NEW TECHNIQUES FOR QUALITY ASSURANCE OF MULTIFIBER CONNECTORS

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ABSTRACT

Industry requirements for compact, high fiber count connectors in both telecom and datacom have created increased global demand for guide pin based multifiber connectors such as MT(MPO/MPX) and MiniMT(MT-RJ) connectors. To realize the cost/performance benefits of these type of connectors, the manufacturing processes must be precisely controlled to maintain the extremely critical tolerances of angle, alignment and height of the multiple fibers. A major part of gaining control of this process is the measurement of the endface geometry. Feedback on physical parameters such as flatness, radius of curvature, surface angle, and the protrusion of the fibers allows fine tuning of the polishing process. This hard data provides the manufacturer with a basis for quality control and crucial information for quality assurance to guarantee long term performance in the field.

The Telephone Industry Association (TIA) and the International Electrotechnical Committee (IEC) are working in parallel on writing Fiber Optic Test Procedures (FOTP's) for measuring multifiber end face geometries. This paper will discuss the latest ideas on procedures which are being recommended and the standards being proposed in the industry for defining and measuring these connectors. Agreement on standards will allow the industry to advance its technology by improving quality, consistency, and intermateability of these intricate products.

INTRODUCTION

Multifiber connectors allow anywhere from 2 to 24 fibers in a single ferrule to be intermated with one another. These high densities offer advantages in time, money and size for the growing demands of data hungry applications. In general, transmission loss at the fiber to fiber interface is attributed to three main factors[1]:

1. Transverse offset
2. Fiber end gap
3. Mechanical stability

The transverse offset is the error due to misalignment of the cores. This is controlled by dimensional tolerances of the fiber and the ferrule and is separate from our present discussion. We are concerned with the polishing process which affects the fiber end gap, that is, how the fibers mate, and the mechanical stability which is how the ferrules mate.

Polishing methods are still being optimized. Depending on the performance requirements, the final geometry may be a flat polish, a protruded fiber polish or an angled protruded fiber polish. Ideally, for good physical contact, the fiber ends of the connector should be in the same plane. For mechanical stability, the critical requirement is that the endface geometry must be controlled to allow the fibers and not the ferrule to be the first to contact. When two connectors mate, the fibers align and compress uniformly to provide controlled, intimate, optical contact.

PHYSICAL PARAMETERS

To insure this type of contact, the geometry of the ferrule surface and the fibers must be characterized and measured. At present, the geometry is generally characterized by five key physical measurements:

1. Angle of the polish - Horizontal or X axis
2. Angle of the polish - Vertical or Y axis
3. Fiber Protrusion - Planar Height
4. Planar Height Differential
5. Flatness Deviation

These terms look relatively straight forward. The angle of the polish is the ferrule endface position relative to its alignment surfaces. The protrusion is the distance the fibers are extending out of the ferrule and the differential planar height is the difference between the highest and lowest protrusion. The flatness deviation characterizes how flat the ferrule surface is. It measures the drop off from the center of the connector to the edge of our region of interest. As we will see, care must be taken in defining these parameters for repeatability and accuracy of measurements

TEST EQUIPMENT

Before elaborating on these terms it is helpful to describe the typical test equipment used to measure physical parameters. The most common instrument that allows fast, accurate measurements is the interferometric microscope.

