NATIONAL INSTITUTE OF RESEARCH AND DEVELOPMENT FOR OPTOELECTRONICS

Certificate No.: AJAEU/09/11337

409 Atomistilor Street, PO BOX MG-5, RO 077125, Magurele – Ilfov, Romania, Tel./Fax: +40.21.457.45.22, E-mail: inoe@inoe.ro, http://inoe.inoe.ro

INDICO

SERVICES OFFER

Measurements

DESCRIPTION OF THE LAB

The laboratory characterize by optical and complementary methods of the materials, components and systems with application in optoelectronics. The destination of this laboratory is to provide services of evaluation of the conformity according to the harmonized European standards, associated to the required directives both to the public authorities supervising the market and to the manufacturers to fulfill their obligations. It is looking for characterization of some materials, optical fibers, optical amplifiers and lasers in an integrated form that assure a continuity in the applied research activities, leading to the achievement of products vendible in Romania and EU. The used methods refer to the measurement of the specific optical parameters for optoelectronic applications (identification and characterization of the composition of some materials used in optoelectronics, measurement of the output level in optical fibers and amplifiers, laser emitted energy, laser pulse width, laser beam diameter, intensity distribution, deviation from the Gaussian form, divergence, polarization). The measurement of the components parameters underlying optoelectronic systems and parts is necessary to accomplish devices that incorporate lasers, optical fibers, optical amplifiers, optoelectronic materials, according to European standards of quality.

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Contents

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1. LASER ENERGY / POWER

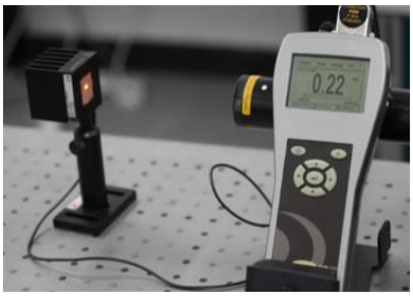
One of the most important characteristic of a laser source is its energy (for a pulsed laser) or its power (for a CW laser). Measurements can be done at high acquisition rates allowing thus an accurate determination of pulse-to-pulse energy fluctuation. All measured data are stored and processed to get statistics (average, standard deviation, RMS, maximum, minimum, peak-to-peak). Report contains also measurement uncertainty data.

Laser energy can be measured using a Gentec SOLO-PE Energy/Powermeter together with the next measuring heads (QE 50 SP-MB and XLE4):

Measuring head	**QE 50 SP-MB**	**XLE4**
Measured energy range	15 µJ – 75 J	100 nJ – 4 mJ
Wavelength range	190 nm – 20 µm	190 nm – 2.5 µm
Sensor area	50 x 50 mm	Ø 4 mm
Rise time		10 µs
Max. pulse width	225 µs	5 µs

Laser power can be measured using a Gentec SOLO-PE Energy/Powermeter together with the next measuring heads (PH100-Si, PH20-Ge, UP12E, UP25N and UP55N):

Measuring head	**PH100-Si**	**PH20-Ge**	**UP12E**	**UP25N**	**UP55N**
Measured power range	600 pW - 30 mW	2 nW - 30 mW	1 mW – 70 W	3 mW - 300 W	5 mW - 400 W
Wavelength range	300 nm - 1100 nm	800 nm - 1650 nm	190 nm - 11 µm	190 nm - 11 µm	190 nm - 11 µm
Sensor area	Ø 11.28 mm	Ø 5 mm	Ø 12 mm	Ø 25 mm	Ø 55 mm



