Dream Merchants - The Evolution of Fibre Optics

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(*This essay is dedicated to those scientists and technologists who had to had unfortunate second deaths from the world of memory, unsung and unwept.)*

Prasanth got some new information on quantum well structure, which he wanted to pass on to his friend Jayaprakash who is working for a Photonics firm in Delhi. Sitting in his research room in the Physics Department of Eindhoven Univesity of Technology, The Netherlands, Prasanth called Jayaprakash. He agreed to pass on the message to their batch mate Mary Praveena who is at present working on behalf of Tata Consultancy in UK. Mary got the message within minutes through a clear and sharp telephone call from New Delhi. During the fifties and sixties it was a luxury to call relatives living few hundred kilometres away – it was in deed a luxury to own a telephone at all! Such and similar technological wonders are the daily work of fibre optics.

When one starts to document the history of fibre optics (FO), which is said to came in existence and development only during the last fifty years, he gets astonished to find the roots of F O extends back to more than one and a half century. It took the cast of thousands to develop the pieces and putting them together to solve the jigsaw puzzle of FO.

The basic concept behind the FO began as a thing of beauty (which is joy for ever). Over the decades scientists, most of them melted in to oblivion, exchanged ideas, invented and re-invented ways to guide light through curved paths. The trickle of innovation reached a critical mass in 1950s and the young technology slowly emerged in to the daily world. In 1956 Narinder Kapany who took an important role in the whole drama coined the word Fibre optics. In twenty years a series of break through transformed a crazy idea in to the backbone of the global telecommunication network. In the present course, we are going to do a systematic study of the Science & Technology of FO and its applications in variety of fields.

Daniel Colladon, a 38-year-old professor at University of Geneva, demonstrated the light guiding for the first time in 1841. He wanted to show the fluid flow through various holes of a tank and the breaking up of water jets. In the lecture hall audience could not see the flowing water. He solved the problem by collecting and piping sunlight through a tube to the lecture table. The light was focussed through the water tank and was made to incident on the edge of the jet at a glancing angle. Total Internal Reflection (TIR) trapped the light in the liquid forcing it to follow the curved path till the water jet broke up. Instead of travelling in straight line, the light followed the curvature of the water flow. Colladon later on wrote:

I managed to illuminate the interior of a stream in a dark space. I have discovered that this strange arrangement offers in results one of the most beautiful, and most curious experiments that one can perform in a course on Optics." (Comptes Rendes, **15,** 800-802 Oct. 24, 1842).

Colladon demonstrated light guiding in water jets through a number of public performances to the urban intelligentsia of Paris. Auguste de la Rive , another Geneva Physicist, duplicated Colladon's experiment using electric arc light. Colladon designed a spectacular device using arc light for Conservatory of Arts and Science of Paris in 1841, Oct.. Colladon sent a paper to his friend Francois Arago who headed the French Academy of Sciences and edited its journal *Comptes Renedes*. Arago recalled that jacques Babinet, a French specialist in Optics (remember Babinet compensator) had made similar demonstrations in Paris. He focussed candle light on to the bottom of a glass bottle as he poured a thin stream of water from the top. TIR guided the light along the jet. Arago asked Babinet to write down his work. But Babinet did not think that the work is very important. Yet he made a comment "*the idea also works very well with a glass shaft curved in what ever manner and I had indicated that (it could be used) to illuminate the inside of the mouth (*Comptes Rendes **15, Oct. 24,** 1842). After sending his letter to Arago, Babinet never returned to guiding of light before he died in 1872.

In 1849,Paris Opera was experimenting with arc light in lighting the theatre, especially for special effect. Colladon helped the Opera to duplicate his light guiding trick to catch the attention of the audience. In Gounod's Opera, " *Faust"*, Mephistopheles made a stream of fire flash from a wine barrel. Audience exploded in delight when light from an arc lamp focussed along red glass tube filled with water causing the magic to occur. In 1885, Opera became a crowd puller and tricks like creation of suns, rainbows and lightning were brought to the theatre. Colladon's assistant Duboscq designed and illustrated an 1877 catalogue with a number of luminous fountains where light played on dancing water in a variety of hues. Paris, in fact, became famous as the City of Light.

