分布式振动感知（DAS）光纤性能测试

测试光纤：FIBRE-SM-BK-TBF-XRCD |
报告编号：DASFIBRE-PT-20250224-01

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测试设备、光纤与相关参数

Equipment, Testing Environment & Parameter Settings

测试用设备与器材

本次测试基于如下设备：

DAS 设备（DAS Equipment）		测试协议和器材（Protocol & Instrument）	
DAS型号	`DAS-CRP-PDN-CS-RAN-PORD`	测试协议	`OpticalSpec (R) v1.0.3`
设备编号	`S2511101`	系统软件版本	`OpticalOS (R) v1.3`
技术路径	扫频型 Phi-OTDR	测试采样频率	**2000Hz**
设备解调	启用	信号发生器	DS 852
偏振分集	无	振子型号/编号	VIB-SUB-BK-5004-RWHQ / S250812
采样点数与频率	4096 / 1000MHz	功放型号/编号	AMP-SUB-BK-MONO-HQSD / S250812
脉冲宽度	5000ns	等效功率与阻抗	50W / 4Ω
空间平均点数	解调程序自行设置	标称响应范围	20Hz – 20kHz
空间差分点数	解调程序自行设置	有效工作区间	20Hz — 300Hz
去DC设置	高通滤波 (>= 20Hz)	链接接口	BNC -> 3.5mm TRS -> 4mm Binding Post

