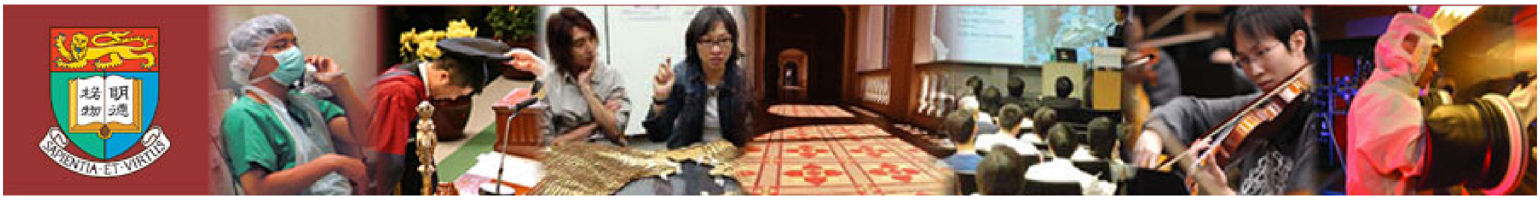

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Comparison of Optical Modulation Methods for RF Coil Interlinks

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Introduction:

Optical interconnect by glass fibers for MR receive arrays has been put forward and demonstrated [1] to remove electromagnetic interactions in the link absolutely. Optical modulation methods are one of the key factors in the optical link design, because they determine the link performance. Frequency response (FR), noise figure (NF) and dynamic range (DR) are most critical for optical links used in the MRI applications. The link performances in these aspects by two modulation methods are compared and their feasibilities for MRI applications are analyzed.

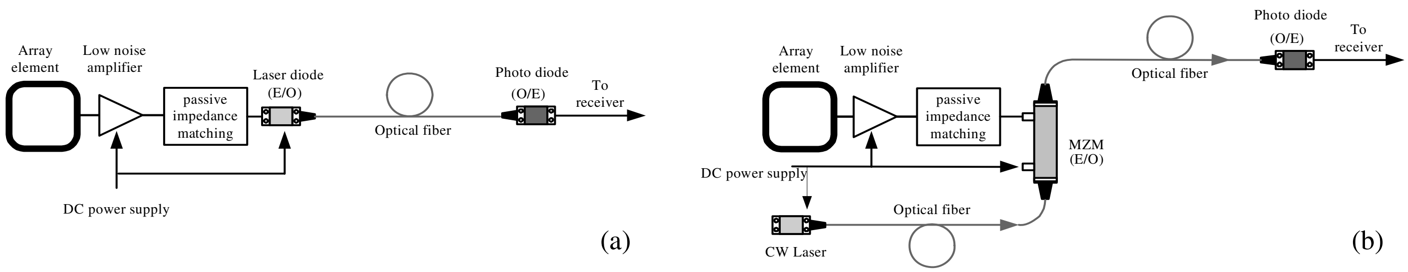

Fig 1. Optical link architectures of direct modulation by LD (a) and external modulation by MZI (b)

Optical link performance:

Direct modulation (DM) and external modulation (EM) are two major optical modulation methods. The optical link architectures by these two methods are illustrated in Fig 1 (a) and (b) respectively. The major difference between these two links is the modulator, usually laser diode (LD) for DM link and Mach Zehnder Interferometer (MZI) for EM link. Their characteristics determine the link performance, provided the same photo diode (PD) is used for optical signal detection. Link performance is evaluated by power gain (G), frequency response (FR), noise figure (NF) and 3rd order intermodulation-free dynamic range (IMF3) normalized to 1Hz. The typical characteristics of the optical components are listed in Table 1. With these values, the expected link performances are compared in the Table 2.

LD slope efficiency (η)	0.15 W/A
LD relative intensity noise (RIN)	-150 dB/Hz
LD maximum output power	5mW
MZI half-wave voltage (V_π)	3.5V
Constant power (CW) of laser (P_I)	100mW
RIN of CW laser	-170 dB/Hz
DC bias point of MZI	90°
Insertion loss of MZI (L_S)	3dB
PD responsivity (R)	0.85A/W

Table 1. Specifications of optical components

Discussion:

It seems that the EM optical link shows better performance than the DM link from Table 2, which should owe to the use of the better laser with lower relative noise intensity (RIN) and higher power in the EM link. The modulation bandwidth (BW) of both optical links is enough for most present MRI applications. The low G and high NF of both optical links can usually be compensated by the use of a low noise preamp. However, the use of a preamp brings the side effect of IMF3 reduction. Referring to the required DR at 7T by [2], such a wide DR of 117dB with 50kHz BW, is hard to be achieved by either DM or EM optical link, which becomes a major challenge in high field application by optical links. From the perspective of engineering feasibility, DM optical link would be more attractive for interconnect of large arrays, because a LD is much easier to be integrated into a coil together with a preamp due to its much smaller size than a MZI. In an EM link, an additional fiber and a high power CW laser have to be used for each channel, so the link structure becomes much more complicated. In addition, DM links show better performance-cost ratio due to the much lower cost of a LD than a MZI and high power CW laser, especially for large coil numbers.

	DM link	EM link
Power gain (G)	~ -18dB	~ -2 dB
Maximum modulation bandwidth (BW)	~500MHz	> 1GHz
Noise figure (NF)	~29dB	~ 22dB
3rd intermodulation-free dynamic range (IMF3)	~110dBHz$^{2/3}$	~120dBHz$^{2/3}$

Table 2. Performance comparison of DM and EM optical links

Conclusion:

An EM link, with the use of high power and low noise CW laser, can achieve better performance than a DM link, for the use in a single MR coil. But for arrays with large numbers, a DM optical link is much more feasible. Low noise preamps are necessary for both types of optical links to reduce the noise figure. The dynamic range of optical links should be further improved to meet the critical requirement for MR applications.

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