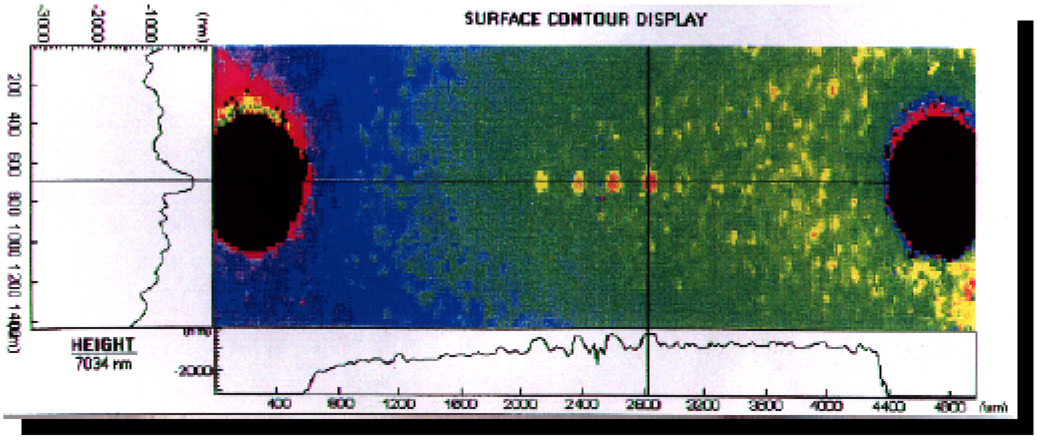

Figure 1 – Contour and Profile of 4 fiber connector

The interferometric microscope is able to make submicron measurements of differential height by reflecting coherent light off the connector endface and combining it with light reflecting off a reference surface to form constructive and destructive interference waves. Automated interferometric systems are required for the multifiber connectors' complex surfaces. These use computers which "scan" across the surface with the microscope to capture information on the height of every point on the surface. This can be displayed as a contour map to visualize the entire surface.

Any cross sectional profile can be extracted for viewing. With the entire surface mapped, any measurement we desire is available using the proper formula and appropriate definition.

The latest polishing techniques give multifiber connectors which often have extremely rough surfaces, and high fiber protrusion. To scan these types of surfaces, the interferometric microscope requires a white light scanning mode, sometimes called a broadband scanning mode, to accurately characterize the surface.

STANDARDS

Because the multifiber connector surface is not uniform from center to edge, it is important to define the measurement areas to be used in calculating the ideal shape. This is necessary to assure consistency in measurements among manufacturers and end users.

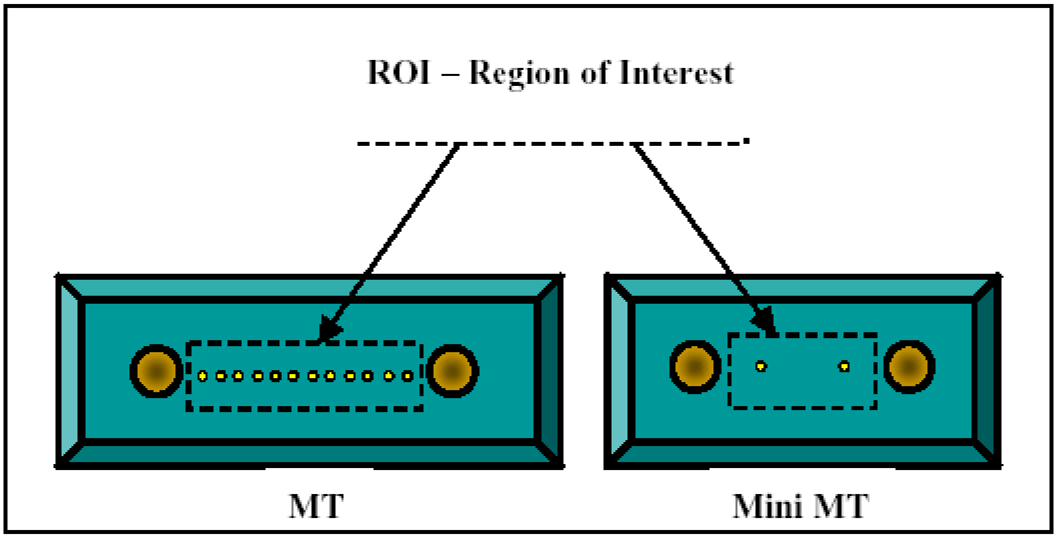

Figure 2 – Measurement Area

The Region of Interest (ROI) on a multifiber connector is defined by a rectangular area having a length - L and a width - W. The recommended value for different ferrules are listed in Table 1. In addition to the ROI, other measuring areas must be defined to map the surface correctly. These include the Extracting Regions, Fitting Region, and Averaging Regions. The Extracting Regions are equal to 140 microns and centered on each fiber. The Extracting Regions are subtracted from the Region of Interest to form the Fitting Region. This is the area used to calculate the best fit curve or plane for the ferrule surface. The Averaging Regions are equal to 50 microns and are centered on each fiber. This is the area used to calculate the height of the individual fibers.

Ferrule type	Length – L, microns	Width – W, microns

MT	2900	675
MiniMT	900	675

Table 1

Because of the non-uniformity of the surface, other points must be taken into consideration before defining the physical parameters. How can a planar surface be repeatably measured from such a complicated, extremely rough surface with many peaks and deep valleys? From an interferometric standpoint, the angled slopes of these surfaces are often difficult to measure accurately. They have low modulation because they do not reflect the light directly back into the system. The accuracy and repeatability of these low modulations points are questionable.

