Training module

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LEVEL 2 PERIODIC MAINTENANCE TRAINING - ILLUMINATION & PROJECTION

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ABOUT THIS MODULE TT-L2-IP-3v0

MODULE INTRODUCTION

This student training reference contains five chapters and one appendix. Chapter One is an overview of the Illumination and Projection systems. Chapter two provides specific information related to Deep Ultraviolet (DUV) illumination systems. Chapter three is an overview of the projection system. Chapter four is an overview of the maintenance procedures. This is followed by a series of Appendices covering the illumination and projection for systems prior to the 1400. At the end of the module is an appendix containing a glossary of terms used during this training module.

GENERAL MODULE INFORMATION

Objectives

Upon successful completion of the module, you are able to:

- Describe the Illumination and Projection components and locations of those components for an XT 1400 system
- Explain the functions of the Illumination and projection systems
- Briefly describe lens aberrations, specifically COMA and Spherical Aberration
- Explain the purpose of Pupil Mapping and ILIAS
- Describe the Nitrogen Purge System
- Describe the Lens Purge System, including the Gas Control Unit

Test

Prerequisites

Twinscan Level I training must be completed

Additional Materials

ASML Coach Documentation

ASML Applications notes

SAFETY

Safety related items are indicated in this manual by:

- A pictogram
- A description that tells how serious the danger is and any actions necessary to prevent it

The three levels in safety are:

- Danger, shows a very dangerous situation that, if not prevented, could result in death or a very serious injury
- Warning, shows a dangerous situation where there is a risk of serious injury
- Caution, shows that equipment or property could be damaged or there is a risk of minor injury

Before you install, operate or maintain the system, read the applicable safety manual. There is a safety manual for each system.

Definition of pictograms

The following pictograms are used in ASML equipment:

:


General hazard


Electrostatic damage


Laser radiation


UV radiation


Electrical hazard


Flammable substance


Toxic hazard


Chemical hazard


Hot surface(s)


Sharp object(s)


Strong magnetic field(s)

Lifting heavy object(s)


Moving parts


Moving heavy object(s)


Radio frequency radiation

General warnings

Warning All forms of operation, installation work, maintenance, repair, modification and all other activities involving the different systems must only be carried out by authorized, fully qualified personnel.

Warning Only personnel who have received ASML maintenance training are allowed to open system covers.

Warning All safety and other requirements described in ASML manuals, the applicable contracts and the law must be observed at all times.

Warning Use of controls or adjustments or performance of procedures other than those specified in ASML manuals may result in hazardous radiation exposure.

Warning The mains power switch can be locked off during maintenance. Lockout/tagout procedures should be according to local fab standards. In the U.S.A. these procedures must conform to OSHA standard 1910.147.

Warning During maintenance, all machine operating control points must be tagged to prevent accidental operation.

Chapter 1 DUV Illumination Systems

Chapter 2 Projection Systems

Chapter 3 DUV Procedures

Chapter 4 UV Illumination System (I-Line)

Chapter 5 UV Procedures

Appendix 1 Glossary of Terms and Acronyms

1

DUV ILLUMINATION SYSTEMS

INTRODUCTION

The Twinscan DUV illumination system utilizes a light source (laser) and a beam delivery system to bring the beam of light to the bottom module at the exposure unit. In this chapter we will discuss the illumination system for the generic DUV system, from the laser to the projection lens

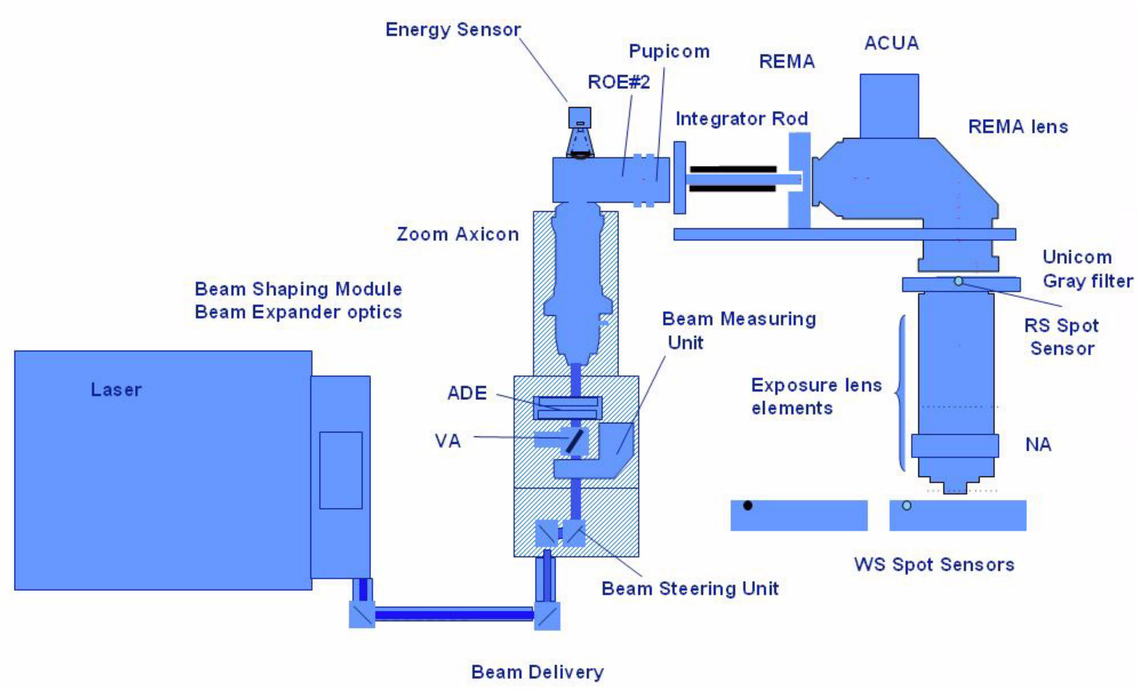

Figure 1.1 DUV system overview

Laser

The laser provides pulsed deep ultraviolet light at around 248 or 193 nm with a remotely adjustable average power.

The maximum pulse repetition rate of the laser is from 1 kHz to 6 kHz depending on the system. The laser makes use of electrical discharges in a mixture of different gases. The discharge is a result of building up a high voltage over the gas in the laser chamber.

Laser control can be taken over manually by a paddle.

Laser concept

In order to understand the laser, we have to look at two main components:

- Laser chamber
- Line Narrowing Package

See the figure below.

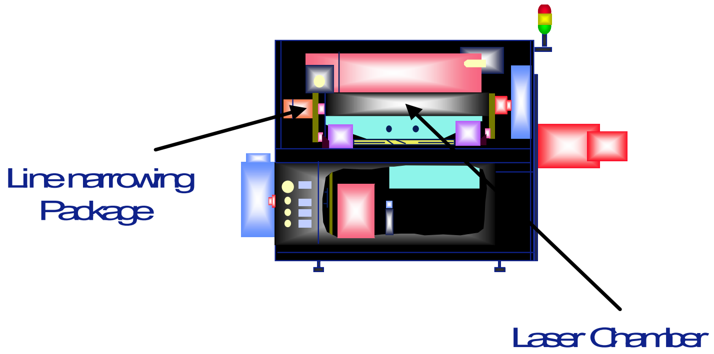

Figure 1.2 Example of a laser

In the laser chamber, the laser reaction takes place.The laser uses a high voltage control system. The high voltage is calculated by the energy control software. This is shown in the figure below

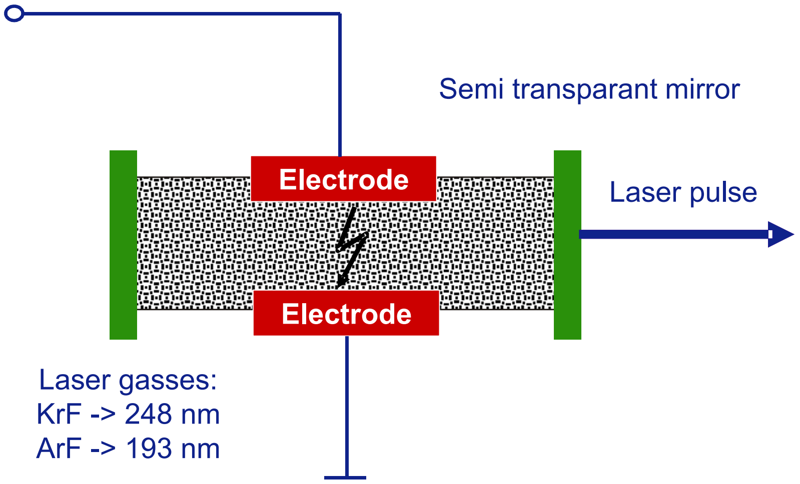

Figure 1.3 The laser chamber gives a pulse after each discharge between the electrodes.

When the laser gas in the chamber deteriorates (decrease of fluorine content), it is difficult to control the pulse energy. Fluorine can then be injected or the gas can be refilled automatically or by giving a manual command.

The duration of one laser pulse is very short compared to the time between two pulses. This is shown in the figure below.

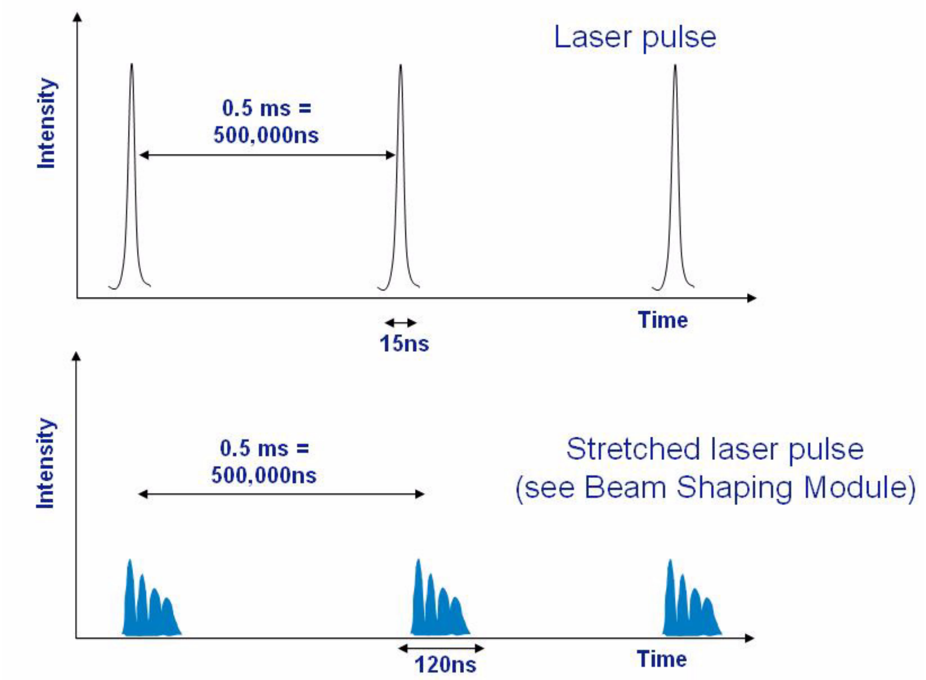

Figure 1.4 Example of a pulse sequence

A wavelength measurement system detects the actual wavelength of the beam.