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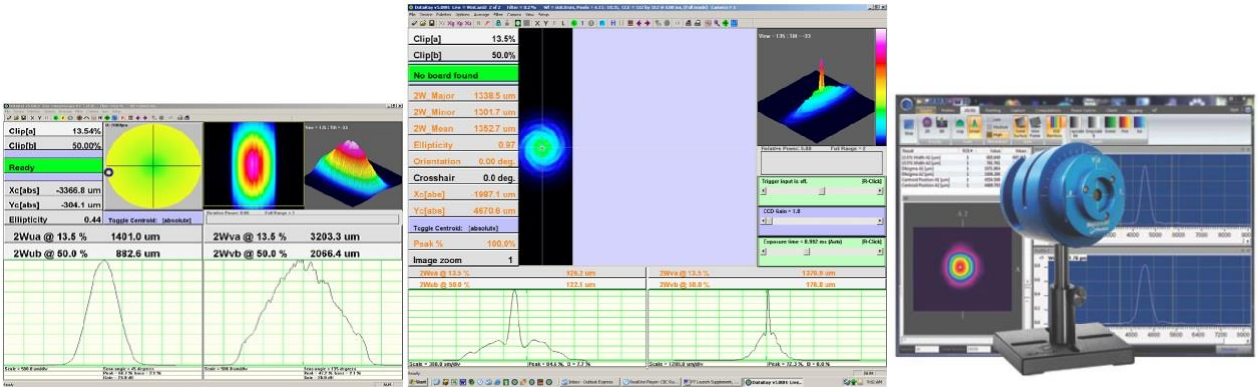
2. LASER BEAM PROFILE

A more precise diagnostic of a laser source requires an analysis of the laser beam profile. A laser beam profiler provides important information characterizing the laser, as the energy (pulsed lasers) or power (CW lasers) distribution in a cross section of the laser beam, the waist of the beam, its divergence and M^2 factor (that quantifies the beam quality of laser beams).



These measurements can be done using one of the next three heads (NS2-Si/9/5-PRO, NS2-Ge/9/5-PRO and NS2-Pyro/9/5-PRO), depending on the required wavelength:

- **Ophir NS2-Si/9/5-PRO**: NanoScan2 Si Detector 9 mm aperture 5µm slits. High-resolution head featuring Si detector, 63.5 mm diameter head with rotation mount, 9 mm entrance aperture, and matched pair of 5 µm wide slits. Use for wavelengths from 190 nm to 1 µm.
- **Ophir NS2-Ge/9/5-PRO**: NanoScan2 Ge Detector 9 mm Aperture 5 µm slits. High-resolution head featuring Germanium detector, 63.5mm diameter head with rotation mount, 9 mm entrance aperture, and matched pair of 5 µm wide slits. Use for wavelengths from 700 nm to 1.8 µm.
- **Ophir NS2-Pyro/9/5-PRO**: NanoScan2 Pyro Detector 9 mm Aperture 5.0 µm slits. High-resolution head featuring pyroelectric detector, 63.5 mm diameter head with rotation mount, 9 mm entrance aperture, and matched pair of 5 µm wide slits. Use for wavelengths from 190 nm to 100 µm.

M^2 measurements require the use of **Ophir RAL-FXT** (Rayleigh fixture for manual M^2) and **Ophir COL-FXT 250** (250 mm FL collimation fixture).

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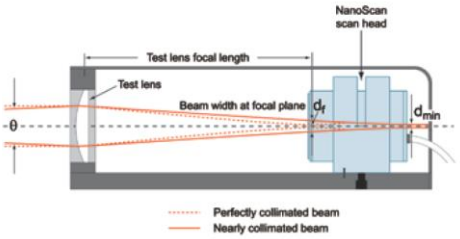
The optional Translation Test Fixture makes manual M2 measurements accurate and repeatable



COL-FXT 250	Nominal 250mm focal length lens. Includes an enclosure to block stray light

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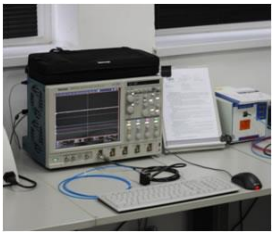
3. LASER PULSE WIDTH

Temporal behavior of the pulsed lasers is characterized by the pulse width (duration). Because the commercially available lasers have pulse widths of few ns, the pulse width measurement requires both a wide band oscilloscope and an ultrafast photodiode.
As oscilloscope we use a Tektronix DPO7254, with a 2.5 GHz band and a rise time of 150 ps.
The ultrafast photodiode is UPD-200-UP from Alphalas:



UPD-200-UP	
Rise time	< 175 ps
Bandwidth	> 2 Ghz
Spectral range	170 – 1100 nm
Sensitive area	Ø 0.4 mm
NEP	$1.5 \cdot 10^{-15}$ W/√Hz
Dark current	1 pA

All measured data are stored and processed to get statistics (average, standard deviation). Report contains also measurement uncertainty data.

