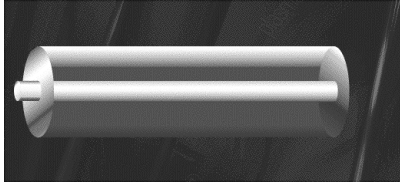


B08: HiCap™

Multi mode optical fibres for high speed LAN's



INTRODUCTION

A major new datacom standard has recently been developed for powerful Gb/s-speed backbone applications called Gigabit Ethernet, it responds to the increasing demand for data transmission.

The outstanding feature of this new standard is that it requires the use of lasers instead of traditional LED light sources.

During the development of this standard a remarkable differential mode delay (DMD) phenomenon was observed.

The use of lasers in combination with certain central core profile distortions introduced dramatic eye-closure and high bit-error rates in some GIMM fibres.

Solutions for these problems were found by introducing a special patch cord for the 1300 nm application; at 850 nm a (provisional) conditioned launch was defined.

Both solutions have been incorporated in the Gigabit Ethernet standard.

In addition, rather conservative link distances have been standardised to take account of already installed fibre in cable networks, including fibres with some amount of core profile distortion.

HiCap™ : THE INTELLIGENT STEP FORWARD

To meet the challenges of this new standard, Plasma Optical Fibre is using its proprietary Plasma-activated Chemical Vapour Deposition (PCVD)

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process to produce a new family of laser-certified fibres - the HiCap™ class.

These fibres with high profile accuracy offer enhanced Gigabit Ethernet system distances and also eliminate the need for expensive mode-conditioning patch cords.

GIMM FIBRE AND DATACOM DEVELOPMENT

The fast-growing demand for higher data transmission speeds is fuelling a need for high-performance backbone applications at 1000 Mb/s (1 Gb/s) and above. In June 1998, the Institute of Electrical and Electronic Engineers (IEEE) approved the Gigabit Ethernet standard, as developed by the IEEE 802.3z Committee.

Clearly, the advent of compulsory laser light sources sets new requirements for GIMM fibres. These new applications have triggered the third life cycle of the GIMM fibre, moving forward to the next milestone in optical datacom systems.

GIGABIT ETHERNET

LED light sources, used in systems up to 100 Mb/s, cannot be used in Gb/s applications because they cannot be modulated at these higher speeds. Furthermore their spectral width is too high, causing too much chromatic dispersion at 850 nm for Gb/s systems.

Fortunately a new 850 nm laser diode has become available: the Vertical Cavity Surface Emitting Laser (VCSEL), which is only slightly more expensive than conventional LEDs. (For datacom systems, minimising component costs is crucial).

VCSELs can be modulated at Gb/s speeds and their spectral width is small, as too is the resulting chromatic dispersion: essential aspects at these transmission speeds. VCSELs (and CD-lasers) have been chosen as the 850 nm

light sources for Gigabit Ethernet SX (short wave) application.

For the 1300 nm (LX, long wave) application, a Fabry Perot (FP) type single mode laser has been defined as the light source, capable of being launched either into a single mode fibre or a GIMM fibre.

DIFFERENTIAL MODE DELAY EFFECTS

During the development of Gigabit Ethernet, experts observed strong differential mode delay (DMD) effects in a small number of GIMM fibres.

Fig. 1 illustrates a distorted pulse where a portion of the detected power from certain mode groups arrives with additional delay (DMD), causing a plateau in the output pulse, which scales with the fibre length.

Such a pulse distortion introduces a high level of system errors (high Bit-Error-Rate (BER)).

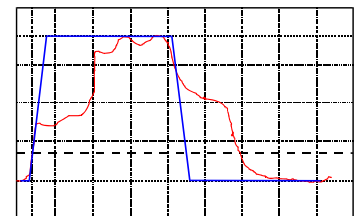


Fig. 1. Example of distorted pulse due to DMD.

Investigation showed that these particular fibres exhibit distortions in the central part of the core refractive index profile, and so deviate from the ideal profile.

These distortions may originate in certain fibre production processes or under certain uncontrolled process conditions.

Some refractive index profile examples of non-PCVD fibres are shown in Fig. 2. Local profile distortions may cause DMD for some modes when launched. An extraordinarily accurate graded-index profile is needed in order to match the delay time of all launched modes.

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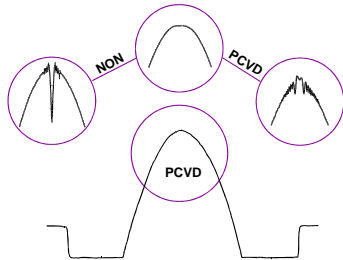


Fig. 2. Typical refractive index profile of PCVD GIMM fibre and some examples of non-PCVD fibre central core profile distortions (dip/flat top/peak).

