There is a single light of science, and to brighten it anywhere is to brighten it everywhere. Isaac Asimov

Fabrication of Polymer optical fibers

For drawing polymer optical fibers (POF), an indigenously developed optical fiber drawing tower has been used. This chapter discusses in detail about the fabrication and working of the POF drawing tower.
2.1 Introduction:

Polymer optical fibers (POFs) [1] were introduced by Dupont in the mid 1960s at approximately the same time when glass optical fiber (GOF) was suggested as a transmission medium for communication. Dupont's fiber was having a polymethylmethacrylate (PMMA) core and fluoropolymer cladding, with a step index refractive index profile. Even though POF has the fascinating ability to guide light, it had limited applicability due to large attenuation (~dB/m) and hence negligible commercial value. At the same time GOFs had attenuation in excess of 1000dB/Km, which made its use in optical communication impractical [2]. In 1976, Mitsubishi rayon introduced Eska™ by further developing DuPont's extrusion technology. It had an attenuation of 300dB/km which limited its application to lighting only (illumination). The core was PMMA and polyfluoroalkyl methacrylate was the cladding for Eska™[3-5].

By 1970s the attenuation of POF came down to 160dB/km at a wavelength of 650nm and 20dB/km at 680nm using deuterated PMMA (PMMA-d8) [6, 7]. All these were SI fibers. Only by 1976 the first graded index (GI) POF came into existence. It was Ohtsuka and Hatanaka who made GIPOF by heat drawing graded index plastic rod [8]. Earlier, graded index plastic rods were prepared by two different methods, namely two-step copolymerization and photo-copolymerization [9-15]. But the attenuation was found to be fairly large for the fibers drawn from preforms made by the above methods. Soon interfacial gel polymerization technique came into existence and fibers with fairly negligible attenuation were fabricated [16-22].

With great strides made in the field of GIPOFs in reducing loss parameters, many applications like high bandwidth data communication for LAN and home network were realized [23,24]. Possibility of realizing larger diameter...
of POFs made splicing more easy and allowed the use of low cost light sources and connectors.

2.2 Fabrication of step index and graded index plastic optical fibers

2.2.1 Step-index fibers

A step index fiber has a simple structure owing to its simpler fabrication techniques. The most common methods used are a) continuous extrusion method and b) preform method.

2.2.1.1 Continuous extrusion method:

This method was successfully developed by Mitsubishi rayon [3, 4], and is one of the well-developed methods for developing step index polymer optical fibers (SIPOF). In this method, a purified monomer (methylmethacrylate), an initiator and a chain transfer agent are fed into a polymerization reactor, where polymerization takes place. The polymer thus formed is then fed into an extruder by a gear pump. This is the core material for the SIPOF. The core material and the cladding material, which are fed by separate extruders, proceed into a co-extrusion die or spinning block, where concentric core–cladding structure of SIPOF is formed.

The most important advantage of continuous extrusion is high production rate. The drawback is that this cannot be operated continuously since the materials used for extruding SIPOF gets thermally degraded as time progresses. This will, in turn, have adverse effect on the optical properties of the fiber.
2.2.1.2 Preform method:

Fabrication of POFs by preform method involves two stages. In the first stage a cylindrical preform of 1-5 cm in diameter and up to 1m in length is made. In the second stage, the preform is drawn into fiber by the heat-drawing process.

Preform –making process:

In the fabrication of glass optical fibers, fabrication techniques like MCVD (modified chemical vapour deposition), OVD (outside vapour deposition) and VAD (Vapour axial deposition) methods are used. One of the familiar methods is applied here to make a preform for POFs. A cylindrical tube, which serves as the cladding layer is made by polymerizing a cladding material inside a rotating cylindrical reactor. Materials that can be polymerized by the radical polymerization reaction are used and the reaction is induced thermally or by UV radiation using photo initiator. Due to the fast rotational speed of the reactor about its axis, a tube of uniform thickness is formed once the reaction is complete. This tube is then removed from the reactor and filled with a core material mixed with an initiator and a chain transfer agent. The core material is then polymerized to make a preform that is drawn to a fiber by heat-drawing process.

There are two other commonly used methods for preform fabrication. First is the rod-in-tube method, in which a pre-fabricated polymer core rod is inserted into a pre-fabricated polymer cladding tube with a tight-fitting [25]. The disadvantage of this method is that the rod diameter is usually too large for the drawn fiber to achieve a single-mode operation. Also bubbles may be trapped at the core-cladding interface. The second method is the hole-in-rod technique [26] where a hole is drilled into a cladding polymer rod followed by pouring in core monomer. A polymerization process is then initiated to
obtain a composite core-cladding polymer preform. The core-cladding interface of this preform may not be smooth because of drilling. This could lead to excessive loss.