In 1884, at the international Health Exhibition in South Kensington district of London, an engineer by name Sir Francis Bolton constructed huge multilevel luminous water fountain. Colladon did not want his light jet to be forgotten. *La Nature* published "Colladon Fountain" in 1884. To make the 50th year of Queen Victoria's reign W.J Gallows & Sons of Manchester constructed 120 feet " fairy fountain" at the cost of 3943 pounds.

Planners of Paris Fair made water engineer Bechmann to construct a spectacular water fountain in the entrance of 1889Universal Exposition Fair, As in *Faust* water seemed alive with light as luminous water sprouting from the mouth of sculptured dolphins and then descending in graceful parabolas. *Scientific American* of Dec. 14, 1889 described the wonderful displays in detail.

Variety of luminous fountains brightened nights at the 1894 World's Fair in Chicago also. An American Engineer William Wheeler was more practical. In 1880 he filed a patent to illuminate houses by piping light from an electric arc in the basement. Just like gas and water, light can also be piped out. The heart of Wheeler's idea was a hollow glass pipe coated with silver on the outside and protected by asphalt. They did not guide light TIR but by continued light reflections at the wall of the tubes. Solid glass rods did not enter the picture since it cannot transmit light with out losses. Edison invented year before he filed the patent, incandescent bulb and the light pipes never got off the ground. But Wheeler Reflector Company did make street lamp reflectors until late 1950s.

In 1884, Dr Roth and Prof Reuss of Vienna devised a method of using TIR through a glass rod to illuminate internal organs. In 1898, David Smith of Indianapolis patented a dental illuminator using curved glass rod. These and many of the similar designs were only in papers without any body trying to make them.

In 1930s Dupont developed clear, lighter, cheaper and durable plastic that quickly replaced glass and quartz illuminators. Light guiding effect that Colladon had conceived as a thing of beauty was evolving in to a useful technology with mundane applications. Yet he would have been furious to see the pioneers of FO assigned the credit of light guiding in a water jet not to him but to John Tyndall, who first demonstrated it 13 years after the performance of Colladon (see for example *Introduction to Fibre Optics,* Thyagarajan & Ghatak).

John Tyndall joined the Royal Institution in London in 1853 and quickly made a name himself by giving informative and entertaining talks in a long running series of Friday evening lectures. He was in trouble on May 19, 1854 since the demonstration he planned was not ready. His mentor Michel Faraday suggested him to demonstrate the flow of water jets and how TIR could guide the light along the flowing liquid. The demonstration was well received. Tyndall did not give much importance to the phenomenon of light guidance since TIR was a well-known phenomenon. He considered the light guiding as too obvious to be named as an application. He did not credit it to any body. Probably he did not know whose idea it was. Then how come that the credit is attributed to Tyndall by the later scientists?

Faraday's failing memory by 1840 could not point out the name of some one who performed the demonstration in Paris earlier even though he could remember the event. The name could have been Daniel Colladon since Faraday spent the summer of 1841 in Switzerland and was the friend of de la Rive who duplicated Colladon's experiment exactly at that time. Faraday could not remember the name and Tyndall ignored the issue.

An outspoken man of wide range of interest, Tyndall was a Victorian version of Carl Sagan, scientist, populariser and public figure. In one of his widely circulated books (Light & Electricity, by John Tyndall, published by Appletons & Co, NY, 1871) he described the water jet experiment and was in print for many years. When later scientists went back to look for the origins of light guiding, they came up on Tyndall's account. By then Colladon's papers were buried on the back of shelves of scholarly libraries, unreferenced and forgotten and Tyndall was credited with the invention over half a century after he and Colladon had died

The first publication to credit Tyndall was that of Narinder Kapany (“ Fibre Optics”, Scientific American, **203** (5), 1281, 1960. As FO spread most people accepted Tyndall as the originator of the idea. The OSA later named its annual FO award after Tyndall. A few people uncovered Colladon’s and Babinet’s papers in late 1960s. But n one took notice of it.