测试光纤

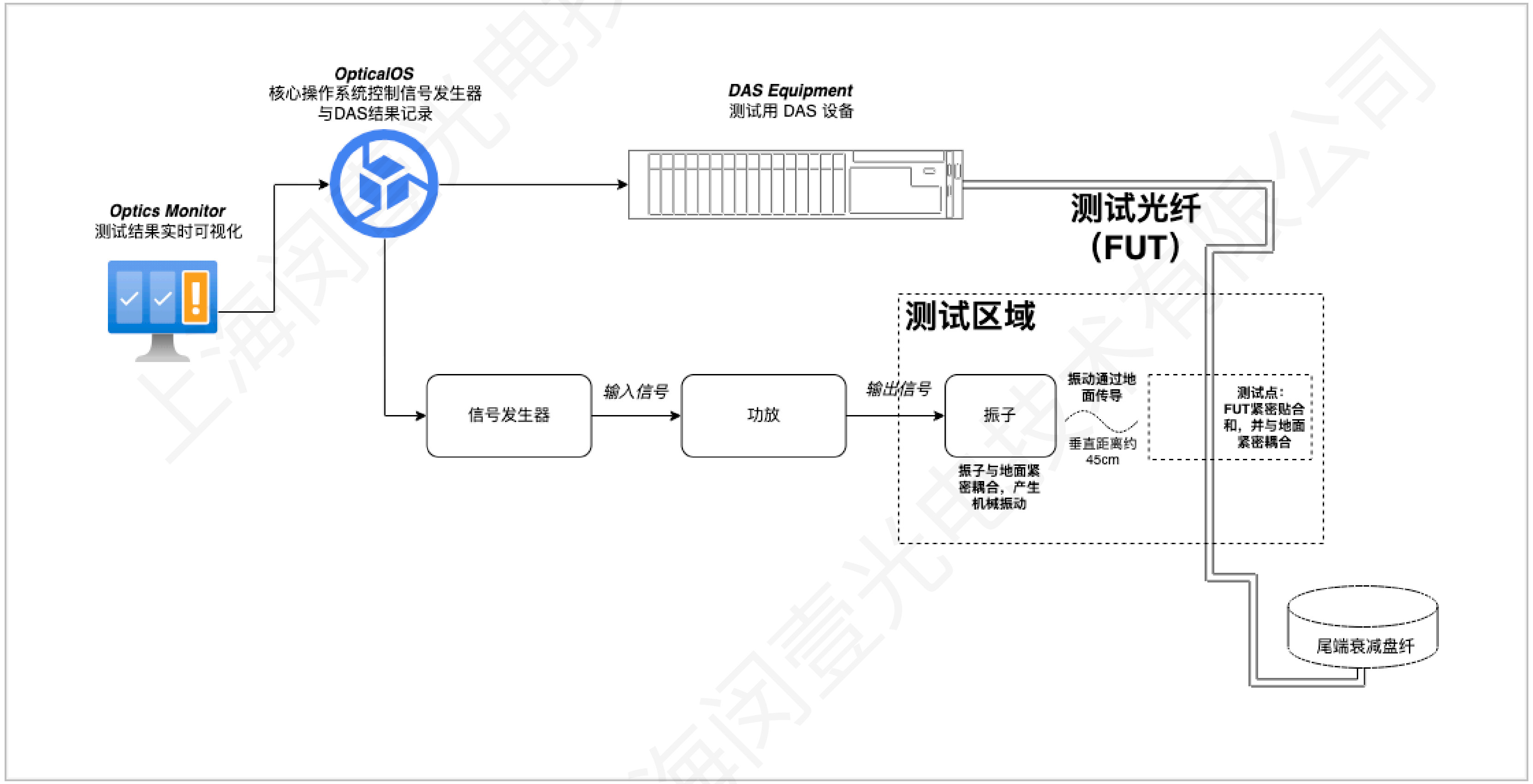
对如下光纤进行了测试：

FIBRE-SM-BK-TBF-XRCD	
光纤类型	单模单芯抗弯光纤（G.657B3）
连接形式	FC/APC – FC/APC
芯径 / 包层	9 / 125 μm
结构形式	芳纶加强
外被类型	杜邦芳纶
适用场景	通用型（非极端环境）
标称损耗	≤ 0.3 dB/km (1550)
被测光程长度	约 200m