"Teflon technique" [27] is the most successful technique for the fabrication of the preform. In this technique a thin teflon string is properly fixed in the center of a glass tube. The thermal polymerization of the filled tube is carried out in a temperature controlled oil bath. After the monomers are fully polymerized and heat treated, the teflon string is removed and we obtain a polymer tube (polymer rod with a small hole in its center). The bottom side of the core is sealed and the hole is then filled with the initiated monomers for the core. Again it is kept in an oil bath for further polymerization.

The advantages of using the Teflon technique in the fabrication of polymer preform are a) its nonsticking property allows the string to be easily removed b) it has a very good chemical and thermal stability c) it gives smooth finish for the inner surface of the polymer tube. d) it gives good core-cladding interface and hence reduces the losses due to scattering.

Heat drawing process:

The heat drawing process is shown schematically in figure 2.1. The preform is positioned vertically in the middle of the furnace (or oven) where its lower portion is heated locally to the drawing temperature [28-30]. Both convective and radiative heat transfer mechanisms are important in heating the preform. When the lower part of the preform reaches a temperature beyond its softening point, it necks downward by its own weight due to gravity. Once this initiation of the drawing process is achieved, tension is applied to the fiber by drawing rollers and the fiber is drawn continuously while the preform is fed at a pre-determined rate.
The fiber diameter is continuously measured and the desired value is maintained by controlling the speed of the roller. Another design of the fiber drawing system is the horizontal drawing rig. The only difference in this case from the conventional drawing system is that the whole drawing procedure is horizontal. GD Peng et al [27] has widely used this type of configuration and has observed no fiber sagging during drawing and the fiber diameter was kept at an acceptable tolerance. The horizontal machine offers an additional advantage of convenience of saving the need of climbing up and down the ladder during the draw initiation phase.
Chapter 2

2.2.2 Graded index Polymer optical fibers

To date, several methods have been suggested for the manufacture of GI-POFs. Although continuous extrusion is the dominant method for the manufacture of GIPOF as in the case of SIPOF, the preform method appears to be the preferred approach due to its versatility.

2.2.2.1 Preform method

For the fabrication of graded index polymer optical fibers the most common approach is the preform method. Both photocopolymerization and interfacial gel polymerization techniques are widely used for this purpose.

Photocopolymerization

The first GI POF was fabricated by Ohtsuka and Hatanaka in [8, 9] 1976 by heat drawing graded index plastic rods. At that time, graded index plastic rods were made by two-step co-polymerization and photo-copolymerization techniques [10-15]. In two step co-polymerization, a polymerized rod is prepared and immersed into a co-monomer that has a lower refractive index. The co-monomer then diffuses into the rod to form a concentration gradient in the radial direction. This is subsequently fixed by further polymerization. To prevent the immersed rod from dissolving too much while allowing the co-monomer to diffuse inward, the pre-polymerised rod has a cross linked network structure. Conversely, a GI rod made by photo-copolymerization does not have a network structure, and can be heat drawn into POF.

Figure 2.2 shows schematic of the photo-co-polymerization apparatus by Ohtsuka et al [13]. A 2.9mm diameter glass tube reactor was positioned vertically in a constant temperature chamber and rotated about its vertical axis while being irradiated by UV radiation. The UV radiation quickly induces polymerization reaction forming a gel phase. Since the UV intensity
Fabrication of POF

was higher near the wall of the glass tube, the gel phase formed first on the inner wall of the glass tube and grew inward towards the center of the tube.

Figure 2.2 Schematic of photo-co-polymerization
Interfacial gel polymerization

The best known method for the fabrication of GIPOF is the interfacial gel polymerization method which was pioneered by Koike and his co-workers [16, 17]. At first, this method was applied to the co-polymerization of the monomer mixture with different reactivity ratios and different refractive indices. Later it was applied to mixtures of a monomer and a non-reacting organic dopant. In this method a transparent polymeric tube (e.g., PMMA) is prepared and this tube is then filled with a mixture of two monomers (e.g., Methylmethacrylate and vinyl benzoate) that is polymerized thermally while the tube is rotated. The inner wall of the tube is swollen by the monomer mixture as it forms a thin gel phase. Due to the "gel effect" the polymerization reaction is faster inside the gel phase than in the monomer bulk phase. Consequently, the reaction occurs preferentially on the inner surface of the tube and the co-polymer phase extends inward towards the center of the tube as reaction proceeds. Due to the difference in the reactivity ratios the composition of the copolymer changes gradually in the radial direction. If the monomer with higher reactivity ratio has a smaller refractive index than the other monomer, the preform will have a gradually increasing refractive index towards the center. The refractive index profile obtained by this method depends on the relative ratios of monomer mixture.

