

OPAL-EC: edge-coupling wafer-level test station

AUTOMATED TEST STATION FOR INTEGRATED PHOTONICS

- Accurate, repeatable, flexible, fast testing of photonic integrated circuits (PIC) with traceable results



KEY FEATURES

- Complete PIC testing platform with production-grade hardware
- Best-in-class repeatability of optical probe and base motion systems
- Industry first multipoint edge-coupling testing at wafer level
- Preparation, automated execution and data processing within one software suite
- Wafer, stretch-tape, multiple dies or bar testing with the same station
- Flexible design with repositionable optical and RF/DC probes
- Compatible up to 300 (mm) / 12-in wafers

APPLICATIONS

- R&D to high-volume multisite production for known-good-die identification
- Opto-electronic testing on integrated photonics platforms: silicon photonics, indium phosphide, III-V, polymer, heterogeneous
- Application-agnostic: telecom and datacom transceivers, quantum, LIDAR, sensors, AI

OPAL-EC PLATFORM

The OPAL-EC edge-coupling wafer-level test station provides industry-leading performance for integrated photonics characterization with accurate, repeatable, flexible and fast hardware. The PILOT software suite enhances the OPAL-EC hardware capabilities by transforming the hardware into an automated testing station and a source of quality measurements that can be digested into actionable data. The complete suite of applications is a platform that supports the full test-and-measurements flow and help users to become more data-driven. Combined with EXFO's advanced optical measurements capabilities and open to any third-party instrument, this complete platform is the ideal PIC testing solution.



Figure 1. EXFO's platform for wafer-level PIC testing, with OPAL-EC test station, PILOT software, and EXFO's leading solutions for optical characterization of PIC. Third-party instruments can be added and controlled by PILOT.

The station's hardware consists of an ultra-repeatable 4-axis motion system wafer positioning stage, allowing 105° rotation with a chuck to hold up to 12-in (300 mm) wafers with thermal control as an option. Adapter plates enable tests for single dies, bars and multiple dies making it one station to fit all form factors. The station can accommodate up to four probing heads with a choice of optical or electrical probes. It also includes high-resolution, in-line brightfield top vision system and telecentric side vision systems. The system includes dedicated license for the PILOT software suite, installed on an industrial rackmount computer.

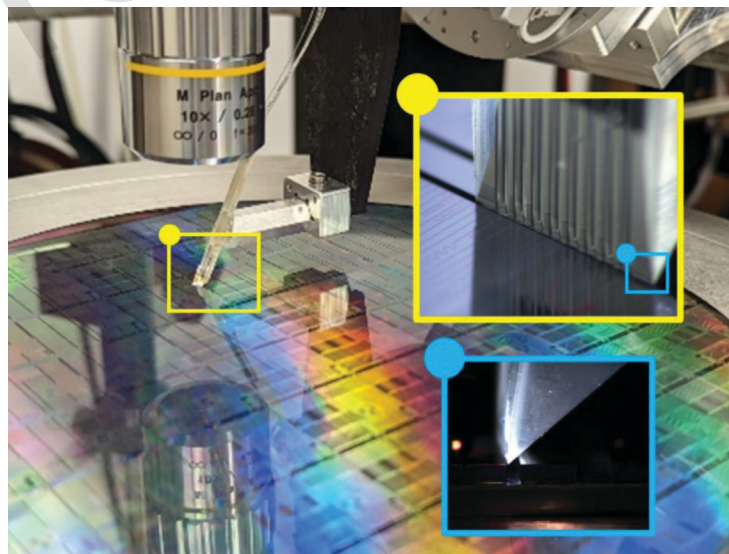


Figure 2. Edge-coupling within trench on wafer using a special fiber array and the OPAL-EC-300 station.

An industry-first: the station's state-of-the-art components enable fully automated, highly repeatable, multi-port, optical edge-coupling alignment at the wafer-level through trench coupling. This accuracy level disrupts the typical reliance on surface grating coupler as additional proxies for die screening at the wafer-level. This, in turn, allows for testing the complete circuit, including the production ports that will be used for packaging, much earlier in the production chain, which eliminates costly steps and increases global yield and circuit performances.

