



Geo's Optical Fibres

Optical Fibres in Geo's Network

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1. Summary

- ☺ Single Mode fibres, as opposed to Multimode fibres, are used almost exclusively in telecommunication networks, because they exhibit much lower pulse dispersion
- ☺ This makes it possible to support much higher data rates
- ☺ There are only two main types of Single mode fibre in use today: G.652 and G.655
- ☺ G.652 is by far the most common type, but G.655 is better for high capacity long haul networks
- ☺ Geo uses both types of fibre in its network - G.655 in the nationwide backbone network and G.652 in the urban networks.
- ☺ Geo maintains high standards in its fibre splicing operations, and rigorous testing of all fibre sections to ensure that mixed G.652/655 fibre sections exhibit the same high quality as sections composed solely of G.652 or G.655 fibre.

2. Introduction

This paper briefly explains the main types of single mode optical fibre that are currently deployed in telecommunication networks, together with their relative strengths and weaknesses and how the different types are used within Geo's network.

Before contrasting the advantages of different types of single mode optical fibre, it is necessary to have a basic understanding of what a single mode optical fibre is. Briefly, a single mode optical fibre is a long thin cylinder of glass (Silica) in which is divided into a small diameter core region, surrounded by a much larger diameter cladding region (Fig 1). The transition between core and cladding is very sharp, and is marked by a change in the refractive index of the glass. The glass in the core has a refractive index which is very slightly greater than that in the cladding, and it is this difference in refractive index which is responsible for confining a propagating light wave within the core. One way of thinking about this is to picture a ray of light zigzagging its way down the core of the fibre by repeatedly bouncing off the core-cladding boundary, as in Fig 1.

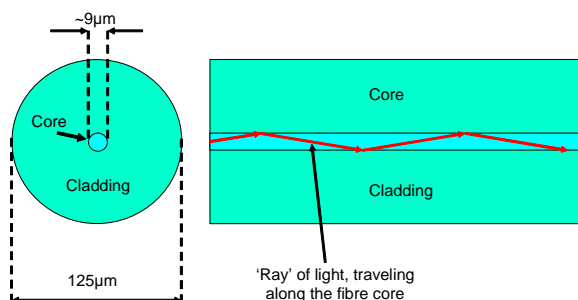


Figure 1 Single mode fibre guiding a single 'mode' of a light wave so that it travels along the core of the fibre

Fig 1 shows a single path for a ray of light which is bouncing off the core-cladding boundary at one particular angle, it is possible, under the right conditions, for a light ray to be reflected at other angles. If the diameter of the core is sufficiently large, then it is possible for light rays to bounce off the core-cladding boundary at several different angles, as shown in Fig 2. It turns out, that for light of a given wavelength, even with a large core glass fibre, the angle of reflection can be restricted to a small set of well defined values. This is due to the way in which a wave of light naturally behaves. It occurs because

the electric and magnetic fields that constitute the light wave can only exist in certain well defined patterns within the core of the fibre. These patterns are usually referred to as 'modes' and the smaller the fibre core, relative to the wavelength of the light, the smaller the number of allowed modes. If the core of the fibre is reduced to diameter of around 9µm, then for light at wavelengths longer than 1250nm, only one mode is allowed - hence single mode fibre.

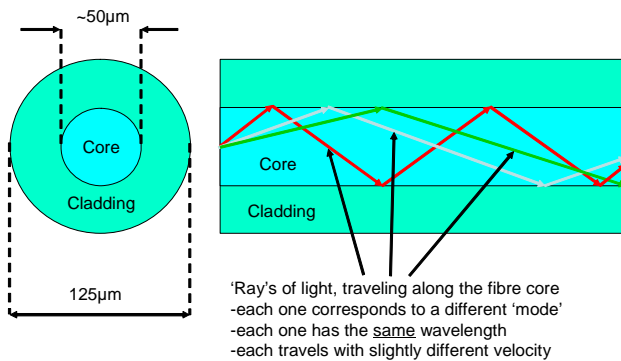


Figure 2 Multi-mode fibre, which allows several 'modes' to propagate simultaneously- all with exactly the same wavelength

