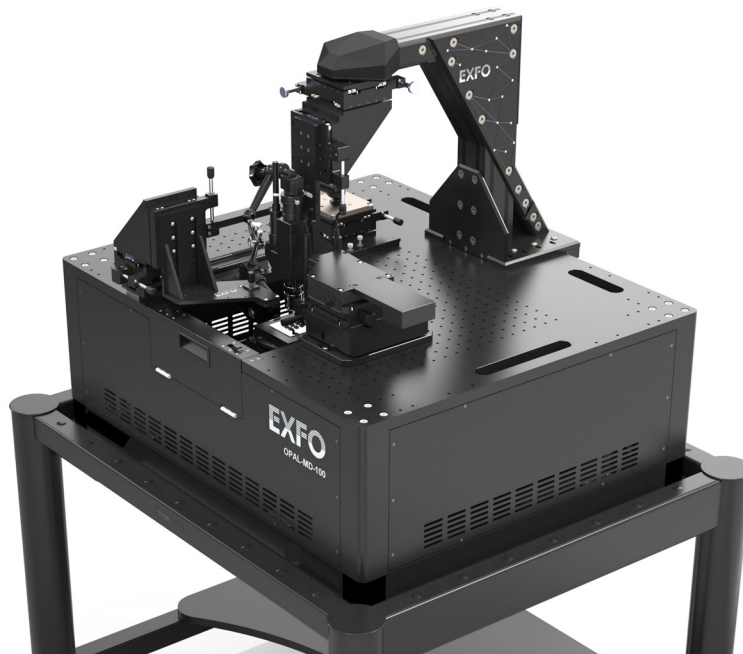


OPAL-MD – Multi-die testing

AUTOMATED TEST STATION FOR INTEGRATED PHOTONICS

- Accurate, automated, fast and cost-effective testing of photonic integrated circuits (PIC) with traceable results.



KEY FEATURES

Characterization of multiple singulated dies in one automated execution

Complete PIC testing platform for precise and repeatable optical alignment and electrical probing

Preparation, automated execution (navigation, alignment, instrument control) and data management (repository, analysis) with the included EXFO Pilot software suite

Flexible design with repositionable optical and electrical RF/DC heads

Different probe head options, as needed: Optical head models with up to 6 motorized axes for surface and edge coupling with single fibers or fiber arrays; Electrical heads with manual or motorized axes

APPLICATIONS

From R&D, design verification and process development to pilot production

Automated testing of multiple singulated dies from multi-project wafer run

DUT-agnostic: can test singulated dies (single to tens), reticles, custom cuts, bars, wafers. All samples up to 100×100 mm.

In-depth analysis of statistical circuit performance and yield

Opto-electronic testing on any integrated photonic platform: silicon photonics, indium phosphide, III-V, polymer, heterogeneous

Application-agnostic: telecom and datacom transceivers, quantum, LIDAR, sensors, AI for surface and edge coupling with single fiber or fiber-array to prototyping and pilot production

OPAL SERIES

The OPAL-MD station is part of the OPAL family of test stations dedicated to PIC testing, offering different performance, capability and throughput levels. These test stations are:

- OPAL-SD: a single-die station
- OPAL-MD: a multi-die station
- OPAL-EC: an edge-coupling wafer-level station

All test stations are driven by the EXFO Pilot software. Therefore, the test process and user training developed on one station is completely transferable to another station of the OPAL family. The optical heads, electrical heads, vision systems and IT kits are also transferable from one station to another, lowering barriers for hardware upgrades.

| | OPAL-SD | OPAL-MD | OPAL-EC |
|---------------------|---|---|---|
| DUT | Single die | Single die up to multi dies | Single die up to 12-in wafer |
| Work area (mm) | 50 × 50 | 100 × 100 | Φ300 |
| Coupling mode | Surface and edge coupling | | |
| Alignment | Manual or automated | Full automated | Full automated |
| Chuck | Ambient or 0 °C to 150 °C (32 °F to 302 °F) 3 vacuum zones | Ambient or 0 °C to 150 °C (32 °F to 302 °F) 4 vacuum zones | Ambient or 5 °C to 200 °C (41 °F to 392 °F) 4 vacuum zones |
| Rotation base stage | Manual rotation: 20° | Motorized rotation: 15° | Motorized rotation: 105° |
| Probe configuration | Optical and electric probes, up to 4 | | |
| EXFO Pilot software | Test plan execution, automation, analysis and a license are included with the station | | |