This information is used by the Line Narrowing Package (LNP) which provides a single wavelength beam with a bandwidth smaller than 1pm, see the figure below.

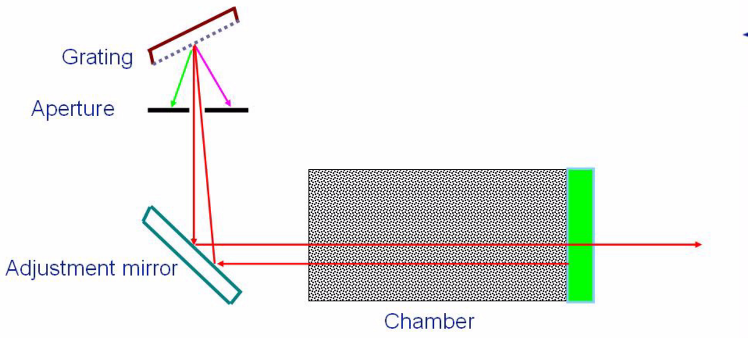

Figure 1.5 Line Narrowing Principle

The line narrowing package uses a special grating that will cause rays of different wavelengths to be reflected at different angles. By slightly adjusting the angle of the mirror, we can control which wavelength is allowed back through the aperture and into the chamber.

Based on the wavelength measurements, the line narrowing package will control the wavelength of the laser beam. Second, the LNP will thus reduce the bandwidth from around 300pm to smaller than 1pm. This is shown in the figure below.

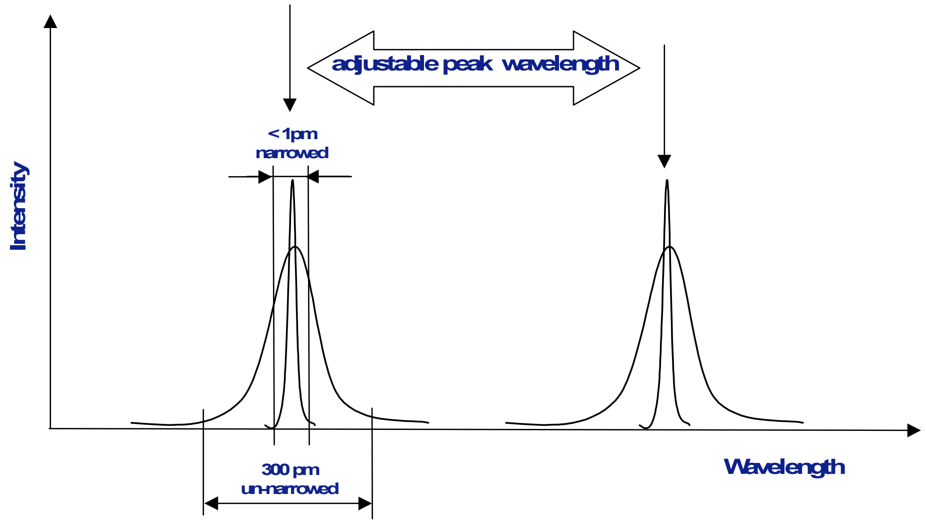

Figure 1.6 Influence of Line Narrowing Package

The wavelength changes are introduced on purpose as a control circuit of the driver lens model.

Beam Expander

The beam that is produced by the excimer laser is small with a high intensity. This beam must be made larger to save optics and to decrease beam divergence such that the beam can travel a larger distance towards the Twinscan. For this reason a beam expander system is used.

By changing the distance between the expanding lenses and the converging lens, we can control the sizes of the beam entering the beam delivery system.

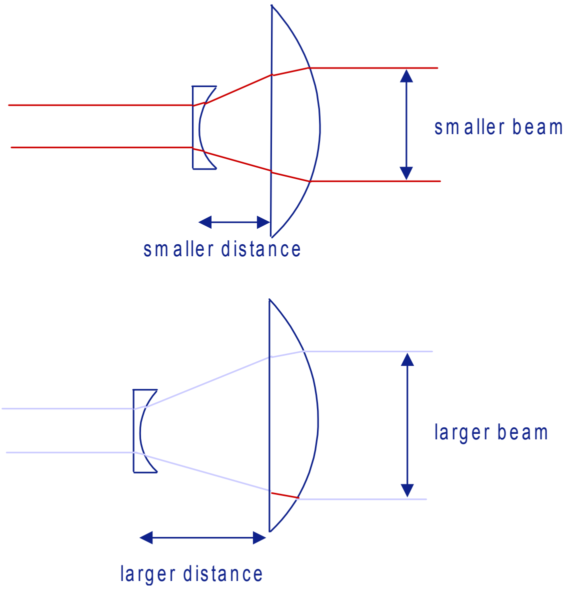

Figure 1.7 The beam expander lenses

Close to the Beam Expander lenses, the beam is reflected by the steering Position Mirror that directs it into a beam delivery tube. The beam may be directed either up or down to accommodate user installation requirements. The position mirror is controlled by software to direct the beam to the correct position in the Bottom Module.

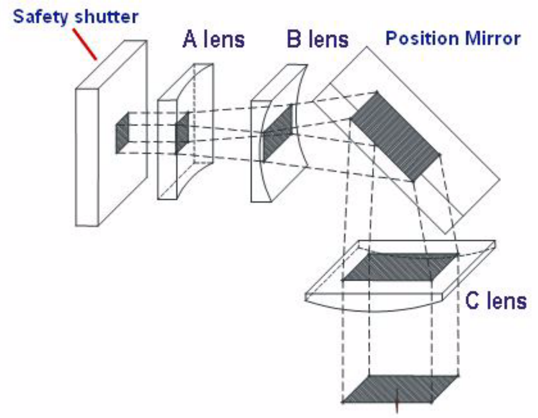

Figure 1.8 Beam Expander Basics

The type of system used will vary based on the machine type, but the basic idea is to use two lenses to expand the beam in the Y and X axis, and then another lens to stop the expansion. The beam expander optics can be contained in a Beam Expander housing or be part of a Beam Shaping Module.

Beam Shaping Module

Some machine types have a Beam Shaping Module installed. The Beam Shaping Module consists of the Beam Expander optics and optics that extend the pulse duration.

Why extend the pulse duration?

The degradation of optics depends on:

- Peak intensity that the optical material is exposed to.
- Total energy per surface unit sent through the optical material.

A lower peak intensity and can be achieved by creating a laser pulse that lasts longer. This is done by the pulse stretching facility in the Beam Shaping Module.

The pulse stretching principle is shown below.

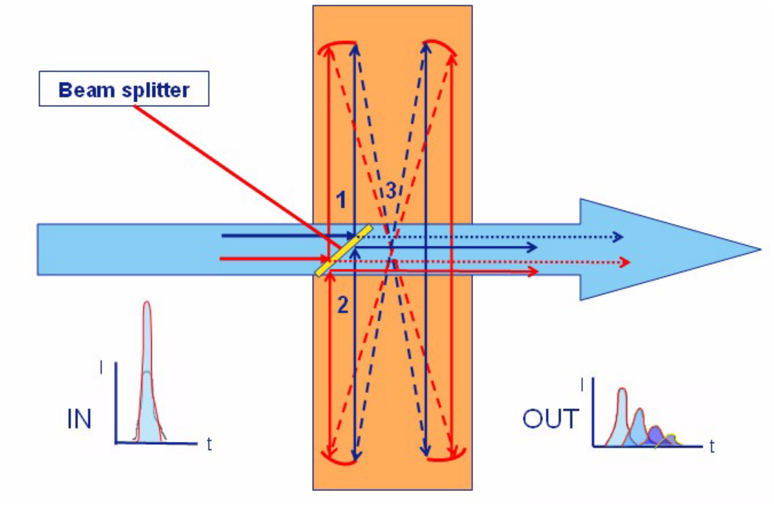

Figure 1.9 Beam splitting part of the BSM

The beam splitting mirror reflects 50% of the beam in upward direction (1), while 50% is transmitted. The reflected part then makes a round trip (follow its path in the figure). It is reflected four times by full reflection mirrors that are mounted on the top and the bottom of the Beam Shaping Module. After the round trip, it arrives at the beam splitter bottom side (2) with a small time delay. Again, 50% of this light will be reflected in horizontal direction, while 50% will pass the mirror to make a second round trip.

Note that the focus point (3) of the top and bottom mirrors, the point where the reflected beams cross, is located behind the mirrors. Looking at the picture on paper, you may state that the crossing point of the beams is behind the paper.

The BSM is shown in the figure below.

Figure 1.10 The Beam Shaping Module stretches the laser pulse in time by extenting the path for parts of the beam.

The DUV beam enters the BSM on the left side, is reflected upwards through the Beam Expander lenses, and is then reflected in horizontal direction, where it is partially delayed by bouncing up and down between reflecting mirrors.

The Beam Expander lenses are used in combination with two full reflection mirrors to expand the beam and to guide it towards two beam splitting mirrors.

In the Beam Shaping Module, the pulse stretching part contains two beam splitting mirrors. See the figure below.

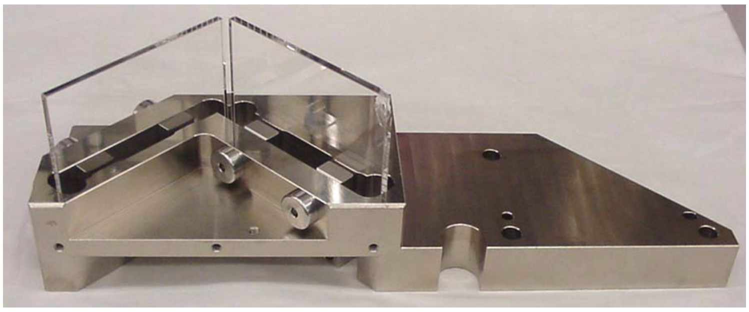

Figure 1.11 The BSM contains two beam splitting mirrors

The second mirror has the same function as the first one, so it stretches the pulse a second time.

Note that the laser itself also contains a pulse stretching facility.

Beam Delivery

After exiting the Beam Expander or the Beam Shaping module, the laser light then enters the beam delivery portion of the Illumination system.

Beam delivery length, from the laser to the bottom module at the exposure unit, can be from 3 to 20 meters in length and may have up to five 90º bending points. The bending points may be mounted in a number of ways, including mounted to the floor, or suspended from a wall, ceiling, or supporting system, and are connected by solid metal tubes.

