A Universal Passive Component Inspection System

This project profile describes a fully automated universal inspection system for passive optical components. The entire optic setup can be mounted on a 30×50 cm^2 breadboard, making it very compact and mobile. The system has very high measurement accuracy and repeatability with high throughput. Different versions of the system have been commissioned at iolon for all its incoming component inspections (linear filters, etalons, gratings, beam splitters, Faraday rotators, and others), at Novalux for frequency-doubling crystal characterizations, and at Coherent for its internal coating operation.

System Description

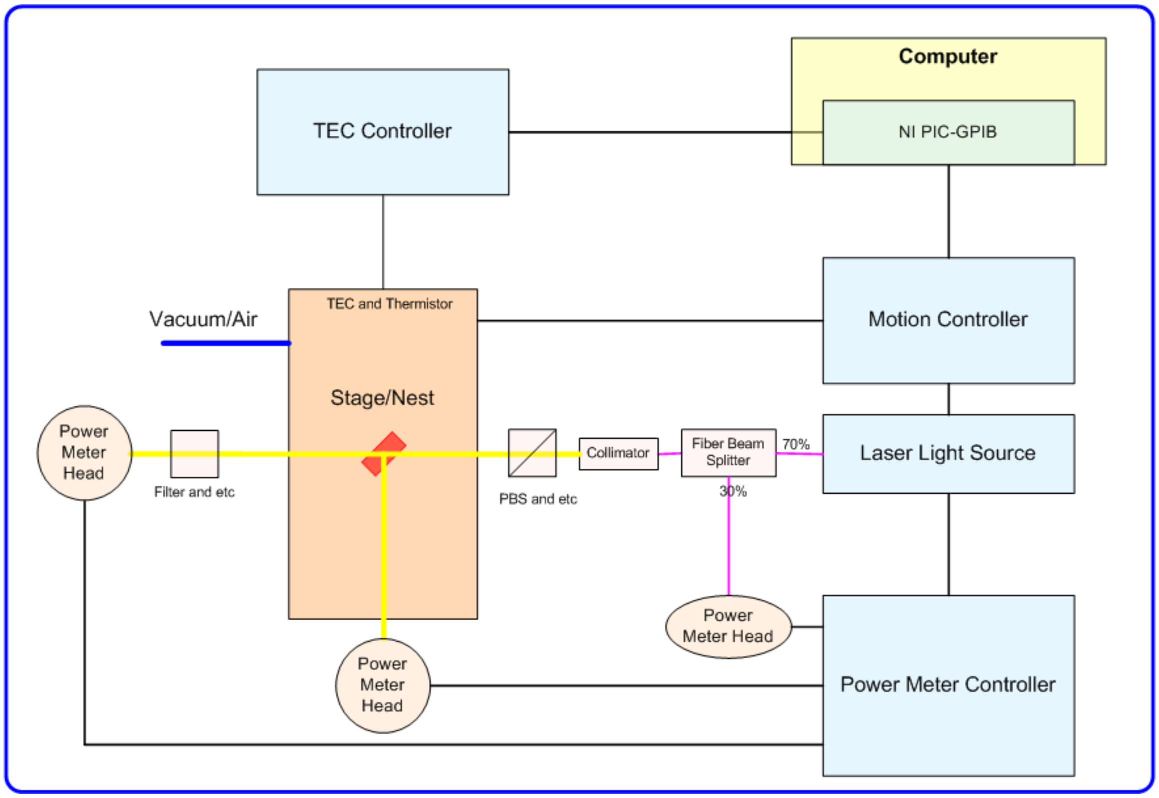
Figure 1 shows basic system block diagram. The light from the (tunable) laser source is coupled into a fiber collimator mounted on a miniature stage. The collimator collimates the beam onto the sample about 10 cm away. Additional optic components can be added to manipulate the beam, such as a polarized beam splitter to deliver P state beam, or a focusing lens for an extra small beam spot.

Depending on the application, the reflected and/or transmitted beams are measured by two integrated sphere power heads. Additional optic components can be added to the exit beam path for different applications. For example, a motorized linear polarizer is added for polarization angle measurement for polarized beam splitters and Faraday rotators, and IR filter is added for frequency-doubling crystal measurements.

The fiber beam splitter between the source and collimator is useful if absolute angle calibration is necessary. The zero-degree incident angle can be determined by maximizing the light retro-reflected into the fiber in the 30% line. A 70-30 splitter is better than a 50-50 splitter because it gives 20% more output while only loses 4% of the retro-reflected beam.