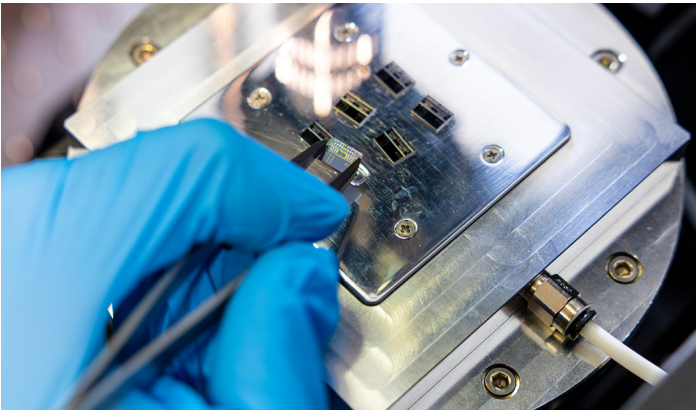


Figure 1. Testing multiple singulated dies at once with motorized base stage and automated navigation.

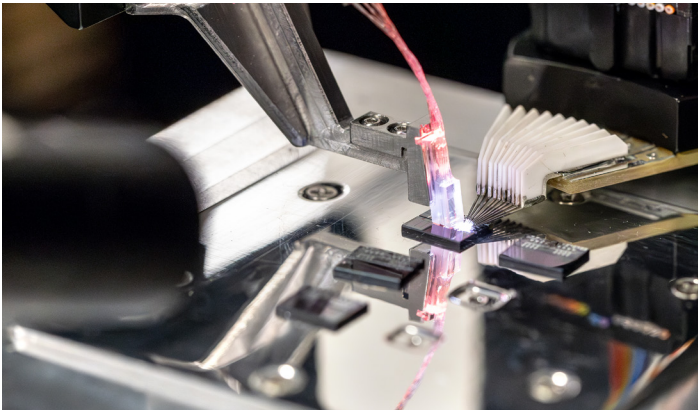


Figure 2. Test setup comprised of EXFO's OPAL-MD, EXFO Pilot software, CTP10, T500S or T200S lasers and a third-party SMU unit, as part of a complete and automated test and data management solution for optical characterization of photonic integrated circuits.

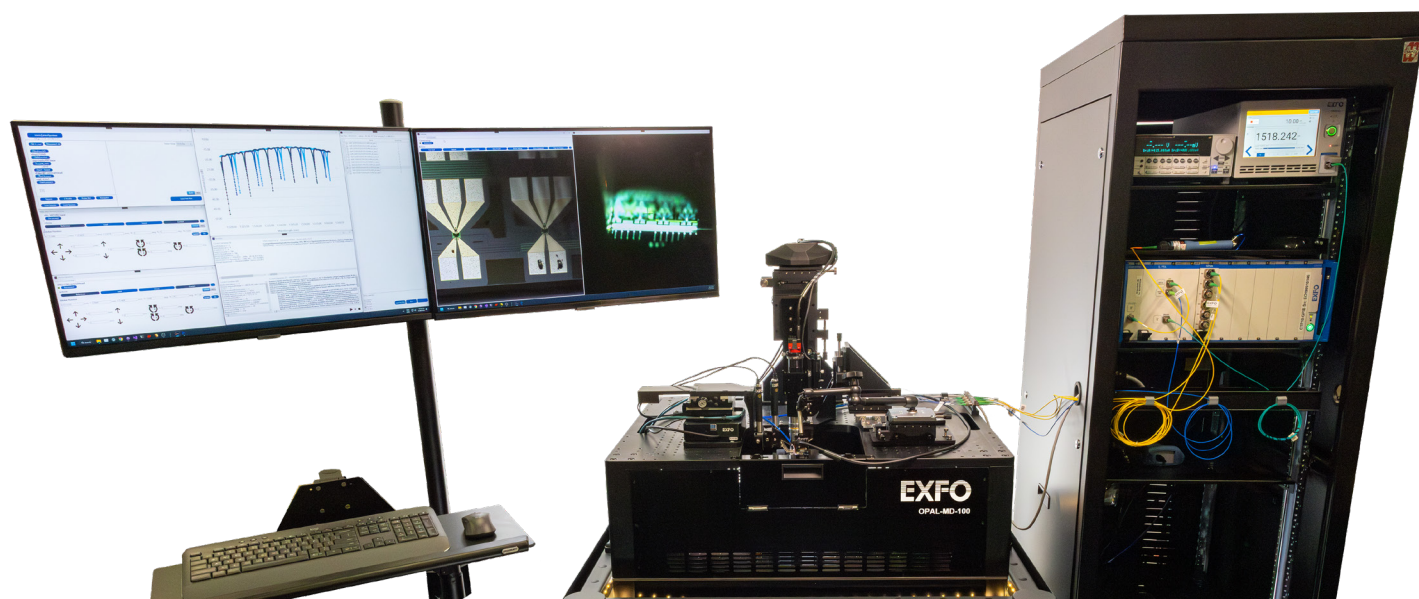


Figure 3. Optical and electrical probing. Shown here with fiber array for surface coupling and DC probe. Probes not included.