In 100 Mb/s systems using LEDs, these DMD effects have not been observed owing to the lower modulation speed and because of the nearly uniform launch of all available modes (equal mode power distribution). In this case, the power of a small number of modes with DMD is practically negligible compared with that of undisturbed modes.

On the contrary, laser diodes (LD) (particularly 1300 nm FP single mode lasers) launch into a much smaller area of the fibre core, exciting only a limited number of low order modes (Fig. 3).

Modes showing DMD currently carry a significant part of the total power, causing a much stronger offset in the arrival time at the end of the fibre.

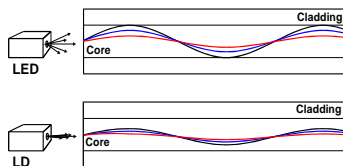


Fig. 3. LED: full core launch (all modes)/LD: limited core launch (low order modes).

DMD SOLUTIONS IN THE GIGABIT ETHERNET STANDARD

For the Gigabit Ethernet Standard, account had to be taken of the fact that already installed cable networks contain some fibres with distortions in the core profile.

For the LX (1300 nm) application, a solution was found by using a special mode-conditioning patch cord (Fig. 4).

Using this patch cord, the laser source is coupled with a single mode fibre, which is offset spliced to the centre of a GIMM fibre (about 17-23 µm for a 62.5 µm fibre).

In this way, the launch power of modes with different delay in the centre of GIMM fibres is greatly reduced.

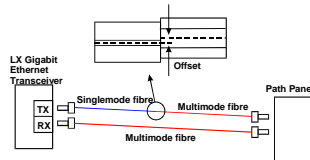


Fig. 4. Mode conditioning patch cord for LX (1300 nm) Gigabit Ethernet application.

Lastly, to enable the use of Gigabit Ethernet systems over already installed GIMM fibre cable networks (including fibres with some amount of core profile distortions), conservative link distances have been defined in this Gigabit Ethernet standard (Table 1).

	SX	Distance	LX	Distance
	850 nm		1300 nm	
62.5 µm	160 MHz-km	220 m	500 MHz-km	550 m
	200 MHz-km	275 m		
50 µm	400 MHz-km	500 m	400 MHz-km	550 m
	500 MHz-km	550 m	500 MHz-km	550 m

Table 1. Gigabit Ethernet (IEEE 802.3z) maximum link distances.

PCVD/ENHANCED FIBRE QUALITY (HiCap™)

Plasma Optical Fibre, using its proprietary PCVD process, produces GIMM fibres with the highest profile accuracy available on the market.

Typically, several thousand layers are constructed in the core region. By comparison, other fibre processes deposit only hundreds of core layers. To bring enhanced quality to the new laser-based Gb/s-speed systems, Plasma Optical Fibre is introducing a new class of laser-certified High Capacity PCVD GIMM fibres: the HiCap™ class.

In the early '80s, a patented etching process had already been developed for the PCVD process to remove the central dip in the core profile.

This is highly attractive because of the inherent high bandwidth potential of PCVD GIMM fibres; a dip otherwise tends to reduce the bandwidth. Thanks to the absence of central core distortions, HiCap™ fibres do not require the use of expensive mode-conditioning patch cords in LX (1300 nm) applications.

This money-saving feature has been confirmed in a series of comprehensive system tests.

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ENHANCED PERFORMANCE

Another feature of the high PCVD profile accuracy is the possibility of optimising the graded-index profile to obtain the highest modal bandwidth at 1300 nm (standard optimised), at 850 nm (850 nm optimised) or between 850 nm and 1300 nm (dual window optimised).

Fig. 5 shows two wavelength optimisation possibilities for the modal bandwidth: 850 nm optimisation and 1300 nm optimisation.

This performance enhancing feature offers the possibility of adapting fibre bandwidth to wavelengths of interest.

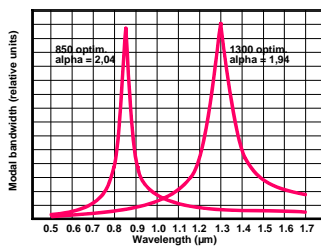


Fig. 5. Examples of calculated modal bandwidth, optimised at 850 nm and at 1300 nm, depending on the profile shape parameter (alpha). A dual window optimised fibre shows the highest bandwidth between 850 nm and 1300 nm.

LONGEST GIGABIT ETHERNET LINK DISTANCES

Against this background a number of successful Gigabit Ethernet system tests have been performed on standard and dual window optimised PCVD GIMM fibres, with both 50 µm and 62.5 µm core diameter.