The difference between the glass rods and fibres is merely a matter of diameter. The Egyptians made coarse fibres by 1600BC and fibre decoration on Egyptian potteries dates back to 1375 BC. During Renaissance, Venetian glass makers used glass fibres to decorate the surfaces of plain glass vessels and the technology was guarded as family secrets. By the turn of the 18th century, Rene de Reaumur, founder of the French iron and steel industry made fibres by rotating a wheel through a pool of molten glass where the hot thick liquid stuck to the wheel. But his fibres were brittle.

By mid 1870s glass fibres finer than silk were drawn which could be woven in to fabrics or decorative feather to hats. The properties of the spun glass caught the eyes of Charles Vernon Boys, a young Demonstrator of Physics at the Royal College of Science in the South Kensington district of London. His passion was building up of sensitive scientific instruments. The classes were unwelcome interruptions for him. H G Wells, who suffered through them, called Boys one of the worst teachers who always faced the blackboard, messing it out and hurrying back to the apparatus in his private room.

In 1887, Boys invented an ingenious way to make thin and uniform glass fibre. He built a miniature cross bow and made light arrows by fastening a needle to a piece of straw of few inches long. The arrow was stuck to one end of a glass rod with sealing wax and heated the glass till it softened. Then the arrow was fired across two long rooms with a foot trigger. The little arrow pulled a fibre tail from the molten glass. When the arrow landed, Boys found a thread 90feet long and 1/10,000 inch in diameter; so uniform that the diameter on one end was only one sixth more than the other. By many trials, he could make thin quartz fibres “*so fine that I believe them to be beyond the power of any possible microscope”* as reported by him at the Physical Society in London on March 26, 1887.

Quartz fibres, which Boys made, were as strong as steel wire of the same size – a marvel for a material, which always considered as fragile. He used the quartz fibre for suspension in torsion balances. Boys devised an instrument that could detect heat from a candle kept at a very large distance (he claimed 3kms!). He also discovered that many fibres kept parallel to each other acted like grating. Yet he did not ventured in to study of light guiding through fibre.

A German immegrant Herman Hammesfahr patented glass fibres in America. In 1892 Chicago World fair, on behalf of Libby Glass Company, he demonstrated the glass fabric for lampshade. Actress Georgia Cayven ordered a dress made of the fabric. Libby showed the dress during the fair. Amongst many others, Princess Eulalie of Spain paid $ 30,000/- for a copy of the dress. However, there was a serious draw back in the glass fabrics, it was brittle.

Industry later on found more uses for fibres besides clothing – liquid filters, bandages and thermal insulator to mention a few.

Glass fibres remained a speciality item for the first three decades of the 20th century. Only in Germany did an industry developed since Allied embargoes cut the supply of asbestos after the first WW. In December 1931, Owens – Illinois Glass Company in Newark, Ohio demonstrated first commercially viable technique for mass producing inexpensive glass fibres. Their process yielded fleecy mass of flexible fibres – glass wool.

The Corning Glass Works was also working on glass fibres and two companies launched a joint venture, the Owens – Corning Fibre Glass Corporation. By 1935, they produced fibres so strong, fine and flexible that they could be woven in to cloth, which could be bent and folded without breaking fibres – thereby, removing the cause of worry of the girls in the glass dress 30 years earlier. Nobody paid much attention to the optical properties of glass fibres, other than when they glittered in fabrics on display.

From Victorian era in to early 20th century, inventors took many approaches to achieve what they called remote viewing. Telegraphs had been sending messages for decades; Alexander Graham Bell had launched the telephone era in 1876; sending pictures seemed just another logical step.

By the early 1920s, electronic technology had brought radio broadcasting to the threshold of practice. To handful men, television seemed to be a natural extension of radio. The early leaders were John Logie Baird in Britain and C Francis Jenkins in America.

