Comparison of FP, VCSEL and DFB laser diode in optical transmission for MR RF coil array

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Introduction:

Optical fiber transmissions of using Direct modulation and External modulation for multi-receiver array have been applied to remove the cable cross talk [1, 2]. For parallel MRI using many receive channels as 32 or more may require a laser diode (LD) with low power consumption and compact size. In this study the comparison of three LDs: Fabry-Perot (FP), Vertical Cavity Surface Emitting Laser (VCSEL) and Distributed Feedback (DFB) used in direct modulation has been presented.

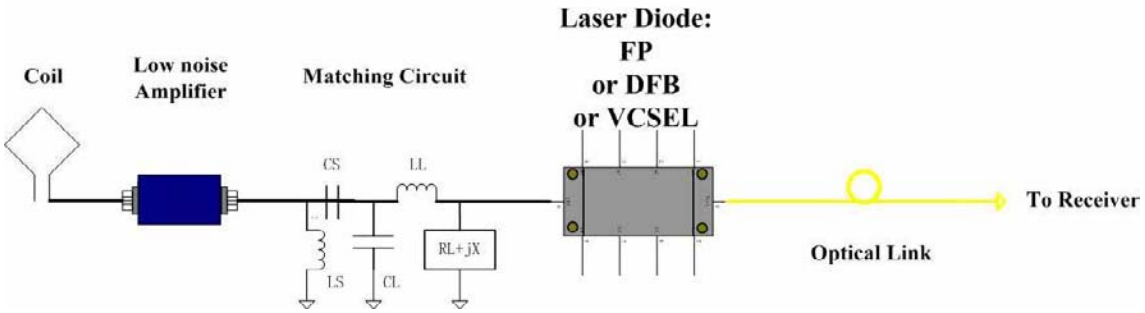

Fig 1. Optical link architecture of direct modulation

Methods:

The optical link architecture of direct modulation is shown in Fig 1. Optical link performance is mainly determined by frequency response, noise figure, power gain, and 3rd order intermodulation-free dynamic range (IMF3). The specifications of FP, VCSEL and DFB are listed in Table 1, which are normalized to 1 Hz. The system link performances of these three LDs are listed in Table 2.

Discussion:

In ultra high field MRI applications (7T or higher), wide dynamic range (141dB) is needed and large signal will be transmitted. However, the narrow dynamic range of FP (110dB) limits the optical link application in MRI [3]. As shown in Table 2, VCSEL and DFB optical links can provide much higher power gain (3 and 30 times) and much wider dynamic range (4 and 10 times) than FP links. This is because of their special structures: DFB has an optical grating which can select its wavelength; and VCSEL use vertical lasing axis which cavity is much shorter than that of FP. However, DFB LD has the largest threshold current, power consumption and physical size (5 times of VCSEL, 2 times of FP), which may cause serious problems for large number elements of RF coil array applications. VCSEL is a better choice for multi-channel optical fiber transmission systems in MRI because it has the smallest size, wide temperature range (-20 to 70˚C), especially, the lowest threshold current. Those features could make VCSEL an ideal LD for MRI optical transmission, particularly in the case that large number of RF channels (32 or more) is required.

	FP	VCSEL	DFB
Slope efficiency	0.15 W/A	0.2 W/A	0.28 W/A
Relative intensity noise (RIN)	-150dB/Hz	-140dB/Hz	-135dB/Hz
Maximum output power	5 mW	1.5 mW	10 mW
Threshold Current	~10 mA	~6 mA	>15 mA

Table 1. Specifications of FP, VCSEL and DFB LDs

	FP	VCSEL	DFB
Power Gain (G)	~ -25 dB	~ -20 dB	~ -10 dB
3rd intermodulation-free dynamic range (IMF3)	~110dBHz$^{2/3}$	~116dBHz$^{2/3}$	~120dBHz$^{2/3}$
Maximum modulation bandwidth (BW)	>1GHz	> 2.5 GHz	~ 10 GHz
Noise Figure (NF)	~29 dB	~ 23 dB	~ 32 dB

Table 2. Performance comparison of FP, VCSEL and DFB LDs

Conclusion:

With its compact size, VCSEL also can provide lower power consumption and wider temperature range than DFB and FP diodes. This makes VCSEL the best choice for direct modulation of optical transmission in MRI multi-channel application.

Acknowledge:

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References:

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