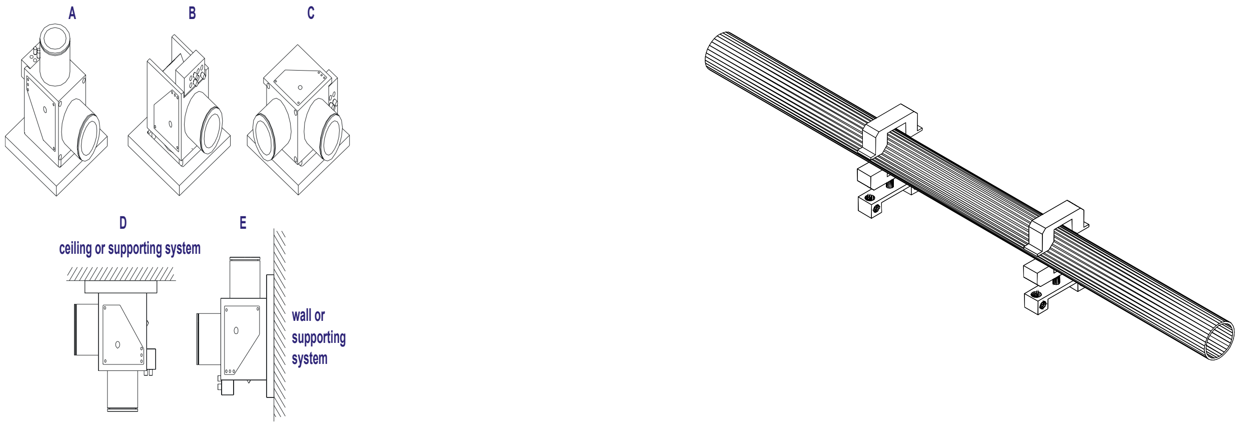

Figure 1.12   Bending Point Configurations

The length of the beam delivery system, beginning at the laser itself, is purged with Nitrogen to prevent contamination of the optics.

The tubes have two supports. Seals between tubes and bending points close after the nitrogen purge pressure has been established.

Bottom Module

After passing the Beam Delivery, the beam enters the Bottom Module. This module holds the beam steering mirror, the fixed mirrors, the Variable Attenuator, the Beam Measuring Unit, the DOE exchanger, the Zoom Axicon, the Energy Sensor and the incoupling Optics.

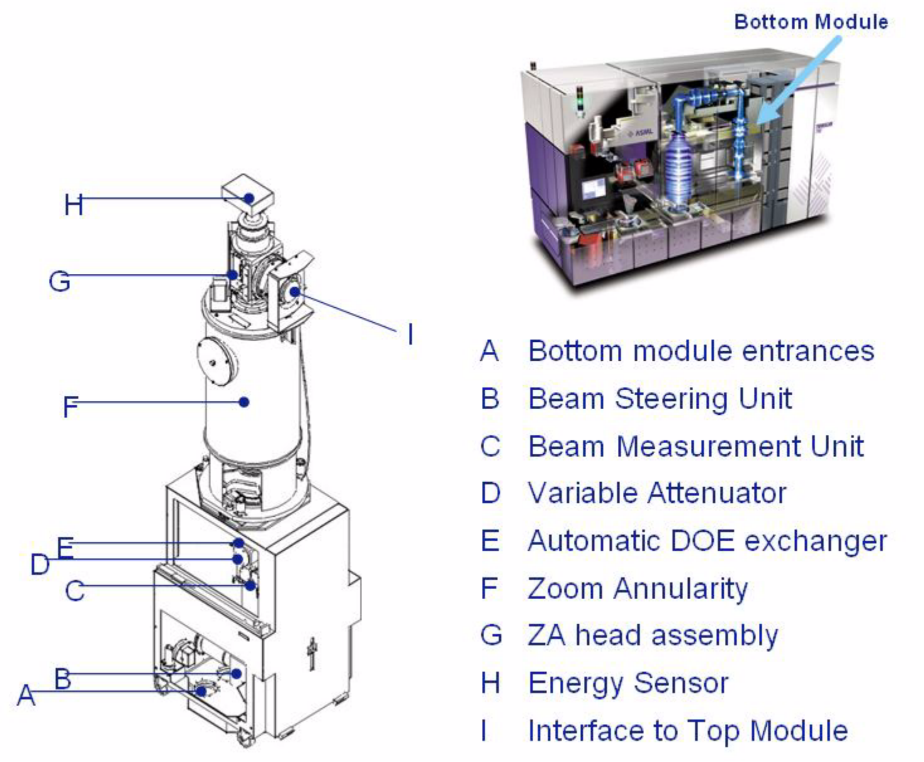

Figure 1.13 Bottom Module bottom overview

Site Dependable Parts

The laser beam must be oriented on the Z axis of the system as it moves through the illumination system. Depending on the orientation of the beam entering the bottom module, it is possible that an extra mirror will be needed to change the beam orientation. This mirror is called a beam orientation mirror, or Site Dependable Part.

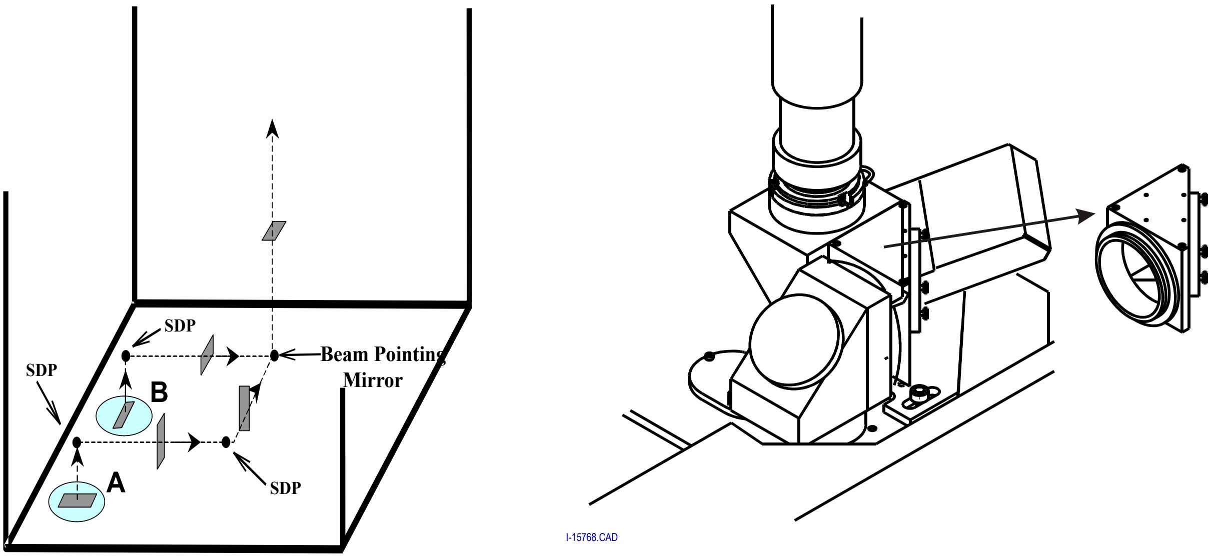

Figure 1.14 The Bottom Module bottom compartments holds the beam steering mirror and the site dependable parts

Pointing Mirror and beam steering

The next component to consider is the beam pointing mirror. This mirror, along with the beam steering mirror at the output of the beam expanding optics, is controlled by software to maintain the correct beam position and angle as it passes through the illumination system.

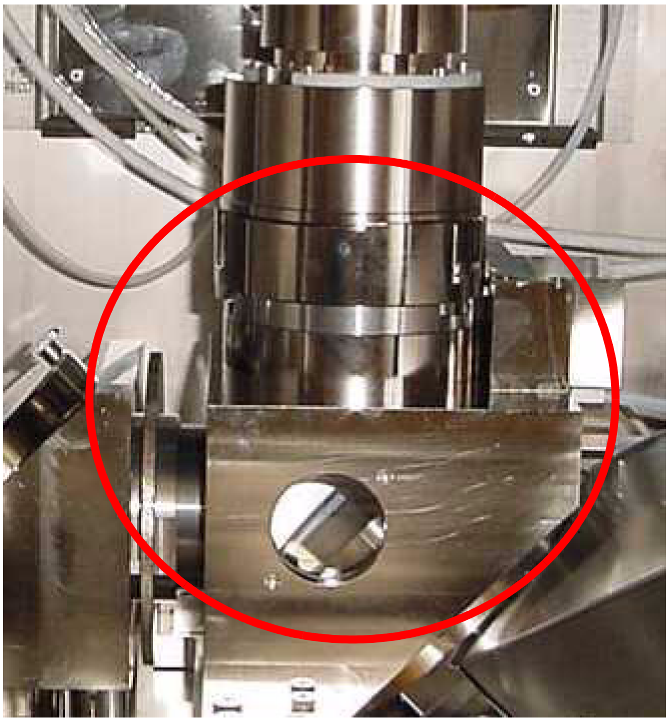

Figure 1.15 Beam Pointing Mirror

The position mirror at the beam expanding optics has the largest effect on beam position.

The pointing mirror in the bottom module has the largest effect on beam angle.

This is shown below.

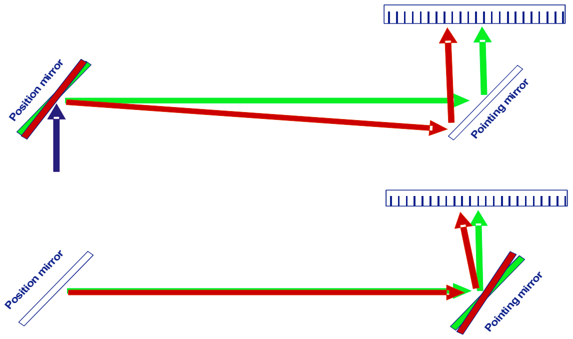

Figure 1.16 Effects of Beam Pointing and Position

The control system used to adjust the position and pointing mirror is called Closed Loop Beam Steering. As a feed back signal, the Beam Measurering Unit is used.

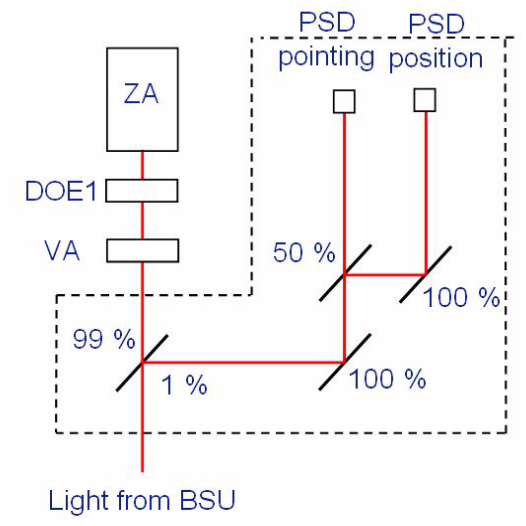

Figure 1.17 Beam Measuring Unit

The beam measurement (BMU) unit samples 1% of the light to measure the position and angle of the incoming beam. The beam measurement unit has two Position Sensitive Devices (PSD) that measure position and pointing (angle) of the beam. Feedback from the PSDs is used to control two beam steering mirrors.

The control principle is shown below.

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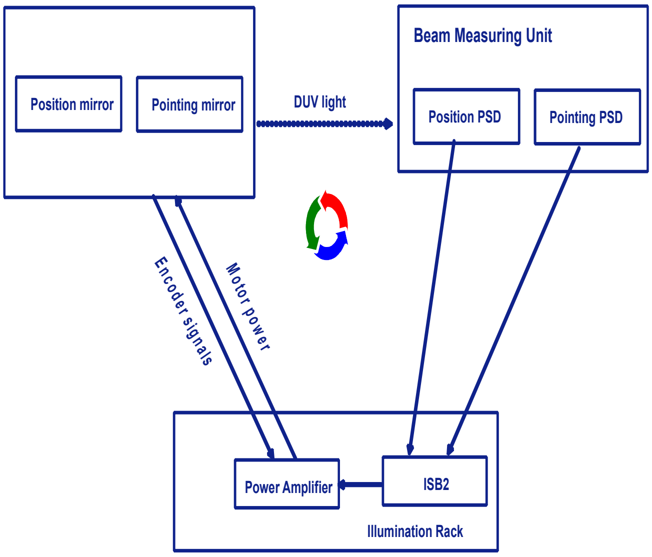

Figure 1.18 Beam Steering control principle

There are two types of beam steering in use. One makes use of mirrors that are motor encoder driven. One makes use of high speed beam steering motors whose tillt is permanently updated.

