

# Automatic measurement platform at EFFECT Photonics: Key Enabler for PDK Development

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*We report on a semi-automated die-level test and measurement platform which has been designed to support several types of electro-optical measurements. The platform is optimized for repeatability, efficiency and minimal operator interference to enable unattended collection of large amounts of data. It benefits from in-house developed control algorithms for automatic alignment of a lensed fiber to the optical facet, as well as progressive coordinates-based jogging between test structures.*

## Introduction

Testing is a crucial part of semiconductor manufacturing process. In a typical production cycle, test procedures are repeated several times, already at wafer level as well as after major back-end processing steps including die/bar cleaving. The scope of this paper is limited to die-level testing. The elementary purpose of the automated test platform, presented in this paper, is to enable repeatable and efficient measurement of a large set of devices. This is of paramount importance in a volume production environment, for instance for fabrication foundries as they develop design libraries or process design kits (PDKs) as well as empirical and compact models.

The platform has been designed to support three main measurement categories. The first category requires the so-called electrical alignment procedure only, in which a multi-pin probe is aligned to electrical pads of the device under test. Examples of this category are IV measurement of PN junctions, as well as LIV characterization of laser structures in front of an integrating sphere. In the second class of measurements, a single lensed fiber is aligned to the optical facet of an active device, i.e. a light generating components such as a semiconductor optical amplifier (SOA) or a laser, as well as a light absorber such as photodetector (PD). The active devices under test are controlled by a multi-channel source-meter, and electrical signals are applied through multi-pin probes. The third class is dedicated to measuring passive optical structures, where two lensed fiber are aligned to either sides of the test structures. Typical examples of this class include measurement of passive waveguide loss and transmission spectra of arrayed waveguide gratings.

## Platform Design and Applications

The measurement platform consists of the software and hardware parts. The software part is referred to as EPAMS (EFFECT Photonics Automated Measurement System) and has been developed in C++. EPAMS is responsible for controlling mechanical motion stages, communicating with the test equipment, executing pre-defined measurement scripts, recording and handling raw data, and eventually storing post processed and raw datafiles on the internal database of EFFECT Photonics. The hardware includes the mechanical units and actuators, electrical and optical probes, and a range of test and measurement equipment.

Depending on the set of hardware, bar-level testing and characterization as well as on-wafer testing of optical circuits have been realized on the current platform. This paper will focus on the bar-level testing. To prepare samples for test and measurement, the bars are mounted on copper chucks using an optical and semiconductor grade epoxy resin. To assure accurate and repeatable placement, a semi-automated die-bonder machine is used.

Fig. 1 shows a schematic diagram of the semi-automated test setup at EFFECT Photonics. The provides a semi-automated solution in the sense that operator needs to carry out a coarse mechanical and optical alignment on the first test structure. This would then act as a reference or starting point for the control software to take over and execute the sequence of actions that are pre-defined in the measurement scripts. Jogging between consecutive test structures on the bar is handled through EPAMS as well, thus eliminating the need for operator intervention while several structures on the bar are being tested. This saves great amount of manual labor, and most importantly provides a high level of accuracy and repeatability.