The sample is secured to the nest with vacuum. The temperature controlled nest (with TEC and thermistor) is mounted on a motorized stage assembly with XYZ and additional rotational capabilities.

Figure 1. System Block Diagram



System Characteristics and Measurement Examples

Beam Size

Figure 2 shows beam size measured with a knife-edge cutting through the beam. At 1/e^2 (i.e. 95.4% of the beam assuming a Gaussian distribution), the beam size is 550 µm. The total beam size is less than 1 mm, which is enough for most of the small passive components. Smaller beam size, when needed, can be achieved by inserting a lens in the beam path (Figure 10).

Figure 2. Beam Size Measurement

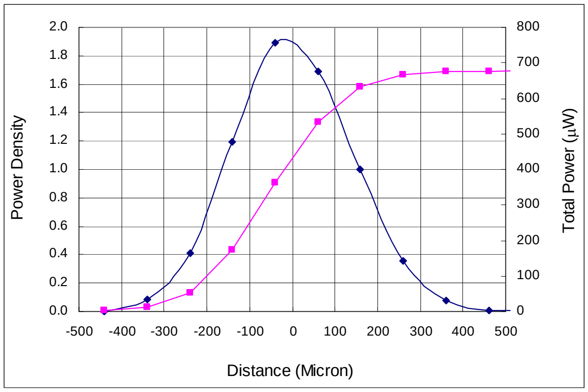
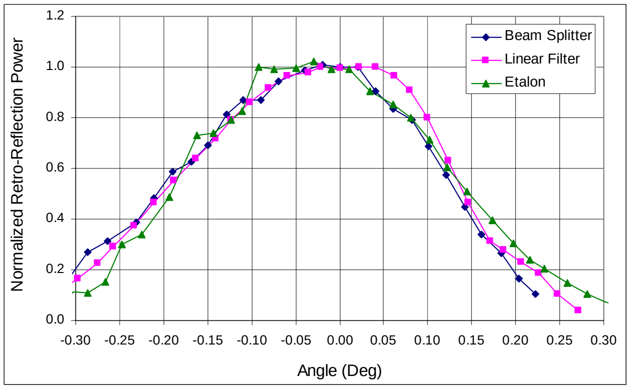


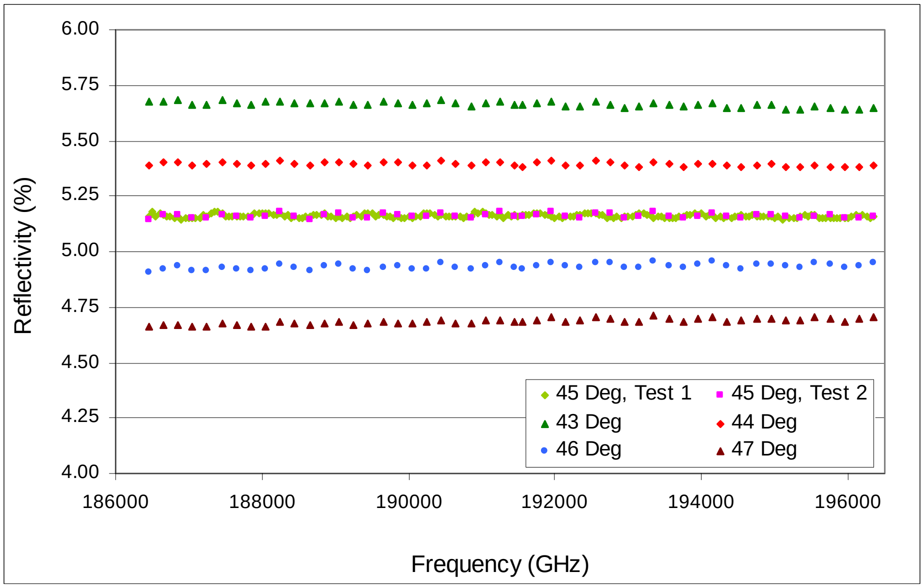
Figure 3. Retro-Reflection Accuracy



Angle Alignment Accuracy

The 70-30 fiber beam splitter is used to accurately determine the normal incident by maximizing the retro-reflected beam in the 30% line. Figure 3 shows the retro-reflection signal as a function of the incident angle for three different types of components. With very low background noises, the reflected signal is large enough to tune the stage for most of the component types. Although the signal intensities are different for different kinds of components, their alignment accuracies are about the same with very similar shapes. By a curve fitting for the peak, the sample alignment can be determined within ±0.05°.

