Fiber-Optic Component Inspection Using Integrated Vision and Motion Components

Introduction

Since the 1980s, fiber-optic technology has been used for long distance telephone systems. Now with the increasing need for bandwidth, fiber-optic systems have become in high demand. These optical systems, whether transmitting data across continents or providing bandwidth for large cities, are very complex and consist of dozens of components, such as dispersion compensators, collimators, gratings, and attenuators, across the whole transmission path. Manufacturers of these optical components are challenged with making amazingly small and sophisticated devices, which will become even more intricate in the future. In addition, these components are made from many different types of exotic materials (such as indium phosphide and gallium arsenide) instead of just silicon. The technologies involved in manufacturing these components are so new that most component manufacturers assemble their products by hand. In fact, Fortune magazine, in a report on JDS Uniphase in its September 2000 edition, stated that of JDS's 18,000 employees 12,000 are in manufacturing. Traditional, labor-intensive techniques cannot keep up with market demands that include tight design specifications, low cost, and high volume requirements. This application note outlines common fiber inspection and measurement techniques and describes the equipment needed to create an automated optical component inspection system.

Advantages of Fiber Optics

Fiber-optic strands provide a significant advantage over standard copper transmission lines. The potential information-carrying capacity of a single fiber strand is much greater than a single copper wire. In addition, with modulation schemes, a single carrier frequency can carry numerous channels of information. The carrier frequencies used in light waveguides are far greater than those deployed in copper lines; light is composed of different wavelengths each of which can carry a separate data channel. The advantages do not end there, however. Optical fiber is very light and has a very small diameter, typically smaller than the diameter of a human hair.

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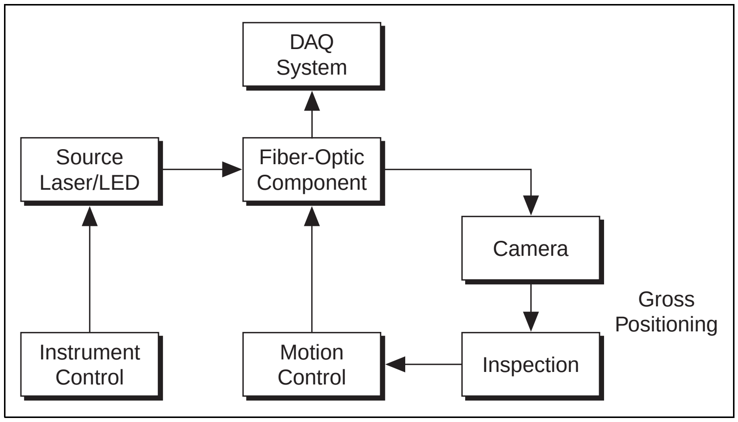


Figure 1. Block Diagram of Important Components of a Generic Fiber-Optic Inspection Platform

Fiber Basics

Optical fiber is the workhorse of any optical communication system. It basically is the conduit for the data and ends up linking all of the other components together. The light wave is transmitted by total internal reflection. A typical fiber consists of the following:

- The core, the actual conduit of the light
- The cladding, a glass material which, by doping, has achieved a certain index of refraction to cause total internal reflection
- Other layers to provide strength and protection from harsh conditions

The light travels down the fiber with minimal attenuation because of the difference in the indices of refraction between the core and the cladding, combined with the angle of reflection. Optical fiber is manufactured as either single mode or multimode. Multimode fiber (50 µm to a few mm) has a larger core diameter than a single mode fiber (4 to 9 µm). These measurements must be accurate because the diameter and concentricity of the core and cladding would affect such things as the modes of light that can travel in the optical fiber, the numerical aperture, and the coupling of light in and out of the fiber.

Fiber-Optic Inspection Platform Overview

The approach to inspecting the fiber is to use vision-guided motion control to perform gross alignment of the fiber and lens. The camera and inspection algorithms look at the core and cladding and perform vision measurements to determine if concentricity and diameters fall within tolerances. In addition, a National Instruments data acquisition (DAQ) board is used to measure the light signal attenuation through the fiber to determine characteristics such as optical loss.