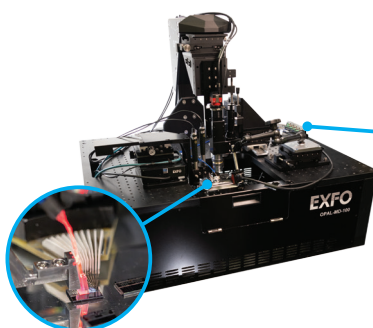
OPAL-MD PLATFORM

The OPAL-MD multi-die test station is the keystone of EXFO's high performance characterization solution for integrated photonics with accurate, repeatable, flexible and fast hardware. The EXFO Pilot software suite enhances the OPAL-MD hardware capabilities to provide an automated testing station and a source of quality measurements that can be turned into actionable data. The complete suite of applications is a platform that supports the full test-and-measurements flow and helps users to become more data-driven. Combined with EXFO's advanced optical measurement capabilities and open to any third-party instrument, the OPAL-MD is a complete platform for PIC testing.

EXFO Pilot software for
automation and data repository



OPAL station for
precise probing



Industry-leading EXFO instruments
for full optical characterization



+ Third-party instruments

Figure 4. EXFO's platform for multi-die testing comprising the OPAL-MD test station, EXFO Pilot software and EXFO test and measurement instruments for optical characterization of PIC. Third-party instruments can be added and controlled by EXFO Pilot.

The station's hardware consists of a motorized 4-axis motion system chuck positioning stage, holding one or multiple samples over an area of 100×100 mm², with thermal control as an option. The station can accommodate up to four probe heads for optical or electrical probes. It also includes a high-resolution, in-line brightfield top vision system and a telecentric side vision system.


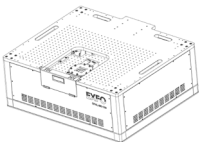
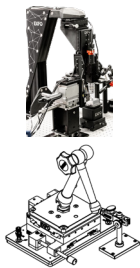


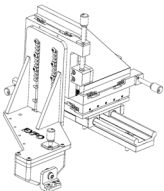
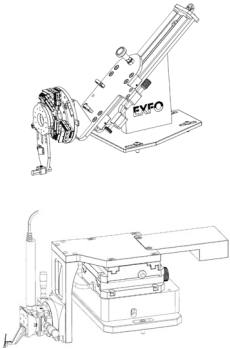
The OPAL-MD includes a dedicated license for the EXFO Pilot software suite, installed on an industrial rackmount computer.

The high resolution and repeatability of the base motion system and motorized optical head translates to lower insertion loss and error margin on optical measurements.

By providing the capability to test multiple dies and circuits efficiently, in a single test execution, the OPAL-MD probe station is effective at building a comprehensive and accurate dataset. It enables the users to get insight from statistical analysis; this data can be used to analyze and extract foundry-specific fabrication variations, system performance and yield. Such information is also valuable to iterate R&D towards high-performance and fabrication-tolerant circuits.

OPAL-MD-100 PLATFORM COMPONENTS

A test station consists of the OPAL-MD main system with EXFO Pilot software, with a thermal chuck as an option. Probing heads (optical and electrical) types and number of units should be added for a complete system, depending on the requirements.

| COMPONENTS | | DESCRIPTION |
|----------------------------|--|---|
| OPAL-MD MAIN SYSTEM | Chuck  | TA: ambient temperature, chuck with vacuum multi-die holders. Electrical surface connection options. TCH ^a : Thermally controlled chuck with heating and cooling capabilities. |
| | Wafer positioning base stage  | Motorized 4-axis multi-die positioning. Optical breadboard. |
| | 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 and flexible arm. Other magnifications/configuration are available upon request. |
| | Additional components  | Industrial rackmount PC and accessories. One 27-inch monitor. All drives and cables. |
| | EXFO Pilot app 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. One dedicated life-time license. Additional floating licenses available, for multi-user collaboration from anywhere. |
| PROBING HEADS ^b | Electrical heads ^c  | PRE-00 : 4-axis manual electrical probe positioners. Fine alignment and long travel range. Probe holders compatible with most DC and RF probes. PRE-MO : motorized, XYZ axis electrical probe positioners, resolution of 200 nm. |
| | Optical heads ^d  | PRO-H : 6-axis motorized piezo-based hexapod (resolution of 1 nm) for precise and fast operation. For edge coupling and surface coupling. Features virtual pivot point capability. Ideal for R&D. PRO-S : up to 6-axis motorized DC servo aligner (25-mm XY travel, resolution of 10 nm). Motorized pitch (injection angle) and manual roll and yaw angular adjustment. For surface and edge-coupling. Ideal for production scenario. PRO-ECO : 6 screw-driven aligner (25 mm) and 6-axis motorized. Ideal for surface coupling. Multiple options of optical probe holders are available, with various configurations and angles for surface and edge-coupling, from single-fiber to large fiber array unit |