Figure 5. Beam Splitter Reflectivity as a Function of Incident Angle



Measurement Accuracy, Repeatability, and Examples

High measurement accuracy and repeatability can be achieved by monitoring the transmitted and reflected beam simultaneously. While it is relatively expensive to have two power detectors, it eliminates the beam stability (total power and polarization) issues the system otherwise would have. It also eliminates the system dependent calibration between the power reading and the source monitor signal. Further more, the power detectors only require standard calibration specified by the vendor, which can be done efficiently and cheaply.

Figure 5 illustrates the typical measurement accuracy of the system. Assuming that all the ripples seen are caused by the system noise, the measurement error is less than 0.01%. The actual system error should be much smaller than this because the ripples in the figure are frequency dependent and most likely caused by some etalon effects.

Figures 6-11 show of measurement results for different type of components. One can easily deduce various measurement capabilities from these plots.

Figure 6. Linear Filter Transmission Signal

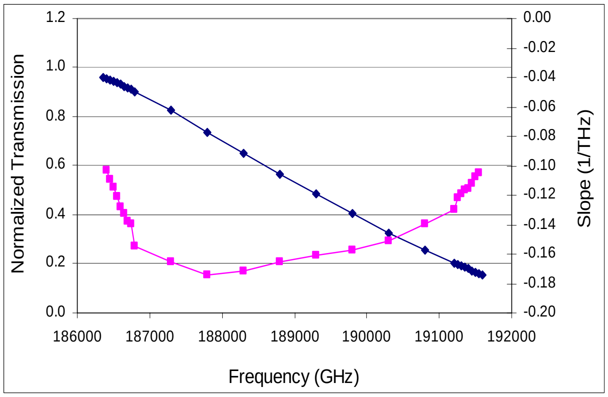


Figure 7. Etalon at Different Temperatures

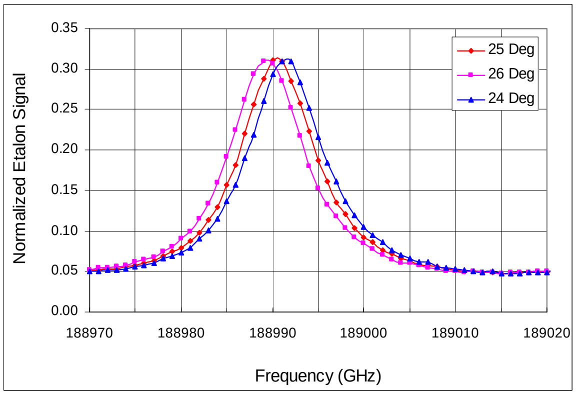


Figure 8. Beam Polarization and Extinction Ratio

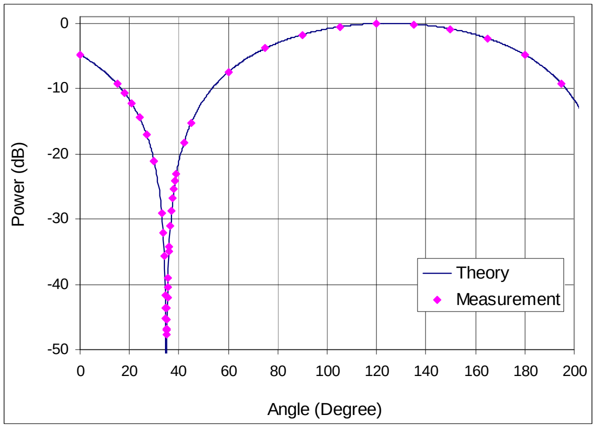


Figure 9. Temperature Optimization for Crystal

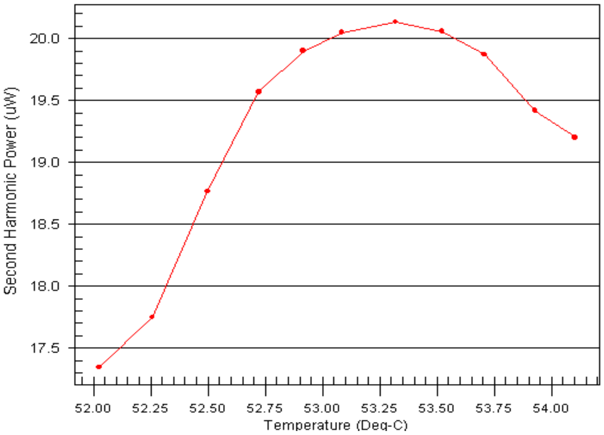


Figure 10 shows crystal nonlinear coefficient 2D profile, measured with a focused beam to achieve 50-µm space resolution. The focal point is determined by maximizing the transmission power while moving the sample (stage) in the beam direction (Figure 11).