VA

The illumination system is fitted with a variable attenuator. The attenuator uses a specially coated optic that will allow some light to pass through, and some to be reflected. This transmission factor will change based on the angle of the optic. The way the softare sets VA will be explained in the section on the Dose Control system. The figure below. Shows the VA principle.

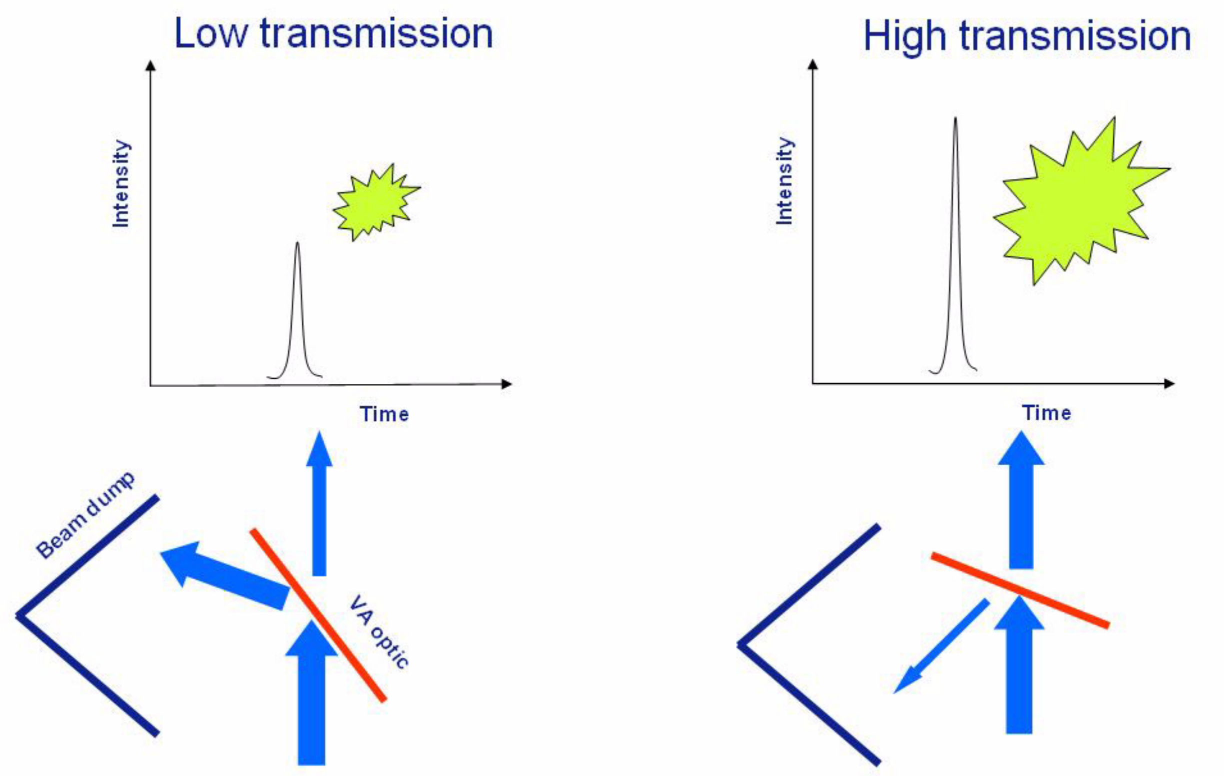

Figure 1.19 Variable Attenuator principle

The variable attenuator is located in the beam path between the Beam Measurement Unit (BMU), and the Automatic Doe Exchanger (ADE). There is also a beam dump to capture the reflected light and prevent it from reflecting back into the system.

Figure 1.20 The optics of the VA allow some light to pass through, and some to be reflected.

Figure 1.21 Variable Attenuator

The VA can move fast by use of a loudspeaker type coil. Current is enhanced by a set of capicitors in the Current Booster board.

The VA coatings must be dry. Water in the system influences the VA transmission. Therefore, the VA has an internal heating system. After a swap, dehydration of the system should be performed.

Diffractive Optical Element

A diffractive optical element (DOE 1) uses a fresnel lens effect to diffract the beam from the laser, while minimizing absorption of the light energy.

In combination with the zoom part of the Zoom Axicon optics, it produces the basic pupil shape.

In the figure below, the basic spreading of the light is shown.

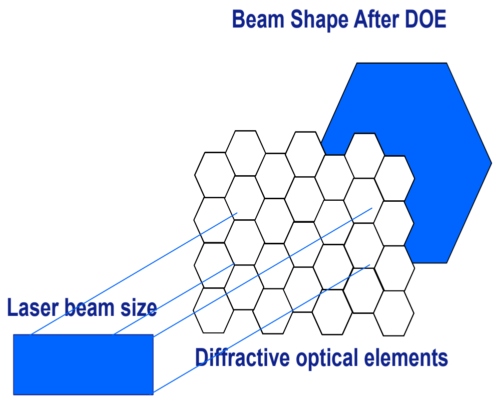

Figure 1.22 The DOE spreads and mixes the laser beam.

Each part of the laser beam is spread over the whole pupil in a shape that is DOE element specific. That way, the laser light is mixed while producing the pupil.

The DOE element also protects the optics of the ZA and further lenses in the illuminator. Without this DOE incoming laser light would damage the optics in the illumination system.

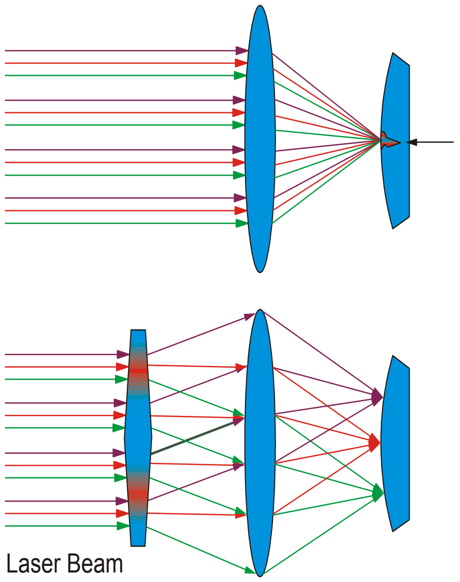

Figure 1.23 Effect on Zoom lens with and without DOE 1

For that reason, the DOE is interlocked. Without a DOE element present, the safety shutter will not open.

Automatic DOE Exchanger

An Automatic DOE Exchanger makes either 5 or 16 DOE elements available to the user, depending on the system type. By selecting a specific element the shape of the beam pattern is determined by the user and may be defined by the lot being run. The DOE exchangers are shown below.

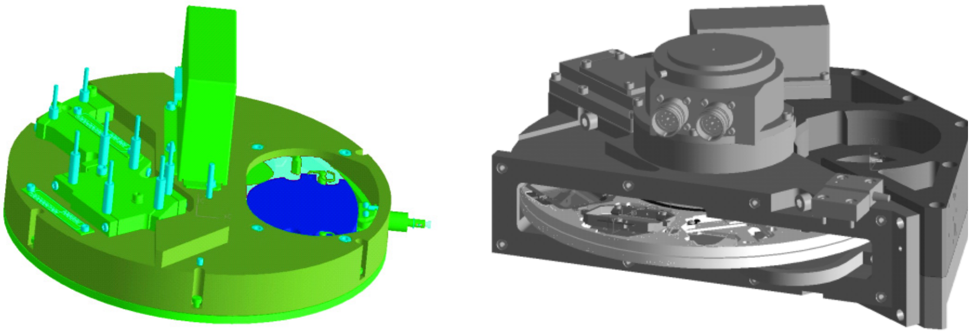

Figure 1.24 **5- slot and 16 slot Automatic DOE Exchangers**

In TWINSCAN systems a DOE is placed in the beam path by an automatic DOE exchanger (ADE) that can be loaded with a user selection of different elements. Each DOE will create a unique angular distribution of the light entering the pupil shaping optics. During initialization, the Automatic Doe Exchanger will identify which elements are installed. During production, if a job calls for a specific element, the ADE will automatically rotate to place the correct DOE in the light path

Pupil Shaping Optics

The Zoom Axicon is a set of lenses that may create and manipulate the pupil shape and size. Its concept is shown below.

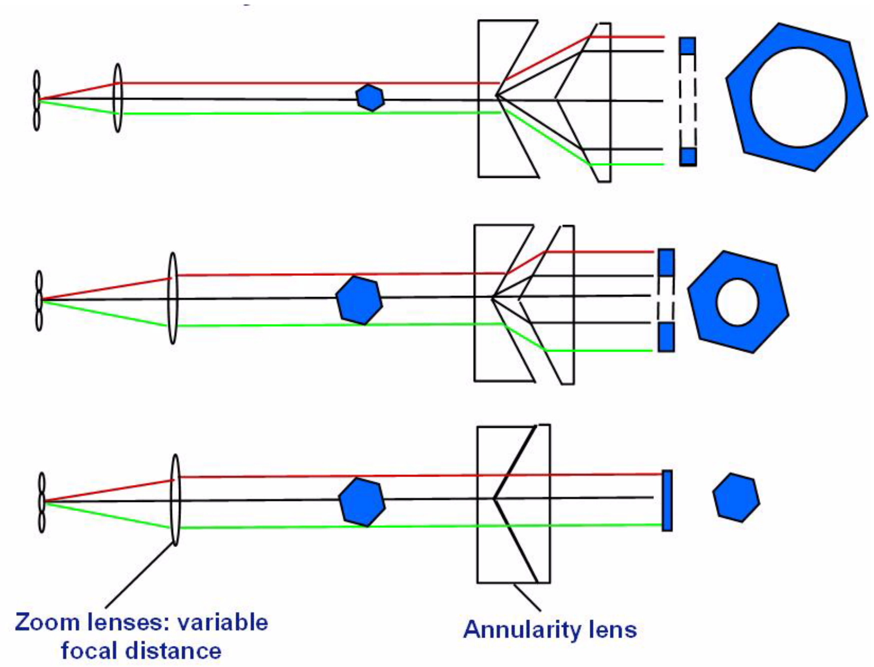

Figure 1.25 Zoom Axicon concept.

The DOE 1 element causes the beam to diverge. The zoom stops the expansion by changing it into a parallel beam.The focal distance (or strength) of the zoom lens determines the size of the beam.

The Axicon lens then can change the shape of the beam into a ring.

Special pupil shapes can be achieved by choosing specific DOE elements. See the figure below.