The same test station can also swiftly be reconfigured in-situ and used for surface-coupling alignment.

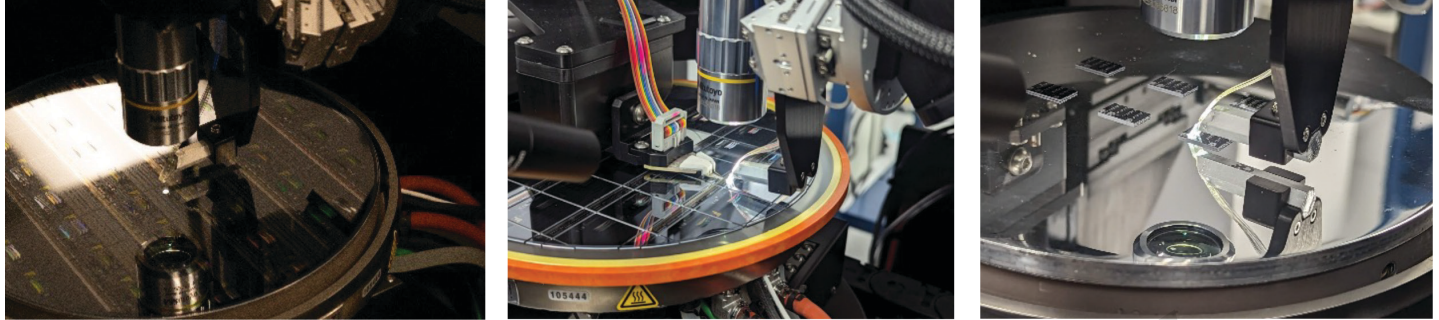


Figure 3. Re-testing the same circuits with a single OPAL-EC station over the process chain: from wafer, to singulated dies on stretch-tape, to multiple depopulated dies on a plate adapter. Here, with optical surface coupling and DC probe.

The OPAL-EC station is part of the OPAL family of test stations dedicated to PIC testing. The family includes a surface-coupling-only station, OPAL-SC and a single-die station, OPAL-SD, all powered by the PILOT software.

PILOT AUTOMATION SOFTWARE

PILOT is a software platform that orchestrate the complete flow of PIC test and measurement: (i) test preparation, (ii) execution of fully automated navigation, alignment and measurements at a high throughput and (iii) analysis and data management of the results.

Insight, knowledge and decision



Big data



Data analysis

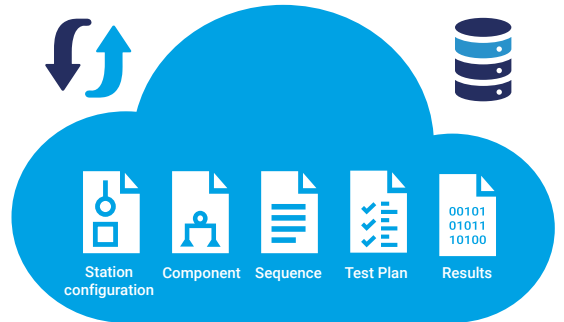


Artificial intelligence



Business intelligence

Database



Automated test station and software

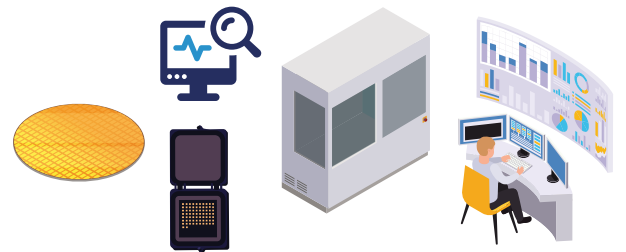


Figure 4. OPAL test stations and PILOT software automates PIC testing with powerful, scalable features, utilizing multiple applications linked to a collaborative database for advanced data analysis and AI.