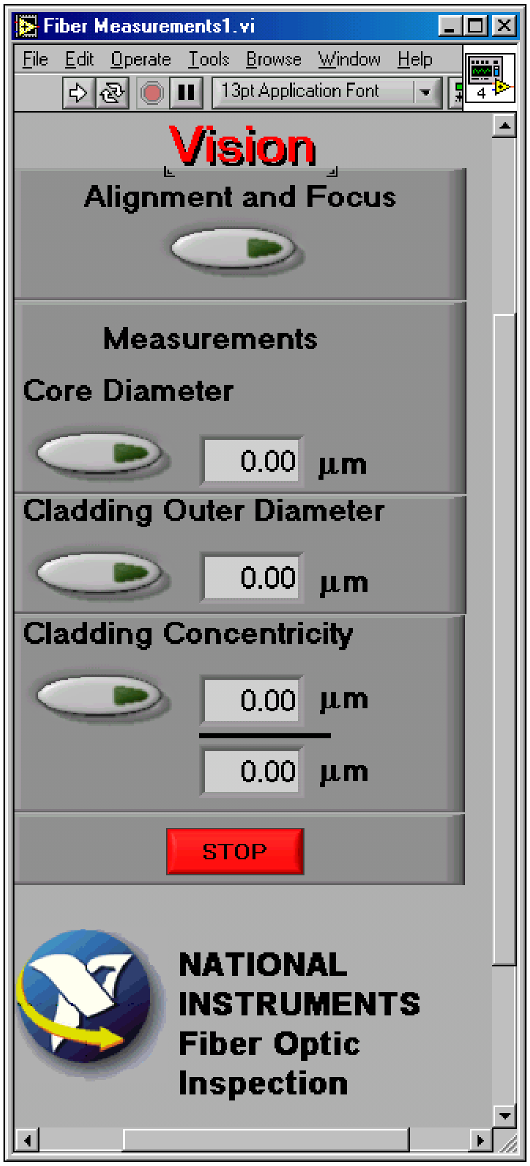


Figure 2. LabVIEW Front Panel of Fiber-Optic Inspection System for Precise Measurements of Important Fiber Parameters

Inspection Measurements

Typical inspection measurements are:

- Cladding diameters
- Core and noncircularities
- Core-cladding concentricity

These parameters can be measured using optical inspection techniques. Surface blemishes can also be detected using thresholding and blob analysis techniques.

Optical Inspection Overview

Using a CCD camera, the optical inspection system can measure the core and cladding diameter using edge detection crossing through the core and cladding boundaries; functions within National Instruments IMAQ Vision software can locate the edges. With IMAQ Vision, use the annulus region of interest tool to draw an inner and outer circle around a boundary as shown in Figure 3. Line profiles are automatically placed perpendicular to the cladding boundary between the regions of interest. IMAQ Vision edge-detection functions precisely locate the boundary of cladding. Once you have located the cladding boundary, the center of the fiber, circularity, and diameter are all calculated using built-in IMAQ Vision functions. Example LabVIEW IMAQ Vision code is shown in Figure 4. To automate the process completely, use the IMAQ Vision pattern matching tools to locate the core and then automatically position the region of interest. Also, you can use standard threshold and blob analysis techniques to locate and count the defects within the core, as shown in Figure 5.

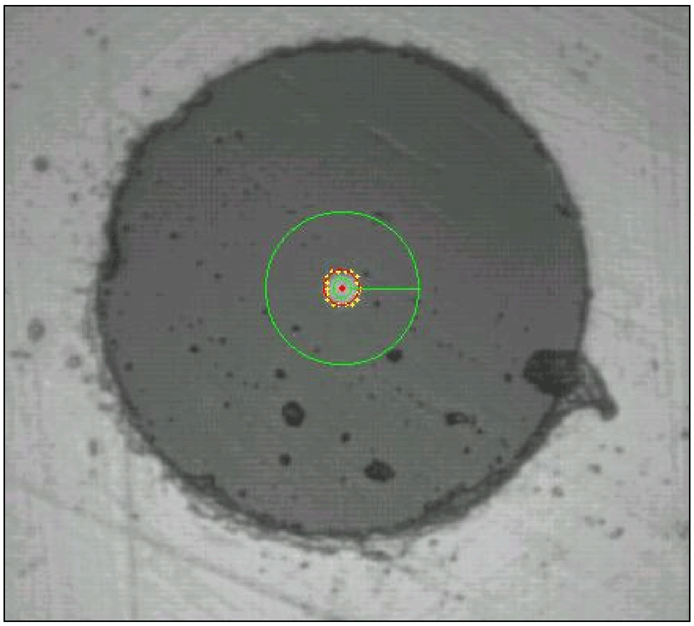


Figure 3. IMAQ Vision functions draw two concentric circles and detect the edges where the core and cladding meet in this single-mode fiber.