2.2.2.2 Drawing GI POF

There are many methods for drawing GIPOF. Some of these methods are a) internal diffusion and surface evaporation b) closed extrusion method and c) co-extrusion method.

The internal diffusion and surface evaporation (IDSE) process was developed by Mitsubishi rayon [31-33]. Here the polymer solution is charged into a
Fabrication of POF

cylinder and pushed by a piston through a nozzle to form a strand fiber. In closed extrusion method which was developed by Ho and coworkers [34-36], a polymer solution for the core is placed in a material supply tank, and another polymer solution for cladding is put in another supply tank. These solutions are heated to a moderate temperature (60°C) and fed into a concentric (or co extrusion) die by separate gear pumps. A bilayer concentric fiber is then extruded from the die and proceeds into an enclosed (or diffusion) zone that is maintained at a constant temperature.

The co-extrusion method was proposed by many workers like Koike and Nchei, Sohn and Park and Park Walker [37, 38]. In all these methods both the core and the cladding material are extruded with a die and feeder mechanism which feeds the core and the cladding material.

2.3 Polymerization process of PMMA:

This section provides the details of PMMA fiber drawing techniques. Polymethylmethacrylate (PMMA) is the widely used polymer to make polymer optical fibers. Polymerization is a process which allows simple low molecular weight compounds to combine and form a complex high molecular weight compound [39]. For this, each molecule of the compound should have the compatibility to react at least with two other molecules of the same or some other compound. In other words, they have a functionality of two. Low molecular weight compounds having a functionality of two or more are called monomers. For them to polymerize, we have only to induce suitable chemical reaction between them. Then these monomer molecules combine to form fewer but higher molecular weight molecules.
Chemical reaction which takes place during polymerization is a) chain polymerization and b) step polymerization.

Chain polymerization is characterised by a self addition of the monomer molecules, to each other, very rapidly through a chain reaction. No byproduct is formed and the product has the same elemental composition as that of the monomer. The bifunctionality is provided by the double bonds present in the monomer. Compounds containing reactive double bonds can therefore, undergo a chain polymerization reaction. Chain polymerization consists of three major steps, namely, initiation, propagation and termination and the process can be brought about by a free radical, ionic or coordination mechanism. Here, we concentrate on free radical polymerization.

2.3.1 Free radical polymerization

The initiation of the polymer chain growth is brought about by free radicals produced by decomposition of compounds called initiators. The term" chain growth" represents a process involving a continuous and very rapid addition of the monomer units to form polymer molecules or polymer chains. As more and more monomer units are added, the length of the polymer chains increases rapidly and the chain grows in length.

2.3.1.1 Initiator

Initiators are thermally unstable compounds and decompose into products called free radicals. If R-R is an initiator, and the pair of electrons forming the bond between the two R’s, can be represented by colon, the initiator can be written as R: R. When energy is supplied to this compound in the form of heat, the molecule splits into two symmetrical components. Each carries with it one of the electrons from the electron pair. This type of decomposition, where the molecule is split into two identical fragments is called ‘homolytic
Fabrication of POF

decomposition'. The two fragments, each carrying one unpaired (lone) electron with it, are called “free radicals”.

\[
\begin{align*}
\text{i.e. } & R \xrightarrow{\mathcal{N}} \overset{\text{R}^0}{\text{R}} \\
\end{align*}
\]

The decomposition of the initiator to form free radicals can be induced by heat energy, light energy or catalysts. A host of low molecular weight compounds comprising mainly of azo compounds, peroxides, hydroperoxides and pre-esters are used as initiators.