a. Operation below 0°C requires top enclosure option to avoid water frost.

b. 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.

c. Includes a probe holder compatible with most DC and RF probes.

d. Includes a probe holder.

SPECIFICATIONS

A standard OPAL-MD test station includes: one OPAL-MD-100 chuck stage motion system, one TA chuck, a top and side vision system, PC with EXFO Pilot software license and accessories.

| CHUCK STAGE MOTION SYSTEM | | |
|---------------------------|---|---|
| OPAL-MD-100 | | |
| MECHANICAL | | |
| X, Y axis | Travel range (mm) | 100 |
| | Resolution (µm) | 0.15 |
| | Accuracy, typical (µm) | 1 |
| | Bidirectional repeatability, typical (µm) | 1 |
| | Maximum process speed (mm/s) | 20 |
| | Motor type | Recirculating ball bearing, stepper motor |
| Z axis | Travel range (mm) | 4.8 |
| | Resolution (µm) | 0.06 |
| | Accuracy, typical (µm) | 0.6 |
| | Bidirectional repeatability, typical (µm) | 0.1 |
| | Maximum speed (mm/s) | 5 |
| | Motor type | Linear ball bearings, DC motor |
| Rz axis | Travel range | 15° |
| | Resolution | 0.9 arcsec; 0.00025° |
| | Accuracy, typical | 36 arcsec; 0.01° |
| | Bidirectional repeatability, typical | 9 arcsec; 0.0025° |
| | Maximum speed (degree/s) | 20 |
| | Motor type | Crossed roller bearings, stepper motor |

| CHUCK | | |
|------------------------------------|---------------------|--|
| Option name | TA-F | TH1-G/F |
| Work area (mm) | 100 × 100, square | 100 × 100, square |
| Range ^a | Ambient | Dew-point (>0 °C) (32 °F) to 150 °C (302 °F) |
| Resolution | - | 0.01 °C (32 °F) |
| Stability | - | 0.05 °C (32 °F) |
| Heating rate | - | 20 °C/min (68 °F/min) |
| Cooling rate | - | -10 °C/min (14 °F/min) |
| Vacuum zones ^{b,c} | 4 independent zones | 4 independent zones |
| Electrical connection ^d | Floating (F) | Grounded (G)/Floating (F) |

| ORDERING INFORMATION | | |
|--|--|---|
| OPAL-MD-100-TA-F Floating ambient chuck, 100 mm, coaxial | OPAL-MD-100-TH1-G Thermal chuck 100 mm (0°C-150°C), grounded | OPAL-MD-100-TH1-F Thermal chuck 100 mm (0°C-150°C), floating, coaxial |

a. Other temperature ranges available upon request.

b. Custom vacuum patterns and zones available upon request.

c. Generic and custom vacuum adaptator plates available upon request.

d. Other electrical connection options available upon request.

| TOP VISION SYSTEM | |
|--|--|
| MECHANICAL BASE HOLDER | |
| Mounting | Compatible with metric and imperial optical breadboard, at 90° and 45° |
| X, Y, Z axis travel range (mm) | 48 |
| X, Y axis displacement/revolution (mm) | 1.41 |
| Z axis displacement/revolution (mm) | 0.3175 |
| VISION SYSTEM | |
| Magnification (X) | 10 |
| Numerical aperture | 0.28 |
| Depth of field (μm) | 3.6 |
| Horizontal field of view (mm) | 0.88 |
| Working distance (mm) | 34 |
| Resolution (MP) | 2.9 |
| Maximum frame rate (fps) | 144 |
| Sensor format (inch) | 2/3 |
| Sensor type | Color, global shutter, 12 bit |
| Wavelength | Visible |
| Illumination type | In-line through video microscope unit, LED illuminator |