Born in Scotland, in 1888, Baird was a blend of visionary engineer, enterpreneur and self-promoter with a dash of crackpot. In April 1925, he conducted the first public demonstration of television at Selfridge Department Store in London. The image showed only eight lines per frame. Later he built first television system used by BBC employing a spinning disc to scan 30 lines per frame. Baird had 178 patents covering a wide range of ideas. One was sending an image through an array of parallel tubes, transparent rods or clear fibres, which could be bent or curved.

Born in Ohio in 1867, C Francis Jenkins began thinking of television in 1894 and preoccupied with it most of the rest of his life. The founder president of Society of Motion Picture Engineers, Jenkins fell behind Baird by a couple of months. However, Jenkins knew more optics. One of his receivers used quartz rods to carry light and on 5th of May 1925, he transmitted “Radio- Movies” across a room.

Jenkin’s Television Company made some receivers and stations in Washington DC and Jercy City. Soon the company ran out of money and in September 1929, De Forest Radio took over Jenkins’ Television. De Forest Radios and Jenkins both failed during the great Depression and Jenkins died in 1934, ill at heart.

After the first WW, many of the bright young engineers joined the fast growing RCA, newly formed and flourishing company of America. Among them was Clarence Weston Hansel, or CW. Born on 20th January 1898 in Medaryville, Indiana; Hansell was the eldest of eight children in a poor family. After earning a degree in electrical engineering, he briefly worked for the General Electric before it directed its radio business to the newly formed RCA. In 1922, Hansell developed and installed the first vacuum tube transmitter for commercial wirless telegraphy across the Atlantic. In 1925, he founded the RCA radio transmission laboratory at Rocky point, Long Island that he headed for over 30 years. He bought a house on the LI and raised the family there. Hansell collected over 300 US patents. In 1926, December 30, he filed an application for patent which says ' *Method for transferring a dial reading to a distance."* The technique involved the use of a cable of parallel-laid quartz fibres the ends of which can be cut off plane. Light from the instrument will fall on the ends of fibres and will get transmitted through fibres as an image in the other end. No light will pass from one fibre to other due to TIR. Hansell described other applications also like flexible periscope and quartz fibre endoscope for surgeons. He also found another use as well – a picture transfer cable using fibre bundle. The image can also be scrambled so that pictures cannot be stolen.

Hansell, however, did not make any device. By the time his patent was issued in 1930, he was on to new inventions. When his friend Edwin Land showed him the Young Polaroid Corporation's plastic polarizing material, Hansell suggested that it might make good sunglasses. Land rewarded him with the first pair of the production line. Hansell also developed a technique to print on paper by controlling the flow of an ink jet. His printer could record 750 words per minutes, from a radio telegraph- an astounding speed in the 30s. However, RCA was not impressed and Hansell reluctantly put off the idea on the shelf. Today millions of low cost inkjet printers are used with PCs.

As Hansell and RCA moved on to other things, a medical student in Germany came up on the same idea of image transfer from a different direction Heinrich Lamm wanted to build a flexible gastroscope that a physician could thread down a patient's throat to peer in to stomach. Physicians of 19th century tried rigid tube, which was not viable. Such rigid gastroscope was described as " one of the most lethal instruments in the surgeon's kit ".

After the WW I, a medical doctor, Rudolf Schindler spent a decade in developing semi flexible gastroscope that could be bent up to 30 degrees. Lamm was his student. He found that the device was not flexible enough. Like Hansell, Lamm realized that a bundle of fibres could be used as flexible gastroscope. Schindler was not impressed with Lamm who was a third year medical student. Lamm got help from a Physics student, Walther Gerlach (who later involved in the development of the abortive programme of German Atomic Bomb) and got fibres from G. Rhodenstock Optical Works. Lamm was able to transmit the image of letter ' V ' using the fibre bundle and recorded the image using photographic film. The glass was not very clear, fibres were not smoothly aligned and ends were not polished smooth, so that the image was not sharp and bright. However, the 22 year old medical student had transmitted the first fibre optic image. The year was 1930.

