# Single Mode and Multimode Fiber

Single Mode (SM) and Multimode (MM) are the names given to two competing designs of optical fiber based on how many paths of light are transmitted along the fiber core – single mode, meaning "one path", or multimode, meaning "more than one path." A mode can be described as a "path" or "ray" of light in the core of the optical fiber.

Optical fiber with just one path in the core was previously referred to as "monomode" (abbreviated as MM) but, due to confusion with the abbreviation also being used for multimode, the term "single mode" and abbreviation SM were adopted.

The size of the core diameter and the wavelength of light used for SM transmission are intricately linked to one another. The most common SM fiber core diameter, approximately 8 to 9 microns, is designed to transmit a single mode for wavelengths from 1260nm and longer i.e. for 1310nm and 1550nm. A shorter wavelength such as 850nm, used for MM transmission, will have more than one mode in a 9/125 micron SM optical fiber.

In a MM optical fiber, there are thousands of different paths that the light can follow depending on the diameter of the core and the transmission wavelength.

## History

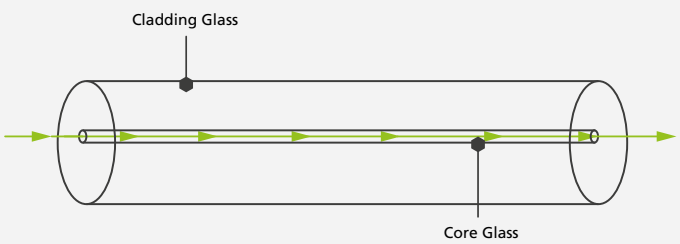
Whilst working at Standard Telecommunication Laboratories (STL) in the UK, renowned physicist and electrical engineer, Sir Charles Kao (affectionately known as the "Father of Fiber Optics"), announced at an Institute of Electrical Engineers (IEE) meeting in London on January 27th 1966 that optical transmission could be made using a few micron glass core with a lower refractive index coaxial glass cladding. The exhibition demonstrated sending a signal equivalent to 200,000 telephone signals and the size of the optical fiber presented was 3/300 micron to 4/400 micron - a SM fiber.

This marked the beginning of a highly competitive development program between companies including STL, Corning, Fujikura and many others to create the optical fibers we use today in long haul communication between and across continents and short haul communication in premises and data centers.

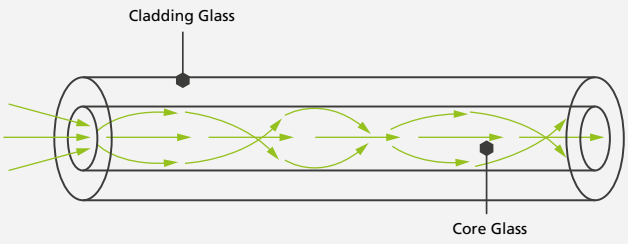
The need to connect optical fibers, e.g. on a cable laying ship mid Atlantic Ocean, led to the development of international standards for optical fibers and connecting technologies, now including at least 23 types of SM optical fiber and 24 types of MM optical fiber. Nowadays, the main data center transmission applications require the use of one type of SM and two types MM optical fiber.

In the 50 years following its conception in 1966, the amount of fiber installed globally per year has risen to more than 422 million km with the balance of optical fiber heavily weighted towards SM (>95% SM vs <5% MM).

**SINGLE MODE**




**MULTIMODE**



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**Similarities**

The overall diameter of the cladding (outer layer of the glass) is the same for telecommunication MM and SM optical fiber, this is seen in other ways to describe optical fiber such as 8/125, 9/125, 50/125, 62.5/125 microns. The first number is the core diameter and the second number is the cladding diameter. The 125 cladding diameter was agreed on in an International Electrotechnical Commission (IEC) standards meeting compromising between the higher and lower diameters made by competing companies.

The materials used for SM and MM optical fiber are the same: silicon dioxide ($SiO_2$) for the glass structure of core, cladding, and additionally very small amounts of germanium (Ge) in the core to achieve a higher refractive index.

The protective coating materials used are common to both: two or three thin, flexible layers of polymer adhering to the 125 surface up to 250 micron. The outer layer contains pigment to help with identification.

Optical fibers must be packaged in protective cables to be used practically. These cables provide different types of protection depending on the installation method, the location in which the cables are being installed and the expected environment.

**Differences**

The most significant difference between SM and MM optical fiber is the size of the core and the impact this has on the transmission of signals and the active transmission/receiving (TX/RX) equipment that can be used.

SM fiber requires SM light sources which are edge-emitting LASERs (Light Amplification by Stimulated Emission of Radiation) for wavelengths from 1260nm to 1625nm. MM optical fiber operates at 850nm using lower cost VCSEL (Vertical Cavity Surface Emitting Lasers) MM light sources.

The key ingredient that makes optical fiber more than just a glass rod is germanium. This is a rare element that is used in other industries and is therefore in high demand. The quantity of germanium in MM fiber is significantly higher than in SM fiber which has an impact on the relative cost of the optical fiber types.

SM fiber can be used for any length of route from a few meters to hundreds of km as it has the benefit of optical amplification along the route for long distances, whereas MM fiber is used for routes from a few meters to 2 km.

The balance between the cost of active equipment and the cost of the optical fiber used is part of network owners' and designers' decision making process for short distance networks.

*Discussion limited to SM and MM fiber used in telecommunication applications*