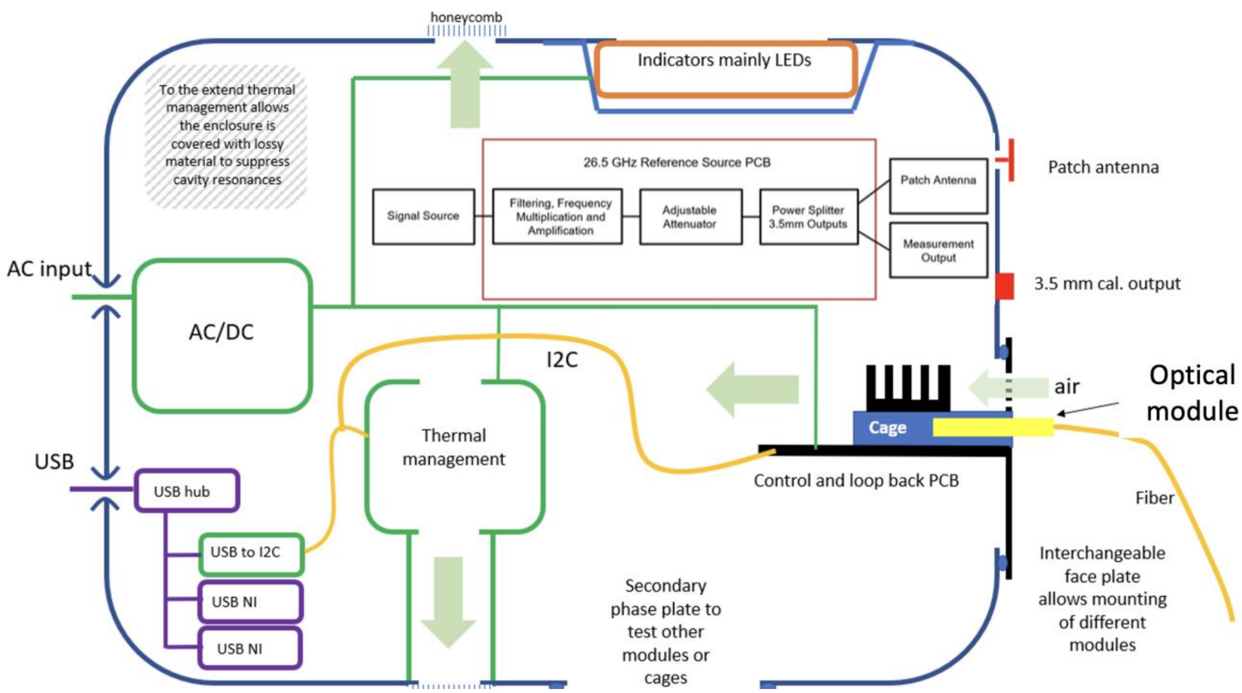

Figure 1 Test platform functional diagram

A picture of the prototype of the hardware test platform diagram is shown in Figure 2. In the left section, a power supply, a control board and interconnects provide the power and the ability to control the parameters of the test such as temperature reading and air speed using I2C protocols. The section on the right contains the high-speed circuits such as the loopback board and calibration circuitry (RF-Source and RF-Amplifier). This section of the design is cooled by fans and temperature controlled to help with repeatability. A barrier of RF absorptive material separates both sides.

Different optical module form factors (QSFP and OSFP), different cage types, or future optical module speeds such as 800G can be evaluated using the same test platform by simply changing the loopback board.

