Fibre Optics in Spectroscopy

Fibre optics are not only revolutionising the way optical instruments are designed but are also opening up many new opportunities for novel measurement techniques and analytical applications. In modern spectroscopy, where bulky optical benches and light-tight seals were once necessary, fibre optic cables now enable us to easily control and confine the optical signals flowing from source to sample and on to the detector. This technology has made it possible to link optical modules as easily as when we use electrical cables to connect between circuit boards.

Benefits of new approach

Many advantages are gained by the use of fibre optics in spectroscopy, but the benefits are much more significant in the new breed of Fibre Optic Coupled (FOC) CCD Array spectrophotometer; when fibre optics are integrated into the design of these instruments they enable a new approach to this established technique. Some key advantages and benefits are:

- No light-tight sample chamber is required - improving operator speed and efficiency.
- A wide range of standard or bespoke sampling accessories are easily fitted – enabling large, awkward or previously impossible samples to be measured.
- The light source can be located outside the main optics bench – reducing stray light and temperature effects and so improving linearity and reducing drift.
- The spectrophotometer is easily adapted for other measurements like fluorescence, turbidity, radiometry, reflectance, etc.
- Maintenance, Calibration and Service are all significantly reduced and much simplified.

Principles of operation

A fibre optic cable is a waveguide that transmits light along its axis by the process of total internal reflection. The active parts of the cable consist of the core (which can be as thin as a human hair) and the cladding that surrounds it. To confine the light (or optical signal) in the core its refractive index must be greater than that of the cladding.
In practical fibre optic cables the core and cladding are strengthened and protected by a tough buffer layer that may be further supplemented by an outer jacket layer. This final covering can be made from Plastic, Teflon or Kevlar, while for heavy duty applications stainless steel or other armoured sheaths may be used.

For analytical and measurement applications the core and cladding are usually made from different grades of silica glass, but plastics and alternative glass materials may be used for telecommunication, lighting and other purposes. The formulations of the silica glass used in the core and cladding will determine the optical performance of the cable. Visible to NIR grade fibre optic cable (Low OH) has an acceptable transmission over the wavelength range of 300 to 2400nm, UV grade (High OH) is designed to work from around 200 to 1100nm, while a special formulation of ‘solarisation resistant’ glass can work down to 180nm in the ultra-violet region.

The acceptance angle is defined by the Numerical Aperture (NA) of the cable; this is the Sine of the half angle of the cone of light that will be transmitted down the fibre. The NA most commonly used in instrument applications is 0.22 giving an acceptance half-angle of 12.5°, this has significant advantages in blocking ambient light interference and helps reduce the effects of stray light in overall optical performance.

Fibre core diameters vary from 50µm to 1000µm (0.05 to 1mm) but in practice a range from about 100µm to 600µm is used. The selection of the right size of fibre can be important in certain applications to ensure that the optimum light energy reaches the sample without saturating the detector or overfilling the CCD pixels. In instrumentation applications fibre optic cables may come directly from a sensor or probe for connection to the relevant instrument (Immersion probe or Reflectance probe etc), in other cases these will be in the form of patch cords, which are lengths of fibre optic cable with connectors on either end, for linking together the different accessories or modules that make up a measuring system.

All fibre optic cable inter-connections are a source of signal or energy loss (attenuation) that has to be minimised by good design practices and the type of connection or connector used. The ends of the core and cladding must be cut perfectly
at 90 degrees and polished so that they mate precisely with the receiving fibre or optical assembly. In many cases micro-
lenses are fitted to focus the light exiting the fibre or gather light entering the fibre. The most common connector used in instrumenta-
tion applications is the SMA905, this is mated with a push fit and screw locking ring. When fitted correctly these connectors offer excellent optical performance and environmental protection.

![SMA 905 connectors](image1)

**Using fibre optic cables**

1. Although they carry out a similar interconnection function to electrical cables, fibre optic cables are made of glass and CANNOT be handled in a similar manner to metal based conductors.
2. Do not exceed the maximum bend radius for the cable, in use or in storage. This is typically 300 times the cladding diameter, so for core diameters of 100µm to 600µm this approximates to a bend radius of 4cm (100µm) to 20cm (600µm), but is dependent on the detail of the construction of each cable type.
3. Ensure all optical surfaces are clean and dust free before making any connections. Always replace dust-caps on fibre ends and instrument SMA905 connectors when fibre optic cables are disconnected.
4. Do not use tools to tighten the screw locking ring on SMA905 connectors, but do ensure they are firmly hand-tight.
5. Do not pull on the cable to remove it when disconnecting, only use the connector screw locking ring.
6. Do not subject the cable to axial twisting in use, installation or storage. Spool or un-spool long lengths of cable in a figure-of-eight (as each part of the ‘eight’ puts an opposite twisting moment in the cable) turn the ‘eight’ over when carrying out the reverse process.
7. Do not subject the cable to pulling stress during installation or use. Fibres are usually stronger in direct tension relative to the cross section, but when fibres are small it is very easy to break them. Unfortunately each cable construction will have its own limits and it is difficult to give fixed rules for this, so minimizing pulling stress is important.
8. Try to restrict movement of cables during the period a measurement is being made.
9. Take extra care not to bend or crush cables at their exit point from probe heads, in use and storage, and do not support the weight of a probe by the cable.
10. Do not use any cable, cable assembly or probe beyond its specified performance limits or outside of its environmental operating and storage conditions. If in doubt consult your supplier, alternatives may be available, specials suitable for most situations can often be supplied or alternative procedures developed.

![A simple fibre connected cuvette holder](image2)