Lamm hurried to German Patent Office, where he was astonished to hear that a British version of Hansell's patent had just issued. The disappointed Lamm wrote to the

British Licencee, the Marcony Company , who said that neither they nor Hansell have tried to utilize this principle.

Lamm wrote a paper which was published by Zeitschrift fur Instrumentenkunde in October 1930. He concluded the paper by saying" *I also hope that some optical firm possessed of more means , sources of supply and experience could be induced by this report to build a serviceable flexible gastroscope."*

Lamm's hope was in vain. His paper and Hansell's patent sank in to oblivion without a trace. The crucial technological puzzle was the low intensity of the image. The rise of Adolf Hitler brought trouble to Lamm, a Jew. He and his physician wife fled Germany. They reached America in 1937. In 1938, they settled down at the exotic place in the southern tip of Texas and started practicing medicine. It was a welcome relief from Germany.

RCA had resources that Lamm lacked but the company filed Hansell's patent and forgot it. Fibre studies were only a foot note to the work of Rocky Point. In 1930, Du Pont invented transparent plastic called Lucite in America and Perspex in England. The durable, light weight material replaced quartz. Dentists used curved lucite rods to illuminate mouth. Yet the idea of imaging through bundles of thin fibres was stillborn. While Hansell conceived the idea at RCA, Company did nothing about it. Jenkins was right in saying *" no great pioneer invention could come from a giant corporaion."* RCA and perhaps Hansell himself never saw the potential of fibres and drifted away leaving its development to others.

Heinrich Lamm and C W Hansell lacked not merely resources but the crucial bit of inspiration. They did not realise that light was leaking between bare fibres where they touched each other. The solution was simple : cladding of the light carrying fibre with transparent material that had lower refractive index. Two decades after Hansell and Lamm, the idea sprouted separately in the fertile minds of two very different men. One was an eminent professor, a product of mid century American science. The other was a Danish inventor labouring in a small home workshop.

Abraham van Heel, president of the International Commission for Optics and Professor of Physics at the Technical University of Delft, the Netherlands was commissioned by the Dutch government to build better periscopes for their subs. Knowing how curved glass or plastic rods could carry light, van Heel thought of thin fibres to relay images in a periscope. His assistant William Brouwer suggested that the fibre bundle could scramble images as well and transmit them – an idea that excited Dutch Security agency. The idea seemed good. But van Heel made little progress. He even tried fibres coated with silver to enhance the reflection. Still the light coming out of the fibre was not intense enough. Dutch Government approached American Allies to recommend somebody to lend a hand. Thus, in 1951, van Heel was talking to Brian O'Brian, President of Optical Society of America (OSA) and director of America's leading school of Optics at the University of Rochester at the residence of the later. The American knew that metal coating will only worsen the situation since it will absorb a part of the incident light so that after 100 reflections only 0.0043% is left inside the fibre. O'Brian suggested to stick on to TIR and clad the fibre with materials of lower refractive index than that of the fibre material. Van Heel was annoyed that he did not thought of this earlier. They came to the conclusion that both will keep the contact live and will discuss before anything send for publication. Lack of communication facility during the 1950s ruptured what could have been a fruitful collaboration.

Brian was not the only one thinking of cladding the light wave guide in 1951. On April 11, Holger Moller Hansen applied for a Danish Patent namely " flexible picture transport cable". Like Lamm, Hansen also thought of fibre bundles of glass or plastic fibre to transmit images. Unlike Lamm, Hansen was a trained engineer. He wrote in the application " eventually the threads wil be coated with a substance whose index of refraction approaches one". Moller had the same idea that O'Brian suggested to va Heel six month later, The segmented eye of the fly inspired Moller to consider the use of fibre bundle to transmit images. He found that Canada balsam oil is a good cladding material.

After filing for the patent in 1951, enthusiastic Moller broke the news to the world. He accumulated a fat file of press clippings. But the patent was denied the patent after discovering the patent of Hansel. Moller could have had a clear priority on the crucial idea of applying loe index cladding. Unfortunately, neither Hansen nor the Danish Patent Office realized the importance of cladding and his patent claims died. Hansen with his home work shop could not continue the work. Frustrated he turned to another idea that he could pursue in his impoverished workshop—plastic bubble " shock absorbers" for mailing envelopes. He did patented the idea, but it did not make him rich. Such envelopes are still being widely used.