Powerful and scalable

From software architecture to implementation, PILOT is designed for scalability in time and volume and helps implement best practices. It streamlines automation of tasks (preparation, data analysis, reporting) and measurements (navigation, alignment, instrument control) to increase effectiveness. The software is composed of multiple applications, each designed for its specific task, with de-coupled concepts and responsibilities.

Database benefits

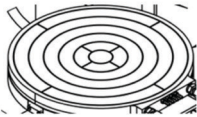

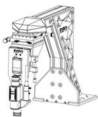
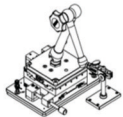


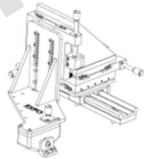

Underlying all applications, the software is linked to a database (cloud-based or on-premises), that acts as a data repository for all of the elements (results and experimental conditions, station configuration, test definition, component definition, drivers, python scripts). PILOT enables multi-users, multi-site collaboration with a shared common workspace of the data. The database is relational, traceable and scalable to high volume, making the system natively compatible and designed to support advanced data analysis, artificial intelligence and business intelligence tools through built-in tools or by interoperability.



Figure 5. PILOT software suite: Prepare – Execute – Analyze with a single software.

OPAL-EC PLATFORM COMPONENTS

A test station consists of the OPAL-EC main system station with PILOT software. Probing heads (optical and electrical) types and number of units should be added for a complete system, depending on the requirements. The OPAL-EC comes in two different options of sizes, either to accommodate wafers up to 200 mm (OPAL-EC-200) or up to 300 mm (OPAL-EC-300). Other options are available to accommodate more specific needs, such as a thermal chuck.

COMPONENTS				
OPAL-EC MAIN SYSTEM	Chuck		Aluminum surface, ground polished, ambient temperature, chuck with 1 x vacuum zone. Electrical surface connection options.	- TCH: Thermally controlled chuck with heating and cooling capabilities, with range from 0 °C to 200 °C, 4 vacuum zones
	Wafer positioning base stage		High accuracy, 4 degrees of freedom wafer positioning with possibility to rotate a wafer by 105°.	- 200: 200 mm (8-in) or - 300: 300 mm (12-in) diameter chuck and XY travel range
	Vision system		Top high-resolution video system with 10X magnification using in-line coaxial illumination and 2.9 MP color camera on XYZ manual adjustment.	
			Magnetic toggleable, side view 2.9 MP color camera with 3X telecentric magnification on XY manual adjustment.	
	Additional accessories		Industrial rackmount PC and accessories (KMV), two 27-in monitors.	- Free-standing workstation - Top enclosure
	PILOT software dedicated license		Full software suite for complete test and measurement flow of PIC. Automation and control of test station, instruments and data for absolute traceability and reliability of results that are report-ready and AI-ready.	- Additional floating licenses available, for multi-user collaboration from anywhere
PROBES ^a	Electrical head		4-axis manual electrical probe positioners. Fine alignment and long travel range. Probe holders compatible with most DC and RF probes.	- PRE-00: Manual, 50 mm range - PRE-MO: Motorized, 25 mm range, 200 nm resolution
	Optical (PRO-XX)		Motorized 6-axis nanometer-precision and piezo-based hexapod for precise and fast operation for edge coupling as well as surface coupling. Features virtual pivot point, ideal for optimization of injection angle during automated coupling. Includes a clamp that fits most fiber arrays and a slider and manual screws concept to toggle between engaged/disengaged positions.	- Other optical head options available (contact an EXFO representative)

a. Optical probes (fiber array, fiber) and electrical probes (DC, RF) are not included in the system. If these components are required, please contact an EXFO representative.

BUILD YOUR STATION CONFIGURATION

The OPAL platform provides a flexible test environment to build a custom configuration, that can be modified at any time based on your needs and lowers design-for-test (DfT) requirements. Optical and electrical probes can be positioned around the wafer or die under test in any cardinal orientation (East/West/North/South), up to a total of four.