Fibres that allow more than one mode (so-called Multi-mode fibres) are still deployed in large quantities (mainly in small, enterprise networks), but telecommunication networks have used single mode fibres almost exclusively for the last 20 years. The reason for this revolves around the speed with which different modes propagate along a multi-mode optical fibre. Even when just a single *wavelength* of light is launched into a multi-mode fibre each of the different modes will travel at a different velocity. This causes a problem when a transmitter launches a pulse of light (or, more likely, a train of pulses); because the optical power will be divided amongst all of the allowed modes within the fibre, and the power associated with each mode will arrive at a slightly different time at the other end of the fibre. This effect, known as 'dispersion', increases linearly with fibre distance, with the result that by the time it reaches the receiver, the initially sharp transmitted pulse becomes smeared out in time (see Fig 3). If the fibre is long enough, the receiver will eventually have so much difficulty in distinguishing between one pulse and the next that it will start to misinterpret the incoming light signals and make errors.

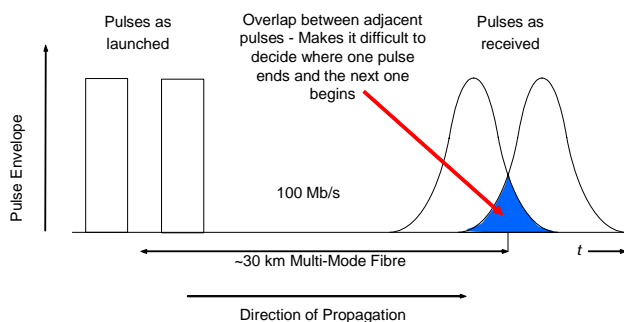


Figure 3 Modal Dispersion blurring the distinction between two adjacent pulses

The complete absence of modal dispersion in single mode fibres is the main reason why they are used so widely in telecommunications networks. Although there are several other mechanisms that also conspire to disperse optical pulses, none of them is as severe as modal dispersion; hence single mode fibres allow optical pulses to be transmitted over the longest possible distances.

As mentioned above, most single mode fibres have a core diameter of about 9um, with the cladding having a much larger diameter - usually 125um. In contrast, multi-mode fibres maintain the same cladding diameter, but have much larger cores - either 50 or 62.5 um.

3. Different types of single mode fibres

3.1. G.652 fibre

In the early 1980's when single mode fibres were just being introduced, there was only one internationally recognised fibre specification, to which all fibre manufactures designed their products. This was (and still is) ITU-T recommendation G.652. Compared to other single mode fibres now on the market, this type of fibre had a relatively large core area, which made it easy to couple in the light pulses from the optical transmitter (usually a laser diode). During the last twenty years, G.652 fibre has been deployed in enormous quantities and is regarded as the 'work-horse' optical fibre, which is found almost everywhere. Over time, the G.652 specification has been progressively tightened so that it is more suitable for very high capacity, long haul transmission systems, but even with these improvements, the latest G.652 fibres still exhibit dispersion which is too large for some long haul applications. This dispersion arises from causes other than the modal dispersion that was discussed above.

3.2. G.655 fibre

The residual dispersion within G.652 fibre prompted the world's fibre manufacturers to develop new designs of fibre that were optimised for reducing dispersion in very high capacity long haul transmission systems. Although several specifications were produced, the only one that has resulted in large quantities of fibre being deployed in the field is ITU-T recommendation G.655. Surprisingly, G.655 does not attempt to reduce the residual dispersion to zero, but purposely retains a small amount of dispersion, as this has been found to be essential for overcoming some of the more exotic non-linear distortions that can occur when very high power pulses are launched into an optical fibre.

Unfortunately G.655 specifies some of the critical fibre parameters rather loosely, and different manufacturer's fibres can perform quite differently, even though they all conform to G.655. One of the main differences between the different products is the size of the core, an issue which has divided the manufacturers into two main camps. One camp designed its fibre to have a large core - the so-called LEAF fibres (Large Effective Area Fibre), whilst the other camp did the opposite. There are pros and cons for both approaches, but broadly speaking, the LEAF designs make it easier to launch high optical powers, whilst the narrow core designs control the dispersion more effectively

G.655 fibre was introduced in the mid 1990s and since then has been deployed extensively for long haul networks in North America. In the UK Geo is the only operator to have deployed it exclusively in its long haul network.