In order to overcome this problem, it was decided to use a fixed percentage (20%) of the high points on the surface to calculate a best fit plane over the region of interest. The high points are typically the glass particles in the ferrule composite and should be accurately detected by all instruments. At present, 10-50% is the amount of the high points being considered. The original data points are filtered through a series of steps to prepare for this calculation.

The procedure is as follows. First the surface is measured and the surface heights of all the points in the region of interest are collected. This is the Base Surface A (Fig.3). Next, a best fit biparabolic curve is fitted to the surface (Fig.4). This best fit curve is then subtracted from the original data to come up with a fitted or flattened surface (Fig. 5). This is the surface that will be used to select a percentage of the high points on the surface.

Before selecting the high points, a small percentage of extreme points are removed. These are the tiny spikes or peaks that are remain after the polishing process but will shatter or break on contact. 3% of the high points are marked and removed first from further calculations.

The next 20% of the points over the region of interest are selected as valid points for the calculation of the surface. Note that these points are selected as a percentage of the total area of the region of interest. Even points that the interferometer could not measure are included in the total area. This provides for the same percentage area used to map the surface no matter what the illumination or instrument used.

The tagged or valid points are then placed in their original position on the base surface map (Fig. 6). Using these tagged points on the base surface map, a best fit plane is calculated (Fig. 7). The **Planar Fiber Height** is calculated by subtracting the height of each fiber in the Averaging Area from the height of this best fit plane.