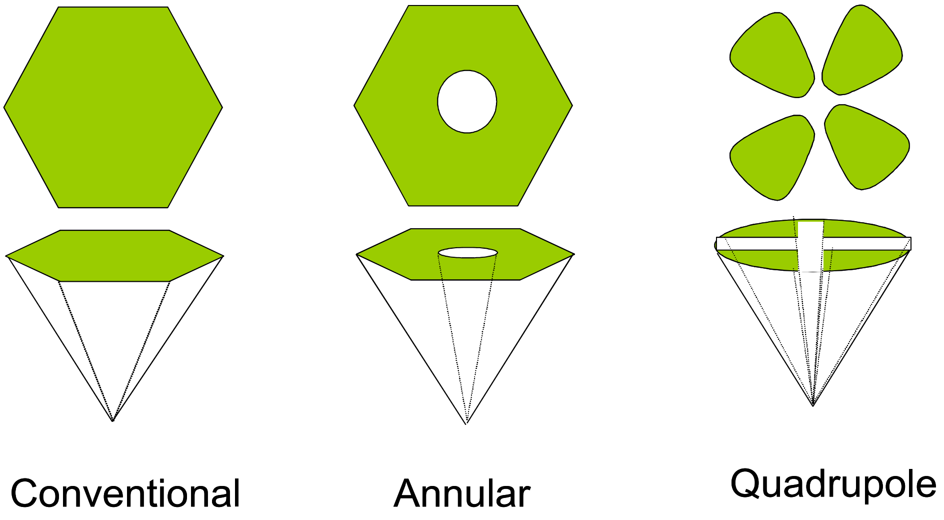

Figure 1.26 Special DOE element will create special pupil shapes.

By combining specific DOE elements with specific Zoom Axicon and NA settings, the customer is able to optimize his lithographic process.

Energy Sensor

The energy sensor is mounted on top of the bottom module. See the figure below.

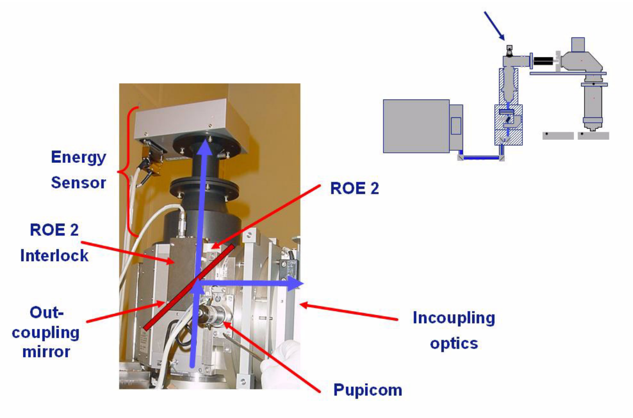

Figure 1.27 An outcoupling mirror transmits 1% of the light towards the Energy Sensor

The outcouple mirror directs 99% of the light towards the outcouple optics and the top module. 1% of the light passes through this mirror and a lens assembly to the energy sensor.

The energy sensor measures the energy for each laser pulse. Based on that value, the energy of the next laser pulse will be set on the fly. This is achieved by setting the laser High Voltage value. See also the paragraph on the laser.

Because there is a lot of optics between the Energy Sensor and wafer level, the Energy Sensor is calibrated with reference to the Spot Sensor. Each illumination setting lead the light in a different way through the optical system. Therefore, illumination settings all need a separate Energy Sensor calibration, which is put in a table with a time stamp.

Incouple Optics and Refractive Optical Element (ROE)

The refractive optical element (ROE) is mounted just before the in-coupling optics in the head assembly. The ROE has an interlocked cover. Both the cover and the ROE must be in place or the safety shutter will close. See the figure below.

Figure 1.28 ncept

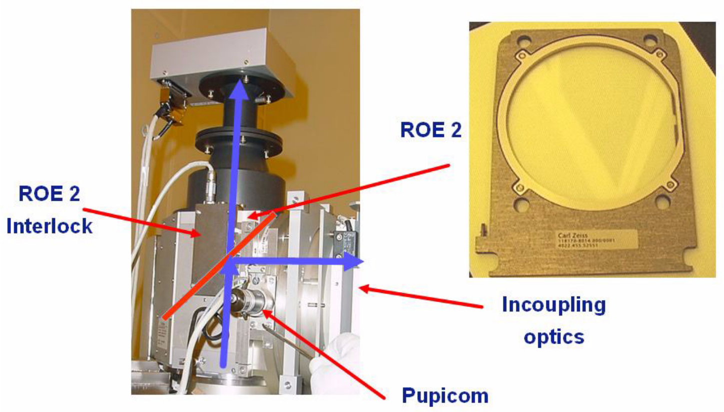

Figure 1.29 Refractive Optical Element ROE2

The Refractive Optical Element (ROE) refracts the light as it enters the outcoupling optics. The ROE, in conjunction with the outcoupling optics, shapes the beam to properly fill the integrator rod. This is shown below.

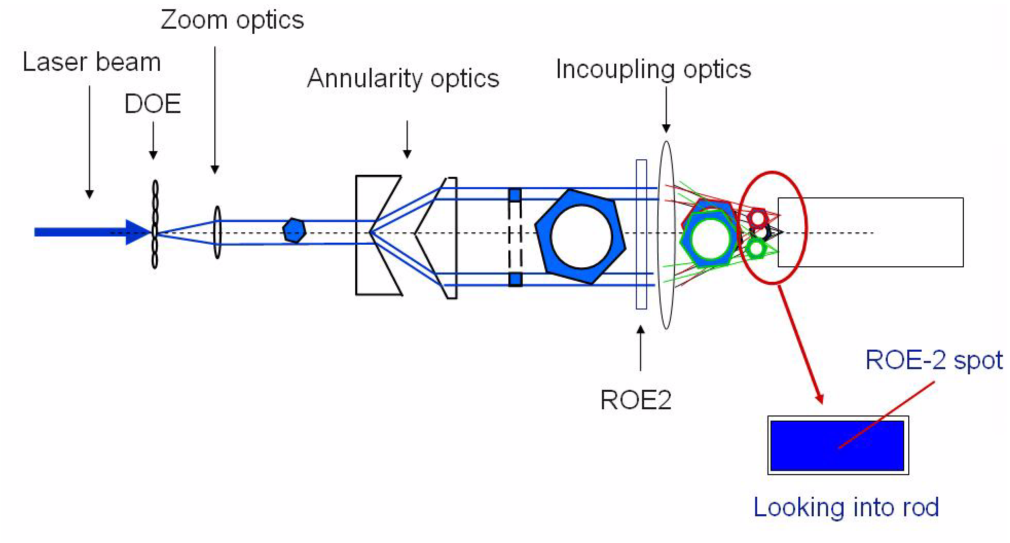

Figure 1.30 ROE2 and the Incoupling optics fill the Integrator Rod entrance.

The incouple optics are mounted just prior to the integrator rod. These optics are able to take the angular offset of the rays of light exiting the ROE2 and convert them to a positional offset. In this way the integrator rod filling is achieved, which results in smooth pupils without strong fine structure.

A second reason to have ROE2 is preventing high local intensities in the Integrator Rod optical material. This is similar to DOE1. Details are shown below.

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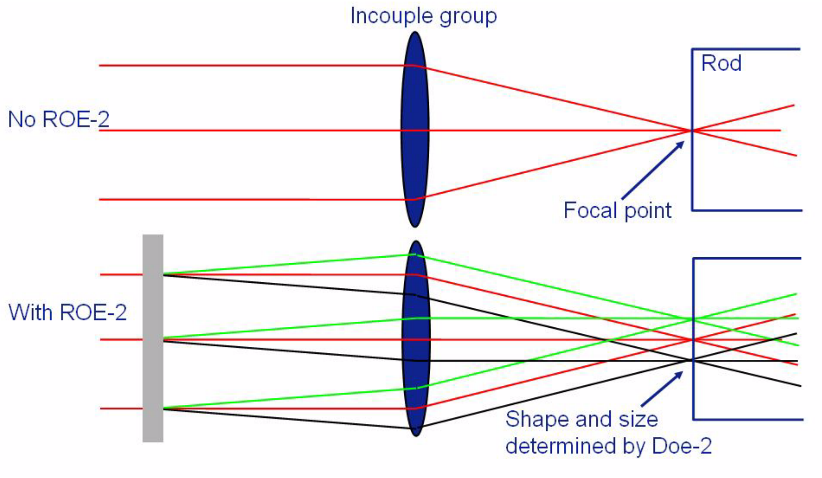


Figure 1.31 The incoupling group creates one focal point, with ROE2 it creates many.

Pupicom

A Pupicom is used to correct an elliptical pupil. Ellipticity is explained in the paragraph about the Integrator Rod. The Pupicom is mounted just before the incouple optics in the zoom/axicon head assembly and is calibrated to move to a specific setting for each illumination setting (DOE/sigma).

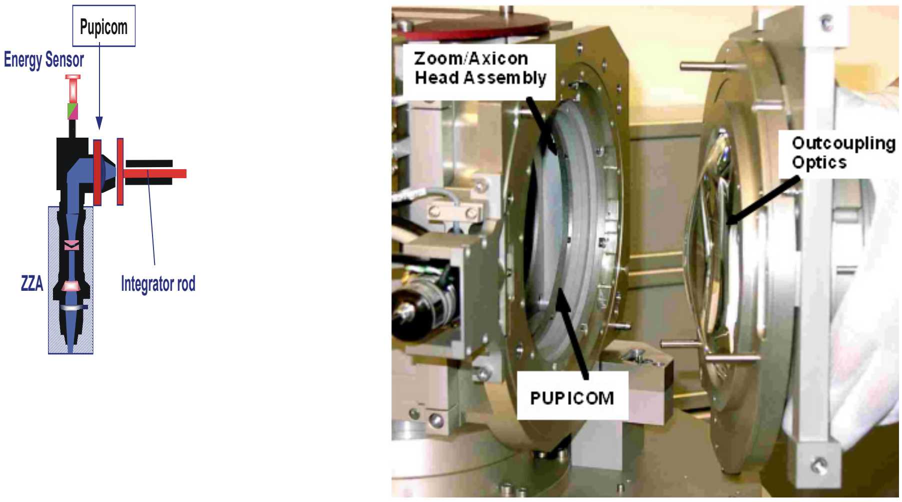


Figure 1.32 Pupicom Assembly

The Pupicom has a plate with for 4 sections. In combination with the two Integrator Rod reflection planes, the influence of the blade rotation on the pupil has a very specific behaviour, as shown below.

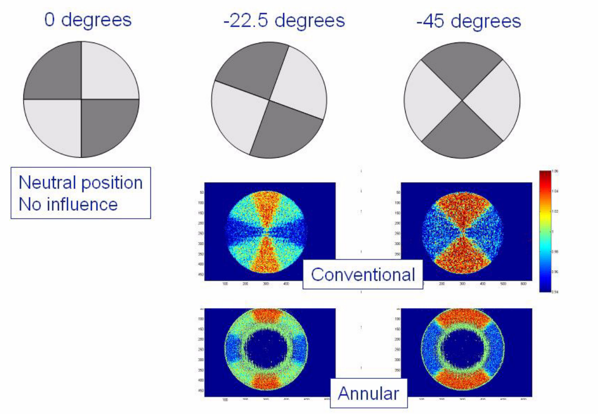


Figure 1.33 Pupicom influence on the pupil.