Van Heel returned from America enthusiastic about cladded fibres. He and Brouwer pulled fibres through liquid plastic so as to get cladded fibres. By April 1952, they sent images through bundles of 400 fibres as long as a distance of half a metre. Seeing more opportunity in America Brouwer left the group and crossed thr Atlantic to join a firm to work on military optics, thus abandoning fibre optics. Van Heel's Dutch colleague Fritz Zernicke returned from England and told va Heel about the work of Harold Hopkins, an optics specialist at Imperial College London who claimed that he had invented a method to send images through fibre bundles.

Van Heel mailed a letter to O' Brian. Trans Atlantic calls were out of question. Receiving no reply, van Heel rushed a note to *Nature* which received on May 21, 1953. He sent a larger version to *De Ingenieur*, a Dutch weekly. The Dutch magazine published the article on June 12, 1953, documenting Heel's priority.

Van Heel did not call his invention Fibre Optics. His article was titled "*optical representation of images with out the use of lenses or mirrors." He* described cladding fibres sending images through fibre bundles up to a distance of 20cms. He wrote that plastic fibres of 0.1 to 0.13mm thick worked best with potential uses in medicine and image coding.

Harold Horace Hopkins was a young rising star in the world of European Optics. Born on December 6, 1918 in Leicester, Hopkins took doctorate from University of London and afterwards became a faculty member at the Imperial College. He designed first zoom lens that worked as standard fixed –focus lens also. At a 1951 dinner party , a physician asked him whether flexible instrument can be made to look in to the stomach.

Hopkins tried flexible bundles of fibres. He tested a fibre of 20micron diameter and found that bright light comes out through the fibre of length 1.2 metres. In July 1952, he got a grant of 1500 pounds from the Royal Society which included money for a research assistant. Hopkins offered the assistanceship to an ambitious Indian called Narinder Kapani.

Kapani was born in Moga, Punjab in a well educated family. After graduating from Punjab University Kapani studied Optics at Imperial College. He was thinking of coming back to India to start an Optics company when the offer from Hopkins came. He jumped at the chance to work with Hopkins. Hopkins and Kapany made bundles of up to 20,000 fibres (each fibre of 25microns dia.)by clamping at both ends as well as at some points in between. It took several months to get the whole thing get functioned. They transmitted the letters 'GLAS' through their fibre cable.

In November 1953, Hopkins and Kapany sent a letter to *Nature* which got published on january2, 1954 just below van Heel's long delayed paper. People like Brouwer believe that Hopkins might have got the publication of Heel's paper delayed or he himself could have been the referee of the Heels paper.. Yet till his death Hopkins denied the responsibility saying that he did not see the paper. The two Nature papers do not refer each other and take rather different approaches. Van Heel used transparent cladding but used only less number of fibre strands while Hopkins and Kapany used thousands of fibres to make fibre cable. The two Nature Papers launched the modern FO.

Hopkins and Kapany worked on fibre bundles through 1954 eventually making 75 cm thick cable. They developed faster winding machinery , a practical necessity when on bundle included about 50km of fibre. They analysed light collection and other properties of the fibre bundle, but never tested claddings.

In 1955,Kapany became the first doctorate in FO . Kapany and Hopkins fell to quarrelling even before the ink of the thesis got dried up. Hopkins complained that Kapany claimed too much credit for the concept. Hopkins died in October 1994 with out bridging the gap between the teacher and the student.

Kapany , seeking better future left for America. Kapany wrote a series of scholarly papers in the JOSA that outlined the basic principle of FO. From 1955 to 65 kapany was the lead author of 46 papers . It was Kapany who wrote a lead article on fibre optics in *Scientific American* and the first on fibre optics. Kapany's writings spread the gospel of fibre optics which cast him as a pioneer in the field.