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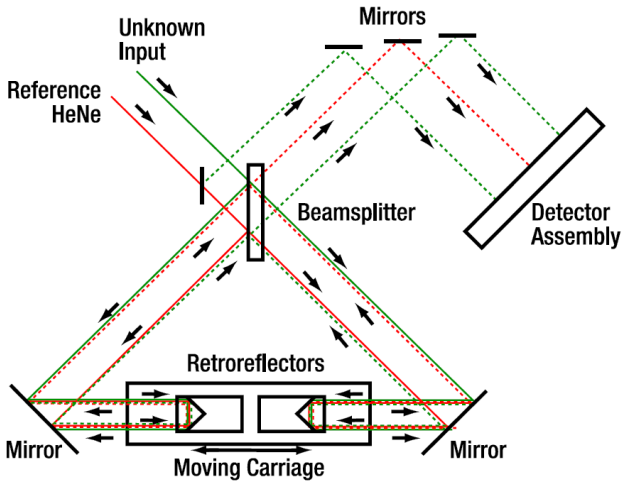
4. FT OPTICAL SPECTRUM ANALYSIS

Some lasers need to be verified from the point of view of the emitted optical spectrum. Depending on the spectral domain two Fourier Transform optical spectrum analyzers can be used: ThorLabs OSA 201 (Fourier Transform Optical Spectrum Analyzer, 350 - 1100 nm) or ThorLabs OSA 202 (Fourier Transform Optical Spectrum Analyzer, 600 - 1700 nm). The optical schematic of the FT-OSA is presented below:



Optical Schematic of the Thorlabs FT-OSA Detailing the Dual Retroreflector Design

Optimized for use in the 350 - 1100 nm spectral range, the **OSA201** measures the optical power of both narrowband and broadband sources as a function of wavelength. The maximum spectral resolution of 7.5 GHz (0.25 cm^{-1}) is set by the maximum optical path length difference of ±4 cm, while the high spectral accuracy of ±2 ppm (parts per million) is ensured by simultaneously measuring the interferogram of a stabilized 632.991 nm HeNe laser. For sources with linewidth < 10 GHz, enabling the Wavelength Meter mode provides 0.1 ppm resolution and ±1 ppm accuracy.
Optimized for use in the 600 - 1700 nm spectral range, the **OSA202** measures the optical power of both narrowband and broadband sources as a function of wavelength. The maximum spectral resolution of 7.5 GHz (0.25 cm^{-1}) is set by the maximum optical path length difference of ±4 cm, while the high spectral accuracy of ±2 ppm (parts per million) is ensured by simultaneously measuring the interferogram of a stabilized 632.991 nm HeNe laser. For sources with linewidth < 10 GHz, enabling the Wavelength Meter mode provides 0.1 ppm resolution and ±1 ppm accuracy.
The OSA's input port is compatible with single mode and step-index multimode FC/PC patch cables with cores up to Ø50 µm. For the highest contrast, single mode patch cables are recommended. To adapt a free-space input to the OSA, the procedures are illustrated next:

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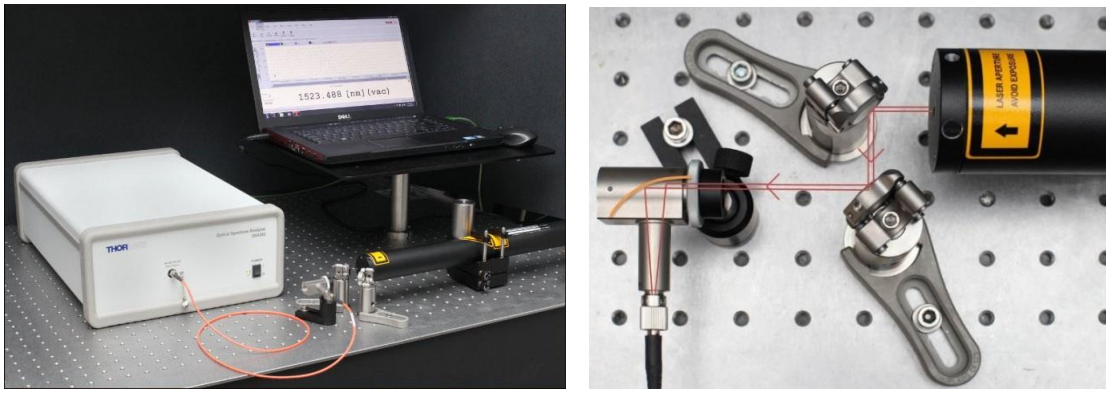