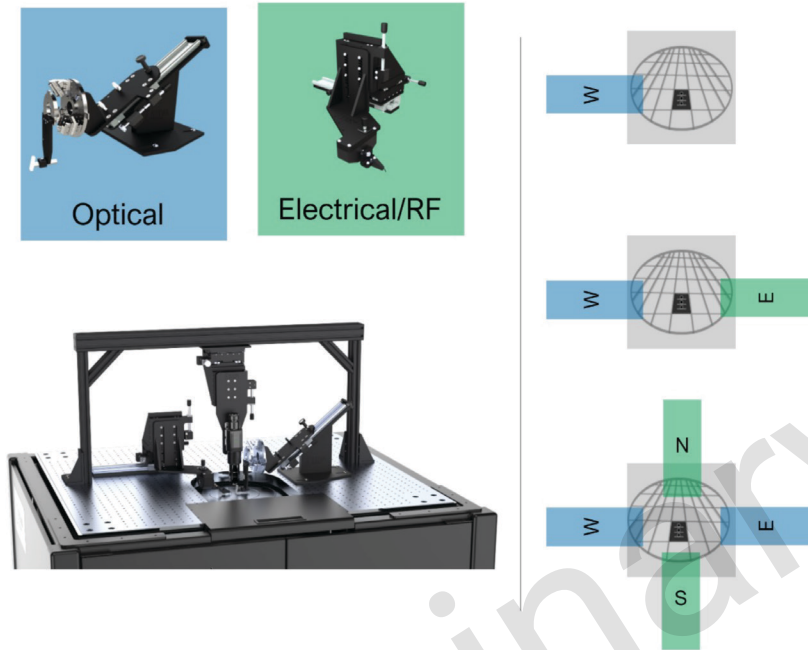


Figure 6. Reconfiguration of OPAL-EC for optical and electrical heads at any time for fast re-tooling.

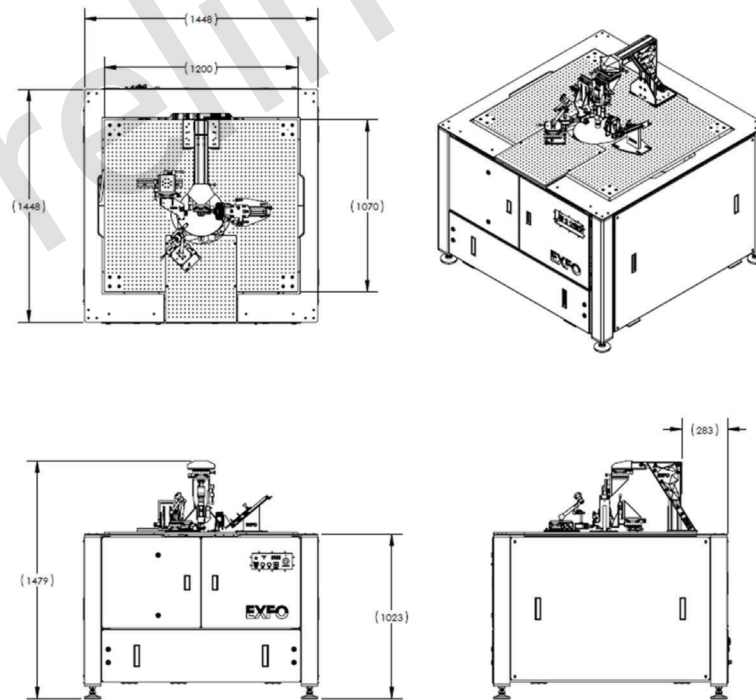


Figure 7. Technical drawing of the OPAL-EC-300 main system with dimensions in millimeters. Shown here with one (1x) PRO-P60 optical head and one (1x) PRE-00 manual electrical head. Not shown are the included the industrial rackmount PC, and the IT Kit (monitors, keyboard, mouse). Not shown are the chiller and the thermal chuck controller included with the (-TCH option). Non-final.