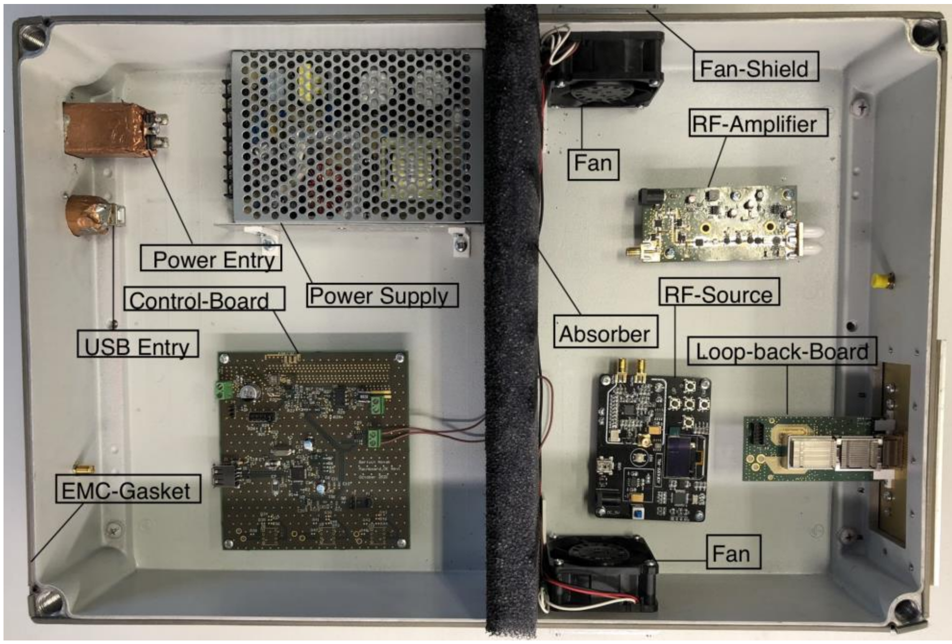

Figure 2 The prototype of the test platform (no cables shown)

1.1. Main Loopback Board

The loopback board provides the signal loopback for the optical module. The loopback board is powered by 3.3V from the control PCB and communicate with control PCB through I^2C. The optical module is plugged from outside of the platform.

For detailed information, see Section 2.

1.2. RF Source

RF reference source is used for verification of the test chamber. The source is generated by a microwave synthesizer, adding filter, amplifier and multiplier, to reach the same frequency as the emission of optical modules. An SMA port is available for measuring the signal strength.

1.3. Control Module

Control module provides the capability to monitors, supplies and controls all the other modules. It should provide the following functions:

1) Converts the supplied 12V from power supply to different supply level required by each module.
2) Monitor status, such as the temperature and the optical module working conditions.
3) Control the test module configurations, such as the reference source settings, the fans and the optical modules.

1.4. Power Supply Module

Power supply module converts the AC input to DC +12V for Control Module. The power supply should be capable to provide enough power for all the modules.

1.5. Shielding, thermal management and absorptive material

All the modules should be placed inside a well shielded enclosure to avoid unexpected emission that would influence the optical model emission measurement. Thermal management includes using fans to cool down PCBs and ventilation for optical modules. Absorptive material is required to reduce the cavity resonance and EMI inside the enclosure.

2. Optical Module & Loopback board

The loopback board is a module to allow for interchangeability in the field by the end-users. The loopback board is designed to provide the power, the low-speed control signals, the loopback of the high-speed signal. The loopback board design has been validated for the speed rates up to 400Gbps. Two types of form factors (QSFP-DD and OSFP) are used as the example of building up the loopback board for the optical modules under test.

2.1. QSFP-DD (Quad Small Form Factor Pluggable – Double Density)

Figure 3 shows the schematic of the loopback board for QSFP-DD. The main idea of the loopback board is to route the Tx pairs to the corresponding Rx pairs so that the high-speed signals can 'loop' back, while providing low speed control interface to the control part of the platform. Decoupling capacitors, filters, pull up/down resistors are selected following the requirements in QSFP-DD Hardware Specification Rev 5.1.

Figure 4 shows the PCB design and the manufactured PCB with QSFP-DD cage mounted. The PCB is designed to have 8 layers so there is sufficient routing space for loop back differential pairs. Megtron 6 is used as the dielectric material to achieve low loss for high-speed signal. Backdrill is required during the manufacturing to minimize the stub in the PCB, which minimize the radiation caused by the loopback PCB itself.

