A Direct Modulated Optical Link for MR Coil Array Interconnect

J. Yuan[1], J. Wei[1], P. Qu[1], G. X. Shen[1]

[1]MRI Lab, Department of Electrical and Electronic Engineering, The University of Hong Kong, Hong Kong, Hong Kong, Hong Kong

Introduction:

Optical fiber is a promising alternative to RF cables for MR receive coil interconnection. Optical fiber has high bandwidth, high data transmission speed and low loss. An optical link is naturally immune to electromagnetic interaction, and thus has the great advantage of removing crosstalk between cables in MR coil array. In addition, smaller cross section and lower stiffness of fiber than cable make it easier to handle. There are two methods of modulation for optical links: direct and external. An external modulated optical interconnect by Mach Zehnder interferometer (MZI) for MR receive coil has been demonstrated by Koste *et al* [1]. In an external modulation link, a constant optical power laser output and the RF signal are introduced into MZI via optical fiber and RF port respectively, and the modulated optical output is transmitted by another fiber. But in a direct modulation, the RF signal is modulated by a laser diode (LD) directly and the modulated optical output is transmitted by a fiber. Therefore, the direct modulation is simpler to implement than external modulation. For applications in MR array, direct modulation is preferable because all components are more easily integrated into the coil and the cost is much lower than external modulation.

Optical link architecture:

The structure of a direct modulation optical link for MR coil is shown in Fig 1. The MR signal is amplified by a low noise preamp and then introduced into a LD. The modulation signal directly changes the intensity of the LD output. The modulated optical signal is transmitted through a fiber and then converted back into electrical signal through a photo diode (PD). Due to the compact size of a LD, it can be integrated into a coil together with a preamp, so a direct modulation optical link can be easily extended to multi-channels for arrays. The characteristics of the optical components are shown in Table 1.

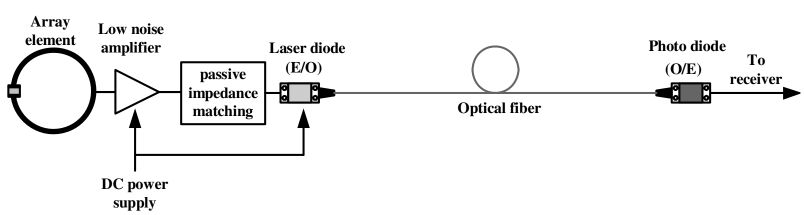

Fig 1. Schematic of a direct modulation optical link for MR coil array

LD wavelength (λ)	1310 nm
LD slope efficiency (η)	~0.15 W/A
LD operating Voltage (Vop)	1.1 V
LD relative intensity noise (RIN)	-150 dB/Hz
PD responsivity (R)	~0.85 A/W

Table 1. Optical components characteristics

Results:

The power gain of the optical link is about –18dB, which means the output power of the PD is about 1.6% of the LD input. Usually the noise of a direct modulation optical link is dominated by relative intensity noise of the LD. The noise figure (NF) of the direct modulation optical link without the preamp is about 29dB, so a low noise preamp (NF_{preamp}=0.5dB) is necessary in the optical link to reduce the system NF. The dependence of system NF on the gain of preamp is illustrated in Fig 2. To achieve system noise figure less than 1dB, 40dB of preamp gain is required. The 3rd order intermodulation-free dynamic range of the optical link is expected to be ~110dBHz by modeling. For a typical bandwidth of 100KHz in MR imaging application, the corresponding dynamic range of the optical link is about 75dB.

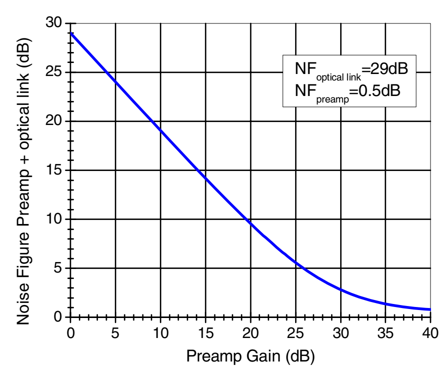

Fig 2. Preamp gain *vs.* system NF

Discussion:

Because this optical link is used for analog signal transmission, it requires that the LD has a high linearity of P-I curve. Otherwise distortion of the MR signal may arise. DC power supply is required for preamp and LD driving at the coil-front. Since the preamp and the LD are both DC driven, the cables to supply electrical power would not cause crosstalk between channels. Since the operating voltage of the LD is as low as 1.1V, power supply by battery may be a feasible solution. Although the major materials in LDs are compounds of groups III and V elements, including gallium arsenide, indium phosphide and indium arsenide, which are not ferromagnetic materials, the package of the commercial LDs often include iron. Therefore the direct modulation optical link has not been applied to imaging in the magnet so far.

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References:

[1] G. P. Koste, M. C. Nielsen *et al*, 13th ISMRM, 411 (2005);