OSA 201 free-air layout (at right, detail).

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5. POLARIZATION STATE ANALYSIS

Polarization analysis provides besides classic polarization measurements also evaluation of optical components with the Jones or Mueller matrix algorithm. It can be also used for determining the Extinction Ratio.

We use ThorLabs PAX5710VIS-T polarimeter (TXP Polarimeter including PC, 400 - 700 nm, with external sensor) together with external sensor PAN5710IR2 (1000-1350 nm). It is a free-space polarimeter, with interchangeable external sensor head, the wavelength range is 400 - 700 nm, the dynamic range is 70 dB, the sampling rate is up to 333 samples/s and the accuracy is ±0.2 ° on the Poincare sphere.

Free-Space Polarimeter Specifications

Item #	PAX5710VIS-T	PAX5710IR1-T	PAX5710IR2-T	PAX5710R3-T
Wavelength Range	400 - 700 nm	700 - 1000 nm	1000 - 1350 nm	1300 - 1700 nm
Maximum Measurement Rate	333 S/s			
SOP Accuracy	±0.25° on Poincaré Sphere			
SOP Resolution	0.01° on Poincaré Sphere			
DOP Accuracy	±0.5%			
DOP Resolution	0.0001			
Dynamic Range	-60 to 10 dBm			
Free Space Aperture	Ø3 mm			
Maximum Input Beam Divergence	2°			
Width	1 TXP Slot			
Warm Up Time for Rated Accuracy	<15 min			
Analog Interface (via Front Panel D-Sub)	5 Analog Outputs: s1, s2, s3, DOP, Power 1 Analog Input: Trigger			
Digital Interface	s1, s2, s3, Power (Watt/dBm), DOP, Azimuth, Ellipticity			
Analog Monitor Output	-2.5 to 2.5 V			
Operating Temperature Range	5 to 40 °C			
Storage Temperature Range	-40 to 70 °C			

Note: All data are valid at 23 ±5°C and 45 ± 15% relative humidity.

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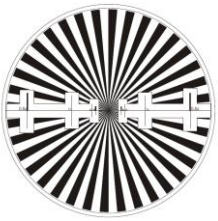
6. CHARACTERIZATION OF OPTICAL COMPONENTS

Characterization of optical components includes measurements as: the focal lengths (effective and back focal length), angle of prisms and flatness of plane surfaces (not only optical).
Dimensions and positions of optical and mechanical components can be accurately measured by a video measuring microscope. Some alignments can be done/verified using an autocollimator or a He-Ne laser.

6.1. Measurement of the focal length

Focal lengths (effective and back focal length) can be measured using Moeller-Wedel Optical device MELOS 530-3.

- Range of focal measured focal lengths: 5 mm ... 500 mm (positive), -5 mm ... -580 mm (negative), 2 mm ... 530 mm (back focal lengths)
- Free aperture: 28 mm
- Max. sample diameter: 200 mm
- Reproducibility: 0.04 % (focal lengths) or 0.03 % ... 0,2 % (back focal lengths)
- Measurement accuracy: 0.3%



6.2. Measurement of the angles of prisms

The angles of prisms and refractive index of the glass are measured using Goniometer Moeller-Wedel model Goniometer II-VIS:

- Telescope/collimator: f = 300 mm
- Accuracy of angle measurement: (mean error of series measurements) < 0.6 arcsec.
- Spectral range: 436 - 650 nm
- Accuracy of refractive index measurements (mean error of series measurements): 10^{-5}
- Alignment: visual with autocollimator
- Reading of incremental circle automatically via computer and built-in counter board
- Evaluation automatically with GONIOWIN software
- Spectral lines : F' (479.99 nm), e (546.07 nm), C' (643,85 nm)