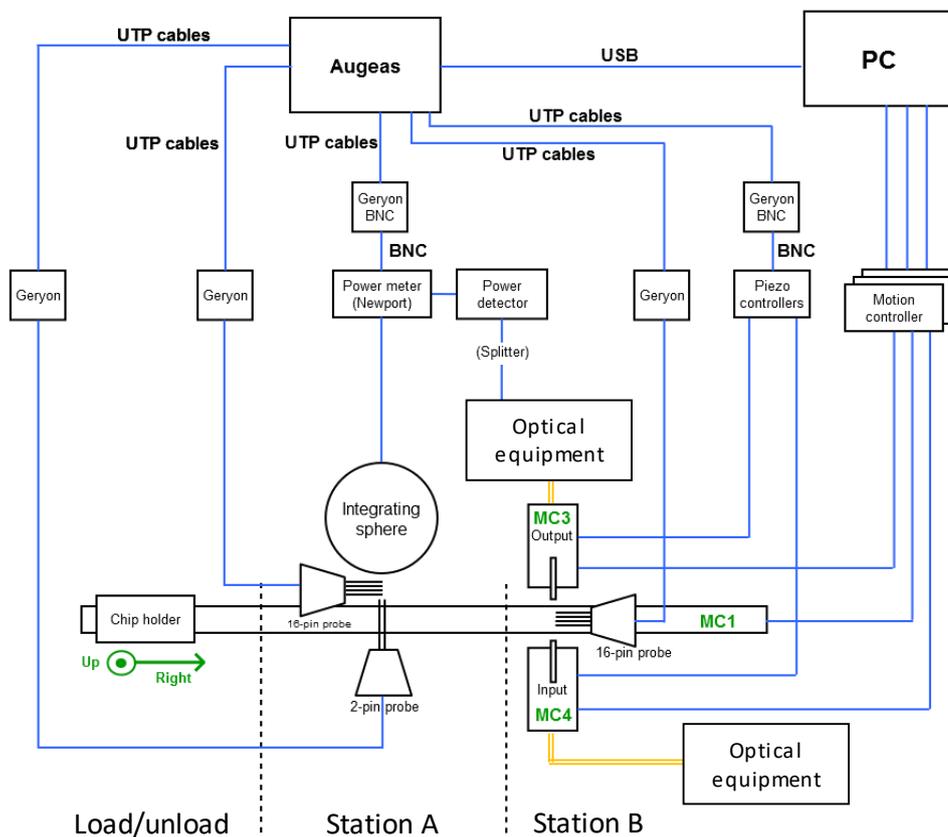


Fig. 1. Schematic diagram of the bar-level test and measurement setup. The setup includes a single lateral translation stage on which carries the mounted optical bar/chip between the so-called stations. Augeas: 64-channel electrical source-meter developed at EFFECT Photonics, MC: motion controller, Geryon: breakout board for fanning out UTP connections to the multi-pin probes. Optical equipment at station B includes a range of devices including a tunable laser, polarization controller, spectrum analyzer, etc.

This setup, as shown in Fig. 1, has three so-called stations. The load/unload station, also known as “home” position, is where the bars can be safely place at and removed from the holder without the risk of damaging the probes or measurement heads. The first test station that is labeled as side A in Fig. 1, includes two multi-pin probe stages and an integration sphere. This station is intended for laser LIV characterization where continuous wave (CW) characteristics of Fabry-Perot (FP) type or complex multi-section tunable lasers, such as DBR and coupled cavity lasers, are to be measured.

The second test station at the setup, indicated by side B in Fig. 1, has a single multi-pin probe stage and two optical fiber holders which are mounted on 3-axis stages with stepper and piezoelectric actuators. The remotely controllable stages allow for automated alignment of one or both (lensed) fiber to either sides of the devices under test. In the current platform, the positioning resolution is 20nm. The auto-alignment procedure to a ridge-type device typically takes about two minutes with better than 0.1dB repeatability with a high long-time stability. A crucial part of our platform is the 64-channel electrical source-meter, which is developed at EFFECT Photonics and is internally known as the Augeas box. Each channel is independently configurable and the maximum nominal current and voltage ratings per channel are 80mA and 10V respectively. Depending on the selected range, Augeas box allows for a set/measure accuracy of 25nA current and 5mV voltage. The device firmware can synchronize multiple channels as well as multiple Augeas boxes in cases where more than 64 channels, i.e. a single box, are required at a time. Synchronization pulse with a top speed of 50 $\mu$ s interval can be generated to allow for fast electrical sweeps, for instance 100 points per 5ms (300ms) excluding (including) the data handling overhead.

## Examples of Experimental Results

Unlike side A that is purposefully designed to deliver basic functionality at high throughput, side B is compatible with a wide variety of electro-optical measurements and characterization methods that are enabled by a wide range of optical equipment. Measurement of waveguide loss using FP method, characterization of AWG transmission spectrum, PD responsivity versus wavelength and input optical power, modal gain spectra using multi-segment method, and lasing spectra and tuning mode maps of tunable lasers are a few typical examples. In this section, two sets of experimental results are presented.