| ORDERING INFORMATION | |
|---|--|
| OPAL-TVS-00 Standalone vision system (no mount) | OPAL-TVSW Vision system with multi-die and wafer mount as well as manual XYZ adjustment |

| SIDE VISION SYSTEM | |
|--|---|
| MECHANICAL BASE HOLDER | |
| Mechanical positioning | 6D manual coarse adjustment with articulated arm, XY manual translation stage |
| Mounting | Compatible with metric and imperial optical breadboard, at 90° and 45° |
| X, Y axis travel range (mm) | 48 |
| X, Y axis displacement/revolution (mm) | 1.41 |
| VISION SYSTEM | |
| Lens type | Telecentric |
| Magnification ^a (X) | 3 |
| Numerical aperture | 0.093 |
| Field of view (mm) | 2.9 × 2.2 |
| Working distance ^b (mm) | 65 |
| Wavelength range | Visible |
| Resolution (MP) | 2.9 |
| Maximum frame rate (fps) | 144 |
| Sensor format (inch) | 2/3 |
| Sensor type | Color, global shutter, 12 bit |
| Wavelength | Visible |

| ORDERING INFORMATION | |
|----------------------|--|
| OPAL-SVS-00 | |

a. Other magnifications options (0.5X, 1X, 2x, 4X, 6X, 8X) available upon request.

b. Other working distances options (40 mm, 110 mm) available upon request.

OPTICAL HEAD ^a

| Option name | PRO-H | PRO-S | PRO-ECO |
|--------------------------------|--------------------------------------|----------------------------------|---------------------|
| Motorized axis | X, Y, Z, Rx, Ry, Rz | X, Y, Z, Rx, Ry, Rz ^b | X, Y, Z, Rx, Ry, Rz |
| Configuration | Parallel hexapod, piezo ^d | Serial stack, DC servo | Serial stack, screw |
| X axis travel (mm) | 20 | 25 | |
| Y axis travel (mm) | 11 | 25 | |
| Z axis travel (mm) | 20 | 4.8 | 12.5 |
| X axis resolution (nm) | 1 | 10 | 200 |
| Y axis resolution (nm) | 1 | 10 | 200 |
| Z axis resolution (nm) | 1 | 60 | 25 |
| X axis repeatability (nm) | Unidirectional: 50 | Bidirectional: 70 | Bidirectional: 1250 |
| Y axis repeatability (nm) | Unidirectional: 50 | Bidirectional: 70 | Bidirectional: 1250 |
| Z axis repeatability (nm) | Unidirectional: 50 | Bidirectional: 250 | Bidirectional: 125 |
| Rx axis travel (°) | 23 | 10 | |
| Ry axis travel (°) | 38 | 10 | |
| Rz axis travel (°) | 26 | 10 | |
| Rx axis resolution (arcsec) | 0.04 | 4 | |
| Ry axis resolution (arcsec) | 0.04 | 4 | |
| Rz axis resolution (arcsec) | 0.04 | 4 | |
| Rx axis repeatability (arcsec) | Unidirectional: 1.5 | 7 | |
| Ry axis repeatability (arcsec) | Unidirectional: 1.5 | 7 | |
| Rz axis repeatability (arcsec) | Unidirectional: 1.5 | 7 | |
| Full virtual pivot point | Yes | No | |
| Included ^c | | Fiber/array holder | |

ORDERING INFORMATION

| PRO-H-61-20 | PRO-S-XX-20 | PRO-ECO-60-20 |
|-------------|---|---------------|
| | xx = 30 3 motorized axes (XYZ) and 3 manual axes (Rx, Ry and Rz) | |
| | xx = 40 4 motorized axes (XYZ and Rx) and 2 manual axes (Ry and Rz) | |
| | xx = 41 4 motorized axes (XYZ and Ry) and 2 manual axes (Rx and Rz) | |
| | xx = 42 4 motorized axes (XYZ and Rz) and 2 manual axes (Rx and Ry) | |
| | xx = 50 5 motorized axes (XYZ and RxRy) and 1 manual axis (Rz) | |
| | xx = 51 5 motorized axes (XYZ and RxRz) and 1 manual axis (Ry) | |
| | xx = 52 5 motorized axes (XYZ and RyRz) and 1 manual axis (Rx) | |
| | xx = 60 6 motorized axes (XYZ & RxRyRz) | |

a. Other optical options and configurations are available upon request.

b. Various configurations are available. X, Y, Z are always motorized and angles can be motorized, up to all 6 axes.
Specifications here are for all motorized axes, travel may differ for manual version.

c. Multiple options are available for surface and edge coupling configuration, multiple angles available.

d. Piezo equipped with exchangeable drive-units for an easy and fast replacement without the necessity to fully disassemble the positioning system.