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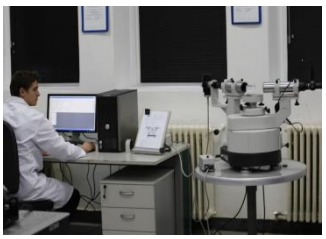

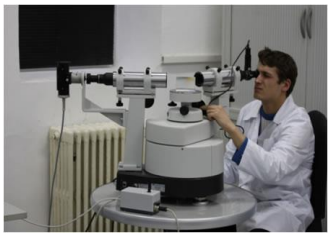

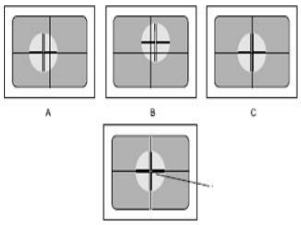

6.3. Measurement of surface flatness

Flatness is determined using the interferometer Moeller-Wedel, model VI-direct SL 100 and the software INTOMATIK-S for fringe evaluation:

- Type of interferometer: Fizeau
- CCD Camera : 752 x 582 pixels
- Laser: fiber coupled He-Ne 632.8 nm
- Exit aperture: 100 mm
- Measurement accuracy: λ/20 (p-v) with software evaluation
- Adjustment range: 530 mm
- Fine adjustment range: 1 µm
- Measurement range: 530 mm
- Resolution: 1 µm
- Accuracy: 3 µm
- Vertical stand with XY- and tiltable table
- 4-axes adjustable mount

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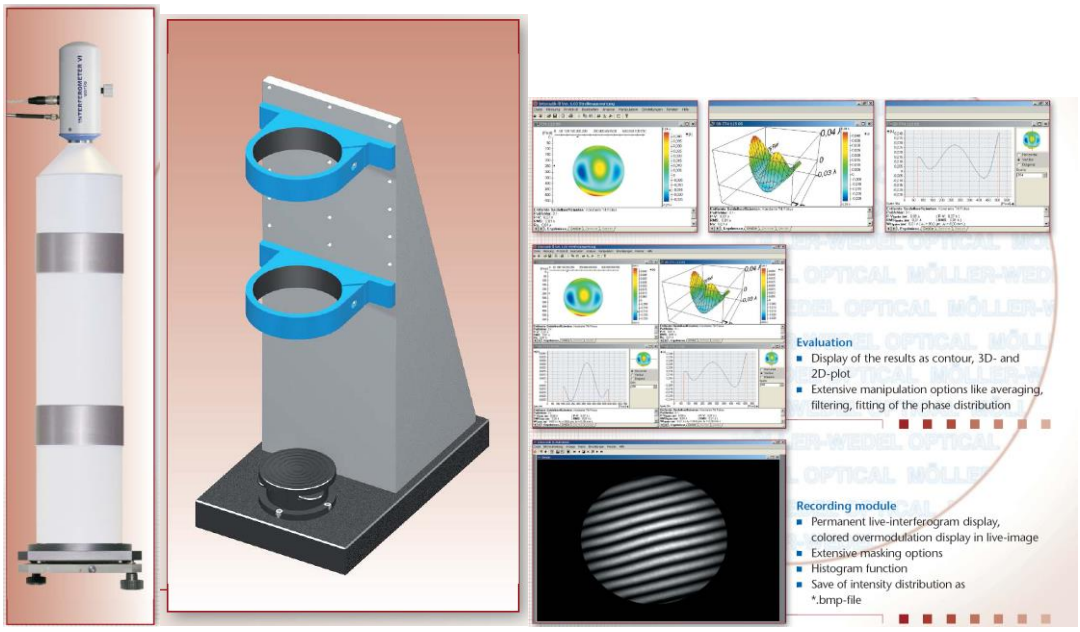

6.4. Dimensional measurements

Accurate dimensional measurements are done using MM1-300/6X GARANT Measuring microscope with incremental measuring system, image processing, 1.3 megapixel color camera, and a Multitouch panel based on a PC.
Incident light: 56 white LEDs in 2 concentric rings. 1 ring and 4 segments can each be separately switched and dimmed. Transillumination: LED, telecentric, can be switched and dimmed. Solid granite base with steel cross table, surface hardened mounted on precision needle bearing. Diode laser as positioning guide. Very high repeat accuracy due to automatic edge detection. With 6-stage raster zoom lens, magnification 0.7× to 4.5×.