注意： 本报告测试结果仅适用于当前架构当前参数设置下所产生之分析，不排除其他参数/架构下会产生不同于本报告测试之更优或更劣之结果，详情见本报告免责声明部分。

拓扑图

本次测试的拓扑图如下：



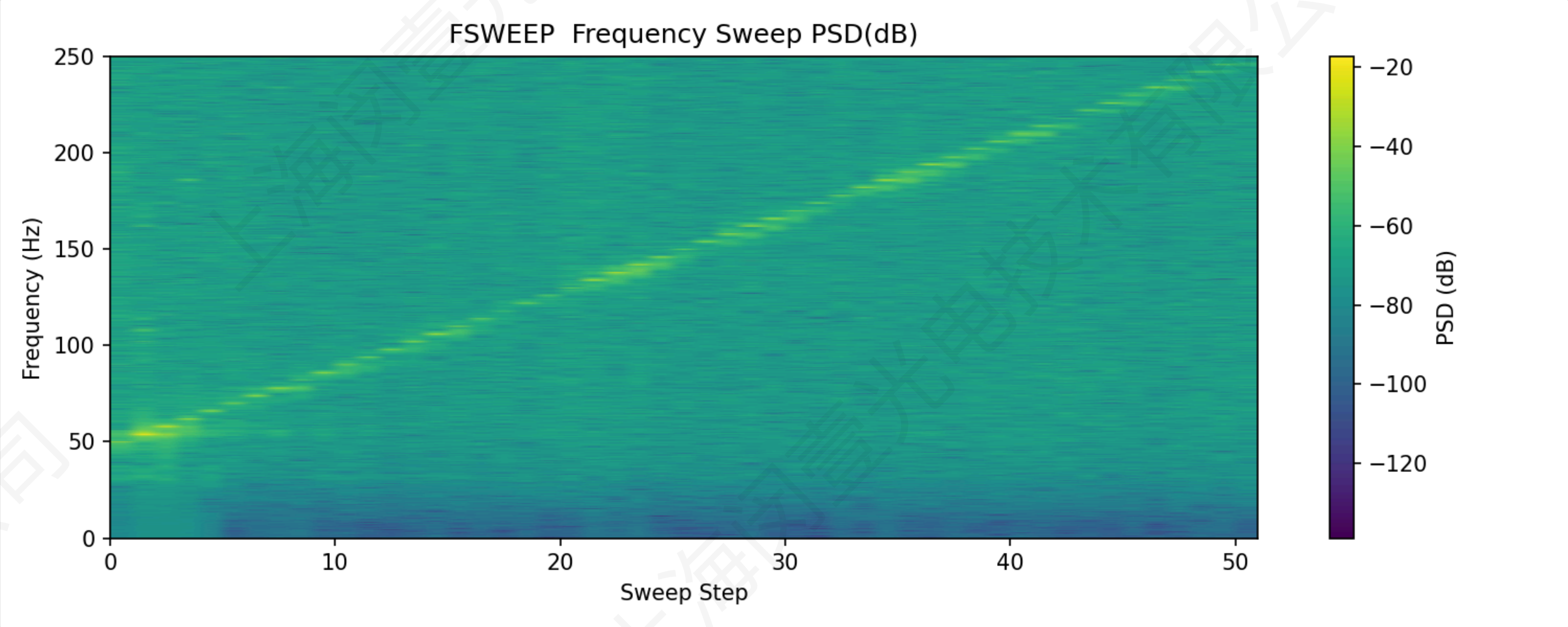
频响测试

Frequency Sweep Testing

频响测试结果

固定信号发生器 $100\,mV$ 电压值进行正弦激励，从 $50\,\mathrm{Hz}$ 扫至 $250\,\mathrm{Hz}$（即 Nyquist 的 5%～25%），进行频率响应区间的测试，得到：

扫频热力图（PSD, dB）：



频响测试说明

测试目的

- 评估被测光纤在目标频段内对外部正弦振动的耦合效率与频率一致性：即光纤—封装—敷设方式对机械扰动的传入/传出是否稳定。
- 观察不同光纤在扫频过程中主峰能量随频率的变化，用于判断光纤结构（外被/铠装/紧套等）带来的机械传递带宽、共振/衰减特征与潜在"盲区"。

指标解读

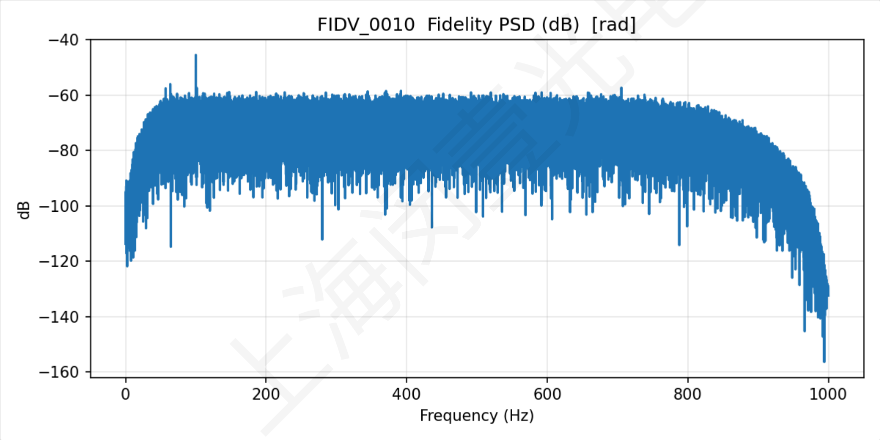
- 频率跟踪稳定性：主峰是否始终锁定在设定频率附近、是否出现偏移/跳变；若跳变明显，常见原因是耦合不稳定、局部滑移或结构对某些频率敏感导致能量泄露。
- 机械耦合带宽：在整个 $50 \sim 250\,\mathrm{Hz}$ 内主峰是否持续清晰可见；若某些频段主峰显著变弱或被噪底淹没，通常反映该光纤封装/敷设对该频段的机械传递效率较低。
- 结构共振与衰减特性：热力图中"能量异常增强/异常衰减"的频段可能对应外被/铠装/紧套结构引入的共振、阻尼或微弯效应；这类频段在工程应用中往往决定"更敏感/更稳健"的工作带宽选择。