SPECIFICATIONS

WAFER POSITIONING STAGE			
Option name		OPAL-EC-200	OPAL-EC-300
XY Axis	Travel range (mm)	200	300
	Resolution (μm)	0.003	
	Accuracy (μm)	0.5	0.75
	Bi-directional repeatability (μm)	0.1	
	Maximum process speed (mm/s)	100	
	Orthogonality arcsec	1	
	Motor type	Direct-drive linear motors, noncontact encoder	
Z Axis (Height)	Travel range (mm)	5	
	Resolution (μm)	0.0008	
	Accuracy (μm)	1.5	
	Bi-directional repeatability (μm)	0.3	
	Maximum speed (mm/s)	4	
	Motor type	Direct-drive brushless linear motor	
Rz Axis (Wafer rotation)	Travel range	105 °	
	Resolution	0.36 arcsec; 0.0001 °	
	Accuracy	80 arcsec; 0.02 °	
	Repeatability	3 arcsec; 0.0008 °	
	Maximum speed (rpm)	600	
	Motor type	Direct-drive brushless rotary motor, mechanical bearing	

CHUCK			
Option name	TA	TH	TCH
Range (°C) ^a	Ambient	Ambient - 200	0 - 200
Resolution (°C)	-	0.01	
Stability (°C)	-	$\pm 0.05^\circ\text{C}$ (>25°C)	$\pm 0.05^\circ\text{C}$ (>25°C) and $\pm 0.1^\circ\text{C}$ (<25°C)
Heating rate (°C/min)	-	15	
Cooling rate (°C/min)	-	-	1.5
Surface flatness (μm)	< 25		
Vacuum	4 independent zones (4", 6", 8", 12"), electronically controlled		
Electrical surface ^b	Grounded		

a. Other temperature ranges available upon request

b. Other electrical surface options available upon request: floating, triaxial

TOP VISION SYSTEM	
Option name	VHD
X, Y, Z axis travel range (mm)	48
X, Y axis displacement/revolution (mm)	1.41
Z axis displacement/revolution (mm)	0.3175
Magnification (X)	10
Numerical aperture	0.28
Depth of field (μm)	3.6
Field of view (μm)	2.4
Working distance (mm)	34
Resolution (MP)	2.9
Maximum frame rate (fps)	144
Sensor type	Color, 12 bit, global shutter
Wavelength	Visible
Illumination type	In-line through video microscope unit, LED illuminator

SIDE VISION SYSTEM	
Mechanical positioning	Magnetic toggleable base, 6D manual coarse adjustment, XY manual translation stage
X - Y axis travel range (mm)	48
X - Y axis displacement/revolution (mm)	1.41
Magnification (X)	3
Numerical aperture	0.093
Field of view (mm)	2.9 x 2.2
Working distance (mm)	65
Wavelength range	Visible
Resolution (MP)	2.9
Frame rate (fps)	144
Sensor format (")	2/3
Sensor type	Color, 12 bit, global shutter
Wavelength	Visible

Optical head options

OPTICAL HEAD PRO-P60	
Option name	PRO-P60
Degrees of freedom	6 motorized
Motor type	Piezo, hexapod
X axis travel (mm)	20
Y axis travel (mm)	11
Z axis travel (mm)	20
X,Y, Z axis resolution (nm)	1
X,Y, Z axis uni-directional repeatability (nm)	50
Rx axis travel (degree)	23
Ry axis travel (degree)	38
Rz axis travel (degree)	26
Rx, Ry, Rz axis resolution	0.04 arcsec; 0.00001 °
Rx, Ry, Rz axis uni-directional repeatability	1.5 arcsec; 0.0004 °
Included	Rail system for toggling into engaged/disengaged positions, fiber array holder and single fiber holder
Possible Orientations	North/East/West/South

a. Other optical head options available upon request

ELECTRICAL HEAD		
Option name	PRE-00	PRE-MO
Translation stages type	Manual	Motorized XYZ, manual probe angle
X, Y, Z axis travel range (mm)	48	25
X, Y, Z axis resolution (nm)	-	200
X, Y, Z axis repeatability (µm)	-	1.25
X, Y, Z axis accuracy (µm)	Typical: 2	2.5
X, Y, Z axis speed (mm/s)	-	0.4
X, Y, Z axis displacement / revolution (mm/rev)	0.3	-
Tilt travel (degree)	10	
Rail system X travel (mm)	180	
Z coarse step travel (mm)	Min: 6.35 Max: 56	Min: 6.35 Max: 57
Possible orientations	North/East/West/South	