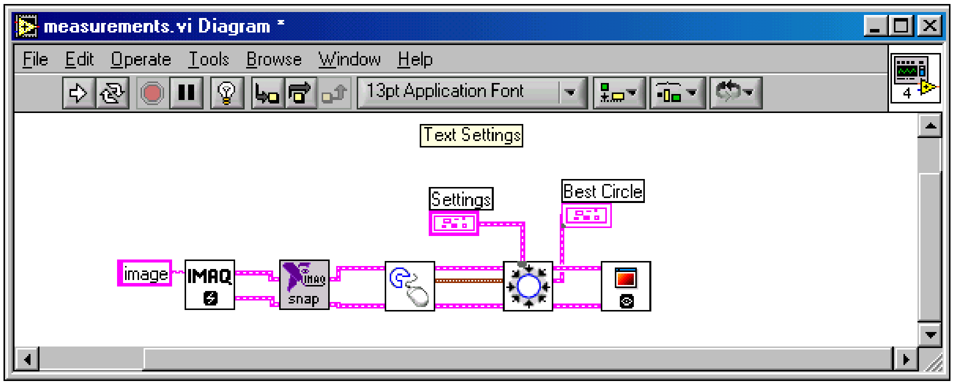


Figure 4. Sample LabVIEW Code for Interactively Measuring the Core and Cladding Diameters

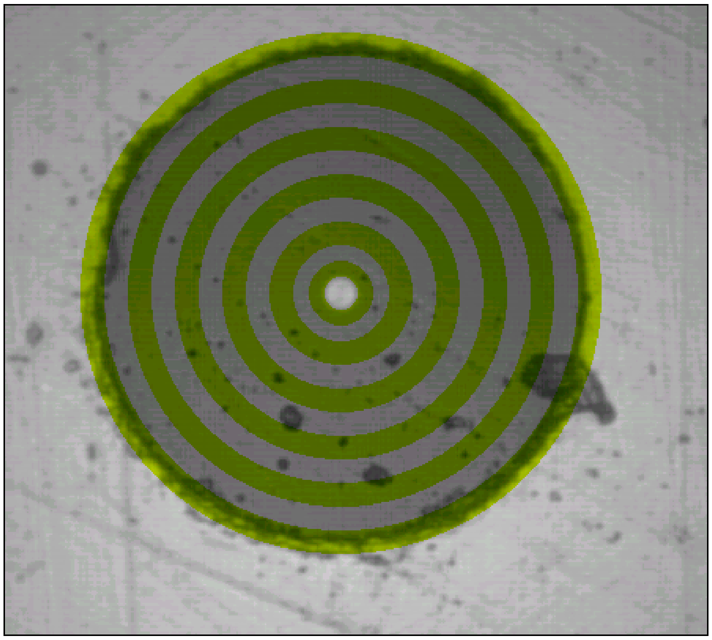


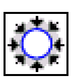
Figure 5. IMAQ Vision functions draw concentric ROIs and in each concentric region detect blemishes, dust, and debris to ensure that the fiber is of good quality and properly cleaved before bonding.

Real Measurements

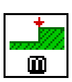
Image information can be misleading at times because these measurements are typically recorded in pixel values. For fiber-optic applications, it is important to record measurements in real world units such as microns. National Instruments IMAQ Vision contains easy-to-use functions to calibrate your data so that image output and measurements are done in microns rather than pixels.

IMAQ Vision Functions

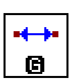
IMAQ Select Annulus (Motion & Vision»Machine Vision»Select Region of Interest»IMAQ Select Annulus.vi) – After the user specifies an annulus area in an image, IMAQ Select Annulus displays the image in the specified window, provides the annulus tool, and returns the coordinates of the annulus selected when you click OK.



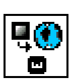
IMAQ Find Circular Edge (Motion & Vision»Machine Vision»Locate Edges»IMAQ Find Circular Edge.vi) – IMAQ Find Circular Edge locates a circular edge in a search area. It locates the intersection points between a set of search lines defined by a spoke and the edge of an object. The intersection points are determined based on their contrast and slope.



IMAQ Edge Tool (Motion & Vision»Machine Vision»Caliper»IMAQ Edge Tool.vi) – IMAQ Edge Tool finds edges along a path defined in the image. Edges are determined based on their contrast, slope, and steepness.



IMAQ Point Distances (Motion & Vision»Machine Vision»Analytic Geometry»IMAQ Point Distances.vi) – IMAQ Point Distances computes the distance between consecutive pairs of points.