Type		MM1–200	MM1–300	MM1–200/6×	MM1–300/6×
40N 49 1910 Garant Video measuring microscope MM1		XXX	XXX	XXX	XXX
Measuring range X : Y : Z	mm	200 : 100 : 100	300 : 200 : 200	200 : 100 : 100	300 : 200 : 200
Length measurement variation E1	µm	1.5 + L / 100 (L in mm) at 20 °C ± 1 K			
Length measurement variation E2	µm	2.9 + L / 100 (L in mm) at 20 °C ± 1 K			
Camera system / display screen		1.3 megapixel CMOS / HD Multitouch panel			
Lens / magnification	times	1.5 / 84		0.7 – 4.5 / 31 – 201	
Field of vision	mm	4.3×3.2		10.2×8.2 – 1.6×1.3	
Maximum component height	mm	100	200	100	200
Working distance	mm	80			
Maximum component weight	kg	20			
Electrical power supply	V	240 / 1 A			
Weight	kg	60	115	60	115
Length×width×height	mm	500×600×770	730×900×950	500×600×770	730×900×950

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Version with **raster zoom lens size ... /6X.**

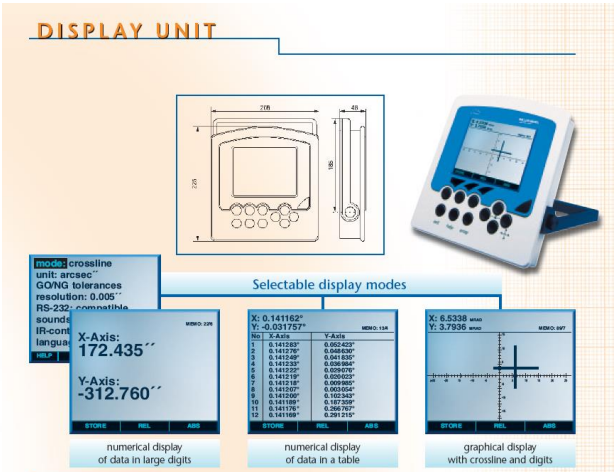
Zoom level	Display presentation	Image field
0.7×	31×	10.2×8.2 mm²
1×	45×	7.2×5.8 mm²
2×	85×	3.8×3.0 mm²
3×	129×	2.5×2.0 mm²
4×	179×	1.8×1.4 mm²
4.5×	201×	1,6×1.3 mm²

6.5. Alignments

6.5.1. Electronic autocollimator

Moeller-Wedel Optical Elcomat vario D 500T/65 electronic autocollimator may be used to set/determine the perpendicularity to a given surface.

- Measuring range: 0.4 ° on x-axis, 0.3 ° on y-axis
- Recommended resolution: 0.05 arcsec
- Accuracy: ±0.4 arcsec
- Reproducibility: 0.05 arcsec
- Focal length: 500 mm
- Free aperture: 50 mm



6.5.2. He-Ne laser

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For alignments and references a very stable He-Ne laser that can be used is ThorLabs model HNL210L-EC:

- Wavelength: 632.8 nm
- Minimum Output Power (TEM00, 633 nm): 21.0 mW
- Minimum Polarization Ratio: 500:1
- Beam Diameter (TEM_{00}, 1/e2 points + 3%): 0.70 mm
- Beam Divergence (TEM_{00}, +3%): 1.15 mrad
- Mode Purity (TEM_{00}): >95%
- Longitudinal Mode Spacing: 257 MHz
- Maximum Noise (RMS) (30 Hz to 10 MHz): 0.5%
- Maximum Drift: ±2.0% (With respect to Mean Power over 8 hrs.)
- Maximum Mode Sweeping Contribution: 1%
- Beam Pointing Stability (25 °C):
- -From cold start < 0.20 mrad
- -After 15 minute Warm-Up < 0.03 mrad
- Operating Voltage (±100 V): 3800 V_{DC}
- Operating Current (±0.1 mA): 6.5 mA
- Max Starting Voltage: 10 kV_{DC}