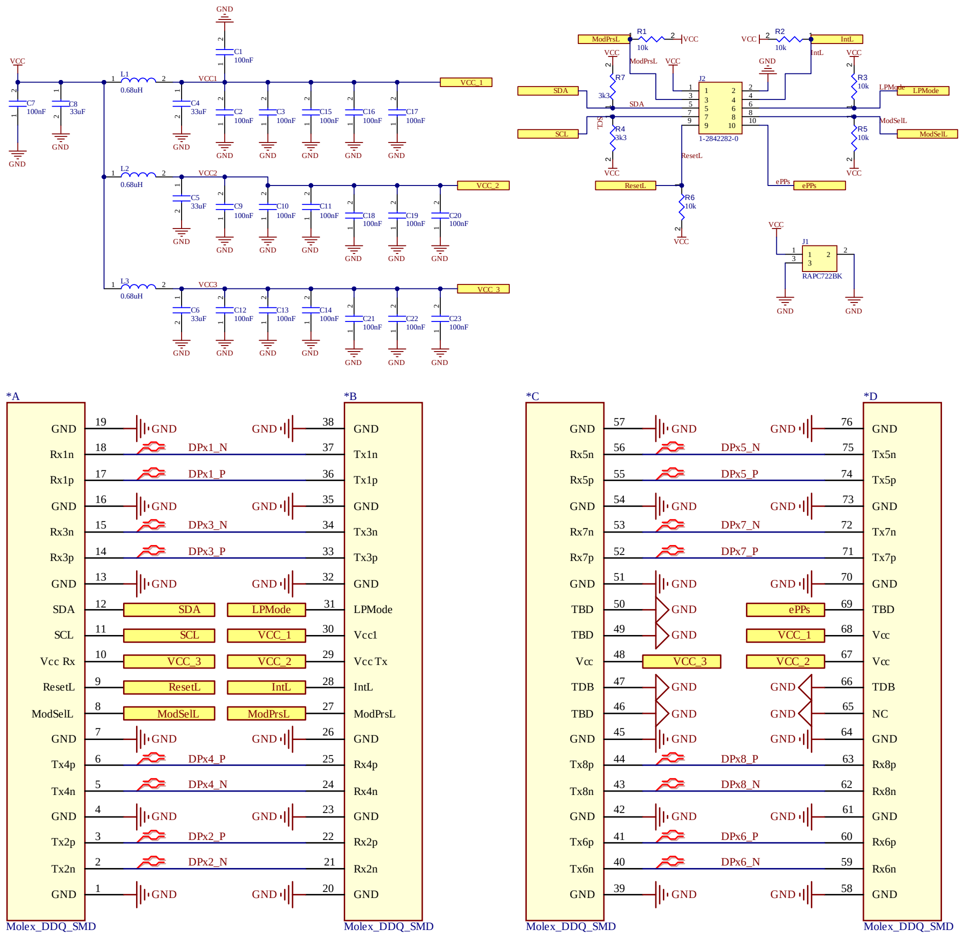

Figure 3 Schematic for QSFP-DD loopback board

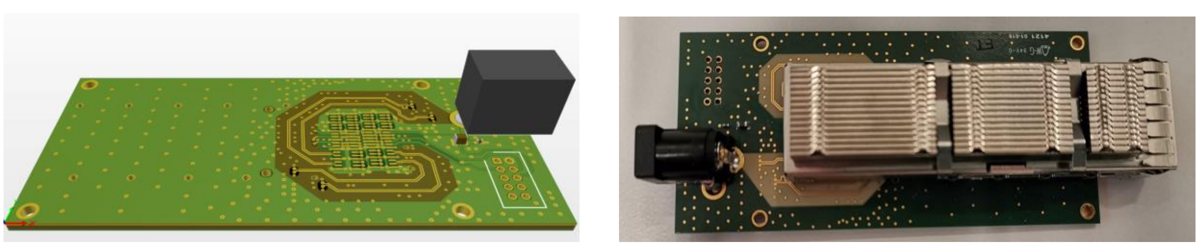

Figure 4 PCB design and manufactured loopback PCB with QSFP-DD cage mounted.