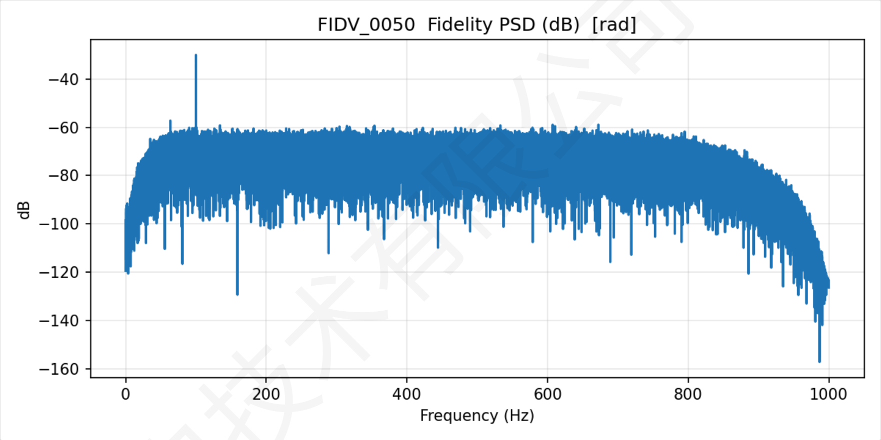
保真度测试

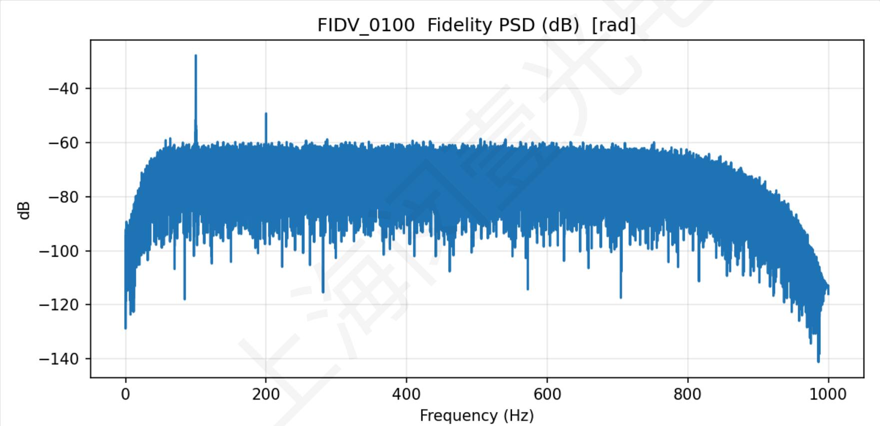
Fidelity Testing

FIBRE–SM–BK–TBF–XRCD

固定频率为 100 Hz（Nyquist 的 10%）。在该频点下，分别施加 $10mV, 50mV, 100mV$ 三种激励幅度，每种持续 60 s 的信号响应频谱如下：







保真度测试说明

测试目的

- 在固定频点下评估光纤对振动幅值变化的幅度传递线性与谱纯净度保持能力，用于判断光纤结构与耦合方式是否引入明显的非线性、摩擦、松动或局部屈曲等现象。
- 对比不同光纤在同一频点、不同激励幅值下的噪底与谐波水平，反映其对有效信号与结构性杂散的抑制能力。