2.3.1.2 Initiation

We know that a free radical contains a lone (unpaired) electron which is always looking for another lone electron to couple with it and get stabilized. A free radical, is therefore, highly reactive and can attack any molecule which either has a lone electron or is prepared to part with one of its electron. This is what happens in the process of initiation. The free radical \( R^0 \) attacks the double bond in the monomer molecule resulting in the following chemical change.

\[
\begin{align*}
R^0 + CH_2 = CH & \rightarrow R - CH_2 - CH \quad \text{--- [2.2]} \\
\downarrow X & \quad \downarrow X
\end{align*}
\]

2.2.1.3 Propagation

After “initiation”, comes, the step called “propagation”. In the propagation step, the radical site at the first monomer unit attacks the double bond of a fresh monomer molecule. This results in the building up of the second monomer unit to the first and the transfer of the radical site from the first monomer unit to the second, by the unpaired electron transfer process.

\[
\begin{align*}
R - CH_2 - C^\circ H + CH_2 = CH & \rightarrow R - CH_2 - CH - CH_2 - C^\circ H \quad \text{--- [2.3]} \\
\downarrow X & \quad \downarrow X
\end{align*}
\]
It should be noted that this chain still contains a radical site (indicated by a dot) at its end-carbon atom and can, therefore, attack yet another monomer molecule with a simultaneous transfer of the radical site to the monomer unit added.

2.3.1.4 Termination

The process "termination" is the final step. Here, any further addition of the monomer units to the growing chain is stopped, and the growth of the polymer chain is arrested. Since the decomposition of the initiator produces many free radicals at the same time, each one of them can initiate and propagate the chain growth simultaneously and, hence, at any given time, there may be quite a few growing chains present in the system. Depending on factors such as temperature, there exists a statistical probability of the two growing chains coming close to and colliding with each other. Such a collision results in the arrest of the chain growth.

2.4 Fabrication of the fiber preform

The base material used for the fabrication of polymer preform is methylmethacrylate (MMA) monomer. Methylmethacrylate is a suitable candidate for the fabrication of polymer preforms since it has good optical quality and compatible with most of the organic dopants. The refractive index of pure methylmethacrylate is about 1.41 and it will increase up to 1.48 to 1.49 due to volume reduction during phase transition from liquid to solid. We here concentrated primarily on only core fibers (air cladding), neglecting the scattering losses associated with it due to the absence of cladding.

Commercially available methylmethacrylate will contain inhibitors like hydroquinons. Inhibitors are used for transporting MMA without polymerizing. Inhibitors are removed by repeatedly washing the monomer
Fabrication of POF

with 5% NaOH solution followed by flushing with distilled water. The remaining water is removed by adding suitable drying agents like CaCl₂. The monomers are purified by distillation under reduced atmosphere.

Suitable initiators like benzoyl peroxide or azobisisobutyronitrile (AIBN) are used to start the polymerization. We used benzoyl peroxide for the present work since there is no gas such as nitrogen which gets released during polymerization as in the case of AIBN. This reduces the possibility of air bubble formation in the polymer preforms. Along with the initiator, n-butyl mercaptan is used as the chain transfer agent to regulate and terminate the polymerization process. Adding appropriate quantity of chain transfer agents and initiator controls the molecular weight of the monomer. The molecular weight regulation is an important factor that governs the drawability of the polymer preform. An optimum molecular weight (typically between 60,000 and 1,00,000) is fixed by numerous trial and error methods. To make dye doped fibers we have used Rhodamine 6G dye since it has a relatively good photostability and a high fluorescence efficiency. Rhodamine 6G at 460ppm concentration is chosen for this study and it is added along with the initiator and chain transfer agent into the monomer. The resulting mixture is stirred well so as to avoid aggregate formation.

The monomer mixed with initiator, dye and chain transfer agent is poured into a glass tube of required diameter and length. This is then kept in constant temperature bath at 70°C for 48hours, at 90°C for 18hours and at 105°C in air furnace for 8 hours. These steps lead to a high quality polymer preform which can be used for drawing the fiber.
2.5 Polymer Optical Fiber Drawing Tower: Technical details

The polymer optical fiber drawing tower which we used for the fabrication of POF is designed and fabricated indigenously (figure 2.3).

![Diagram of Polymer Optical Fiber Drawing Tower](image)

**Figure 2.3** a) Polymer optical fiber drawing system b) actual photograph of the polymer optical fiber drawing station developed at ISP
Fabrication of POF

The total height of the tower is 2.5 meter and weighs around 900kgs. It has five important stages namely preform feeder, furnace, temperature controller, fiber puller, and winding spool. These five stages are individually controlled by an electronic controller unit. The stages are designed in such a fashion that any alteration or repair can be done individually by removing each stage. The distance between each stage can also be optimized by making small variations. In short the system design is very flexible and appropriate alterations can be easily made to improve the system. Brief descriptions of each stage are as follows.