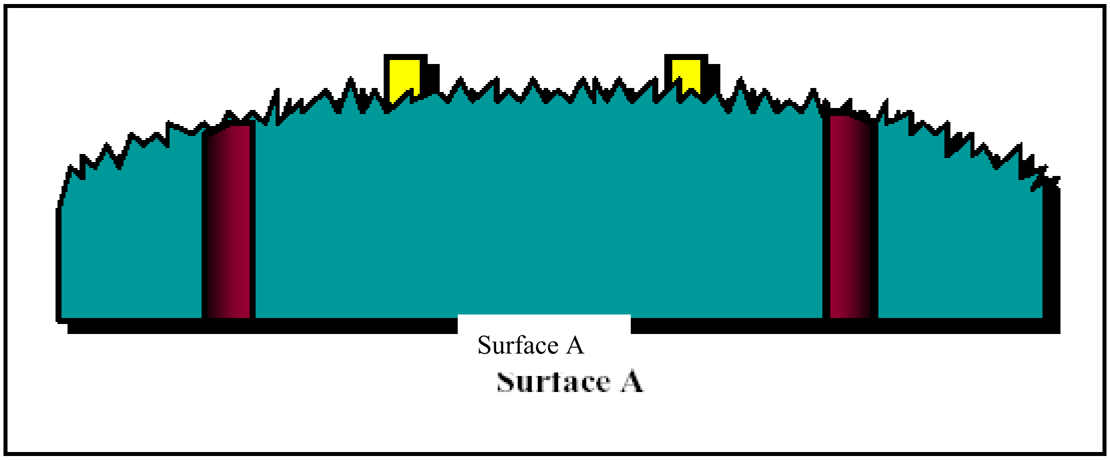

Figure 3 –Measured Surface

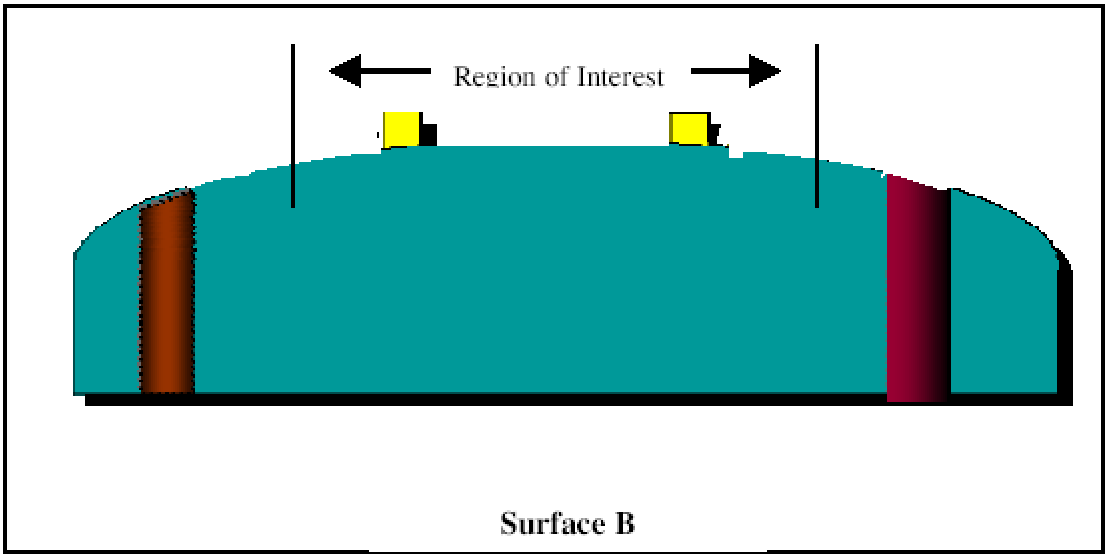

Figure 4 – Ideal Fitted Surface

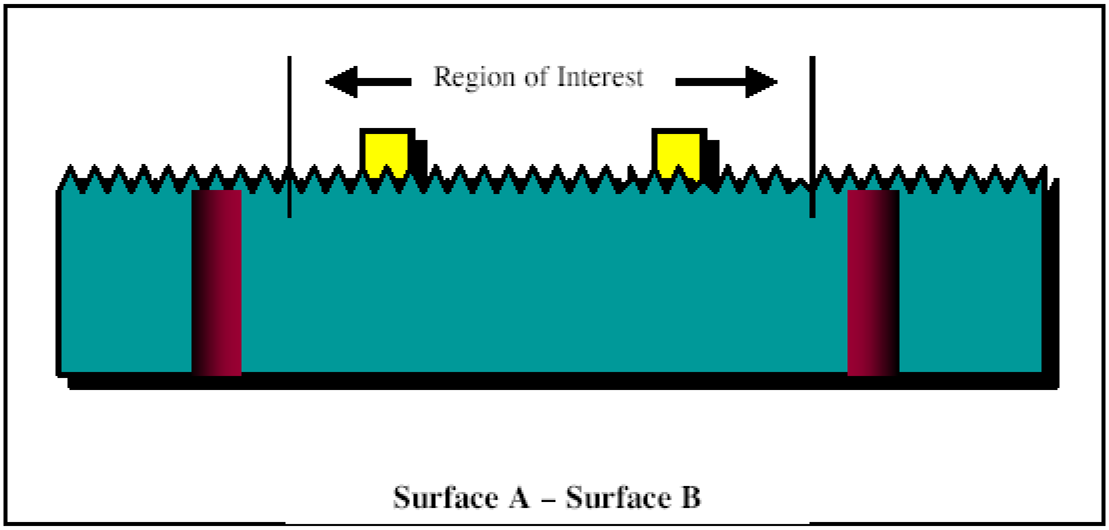

Figure 5 – Surface Fit Map

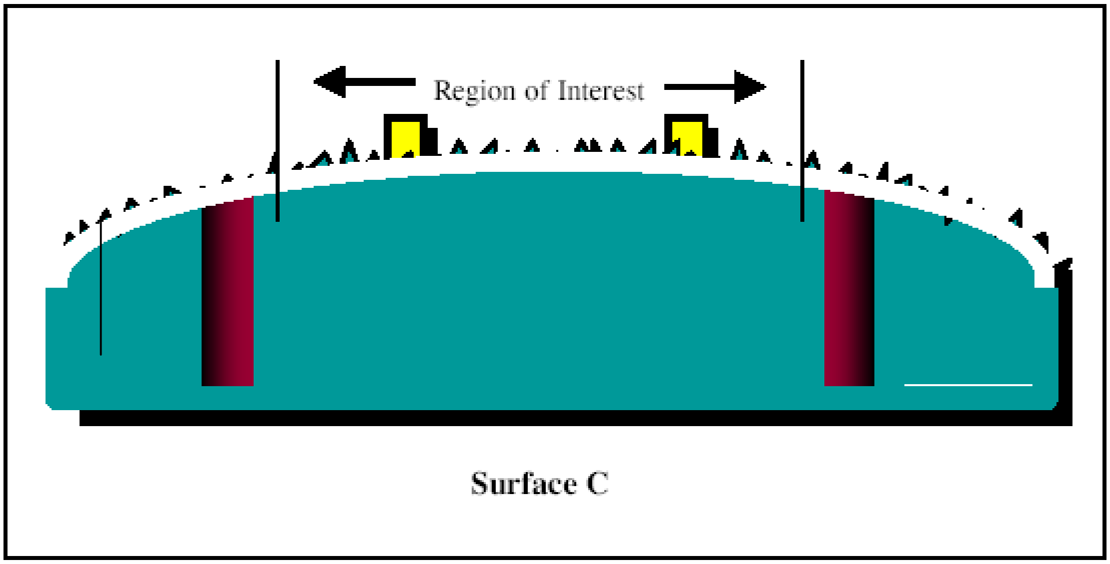

Figure 6 – Filtered Surface