指标解读

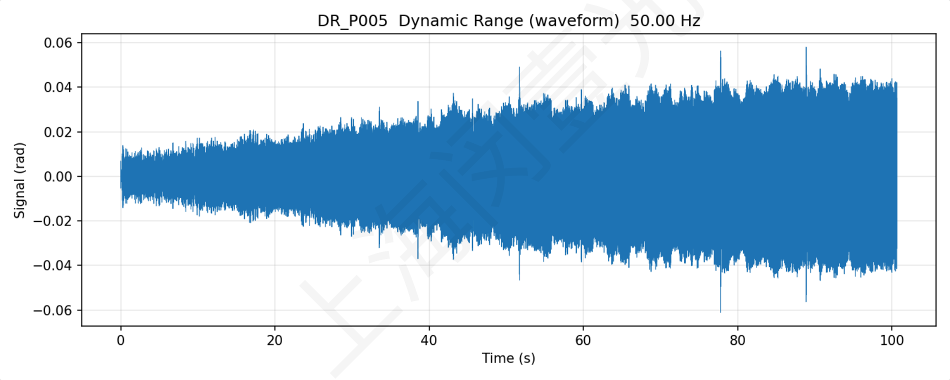
- 幅度传递线性：三档激励下，100 Hz 主峰幅度是否随输入幅值呈单调、近似比例增长；若出现增长变慢或不成比例，往往提示耦合不充分、局部滑移、结构摩擦或非线性阻尼。
- 谱纯净度与结构杂散：除 100 Hz 外的谐波/旁瓣/杂散是否明显抬升；杂散偏高常见于外被松弛、紧套与加强件产生的局部摩擦、或敷设不稳导致的“附加调制”。
- 噪底随幅值变化趋势：理想情况下噪底不应随激励幅值显著上升；若噪底随幅值同步抬升，通常意味着结构振动引入了宽带扰动（例如护套/铠装件碰撞、桌面/固定件共振等），这会降低工程场景下的可用信噪比。