2.2. OSFP (Octal Small Form Factor Pluggable)

Figure 5 shows the schematic of the loopback board for OSFP. Figure 6 shows the PCB design and the manufactured PCB with OSFP cage mounted. OSFP has a different form factor, while other functions are similar to QSFP-DD. The main difference would be the differential pair routing. OSFP board still use 8-layer to route and applies the same methods to achieve low loss and low radiation from PCB.

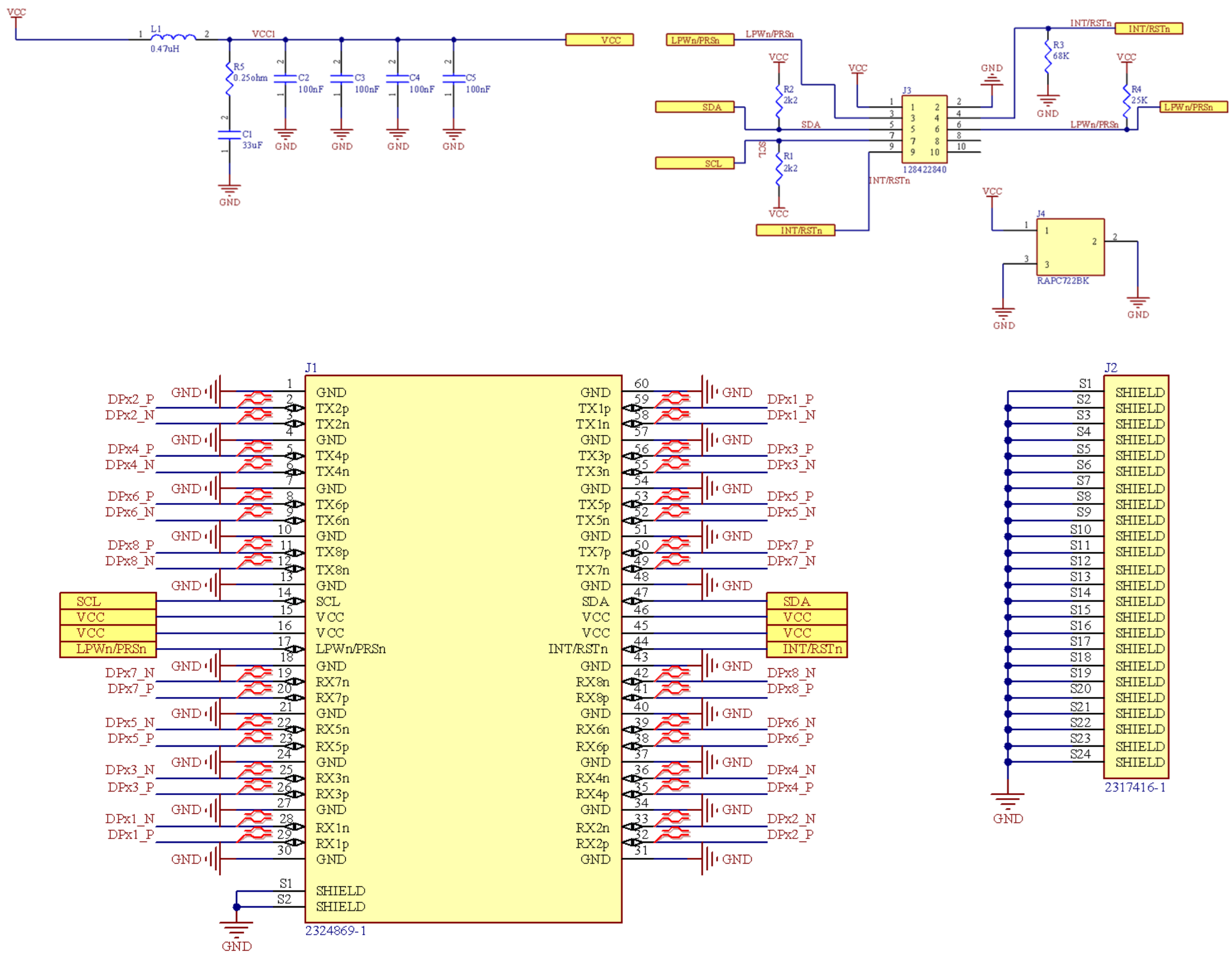

Figure 5 Schematic for OSFP loopback board

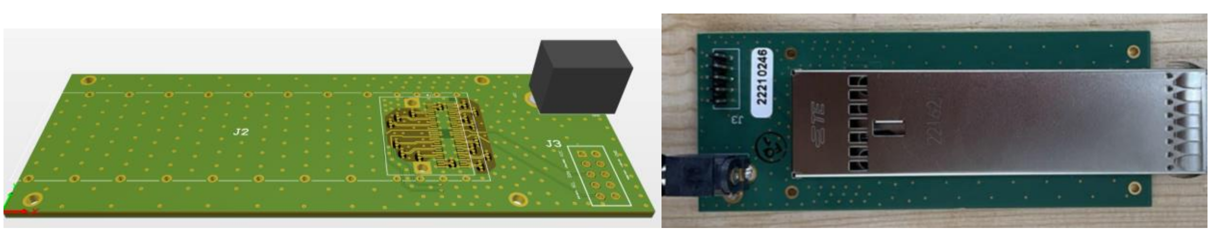

Figure 6 PCB design and manufactured loopback PCB with OSFP cage mounted.

3. Chamber Verification Procedure

3.1. RF reference source patch antenna radiation measurement (with cable loss and amplifier gain compensation)