Figure 10. Crystal Nonlinear Coefficient Profile

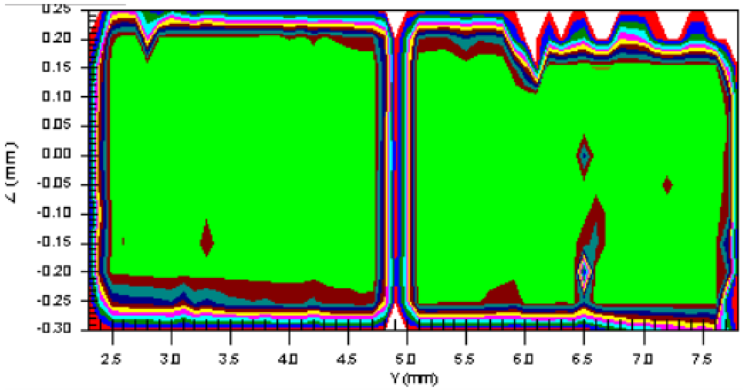
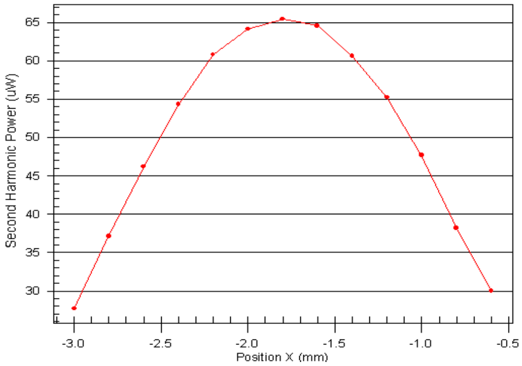


Figure 11. Beam Size Optimization



Software User Interface and Capability

Figure 12 shows software user interface for two different applications. Besides the application detail, the basic features are the same: a manual control panel on the left mostly for engineering purpose, a testing panel in the middle for routine production, and graphic area on the right for plotting results.

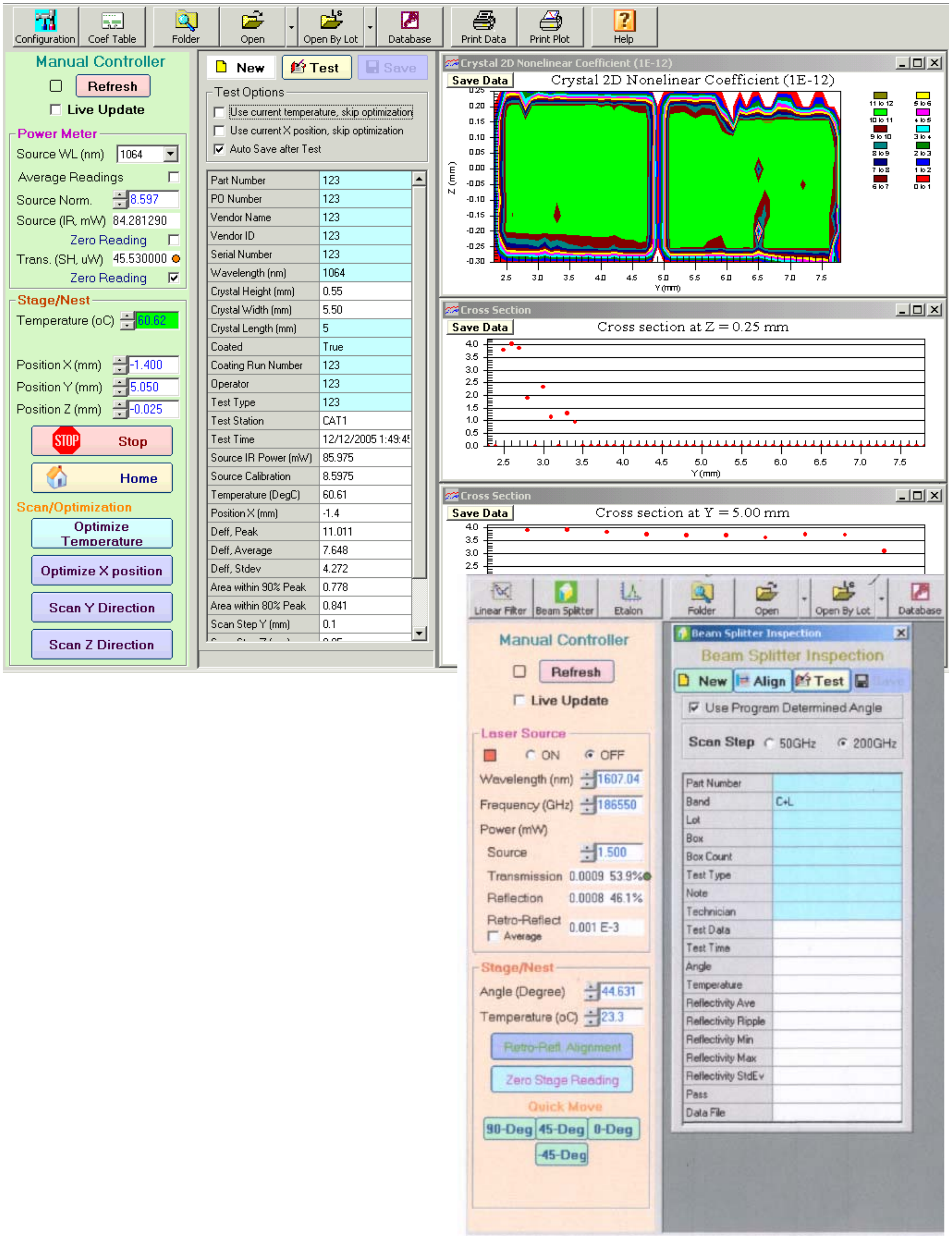
The manual controller allows individual control of each hardware instrument. This is the same as controlling the instrument through its front panel, only with added ease. In addition, it provides some assembled routines for certain basic tasks, such as angle alignment or beam optimization.