ELECTRICAL HEAD

| Option name | PRE-00 | PRE-M0 |
|---|----------------------|---------------------------------------|
| Translation stages type | Manual | Motorized X, Y, Z, manual probe angle |
| X, Y axis travel range (mm) | 48 | 50 |
| Z axis travel range (mm) | 48 | 25 |
| X, Y, Z axis resolution (nm) | - | 100 |
| X, Y, Z axis repeatability (μm) | - | 1, bidirectional, typical: 0.3 |
| X, Y, Z axis accuracy (μm) | Typical: 2 | 5 |
| X, Y, Z axis speed (mm/s) | - | 5 |
| X, Y, Z axis displacement/revolution (mm/rev) | 0.3 | - |
| Tilt travel | 10° | 10° |
| Z coarse step travel (mm) | Min: 6.35 Max: 56 | Min: 12.5 Max: 100 |

ORDERING INFORMATION

| | |
|-----------|-----------|
| PRE-00-20 | PRE-M0-20 |
|-----------|-----------|

EXFO PILOT AUTOMATION SOFTWARE

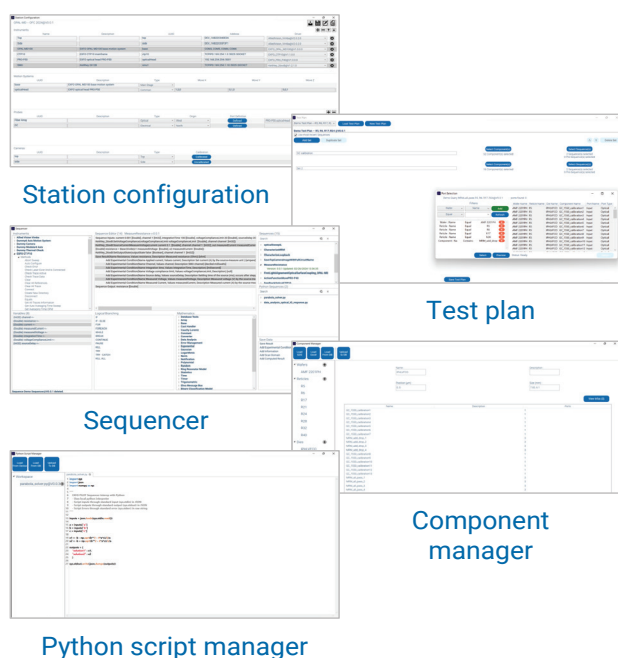
EXFO Pilot is a software platform that orchestrates the complete flow of PIC test and measurement: (i) test preparation, (ii) execution of fully automated navigation, alignment and measurements at a high-throughput and (iii) analysis and data management of the results.

Connect & launch

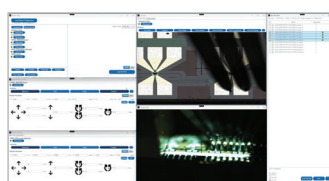


EXFO PILOT app

Prepare

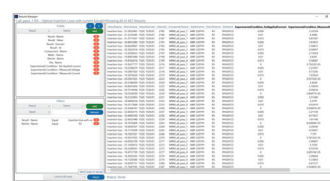


Execute



Station app

Analyze



Result manager

Figure 5. EXFO Pilot app: Prepare – Execute – Analyze with a single software suite.

POWERFUL AND SCALABLE

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

EXFO Pilot's PREPARE apps helps define which components are being tested, with which instruments, how to test and what to test. Existing Python scripts can also be easily included in the test process. The EXECUTE app offer manual and fully automated ways to run the tests and control the connected instruments and station. The ANALYZE apps allow database queries and fetch information relevant to particular characterization.

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). It therefore 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.