Fig. 2(a) shows single-side LI plots of about 200 FP lasers with varying ridge width and gain-section length. The graph shows single-sided optical power measured by the integrating sphere. This type of measurement is particularly interesting because it is simple, quick and straightforward. With a length series of FP devices measured, the LIV curves can be analyzed for threshold current, slope efficiency, output power and thermal roll-over effects to extract several physical parameters of the gain sections, including internal loss, saturation current density, threshold characteristic temperature, etc. EFFECT Photonics use these parameters to develop compact models for (complex) laser structures; eventually fabrication foundries could benefit from such a system in development of their PDKs.

In Fig. 2(b), a total of 9200 lasing spectra are overlaid. The data has been obtained from a set of ten tunable DBR lasers on a single chip at side B of the setup. In this case, measurement time is over five hours; For measuring each structure, the electrical multi-pin probe is first brought in contact with the matching contact pads on the chip. The laser is turned on by

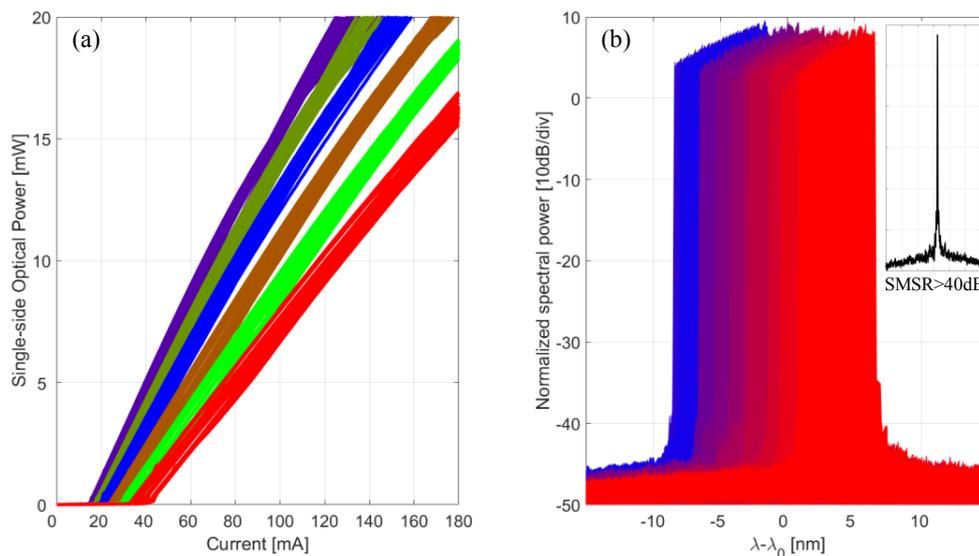


Fig. 2. Examples of measurement results on the test platform: (a) Single-side LI plots of about 200 FP lasers with varying ridge width and gain-section length, measured in front of an integrating sphere. Each color represents a device length in the range of 0.4-1.2mm. For each device length, several ridge widths of 1.5-3.0 $\mu$ m are measured. (b) Overlay plot of 9200 optical spectra, showing lasing wavelength of ten test DBR lasers under tuning; each block of spectra with the same color corresponds to a laser. The inset shows a typical lasing spectrum.

forward biasing the gain section. Then the fiber alignment procedure is kicked off to maximize the fiber-coupled power. After the initial alignment step, control signals on the tuning sections are supplied by the Augeas box and at each step the lasing spectrum is recorded. During the whole measurement session, no operator interference or manual optical (re-)alignment was required, and the successive measurement steps, including the communication with measurement equipment, recording and handling raw data, and jogging between structures are executed by the EPAMS.

Further post processing of the raw data can be implemented as an analysis script in EPAMS as well. For instance, in the case of the DBR lasers under test, recorded spectra are processed to obtain a laser tuning map, i.e. lasing wavelength, peak power and side-mode suppression ratio (SMSR) versus the electrical signals applied on the grating and phase-tuning sections.

## Conclusions

We presented a semi-automated die level measurement platform that is capable of three different optical alignment types, including multi-fiber alignment. This platform enables gathering of statistically significant data sets as input to modeling of optical components.

## Acknowledgements

The authors thank Frits Florentinus for software development and support as well as Adrian Perez and Erwin van Vliet of the EFFECT Photonics test and measure team.