2.5.1 Brief description of the parts

2.5.1.1 The Preform feeder

The preform feeder is a translation stage with a total traverse of 800mm. It is driven by a stepper motor which is controlled by the electronic controller unit. A preform holder is attached to the preform feeder stage so as to hold the preform which has to be drawn to optical fibers. It can accommodate a preform upto 30mm diameter and a length of 1 meter. The speed of traverse of the stage is controlled by the data programmed to a computer which in turn instructs the control unit to perform the operation.

2.5.1.2 The furnace

The polymer preform is melted using a furnace to draw optical fibers. An ideal furnace should have very good temperature stability and temperature profile suitable for drawing the fiber. There are several methods which can be used to manufacture good temperature stability furnaces. The most commonly used furnaces employ inductive heating. In inductive furnaces, usually a heating coil (normally nichrome) is wounded over a ceramic tube which is then fired by passing current through the coil.
The main drawback of these types of furnace is that in order to get good temperature stability, which is essential for fiber drawing, sophisticated temperature controller systems have to be utilized. Moreover, for attaining a desired temperature profiled furnace a number of individual coil windings and controllers are needed. This will also add weight and complexity to the furnace.

In order to avoid these difficulties we employed a novel technique for the fabrication of the furnace. Instead of using wire-wound furnace, we used IR radiation heated furnace. Three 75W IR lamps of Philips make were placed inside the furnace for heating the preform. They provide a maximum temperature of 250°C which is more than enough for drawing POF. The profiling inside the furnace was adjusted by providing appropriate openings inside the furnace and controlling the amount of light inside the furnace. In order to change the furnace temperature profile, either a very slight tilt of the IR lamps or a slight change in the slit width will be sufficient.
Fabrication of POF

To provide uniform heating of the preform the furnace can swing a maximum of $30^\circ$. The swing period can be programmed using the computer and electronic controller unit.

Temperature distribution inside a furnace plays an important role in the fabrication of an optical fiber. An ideal temperature profile is as shown in the figure 2.5. For temperature profiling of the furnace, a resistance temperature detector (RTD), PT100 is used. The detector is inserted into the furnace with the help of a stepper motor assembly. For profiling the furnace temperature, the RTD is inserted slowly into the furnace after it is kept at a temperature of 165°C (which is the typical melting temperature of PMMA preforms).

Usually a multimeter capable of temperature measurement is connected to the temperature detector. The output from the RTD will be typically a change in the resistance in accordance with the applied temperature.

![Figure 2.5 Ideal temperature profile of the furnace](image-url)
Figure 2.6 The set up for temperature profiling of the furnace

Figure 2.7 The temperature profile of the fabricated furnace along its length
The multimeter converts this variation in resistance into corresponding voltage change and a calibrated temperature reading is displayed at its output. The temperature at different points is measured and the profile obtained is as shown in the figure 2.7.

2.5.1.3 The Temperature controller

To control the temperature inside the furnace, the easiest way is to switch on and off the three IR lamps simultaneously. For that a thermocouple is attached to the central portion of the furnace where the temperature is maximum. We used a ‘J type’ thermocouple for serving this purpose. This is connected to a programmable temperature controller for which the accuracy is +/- 1°C. The required temperature can be programmed manually and the temperature controller constantly monitors whether the set temperature is achieved or not. When the set temperature is achieved it operates a relay which cuts off the power to the lamps. The controller then checks whether the temperature has come down or not. If it has come down it will activate the relay to switch the lamps to the ON condition and proceeds with the heating procedure. This can be easily represented by a flow chart as in figure 2.9.

2.5.1.4 The fiber puller

The fiber puller is another important unit of the drawing system. A schematic diagram is shown in the figure 2.8.

![Figure 2.8 Schematic diagram of the fiber puller](image-url)
Figure 2.9 Flow chart representation of the temperature controller
Fabrication of POF

The fiber puller has two rollers which are in close contact with each other. A stepper motor is connected to one of the rollers. The stepper motor is controlled by means of the computer and electronic controller unit. The required draw rate of the fiber can be programmed into the computer and the stepper motor drives the rollers at the specified draw rate. The draw rate along with the preform feed rate determines the diameter of the fiber.

\[
\frac{D^2}{d^2} = \left[ \frac{V_d}{V_f} \right]
\]

Where \( D \) is the diameter of the preform, \( d \) is the diameter of the fiber drawn, \( V_f \) is the feed rate and \( V_d \) is the draw rate.