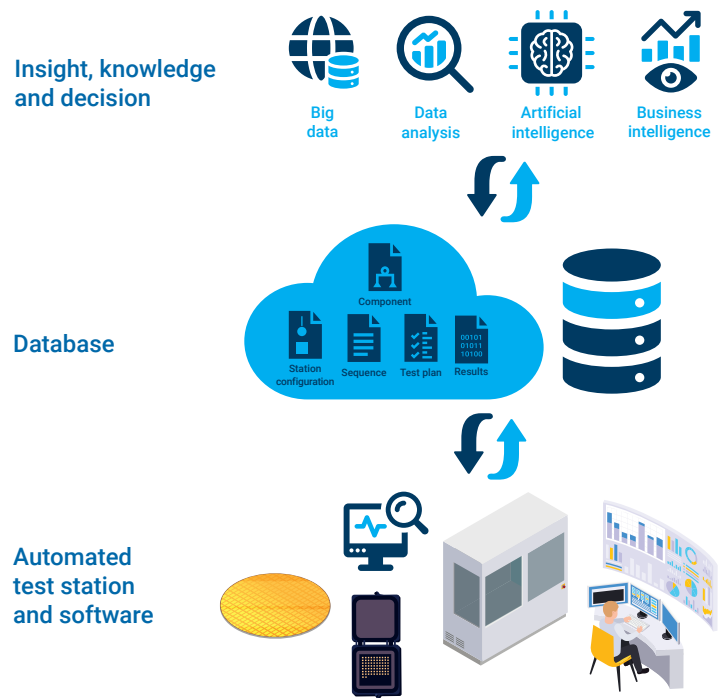


Figure 6. OPAL test stations and EXFO Pilot software automates PIC testing with powerful, scalable features, utilizing multiple applications linked to a collaborative database for advanced data analysis and AI.

BUILD YOUR STATION CONFIGURATION

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

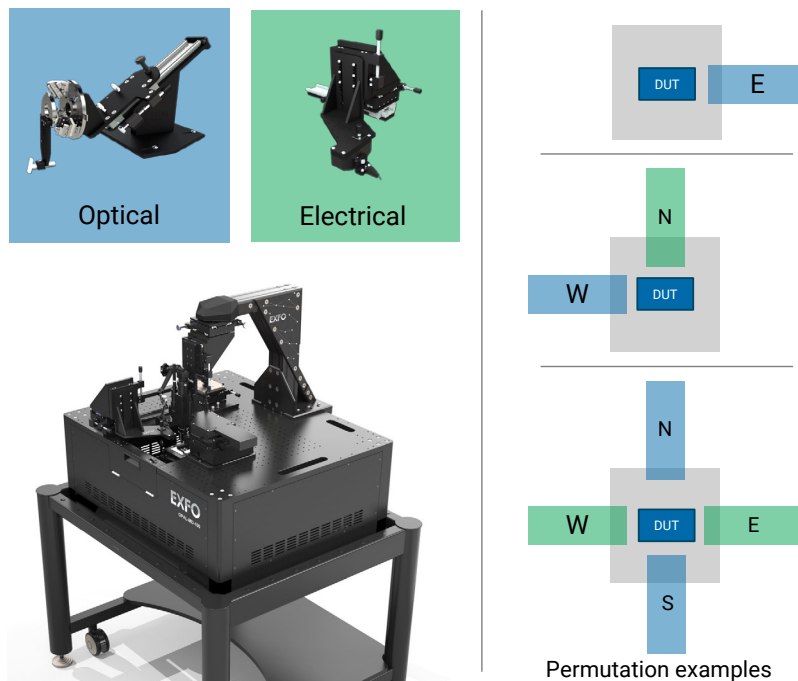


Figure 7. Reconfiguration of OPAL-MD optical and electrical probe heads at any time for fast re-tooling.

| GENERAL SPECIFICATIONS – MAIN SYSTEM | |
|--|--|
| Size (H × W × D) | 1500 mm × 1095 mm × 945 mm (59 in × 43 1/8 in × 37 1/4 in) |
| Weight (kg) ^a | 350 kg (771.6 lb) |
| Operating environment ^b | Use in a clean environment to avoid temperature variations, vibrations, humidity and dust |
| Base | Base frame with passive vibration isolation, canisters and feet |
| Maximum number of electrical or optical heads | Up to 4 |
| Optical breadboard | Grid of M6 threaded mounting holes, 25 mm hole spacing, black anodized for reduced reflections |
| Workstation computer | 3U rackmount industrial, Intel i7 CPU, 2 x 16 GB RAM DDR5, 1 TB SSD, Nvidia RTX 5060 GPU, 3 Ethernet ports, multiple USB ports, additional PCIe slots, Windows 11 Pro, mouse and keyboard included |
| Monitor | 1 × 27-inch |
| Cables, power supply, drive, controllers | All included |
| Additional communication ports on base station for equipment | Ethernet Cat 6 RJ54, USB-A 3.0 |

Note: Use the system in a low-vibration environment. Excessive floor or acoustical vibration can negatively impact system performance. Although the base of the station includes a passive vibration isolation system, the expected vibration level for the operation of the OPAL-MD-100 should be equal to or below the VC-A vibration criteria curve for best performances, especially 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.

a. The exact mass of the main system depends on the selected configuration.

b. Use the system in a controlled environment. Environmental temperature variations will degrade performance.