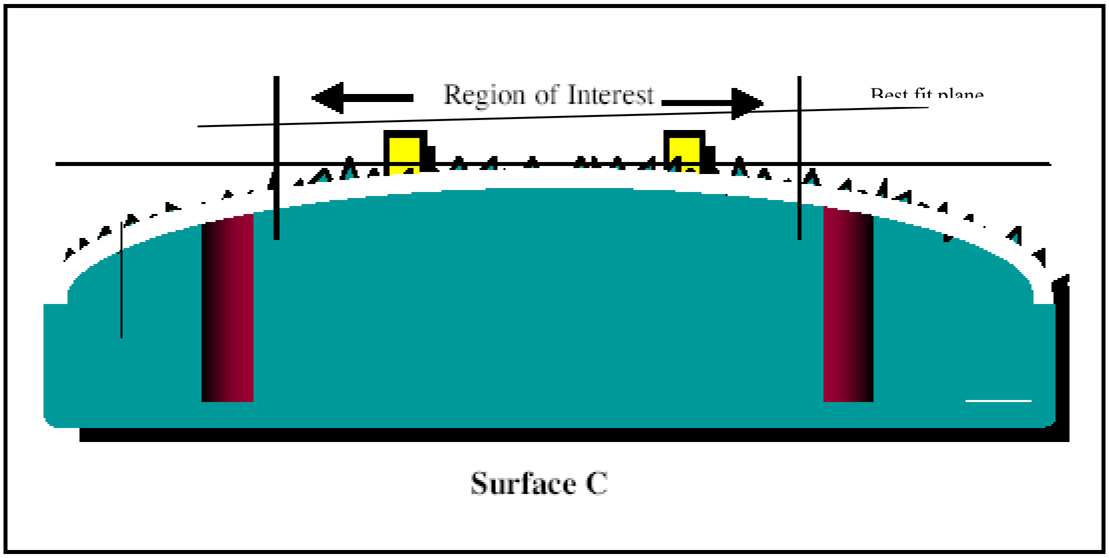

Figure 7 – Best Fit Plane

In order to measure the angle of polish of the ferrule in the X and Y axis, a reference surface must be determined. In multifiber connectors, the guide holes molded in the connector are designed to be, in theory, perpendicular to the ideal end face.