For further explanation, see also the paragraph on the Integrator Rod.

Ellipticity depends on angular distribution and is mainly caused by the difference in the number of reflections in the integrator rod for X and Y angles. This will cause a variation in the critical dimensions between horizontal and vertical lines. Ellipticity varies depending on the selection of DOE used.

Bottom to Top interface

The Bottom to Top Interface Plate consists of two parts. It is shown below.

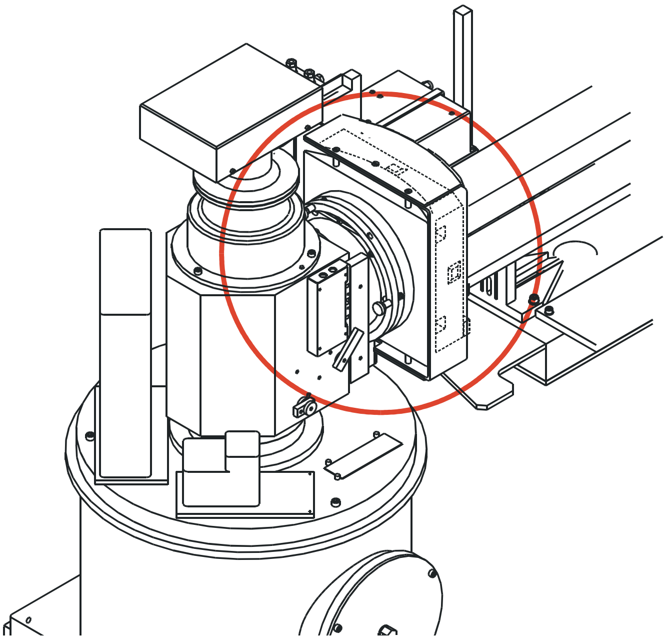


Figure 1.34 Bottom Module to Top Module Interface

A convex plate is mounted around the incouple optics on the Head Assembly, and a concave plate is mounted to the input of the integrator rod. The interface plate is designed to allow enough clearance for rotating the head assembly out for access, while maintaining a close enough fit to allow for purging of the gap between the top and bottom modules.

The Head Assembly is rotated before raising the illuminator Top Module.

Top Module

The top module assembly includes the Integrator Rod, Reticle Masking Assembly (REMA), REMA objective (lens), the condenser lens and Unicom assembly.

The top module is mounted inside the exposure unit cabinet, positioning the condenser lens above the reticle and projection lens.

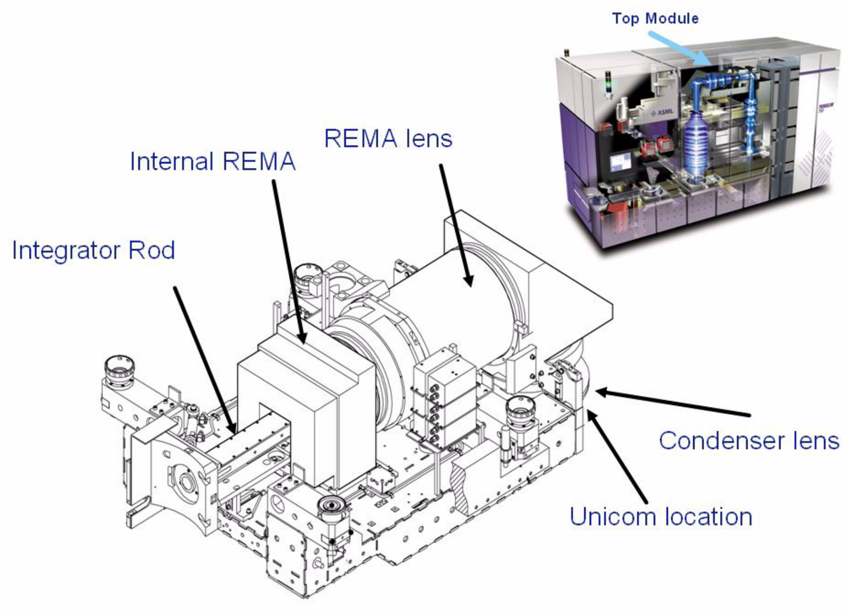


Figure 1.35 Top Module location and main components.

The entire top module unit can be raised to gain access to the gradient filter/Unicom and components of other subsystems.

Integrator Rod

The Integrator rod reflects the incoming light up to 3300 times, increasing the uniformity of the light supplied to the reticle.

By internal reflections, the rod makes many mirror images of a light source, as shown below.

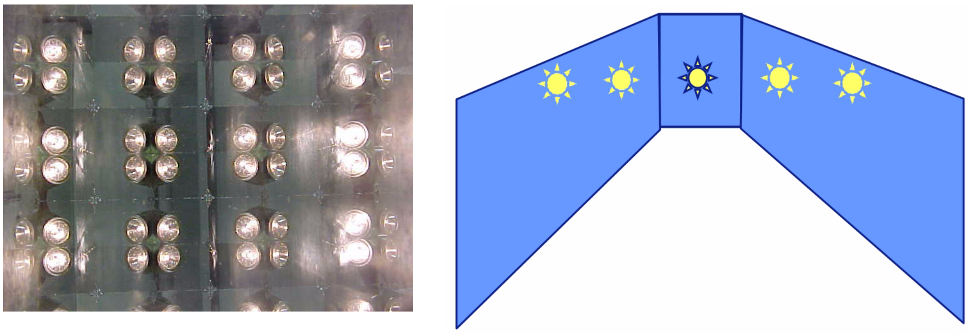


Figure 1.36 The integrator rod makes multiple reflections of the light source.

In the leftmost picture you can see what we get if we hold a lamp at the Integrator Rod entrance while making a photograph at the other end. The rightmost picture shows how the two internal walls reflect the light to make an array of mirrored images. The figure below shown this effect as wel.

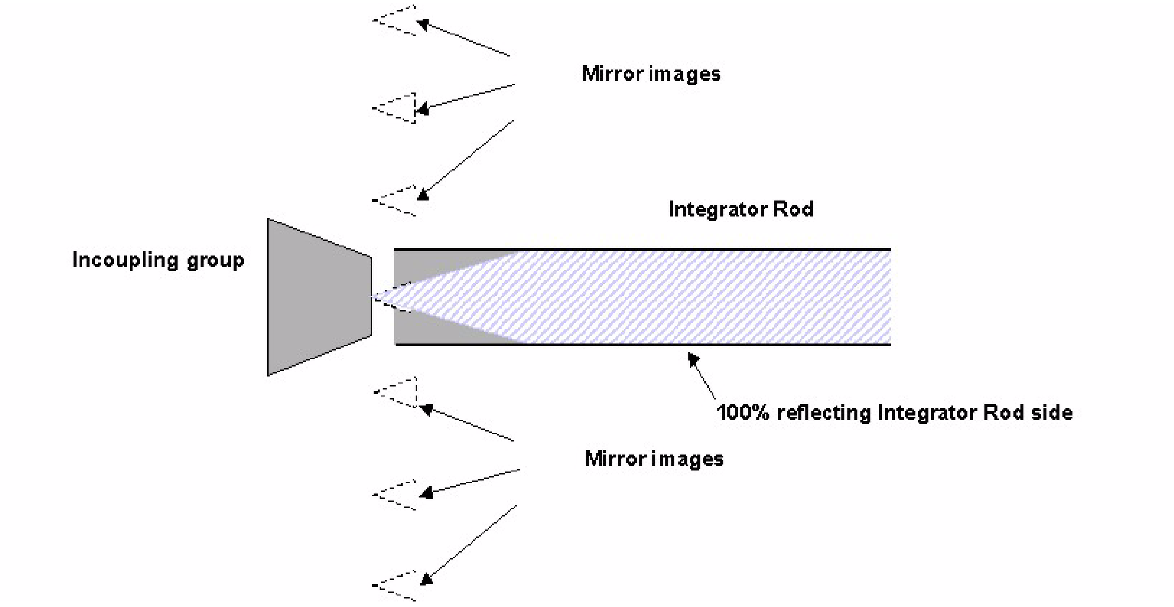


Figure 1.37 Multiple Mirror images made by internal reflections in the Integrator Rod

The multiple reflections give the effect of having a large number of light sources, all illuminating the same point. See the figure below.

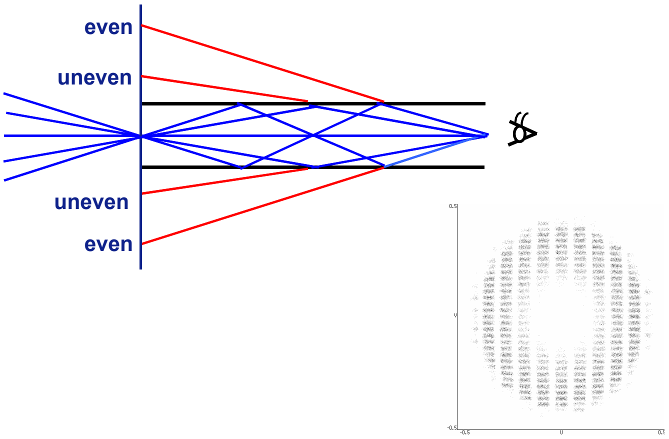


Figure 1.38 Integrator Rod concept

Because of the mirror images, the pupil is not smooth but has a fine structure. This fine structure differs per machine type, depending on the ROE2 that is used.

The effect of having numerous light sources, means that all points within the field are exposed to the same light cone.

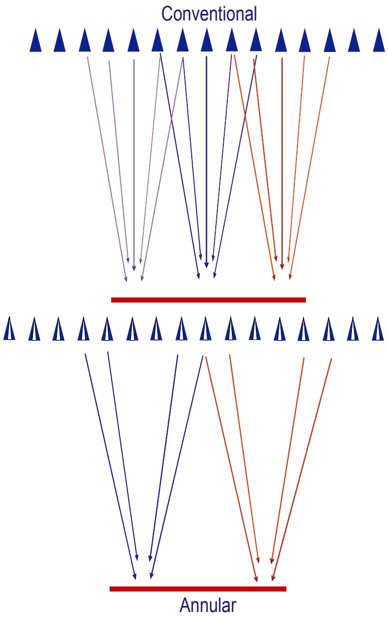
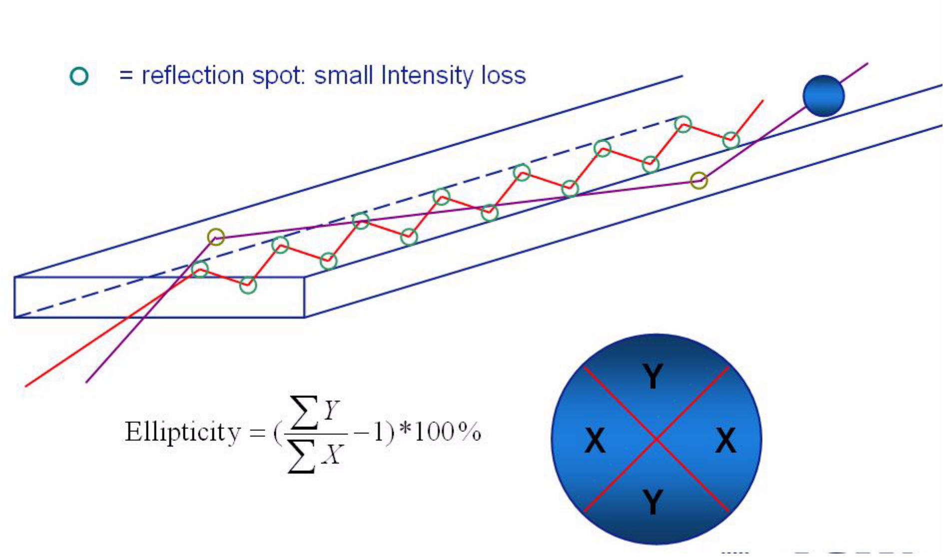


Figure 1.39 The whole array of light sources creates the same pupil for all locations of the illuminated field.