7. SPECTRAL ANALYSIS OF MATERIALS

Spectral analysis of materials is mainly useful to characterize thin films, as optical coatings, but may extend also to bulk or liquid materials. The measurements comprise spectral characterization of optical coatings or thin film filters in a wide spectral range (UV-VIS-NIR), using a

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spectrophotometer, thin film thickness from 1Å to > 45µm, depending on material absorption, optical constants (n,k) for isotropic, anisotropic, and graded films, surface and interface roughness, derived optical properties such as absorption coefficient α and optical bandgap Eg, material properties: compound alloy composition, porosity, crystallinity, morphology, uniformity, Mueller matrix and depolarization, using an ellipsometer.

7.1. PerkinElmer LAMBDA 1050 UV/Vis/NIR Spectrophotometer

- Detector: high energy R6872 photomultiplier in all UV/VIS range and InGaAs with an efficient Peltier cooling system for NIR range.
- Source: Pre-aligned tungsten-halogen and deuterium. Utilizes a source doubling mirror for improved UV/Vis/NIR energy.
- Spectral range: 175 nm - 3300 nm (N_2 purge required below 185 nm).
- Resolution: UV/Vis < 0.05 nm, NIR < 0.20 nm.
- Wavelength accuracy: UV/Vis ± 0.080 nm, NIR ± 0.300 nm.

7.2. HORIBA UVISEL ER AGAS ellipsometer

From thin to thick layers, with or without a transparent substrate, in the fields of semiconductors, flat panel displays, optoelectronics, photovoltaics, and optical and functional coatings, it is the best solution for precise characterization of thin film structures.

- Spectral range: 190-2100 nm.
- Photoelastic modulator.
- Software: data acquisition, modelling and interpreting.
- Surface and interface characterization.
- Determines refractive index and extinction coefficient of thin films, multilayer structures, bulk materials and liquids.

Obtained information

- Thin film thickness from 1Å to > 45 µm, depending on material absorption
- Optical constants (n,k) for isotropic, anisotropic, and graded films

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- Surface and interface roughness
- Derived optical properties such as absorption coefficient α and optical bandgap E_g
- Material properties: compound alloy composition, porosity, crystallinity, morphology, uniformity
- Mueller matrix
- Depolarization

LIST OF INSTRUMENTS

Crt. No.	Item	Manufacturer	Model	Status
1	Video measurement microscope	Hoffmann	MM1-300/6X GARANT	New
2	Laser Beam profiler	Ophir Photonics	NanoScan2	New
3	Electronic autocolimator	Moeller-Wedel Optical	Elcomat vario D 500T/65	New
4	Interferometer and accessories	Moeller-Wedel Optical	Interferometer VI-direct 100 SL	New
5	Diopter telescope	Moeller-Wedel Optical	Diopter telescope ±5.0 dpt, 0.1 dpt div.	New
6	Dynameter	Moeller-Wedel Optical	Dynameter	New
7	Laser He-Ne	ThorLabs	Laser and accessories	New
8	Optical Spectrum Analyzer	ThorLabs	OSA 201, OSA 202	New
9	Polarization analyzing system	ThorLabs	PAX57VIS-T, PAN5710IR2	New
10	Ultrafast photodiode	Alphalas	UPD-200-UP	New
11	Oscilloscope	Tektronix	DPO7254	Exist.
12	Spectrophotometer	PerkinElmer	LAMBDA 1050 UV/Vis/NIR	Exist.
13	Ellipsometer	HORIBA	UVISEL ER AGAS	Exist.
14	Energy/Powermeter	Gentec	SOLO PE	Exist.
15	Goniometer	Moeller-Wedel Optical	Goniometer II-VIS	Exist.
16	Focal length meas. device	Moeller-Wedel Optical	MELOS 530-3	Exist.