The fully automated test panel is specifically oriented for volume production. After entering the necessary part tracking information in the light blue shaded lines, a simple click of the “Test” button finishes the test. The testing results are automatically saved into the database (SQL server or other database systems) and file server (raw test data) with pass-fail information flagged with green-red shade after software compares the results with the specifications.

Besides the production mode, the software comes with offline data review capability. Tested data can be easily retrieved from the database and file server and re-plotted. This is very useful for SPC (statistical process control) and presentations.

Additional tools are provided for system configurations (such as database link updates, specification updates or modifications, testing parameter modifications, and etc) and test recipe management.

Figure 12. Two Software GUI Examples



Manual Controller

☐ Live Update

Power Meter

Source WL (nm) 1064

Average Readings ☐

Source Norm. 8.597

Source (IR, mW) 84.281290

Zero Reading ☐

Trans. (SH, uW) 45.530000

Zero Reading ☑

Stage/Nest

Temperature (oC) 60.62

Position X (mm) -1.400

Position Y (mm) 5.050

Position Z (mm) -0.025

Test Options

☐ Use current temperature, skip optimization

☐ Use current X position, skip optimization

☑ Auto Save after Test

Part Number	123
PO Number	123
Vendor Name	123
Vendor ID	123
Serial Number	123
Wavelength (nm)	1064
Crystal Height (mm)	0.55
Crystal Width (mm)	5.50
Crystal Length (mm)	5
Coated	True
Coating Run Number	123
Operator	123
Test Type	123
Test Station	CAT1
Test Time	12/12/2005 1:49:45
Source IR Power (mW)	85.975
Source Calibration	8.5975
Temperature (DegC)	60.61
Position X (mm)	-1.4
Deff, Peak	11.011
Deff, Average	7.648
Deff, Stdev	4.272
Area within 90% Peak	0.778
Area within 80% Peak	0.841
Scan Step Y (mm)	0.1

Manual Controller

☐ Live Update

Laser Source

○ ON ● OFF

Wavelength (nm) 1607.04

Frequency (GHz) 186550

Power (mW)

Source 1.500

Transmission 0.0009 53.9%

Reflection 0.0008 46.1%

Retro-Reflect 0.001 E-3

☐ Average

Stage/Nest

Angle (Degree) 44.631

Temperature (oC) 23.3

Beam Splitter Inspection

☑ Use Program Determined Angle

Scan Step ○ 50GHz ● 200GHz

Part Number	
Band	C+L
Lot	
Box	
Box Count	
Test Type	
Note	
Technician	
Test Data	
Test Time	
Angle	
Temperature	
Reflectivity Ave	
Reflectivity Ripple	
Reflectivity Min	
Reflectivity Max	
Reflectivity StdEv	
Pass	
Data File	