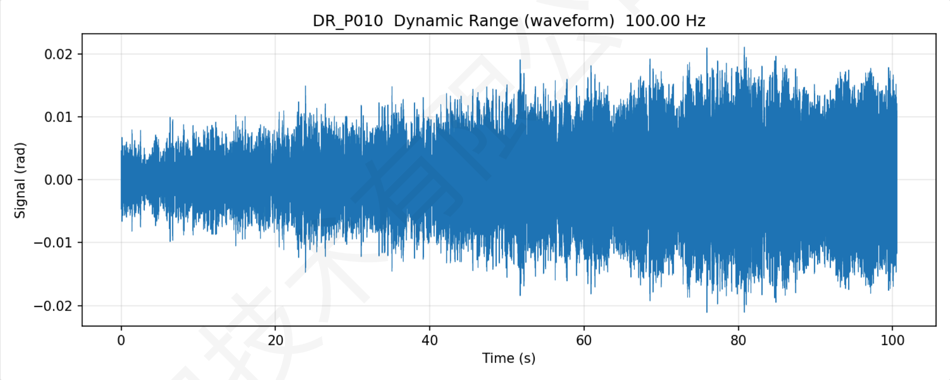
动态范围测试

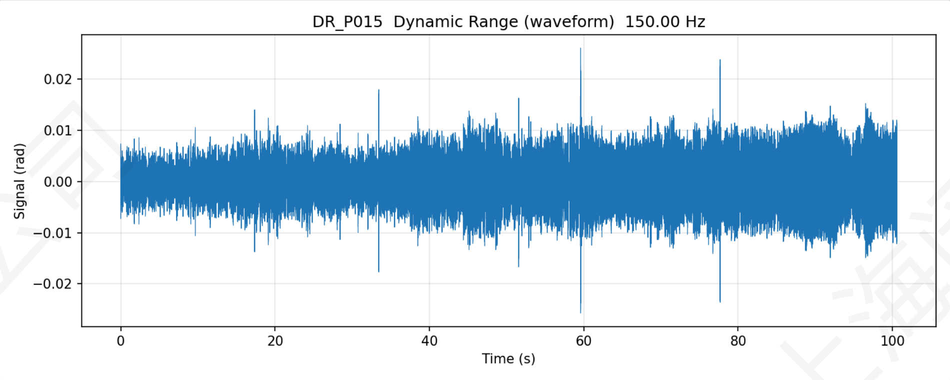
Dynamic Range Testing

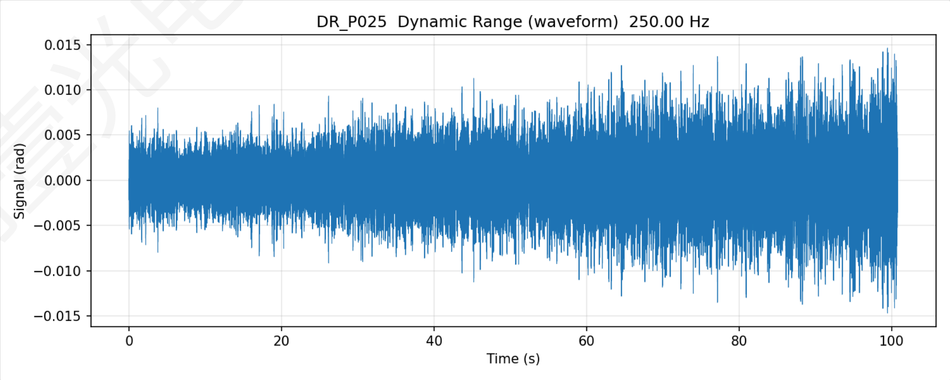
FIBRE–SM–BK–TBF–XRCD 波形图

在四个频点 $50/100/150/250\,\mathrm{Hz}$（分别对应 Nyquist 的 5%/10%/15%/25%）下，将输入应变幅值从 $10mV$ 连续扫到 $100mV$，共 100 档；每档持续 $1\mathrm{s}$，因此每个频点的动态范围扫描总时长约 $100\,\mathrm{s}$，波形图如下：