MAIN STATION SYSTEM	
Size (H x W x D)	1496 mm X 1448 mm x 1448 mm
Mass (kg)	1250
Operating temperature (°C)	18 - 22
Storage temperature (°C)	0 - 40
Operating humidity (RF)	20% - 60%
Storage humidity (RF)	10% - 70%, non-condensing
Base	Enclosed base system Granite base for passive vibration isolation Front doors and removable front optical breadboard for wafer loading
Optical breadboard	Grid of M6 threaded mounting holes 25 mm hole spacing Black anodized for reduced reflections
Workstation computer	4U rackmount industrial, Intel i7 CPU, 64 Gb RAM DDR5, 1Tb SSD, Nvidia RTX 4060 GPU, 3 Ethernet ports (10 + 2.5 +1 Gbit/s), multiple USB ports, additional PCIe slots, Windows 11 Pro, mouse and keyboard included
Monitors	2 x 27-in
Additional communication ports on base station for equipment	Ethernet Cat6 RJ54, USB-A 3.0
Cables, power supply, drive, controllers	All included

- a. The system should be positioned in a low-vibration environment. Excessive floor or acoustical vibration can affect system performance. Although the base of the station includes a passive vibration isolation system, the expected vibration level for the operation of the OPAL-EC should be equal to or below the VC-A vibration criteria curve for edge-coupling alignment. The velocity should be below 50 (µm/s), when measured by the one-third octave bands of frequency over 8 to 80 Hz. At this level, vibrations are not perceptible. Else, contact us for more information on an active vibration damping system.
- b. If at any time the operating temperature deviates from 20 °C, degradation in performance could occur

Preliminary

ORDERING INFORMATION

Probe station

OPAL-EC-XX-XX

Travel range

200 = 200 mm travel range for 8-in wafer
 300 = 300 mm travel range for 12-in wafer

Chuck option

TA = Ambient temperature (no temperature control)
 TA = Ambient - 200°C temperature control (heating only)
 TCH = 0°C - 200°C temperature control (heating and cooling)

Example: OPAL-EC-300-TCH

ORDERING INFORMATION

Optical probe arm

PRO-XX

Probe arm grade

P60 = 6 degrees of freedom motorized

Example: PRO-P60

ORDERING INFORMATION

Electrical probe arm

PRE-XX

Probe arm grade

00 = Manual translation stage
 MO = Motorized XYZ, manual probe angle

Example: PRE-MO

As EXFO continuously improves its products, the delivered station may differ slightly from the one shown in the CADs and images used throughout this document.

EXFO headquarters T +1 418 683-0211 **Toll-free** +1 800 663-3936 (USA and Canada)

EXFO serves over 2000 customers in more than 100 countries. To find your local office contact details, please go to www.EXFO.com/contact.

For the most recent patent marking information, please visit www.EXFO.com/patent. EXFO is certified ISO 9001 and attests to the quality of these products. EXFO has made every effort to ensure that the information contained in this specification sheet is accurate. However, we accept no responsibility for any errors or omissions, and we reserve the right to modify design, characteristics and products at any time without obligation. Units of measurement in this document conform to SI standards and practices. In addition, all of EXFO's manufactured products are compliant with the European Union's WEEE directive. For more information, please visit www.EXFO.com/recycle. **Contact EXFO for prices and availability or to obtain the phone number of your local EXFO distributor.**

For the most recent version of this spec sheet, please go to www.EXFO.com/specs.

In case of discrepancy, the web version takes precedence over any printed literature.