Based on these experiments, maximum distances for Gigabit Ethernet systems are guaranteed for HiCap™ fibres, as shown in Table 2.

These lengths are the longest Gigabit Ethernet link distances reported so far.

		SX 850 nm	LX 1300 nm
62.5 µm	HiCap™ Standard optimised	500 m	1000 m
50 µm	HiCap™ Standard optimised	750 m	2000 m

Table 2. HiCap™ Gigabit Ethernet maximum link distances.

During the investigation it was observed that laser performance varies quite strongly between different types. Figs. 6 and 7 show some examples of Gigabit Ethernet eye patterns for HiCap™ fibres.

In some cases a laser performs so poorly that hardly any margin is left for installed GIMM fibre cable networks; an example is shown in Fig. 8. This aspect certainly needs further standardisation work.

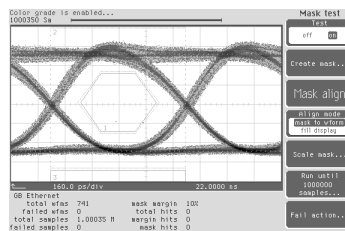


Fig. 6. Eye pattern for 550 m of 62.5 µm dual window optimised HiCap™ fibre, coupled with an 850 nm VCSEL (1.25 Gb/s).

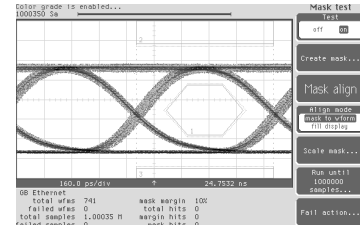


Fig. 7. Eye pattern for 2200 m of 50 µm standard optimised HiCap™ fibre, coupled with a 1300 nm FP laser (1.25 Gb/s).

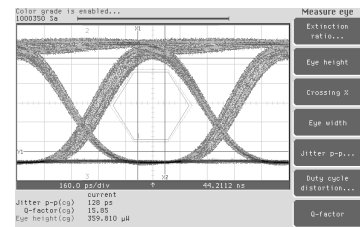


Fig. 8. Eye pattern of a 'poor' 1300 nm FP laser, using 2 m of 62.5 µm fibre.

FUTURE UPGRADABILITY

HiCap™ fibres are defined - for the moment - in terms of link distance for Gigabit Ethernet applications and not in terms of bandwidth.

This is because the traditional (overfilled launch) bandwidth does not entirely describe the fibre behaviour under laser launch conditions. For HiCap™ fibres, however, the highest class of OFL bandwidth is selected: well above the values stated in all premises cabling standards 1. In addition, dedicated tests are being performed in order to check the laser launch performance.

Based on the PCVD core profile quality and this laser launch performance test, higher transmission speeds (2.5 Gb/s and beyond) over hundreds of meters are projected, an important aspect of future upgradability - offering major



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economic and operational benefits for users.

CONCLUSIONS

GIGABIT ETHERNET (IEEE 802.3) STANDARD

- The new Gigabit Ethernet standard is an important milestone along the development track of datacom systems with steadily increasing transmission speeds.
- For the first time, Gigabit Ethernet requires lasers to be used in combination with GIMM fibres. VCSELs make an important contribution to the economical realisation of Gb/s-speed datacom solutions.

- The combination of lasers and GIMM fibres with central core profile distortions may cause severe DMD effects (in non-HiCap™ fibres).
- For 1300 nm, special mode-conditioning patch cords can be used to avoid these DMD effects in already installed GIMM fibre cable networks.

THE INTELLIGENT SOLUTION: HICAP™ FIBRES

Plasma Optical Fibre has developed a new class of enhanced quality PCVD GIMM fibres: HiCap™ 50 µm and 62.5 µm, both in standard optimised and dual window optimised versions.

KEY FEATURES

- The maximum Gigabit Ethernet link distances for HiCap™ fibres (up to 2000 m) are the longest distances reported in the industry.
- HiCap™ fibres are tested for current Gb/s performance, but also for future upgradability to higher system speeds (2.5 Gb/s and beyond).

- HiCap™ fibres eliminate the need for expensive mode-conditioning patch cords.
- No wonder then, that the impending launch of the new HiCap™ fibres is causing such interest among users and spearheading the move to the new standard.

FIBRE SPECIFICATIONS

For further details of the HiCap™ fibres please refer to Draka Denmark Fibre specifications:

- C08: Standard optimised 50 mm HiCap fibre
- C10: Standard optimised 62.5 mm HiCap fibre.

ACKNOWLEDGEMENT

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