Figure 7 shows the setup of the chamber verification procedure. The reference source with the patch antenna is used to verify the EMC chamber calibration and to identify possible problems from the antennas, amplifiers or cables inside the test chamber. The test platform provides the reference connector to measure the output power of the reference source. The receiver system is suggested to have low noise.

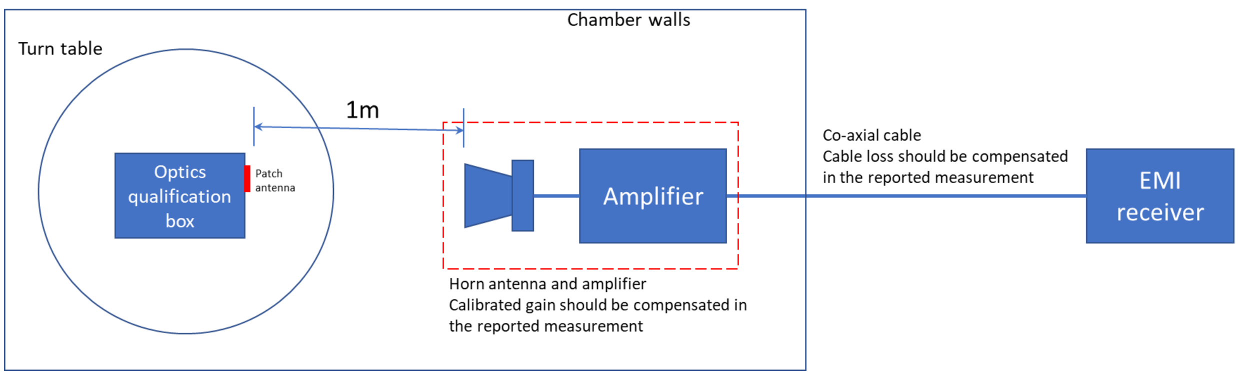

Figure 7 Setup diagram of using patch antenna with RF reference source to do chamber verification.

The general calculation of the E-field received should be:

$$E = \frac{\sqrt{30 * P_t * G_t}}{Distance}$$

where P_t is the reference source power, G_t is the patch antenna gain, $Distance$ is the horizontal distance between the Tx antenna (patch antenna) and the Rx antenna (horn antenna).