Note that the even distribution of the light sources, the tilt of the whole array, as well as the tilt of each individual source, will strongly influence the uniformity accross the illuminated field.

The relationship between the Zoom Axicon setting and the ellipticity is also very essential. It is given below.



$$\text{Ellipticity} = \left(\frac{\sum Y}{\sum X} - 1\right) * 100\%$$

Figure 1.40 Ellipticity depends on the pupil shape.

The integrator rod is protected by a nitrogen purged metal housing and mounted to the top module.

The effective slit width is defined as the width of the rectangular profile containing the same energy as the real profile. The height of the rectangle is equal to the energy density, the average dose in one laser pulse. If the profile were ideal (straight lines) the effective slit width would be the width of the slit at the 50% intensity levels. The effective slit width is used by the Dose Control algorithm. It is determined during the set-up sequence and stored as a machine constant. Figure 80: The slit profile in the Y-direction decreases dose quantization errors. Slit profile in y Rectangle containing the same energy as the profile

Slit profile

The REMA blades are imaged sharply on the reticle because they are in the object plane of the REMA optics. The integrator rod exit is a small distance in front of the object plane. It is therefore not projected sharply onto the reticle. Instead, at the edges a gradual build-up of intensity results. This gives the illumination slit at reticle level. See the figure below.

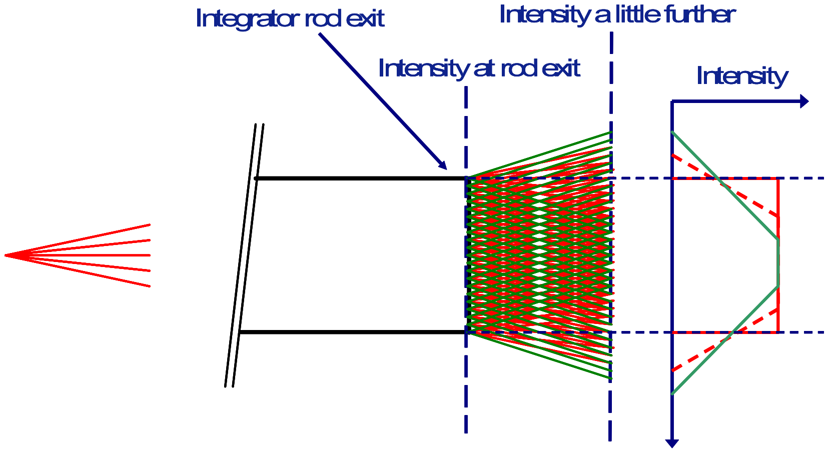


Figure 1.41 The Slit profile has slopes that result from the Integrator Rod defocus.

If we would expose without a reticle, we would see the same slit, but in reduced size, at wafer level.

The cross section of the image of the defocussed integrator rod in the y-direction is called the Slit Profile. The edges at which the intensity increases are called the slopes.

A plot of the intensities in the slit can be made after stepping or scanning the Spot Sensor through the slit and measuring the intensity at each position. The slopes are present in both the scanning (Y) and in the non scanning (X) direction.

The slopes in the X-direction are blocked off by the REMA X blades, or by the limited size of the Projection Lens when the blades are fully opened. The profile in the Y-direction is shown in the figure below. The slopes in the Y-direction are used to decrease dose quantization errors.

If a point on the die receives a laser pulse too much, it will always be at the beginning or at the end of the slit. Because of the slopes, the intensity of a pulse at these positions is very low. This way the contribution of an additional pulse to the dose is reduced to an acceptable level.

Retical Masking Unit (REMA)

The REtical MAsking unit (REMA)uses four moveable blades to mask (block light from) the areas of the reticle that should not be illuminated.See the figure below.

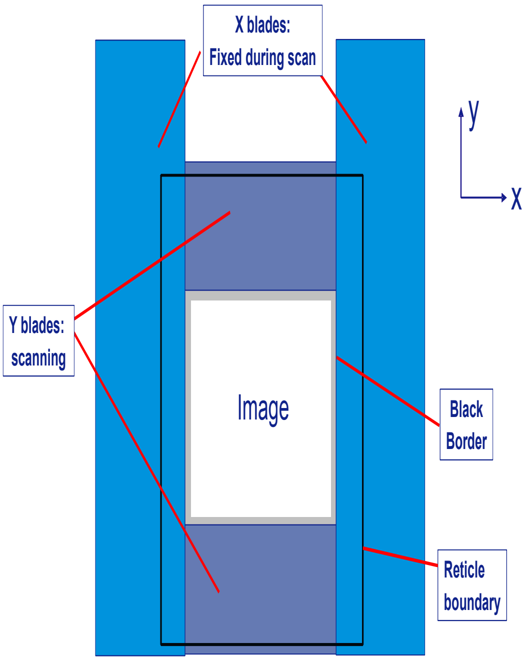


Figure 1.42 REMA Blade Layout

The X blades are positioned prior to the exposure based on the image size, and do not move during the exposure.

The Y blades take part in the scanning movement. See below.

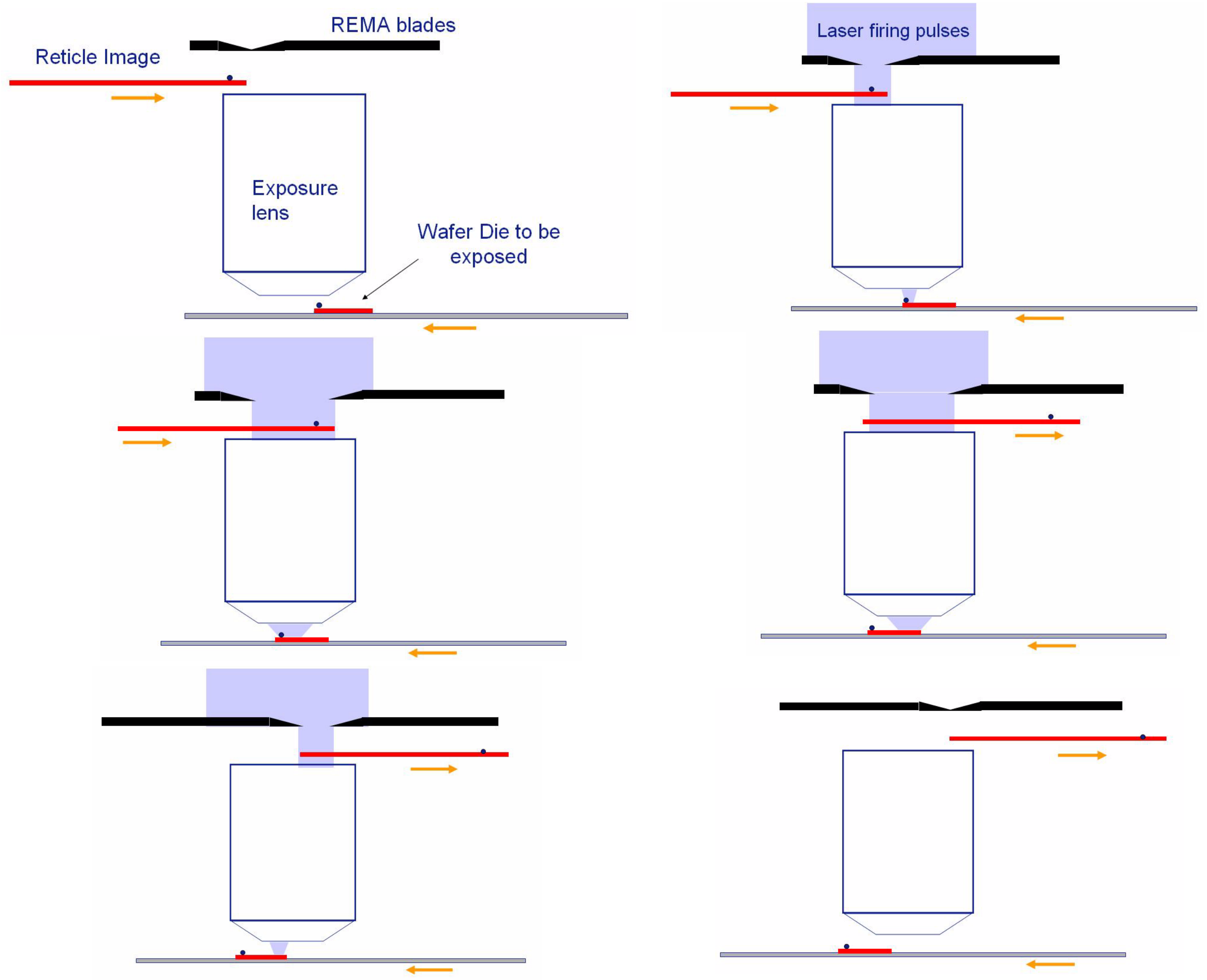


Figure 1.43

The Y blades must start the scan closed, and then open as the image enters the exposure slit.

When the Y blades are open to the size of the slit, they will remain open until the final edge of the image has entered the slit. At this point, the REMA blades will close in synchronization with the image.

Optically, the REMA blades are in the object plane of the REMA lens. This means that the blades throw a sharp shadow on the reticle. See the figure below.

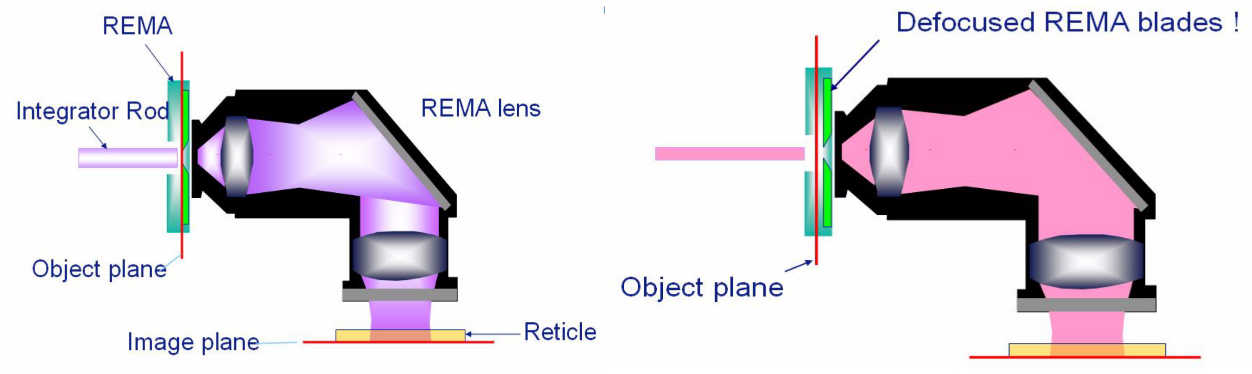


Figure 1.44 REMA blades in and out of focus

When a REMA blade is not in the ideal position, a half shadow is present on the reticle. In practice this is always the case. The penumbra is stopped by a black (chromium) border on the reticle. If the REMA blades are not at the correct positions, or if the half shadow is too large, the half shadow can be present in the die to expose or in neighbouring dies.