IMAQ Convert Pixel to Real World (Motion & Vision»Vision Utilities»Calibration»IMAQ Convert Pixel To Real World.vi) – Convert Pixel To Real World transforms pixel coordinates to real world coordinates, according to the calibration information contained in the image. Calibration information is attached to this image by IMAQ Learn Calibration Template, IMAQ Set Simple Calibration, or IMAQ Set Calibration Info.

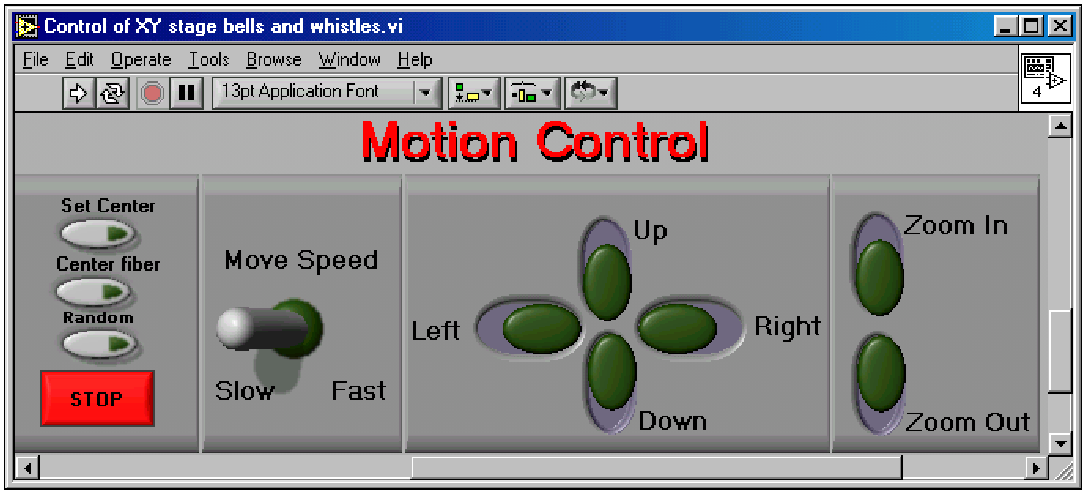


Figure 6. Motion Control Panel for Interactive Alignment of the Fiber and Lens

Motion Control

Precision is key to an inspection solution for optical components. When fiber measurements are in the micrometer range, it is imperative that your alignment be very accurate. National Instruments Motion Control Hardware and Software coupled with a third-party stage achieve the precise micrometer and nanometer accuracy necessary for fiber inspection or fiber alignment and bonding. This motion can all be controlled from the same interface where the visual measurements are being acquired.

Software Components

The basic software component is National Instruments LabVIEW Application Software, the development environment. Motion control software and IMAQ Vision software seamlessly integrate with LabVIEW to provide faster development time. Statistical Process Control software for LabVIEW provides the functionality to determine manufacturing yields, statistical trends, and process analysis.

Hardware Components

The hardware used in a fiber-optic components inspection system is listed below. Use this guide to help you locate components for your system.

Device	Company	Model
Instrumentation Chassis	National Instruments	PXI-1002
Instrumentation Controller	National Instruments	PXI-8156B
Image acquisition hardware	National Instruments	IMAQ PXI-1407
Camera	JAI	CV-M50
Lens	Infinity	OBJ 18 mm WD, 2.00X 4x Adapter 1.5x Main Body
Motion Control	National Instruments	PXI-7344
Stages	National Aperture	MM-3M-F-0.5
Amplifier	National Aperture	MC-3SA

Automation through Integration

By tightly integrating different test and manufacturing functions and processes, optical component manufacturers can build highly automated systems that result in cost savings, shorter lead times, higher yield, and better quality. The main advantage of this integrated, automated approach lies in removing pressure from labor-intensive procedures. Productivity increases as a result of higher quality. An open-ended system using National Instruments LabVIEW, NI-Motion, and IMAQ Vision software can easily be augmented with National Instruments image acquisition and motion control devices. You can also add DAQ hardware coupled with a light-emitting source to perform beam profile analysis and quantify power dissipation. As new test or inspection requirements arise, you can easily modify the system because you have used a flexible open platform based on off-the-shelf components such as PXI and LabVIEW. Complete turnkey solutions for your fiber-optic inspection needs are available through local integrators. Ask National Instruments for a complete list of integrators.

For more information on National Instruments motion control boards, image acquisition boards, PXI, LabVIEW, IMAQ Vision Software, and other National Instruments products, visit **ni.com**

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