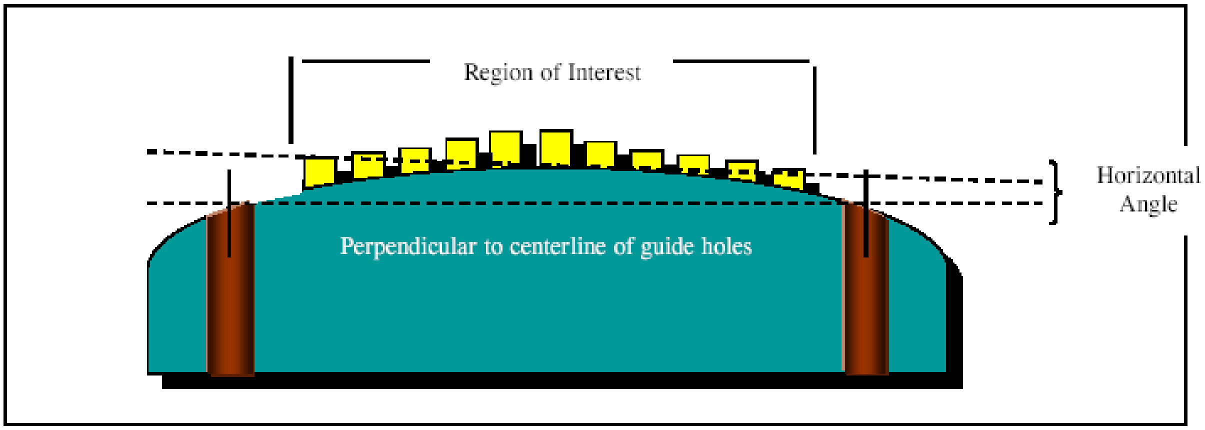

Figure 8 – Angle of Polish

The Horizontal and Vertical Angle of Polish are defined as the angles of the end face compared to the angle of the plane perpendicular to the guide holes (Fig. 8). Guide pins are typically used to translate this center axis to the perpendicular plane but it is the guide holes that are being referenced. In practice, the guide holes are not necessarily parallel to one another, so it is necessary to use the average angle of the two guide holes/guide pins to calculate the ideal perpendicular polished end face.

Note that the fiber height measurements are not related to the angle of the polish. The angle of the polish can vary depending on the accuracy of the guide pins/guide holes used as the reference. By removing this variable, it provides for more repeatable measurements of the fiber height. This can be justified in use because even if the endface is not perfectly perpendicular to the alignment pins, for very small angles there is some ability of the connectors to autolevel on mating. That is, they will position themselves to provide the most stable contact. This is due to the slight amount of movement available between the alignment pins and guide holes. It is important to reiterate that this hypothesis only holds for very small angles of polish.

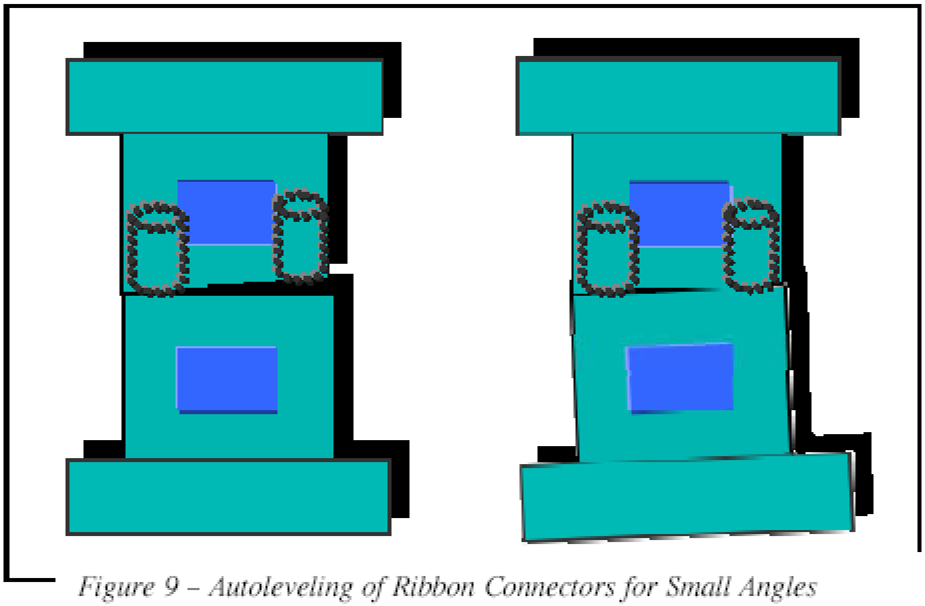

Figure 9 – Autoleveling of Ribbon Connectors for Small Angles

Summarizing the parameters:

The **Horizontal and Vertical Angle of Polish** are defined as the angles of the best fit plane calculated from the 20% high points on the surface over the region of interest (after removing the first 3%) compared to the angle perpendicular to the average center axis of the guide holes. This uses the multistep process previously described.

Planar Fiber Height is the difference in height between the Averaging Area of each fiber centers and the best fit plane calculated from the 20% of high points on the surface over the region of interest (after removing the first 3%). The **Planar Height Differential** (Fig. 10) is the difference in height between the highest and lowest protruding fibers.