3.3. Comparison between G.652 and G.655 fibre

As well as having a slightly lower attenuation than G.652 fibre, G.655 fibre makes it easier to deploy long haul transmission systems chiefly because there is less dispersion than with G.652 fibres. G.652 fibres can still be (and still are) used for long haul transmission, but their greater dispersion means that more money needs to be spent to compensate for this dispersion than is the case with G.655 fibre. This situation is manageable (but not desirable) for a transmission system running at 10Gbit/s per optical wavelength, but it becomes much more problematic for a system running at 40Gbit/s. The move from 10Gbit/s to 40Gbit/s requires a 16 fold increase in the accuracy with which any residual dispersion must be compensated for, which is where the lower dispersion of G.655 fibre is extremely useful.

On the other hand, G.652 fibre is simpler and therefore less expensive to manufacture, hence it is still the fibre of choice for those applications that do not demand the ultimate in performance. This is why G.652

fibre is used almost exclusively in Metro and Regional networks worldwide, and no change to this position is expected in the foreseeable future.

4. Connecting together different types of fibre

Generally speaking there is no problem when connecting different types of single mode optical fibre together, even though the core diameters are different. In practice what happens is that all optical components are manufactured with G.652 fibre 'pig-tails' (e.g. lasers, receivers etc), on the assumption that most of the time, these components will be connected into long lengths of G.652 fibre, rather than the rarer G.655. Even with Optical Distribution Frames, it is recommended that all patch leads are constructed from G.652 fibre, whether or not the long-haul fibres are G.652 or G.655.

There is only one situation in which the connection of a long G.652 section to a long G.655 can potentially cause problems, and that is where very high optical powers are being launched in many closely spaced wavelengths, by a Dense Wavelength Division Multiplexing transmission system. However, it is worth noting that even under these extreme circumstances, this problem almost never occurs with the high effective area variety of G.655 fibre, which is one of the reasons why Geo chose to use this variety, as opposed to the low effective area variety.

It is, of course, entirely possible that better fibre designs will be developed in the future, however the vast quantities of G.652 and G.655 fibre which have already been deployed force transmission equipment manufacturers to engineer their systems to overcome any shortcomings in these types of fibre. Any new design of fibre would have to exhibit very considerable advantages in order to justify the large expense of pulling in new optical cables that could only be properly exploited by specialised optical transmission equipment. For this reason, it is likely to be several years before there is a practical successor to these established fibre types.

5. What types of fibre does Geo use, and where

Geo's optical fibres can be divided roughly between those in the backbone, and those in the urban areas. With very few exceptions, G.655 fibre of the high effective area variety is deployed everywhere in the backbone, whereas G.652 fibre is used exclusively in the urban networks. This combination delivers Geo's customers all the advantages of optimum long haul performance, with cost effective metro performance, plus the freedom to mix and match sections of different fibre types.

The one area of the UK where there is some mixing of fibre types is in London, where Geo's London fibre network (Geo.Metro) uses G.652 fibres. Geo's G.655 backbone fibres also extend into central London, and can be spliced into the London fibres at several points.

Furthermore, the use of high effective area G.655 fibre in the backbone makes it easier to connect into the (overwhelmingly) G.652 fibre of Other Infrastructure Operators, enabling the creation of bespoke dedicated fibre networks.

As mentioned above, there is generally no problem when splicing together Geo's LEAF G.655 fibre to G.652 fibre from either Geo or other operators. Despite this, Geo takes no chances, and has done extensive work to characterise mixed G.655/652 splices. In practice, mixed fibre splices are subject to the same high standard of splicing that Geo applies to all its splice joints, with Optical Time Domain Reflectometer measurements being made in both directions in order to identify any splices that are out of specification, so they can be remade. Furthermore all Geo fibre sections are subject to full Chromatic Dispersion testing before handover to the customer, with the option of Polarisation Mode Dispersion testing as well. With this comprehensive level of testing, it is incredibly unlikely that any fibre section handed over to the customer would have any splicing or performance problems.

6. Conclusion

There are only two main types of single mode fibre in widespread use in telecommunication networks today, and this duopoly is not likely to change anytime in the near future. Geo uses both of these types - G.655 in the backbone, and G.652 in the urban portions of its network - to deliver the ultimate combination of high performance and cost effectiveness to its customers.