2.5.1.5 The winding spool

The winding spool (figure 2.10) has a two axes controller along with its rotation. The two axes controller helps the winding spool to precisely wind the drawn fiber so that the fiber will not get wound one over the other before one full spool traverse along the axis is completed. The traverse of the spool along the axis is controlled by a translation stage-stepper motor assembly over which the spool is attached. When the diameter of the fiber to be drawn is specified to the computer, the spool will move along its axis which corresponds to the fiber diameter exactly, along with the rotary motion. This will ensure that the fiber will not get wound one over the other and hence correct spacing is ensured. After one whole movement along the axis is completed, the spool will be moved perpendicular to its axis. The magnitude of the movement will be exactly in relation to the fiber diameter and the process continues.
The whole process is controlled by a limit switch on the preform feeder. If the preform feeder comes down and reaches its limit, the whole system will come to a halt.

![Diagram of fiber winding spool]

**Figure 2.10** Schematic of the fiber winding spool

### 2.6 Electronic control unit

The electronic control unit is the most important element in the polymer optical fiber drawing system. It controls the whole fiber drawing system with respect to a set of preprogrammed values stored in its registers. A block diagram representation of the electronic control system which is interfaced to the computer is shown in the figure 2.11.
Fabrication of POF

Fiber 2.11 Block diagram of the electronic controller module
A control software in visual basic acts as the user interface with the computer. The software window is as shown in the figure 2.12.

![Software controller window](image)

**Figure 2.12 Software controller window**

Values entered into this window are converted into hexadecimal values and are transferred to the microcontroller based electronic controller via RS232C interface. The microcontroller routes these data to the stepper motors (SM1 through SM6). Rotation sensors attached to the spooling and drawing stages feed back data to the control unit which in turn automatically corrects if it alters from its preset value.
**Fabrication of POF**

A manual mode is provided to the preform feeder (Z) and to the winding spool (X and Y) to control the system manually if the system gets stuck in between due to some unwanted reasons.

We can specify the optical fiber diameter in the software, which will then allocate the exact spacing on the winding spool by adjusting the X and Y movements. The winding spool speed can also be controlled individually adding flexibility to the system. By varying the draw speed and the feed speed we can get fibers from 1.5mm to 150μm in diameter. We used 5cm long and 1.5cm diameter preform for the following study. Table 2.1 shows the comparison between theoretical and experimental values of fiber diameters obtained. Comparison is also represented graphically in figure 2.13. Values obtained are quite comparable.

![Graph](image-url)

**Figure 2.13:** Comparison of experimental and calculated values of fiber diameter for various feed rates
### Table 2.1

<table>
<thead>
<tr>
<th>Feed rate (µm/sec)</th>
<th>Vf (µm/sec)</th>
<th>d- fiber diameter (Calculated)</th>
<th>d- fiber diameter (experimental values)</th>
</tr>
</thead>
<tbody>
<tr>
<td>300000</td>
<td>1000</td>
<td>866µm</td>
<td>901µm</td>
</tr>
<tr>
<td>500000</td>
<td>800</td>
<td>774µm</td>
<td>793µm</td>
</tr>
<tr>
<td>300000</td>
<td>700</td>
<td>723µm</td>
<td>742µm</td>
</tr>
<tr>
<td>300000</td>
<td>600</td>
<td>671µm</td>
<td>682µm</td>
</tr>
<tr>
<td>300000</td>
<td>500</td>
<td>612µm</td>
<td>628µm</td>
</tr>
<tr>
<td>300000</td>
<td>400</td>
<td>547µm</td>
<td>562µm</td>
</tr>
<tr>
<td>300000</td>
<td>300</td>
<td>474µm</td>
<td>491µm</td>
</tr>
<tr>
<td>300000</td>
<td>200</td>
<td>387µm</td>
<td>396µm</td>
</tr>
<tr>
<td>300000</td>
<td>100</td>
<td>273µm</td>
<td>280µm</td>
</tr>
<tr>
<td>300000</td>
<td>50</td>
<td>193µm</td>
<td>208µm</td>
</tr>
<tr>
<td>300000</td>
<td>25</td>
<td>136µm</td>
<td>150µm</td>
</tr>
</tbody>
</table>

**Table 2.1** Data showing the theoretical and experimental diameters obtained for various draw and feed rates.
2.7 Conclusion:

Polymer optical fiber drawing station for drawing polymer optical fibers was indigenously designed and fabricated. The temperature profiling of the furnace was carried out and was found to be comparable with the ideal temperature profile. Polymer optical fibers using this facility were fabricated and were found to have satisfactory properties comparable with the theoretical values.
References:

Fabrication of POF