A native of South Africa born in 1925, Hirschowitz studied gastroenterology in London. In mid 1953, he joined the University of Michigan to take up a fellowship. Hirschowitz saw the Nature papers and found the possibility of a flexible gastroscopes. He and his supervisor , Marvin Pollard of Michigan and C Wilbur 'Pete' Peters , a 36 year old Optics Professor in the Physics Department formed a team. Pollard invited Kapany also to join them. Kapany, however, joined the team of Bob Hopkins at university of Rochester. His job also included consulting for Bausch & Lamb, a big Rochester Company.

Peters filled the vacancy of physicist with a bright physics student , Lawrence Curtiss who was still in his teens and has yet to complete graduation. Curtiss studied papers of van Heel and Hopkins& Kapany. Curtiss followed instructions of Hopkins and Kapany to make his own fibre bundle. He found that his short bundle did not transmit light at all. The Michigan Team got clear gall rods with high refractive index of 1.69 from Croning Glass works. With tiny budget the little group developed an apparatus which cost them less then $250. They were able to draw good fibres . But when the fibres were bundled , problem has arisen again. The bundle did not transmit light effectively. In summer of 1956, Curtiss took the problem to a group of professors who were playing bridge during the lunch hours in the laboratory basement. They gave a unanimous solution- use cladding to the fibre and the glass cladding would be better. The team presented a brief report in October 1956 at Lake Placid, NY, in which the use of plastic cladded fibre to reduce cross talk was high lighted.

In Dec.1958, while professors were away for attending a conference, Curtiss developed a novel technique to produce glass cladded fibre. He put a glass rod of high refractive index inside a glass tube made of low refractive index glass and the tube was melted on to the glass rod to make a preform. Curtiss used this preform to draw glass cladded OF for the first time. He built a system which can draw fibres at the rate of 8fm per hour . They made 40 km long fibre to fabricate a fibre cable with 40,000 fibres.

Hirschowitz filed a patent on gastroscope on 28th Dec 1956 with rights shared between Peters and Curtiss. Curtiss applied for patent on glass cladded fibres on May 1957 assigning part to Peters and Hirschowitz. The Michigan team made the first gastroscope with glass cladded fibre. The tip which went inside the stomach included a small illuminating lamp and optics to collect and focus light on to the end of the bundle in the stomach. Hirschowitz swallowed it first. Few days later , Feb18, 1957, he tested on his first patient , a small woman who had an ulcer.

Marvin Pollard arranged a reception in which he wanted to test it first. But Hirschowitz did not wait for him and exhibited the device to the guests. Furious Pollard confiscated the endoscope and locked it in a safe. To make matters worse, Pollard was not given a part of patent right since he was not involved in the programme. He blocked Hirschowitz from getting a permanent job at Michigan. Curtiss made a second piece for Hirschowitz which was demonstrated publicly. The whole project cost the Michigan team about $ 5500 for two years; nearly $4000 being the pay of Curtiss. Ao, CIA, Bawsch & Lomb probably spent far more.

CIA was frustrated that AO project was not progressing. They sought new talent. Will Hicks, a 30 year old Physicist from Greenville, South Carolina, arrived at AO in September 1954. After initial briefing O'Brian gave Hicks the job right away: develop image scrambler using plastic clad fibres. Security- conscious CIA used gastroscopes as 'Cover" the project. By 1956, Hicks deviced a method of producing glass cladded fibres instead of plastic cladded ones. He used a pair of nested platinum crucibles melting the low index glass in the outer one

and high index glass in the inner crucible. He pulled the bibre through concentric holes at the bottom of the crucible. But the quality of the fibre was not good.
Hicks met Peters and Curtiss at Lake Placid meeting and had mutual discussions. In October 1956, a retired profess of Physics from MIT , Frederick H Norton joined the AO. Norton , taking the idea from ancient makers of miniature glass portraits, suggested that many cladded fibre could be assembled together and in the same way as glass artists do with coloured glass rods (the method is known as millifiori) and can be drawn in to a rigid multifibre. Hicks made the device in Jan 1957 and demonstrated the image scanning. But there was a catch. An efficient person can decode the message just by 18 scrambled pictures.