The measured E-field should be compared with the expected calculation result after the compensation of the amplifier and the cable loss. If there is large gap between the calculated field strength and the measured field strength, the setup, including antennas, amplifiers and cables should be checked.

4. Equipment details

4.1. PRBS Generator

Data collection in progress.

4.2. Test Receiver/ Antenna

Data collection in progress.

4.3. Preamplifier & Cable Loss Correction

Data collection in progress.

5. Test Procedure in the Semi-anechoic Chamber

Figure 8 shows the diagram of measuring the optical module's radiated emission in the semi-anechoic chamber with the test platform. Testing in an anechoic chamber uses the test methods described in FCC 47 CFR, Part 15 or CISPR 32 standards by default. Pre-scan parameters are described in 5.1 and Maximizing scan parameters are described in 5.2.

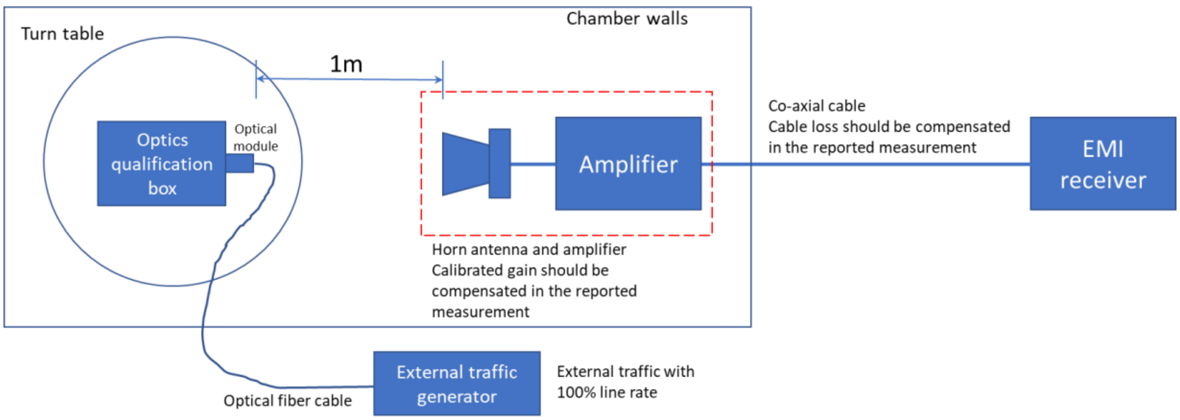

Figure 8 Setup diagram of measuring optical module's radiated emission.

5.1. Pre-scan parameters

Pre-scan is to determine the frequencies at which the optical module produces the highest level of radiated emissions and help to select the configurations to be used in the formal test. Pre-scan is not necessary as long as the frequency of the reference source and the optical module is known. The configuration parameters of the pre-can is listed below as one case for reference if pre-scan is needed.

Parameter	Setting	Note
System to Antenna Distance Reference Point	Module to Antenna	
System to Antenna Alignment Reference Point	Center on Module	
Start Frequency	24 GHz	
Stop Frequency	27 GHz	
RBW	1 MHz	RBW can be adjusted for clearer observation
VBW	10 Hz	
Turn Table Step Size	1˚	

Antenna Start Height	1m	
Antenna Stop Height	2.5m	Boresiding may needed
Antenna Distance	0.5m	

5.2. Maximizing Scan parameters

Parameter	Setting
Auto/Manual	Manual
Turn Table Step Size	1˚
Antenna Height Step Size	0.1m
RBW (AVG Detector)	50 kHz
VBW (AVG Detector)	10 Hz
Polarization	Vertical & Horizontal
Antenna Distance	SNR driven

5.3. Mode Stir Chamber

Figure 9 shows the setup inside the mode stirred chamber (reverberation chamber). The chamber factor needs to be known in advance at the frequency of interest. Next, the validity of the test system is checked using the patch antenna signal. Mode stir chamber is easier in some cases as it doesn't need boresiding. Reference to IEC 61000-4-21 standard to calibrate and measure inside the mode stir/reverberation chamber.