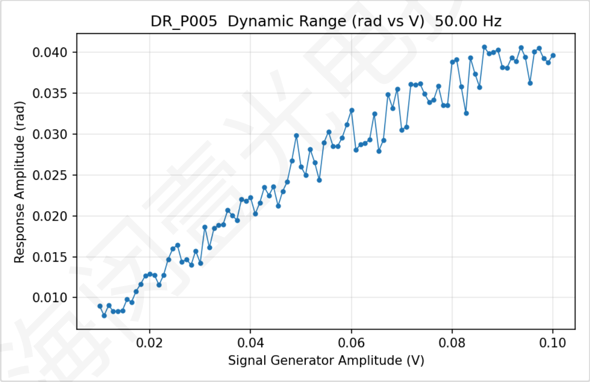


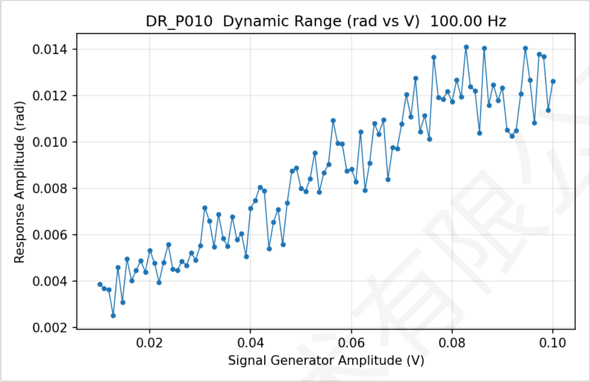


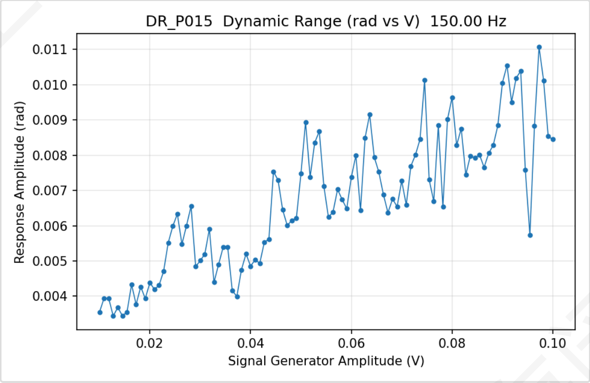


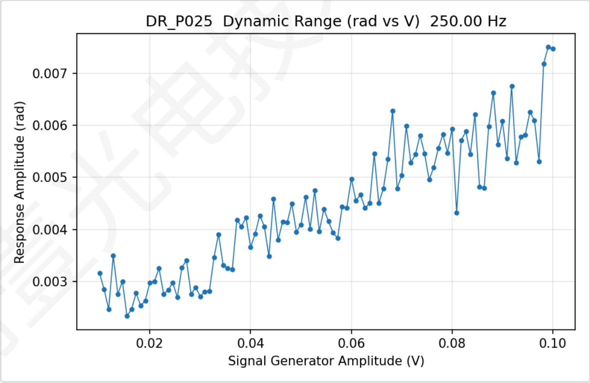
FIBRE-SM-BK-TBF-XRCD 幅度统计图

幅度统计图如下：









动态范围测试说明

测试目的

- 在多个代表性频点下，评估光纤对振动幅值从弱到强的可用线性工作区间、检测下限（噪声主导区）以及高幅值下的耦合饱和/失真趋势。
- 动态范围的优劣在工程上对应“同一根光纤既能测到多小的扰动、又能承受多强的扰动而不失真”的边界。

指标解读

- 检测下限（噪声主导区）：在低电压端，若输出幅度接近噪声水平、曲线起伏大或不可重复，说明该光纤在此频点的有效耦合不足或噪声占主导——这决定最小可检扰动。
- 线性工作区间：曲线在中等幅值段若近似线性、且不同频点趋势一致，说明该光纤的机械传递较稳定、耦合机制可预测；线性区越宽，工程可用性越好。
- 高幅值饱和/失真：在高电压端若出现幅度压缩（曲线变平）、突变、波形削顶或明显畸变，通常反映：光纤敷设/固定发生滑移、封装结构进入非线性、或局部应力集中导致耦合机制改变。
- 频点差异：同一光纤在不同频点的线性区、下限与饱和点若差异很大，往往提示结构存在频率相关共振/阻尼特征；工程部署时应优先选择表现更均匀的工作带宽。