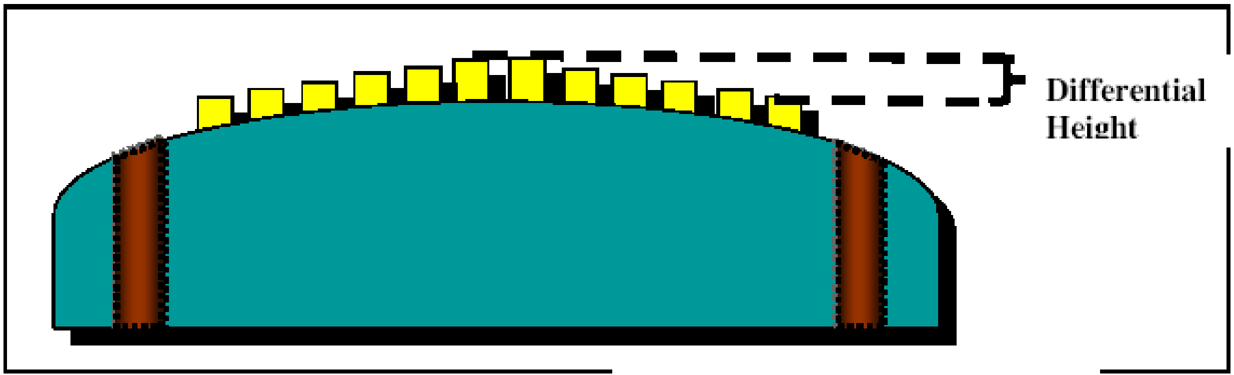

Figure 10 – Planar Height Differential

Another useful measurement for production control is the **Flatness Deviation** (Fig 11). This is the difference in height from the center of the best fit biparabolic curve to the height at the edge of the region of interest. (The curve is calculated using 3-20% of the high points.) This indicates how flat the surface is over the region of interest. If this number is too large the planar height measurements do not accurately measure the true distance above the surface of the connector.

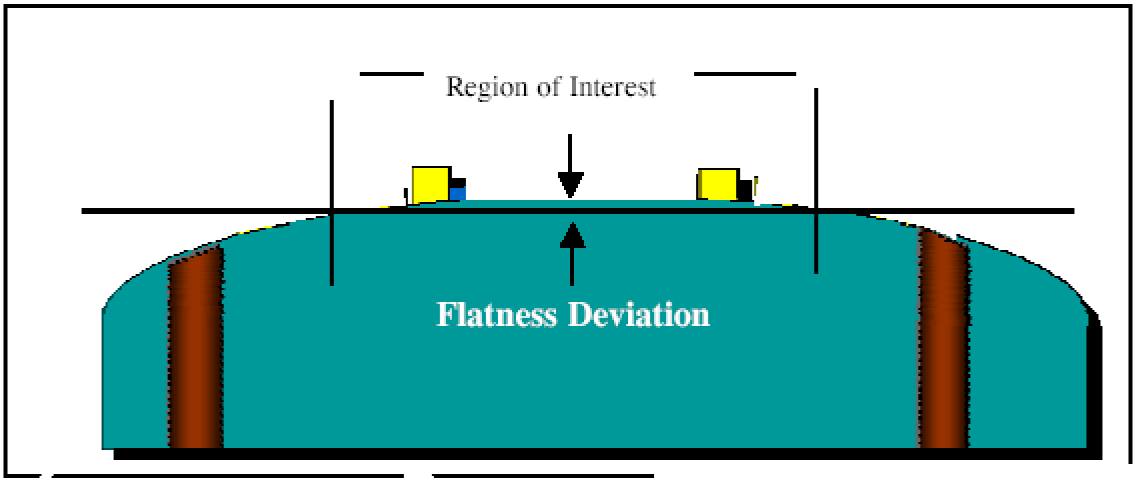

Figure 11 – Flatness Deviation

SUMMARY

In summary, the fiber optics industry is improving multifiber connector quality by exploring which key physical parameters need to be measured and the best way to measure them. We have concentrated our discussion on the MT type ferrule but similar definitions can be applied to other multifiber connectors. This is an evolving process that requires constant re-evaluation as new technologies are developed and tested. With the proper definitions and standards for the polish geometries and procedures, manufacturers can make multifiber connectors providing good physical contact with low attenuation and return loss which will stand up to the long term demands in todays' fiber systems.

REFERENCES

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2. D. Knasel, T. Satake "Low Loss, Single Mode Multifiber Connectors," Proceedings from NFOEC96, September 1996, Denver CO.