For a mode stirred chamber, the system does not have to be very low noise, as the chamber resonances enhance the signal.

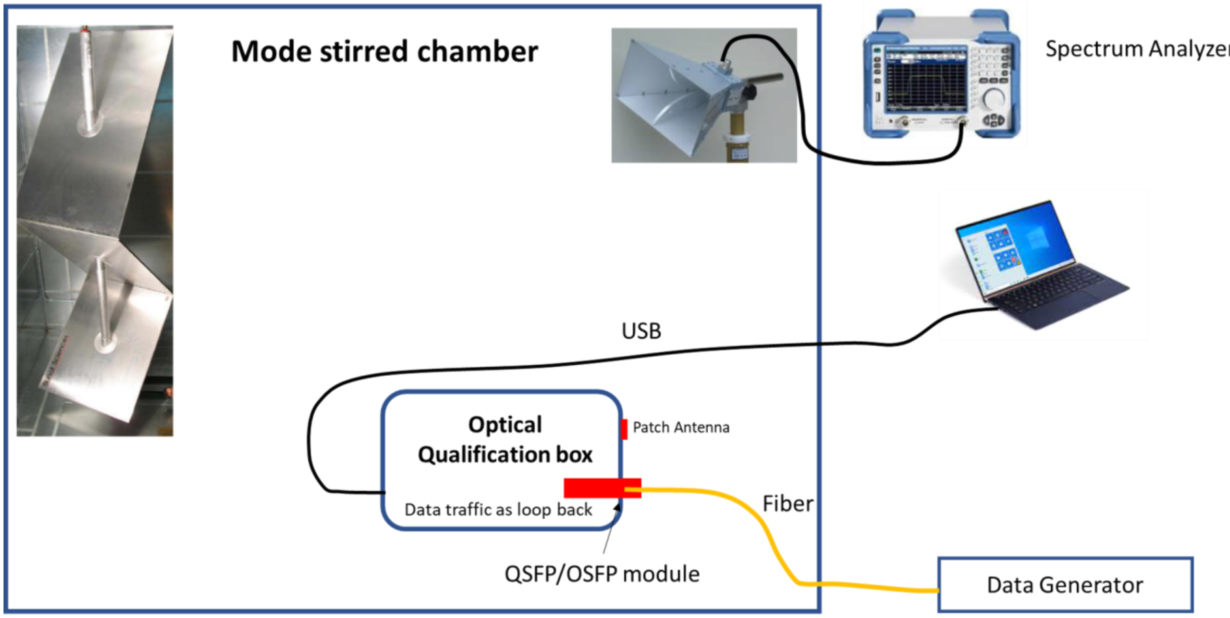

Figure 9 Setup diagram of mode stirred chamber measurement.

6. Test Result Examples

Table I shows some examples of optical modules from different manufacturers. Each manufacturer has 1~3 samples measured to show the variance. The result has been presented in Designcon 2022 [1].

Table I Examples of measurement result with optical modules from different manufacturers.

Manufacturer	SN	TRP (dBm)	E field-Average detector (dBuV/m)	E field- Peak detector (dBuV/m)
A	A1	-53	56	59
B	B1	-50	55	60
B	B2	-58	51	57
B	B3	-55	52	57
C	C1	-56	51	58
D	D1	-64	48	54
D	D2	-62	48	56

7. Appendix

7.1. Tips for loopback board

Note that optical modules are working at a comparably high current with low and sensitive voltage. So low resistance between the supplied power source and the power pad on the footprint of the optical module connector is required. This indicates relatively short and thick power cables, wider power traces on the PCB, low ESR inductor (such as power inductor) used for the filter design.

8. Reference

[1] Philippe Sochoux et al, “EMI Qualification of QSFP & OSFP Electrical/ optical Modules, “DesignCon, 2022.