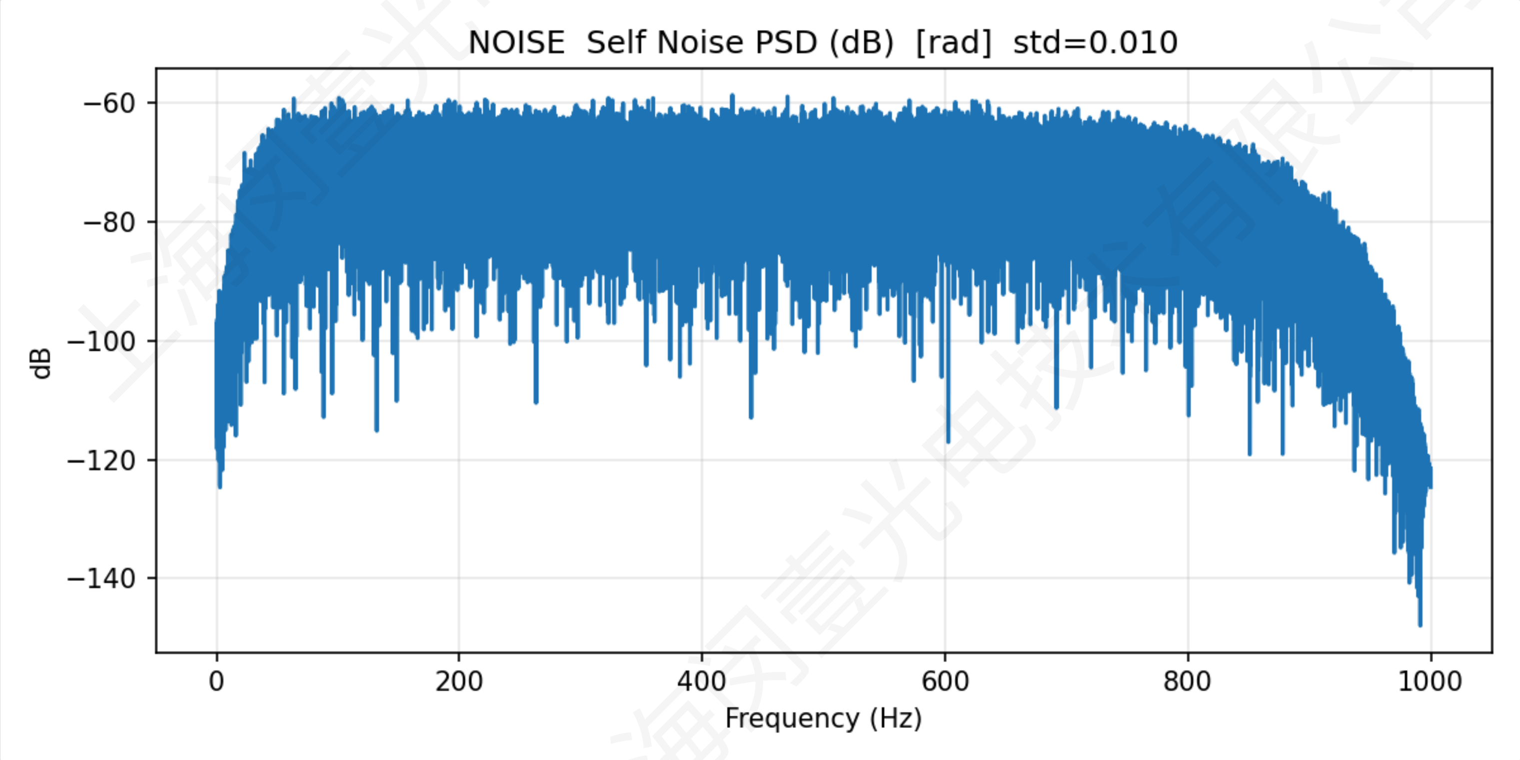
自噪声测试

Self-Noise Testing

自噪声测试结果

信号发生器关闭输出，在无外部激励条件下连续采集 60 s，得到：

噪声频谱图（PSD, dB）：



FIBRE–SM–BK–TBF–XRCD

自噪声测试说明

测试目的

- 在无外部激励条件下测量系统输出的基准噪声，用于表征“在当前敷设与光纤结构下”，光纤本体与封装/固定方式引入的环境耦合噪声、微弯/摩擦扰动、结构自激等对可检能力的限制。
- 自噪声结果可与频响/保真度/动态范围的主峰对比，给出不同光纤在目标频段内的可用信噪比上限与最小可检事件趋势。

指标解读

- 噪声底高低：噪声底越低，说明在当前敷设/封装状态下光纤对非目标扰动更安静，对微弱事件更友好；噪声底偏高则意味着可检下限被抬升。
- 噪声谱形态：若低频段显著抬升，常见于缓慢机械漂移、结构松动或环境耦合；若出现窄带尖峰，往往对应外部电机/风扇/电源或结构共振点——这类尖峰会在对应频点削弱事件识别的鲁棒性。
- 与其它测试的闭环解释：将频响/保真度/动态范围中的主峰幅度与自噪声底对比，可直接判断该光纤在目标频段的主峰是否足够高于噪底，从而决定工程阈值设置、误报风险与可检距离的相对优劣。

主观使用体验与总结

Operational Experience & Summary

主观使用体验与总结

如下是3种光纤的主观使用体验：

FIBRE-SM-BK-TBF-XRCD		
评价维度	**评分**	**备注**
外被与封装	★★★★★	外被较紧实
柔软性	★★★★★	柔软
声音敏感度	★★★★★	对空气中声音敏感度尚可
部署友好度	★★★★★	轻便容易部署，抗弯性较强（B3弯曲半径 ~5mm）
稳定与一致性	★★★★★	未现不稳定一致情况

总体结论： 本轮测试光纤，对于低频振动的动态范围表现优秀。底噪较低。适合对抗弯、柔软度要求较高的一般工程现场环境。

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