Hirschowitz tested first commercial gastroscope in 1960 at the university of Alabama Hospital in Birmingham. Other doctors also adopted them and there was dramatic progress and by late 1960s fibre endoscope replaced lensed gastroscopes completely.

Hick together his friend Bill Gardner found yet another use of fibre – fibre face plates. Fibre face plate can be obtained by slicing fused fibre bundle. The sliced face plate , on polishing, acted as image intensifiers. Relation between Hick and AO became strained and Hick walked out with his technology of face plate and established ‘Mosaic Foundations”. Hick managed to make 12 inch face plate for Navy when the standard was only 1 inch. The Mosaic Foundations grew rapidly to one of the major FO companies in the world.

The Michigan group, American Cystoscope Makers, Mosaic Foundations and AO were concentrating on practical instruments. Both Mosaic Foundations and AO invented Y-shaped bundles that could combine or split images. On tapering the bundles, images are magnified or shrank. America’s first doctorate in FO from Rochestor. Bob Potter, used fibres to make punched card reader (used in computers during that time).

Flexible fibre bundles soon spread beyond medicine. AO developed bundles 9 feet and 15 feet long for NASA to test Saturn boosters used in Apollo. Fibres also entered in the drawing room as decorative item.

Even though laser in 1960 brought optical communication in to spotlight, nobody gave much thought to communicate using fibre. Physicists believed intuitively that no solid can be as clear as air. Hicks made some calculations to get discouraging results. He did not realize until later that he had made a mistake. This was similar to the case of Heisenberg who made a mistake in calculating the criticality condition of fission reaction and this mistake made Hitler to stop activitires related to the development of atom bomb which in turn changed the world history it self.

It was the work of Charles Kao to perfect clear glass fibres which gave a boost to the fibre optic communication. In his words “ *If you really look at it, I was trying to sell a dream….There was very little I could put in concrete to tell these people it was really real.”* His theoretical analysis, experiments and mission like zeal launched Fibre Optic Communication, first at Stanford Telecommunication Labs and later world wide.

Daniel Keck , Robert Maurier and Peter Schultz of Corning made first low loss fibres. Invention of room temperature diode laser by a team of scientists led by Zhores Alferov , Izuottayashi and his group at Bell labs gave a boost to FOC. John Macchesnay and Paul o'Conner of Bell Labs used CVD (Chemical vapour deposition) technique to get 15 kms of fibre from one single perform. Invention of long wavelength semi conductor laser by J Lim Hsieh followed by Masahara Horiguchi opening the long wave length windows for FO are two important landmarks. Revolution in Communication took it highest peak when Mashahiro Kawahata helped FO communication to reach houses.

Another landmark in the history of FO is the progress made in non linear Fibre optics. Raman amplifiers were developed by Will Hicks to produce all optic repeaters. Arrival of erbium doped fibres was a boon to the field of FOC. Shifting to near zero dispersion at 1.55 microns, Mollenauer used optical solitons for communication. Masataka Nakawawa of NTT laboratory claimed " soliton transmission over unlimited distances". In 1993, In 1993, during a FO conference at Sanjose convention centre, Mollenauer used a simple method to send 10billion bits per second through 20,000 km of fibre. In 1996, Bell Labs reached the trillion – bit milestone.

Telecommunication companies are multiplying the capacity of long distance systems by adding extra wave lengths. By the end of 1998, Lucent Technology delivered 400 billion bits per second – 10 billion bits at 40 different wavelengths through a single fibre using a technique called Wave length Division Multiplexing (WDM).

The Global Fibre Net Work has become a reality, In few years, one terminal of SEA-ME-WE FO Link will reach Cochin also – there by linking us also in to the result of the 99% perspiration and 1% inspiration of a number of scientists, technologists and visionaries whose existence has spanned to the remotest past – they had a dream to sell and they really sold it.