TECHNICAL DRAWINGS

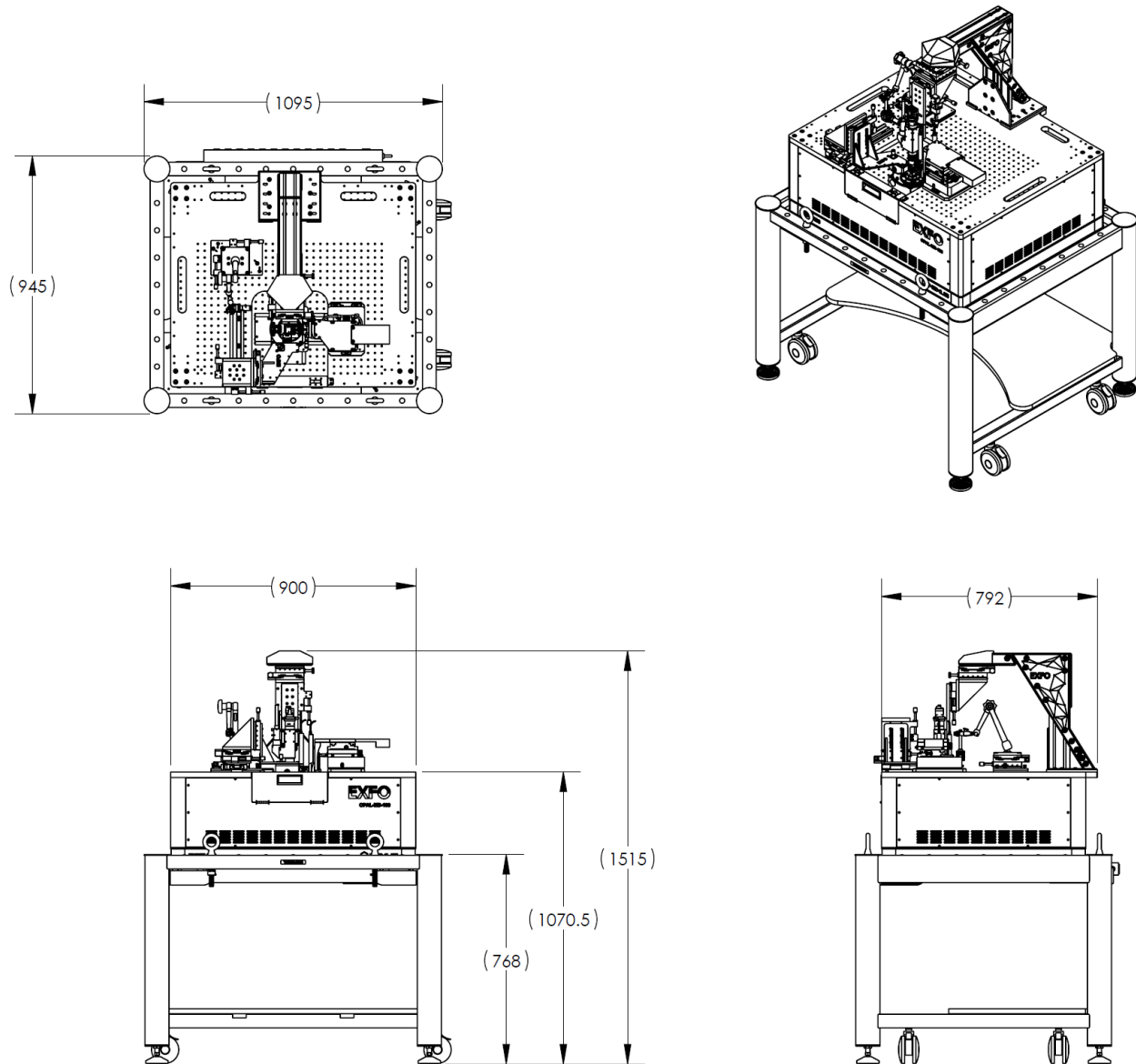


Figure 8. Technical drawing of the OPAL-MD-100 main system with dimensions in millimeters. Shown with one (1x) PRO-S-40 optical head, one (1x) PRE-00 manual electrical head, and one (1x) base frame. Not shown: included industrial rackmount PC and IT kit (monitor, keyboard, mouse). Also not shown: chiller and thermal chuck controller included with -TH1 option, as well as optical and electrical test equipment. Configuration non-final.

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

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