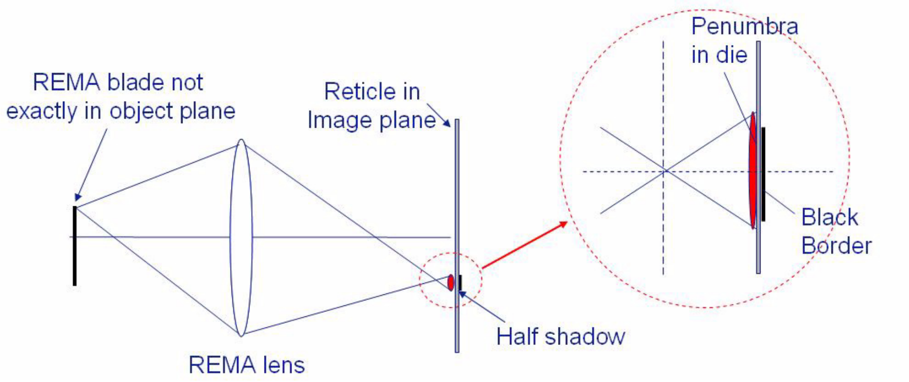


Figure 1.45 An out of focus REMA blade may lead to unwanted exposure of reticle parts.

REMA objective

Immediately after the REMA, is the REMA Lens, or sometimes referred to as the REMA Objective. See the figure below.

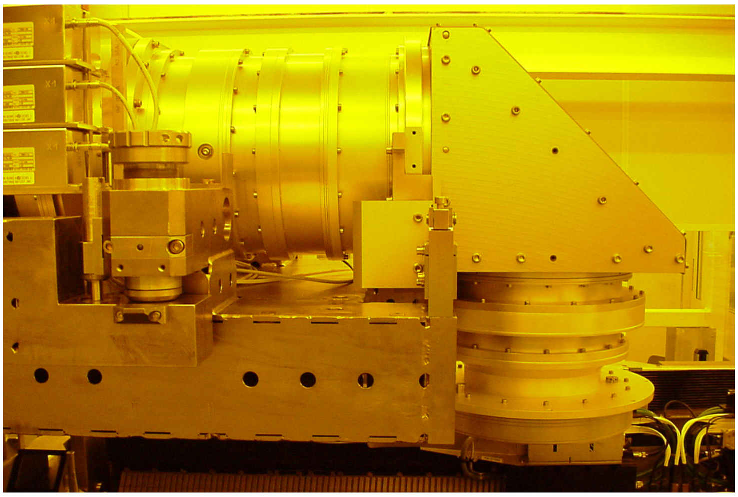


Figure 1.46 The REMA objective

The REMA objective makes an image of the light source above the reticle. This is shown below.

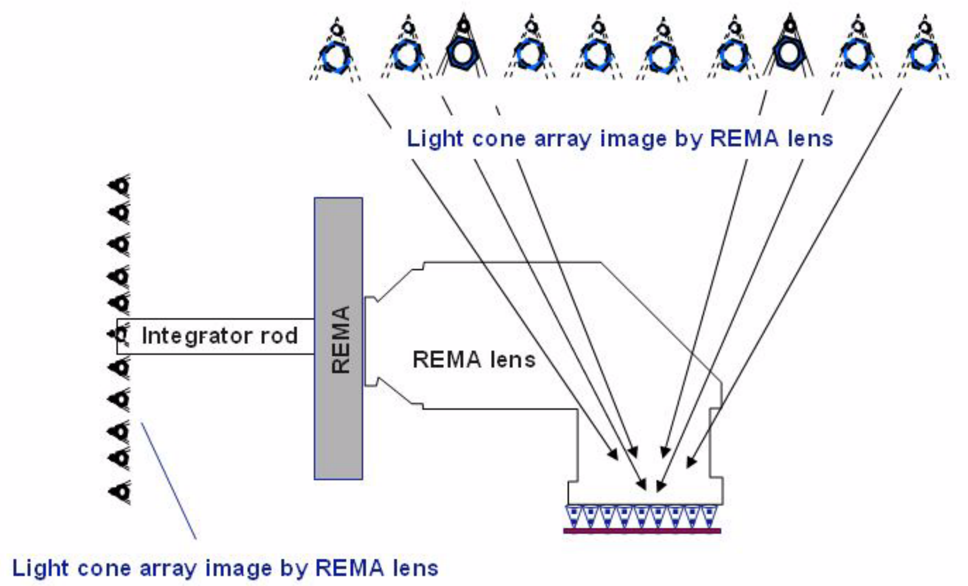


Figure 1.47 The REMA lens makes an image of the light source above the reticle

The last lens element of the REMA lens is called the condenser lens. It is used to adjust the uniformity tilt. This is done using the Uniformity test at a specific illumination setting or the Beam Fine Adjustment test. See the chapter on the illumination set-up.

The REMA lens has a point within the lens where the rays of light cross. At this point, the light source is close to focus. This called the Pupil Plane.

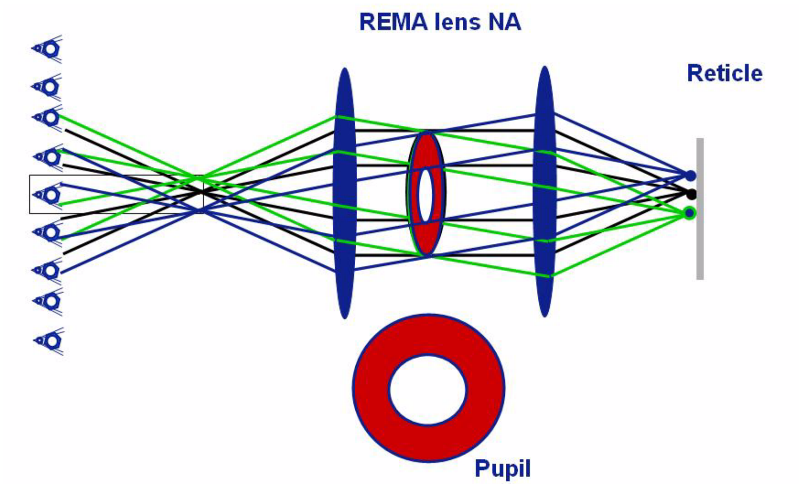


Figure 1.48 The REMA lens pupil plane.

The location of the pupil plane is important because apertures can be inserted at this location for various tests, or on some systems, to clean up and shape the pupil.

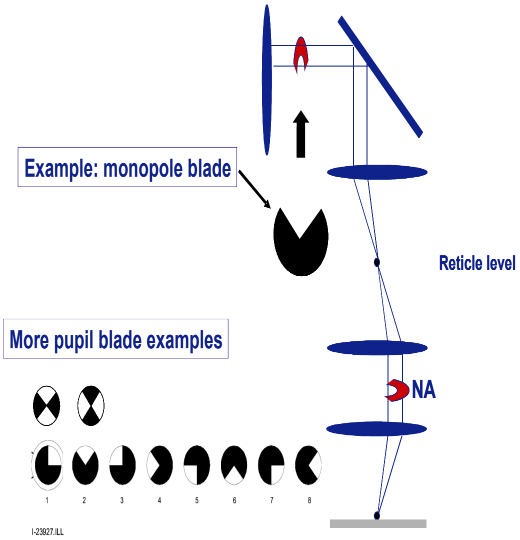


Figure 1.49 MonoPole blades used for testing in REMA lens pupil plane.

Automatic Clean Up Aperture (option)

The Automatic Clean Up Aperture is a mechanism that can automatically insert pupil blades into the REMA lens. It is an option.

The Clean Up Aperture blades can influence the pupil in a positive way, depending on the process that the customer uses. The influence of the blades on the pupil is visualized below.

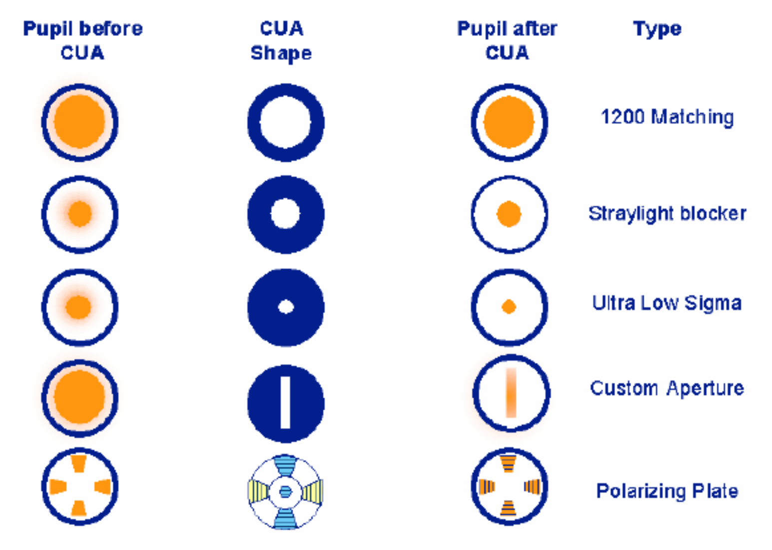


Figure 1.50 Clean Up Aperture Blades can influence the pupil.

Especially the polarization effect can be of great use to the customer. These blades are called Polarization Optical Elements (POE).

For the usage of normal (non polarizing) aperture blades, a library is used that can hold up till six aperture blades.

For the usage of polarization blades, a library is used that can hold up till 2 polarization blades and two aperture blades.

One blade at a time can be mounted into the REMA lens using a gripper arm. See the figure below.

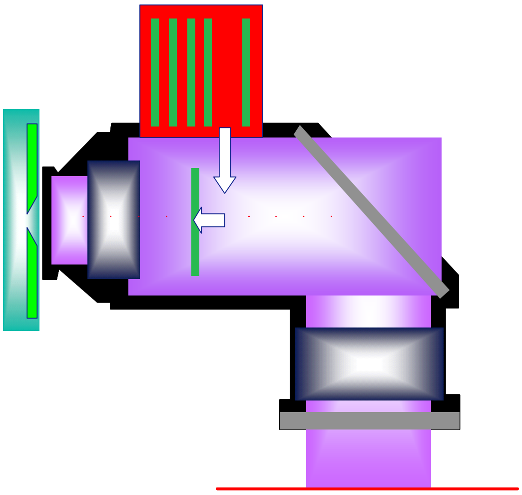


Figure 1.51 Each blade in the library can be inserted into the REMA lens.

Because the location of the pupil plane in Z depends on the pupil filling, apertures of different size are to be placed at different Z locations. The Z range is 34mm. The aperture exchange time is less than 5 seconds for standard 9mm thick apertures.

Blades are fitted into a library. See the figure below.

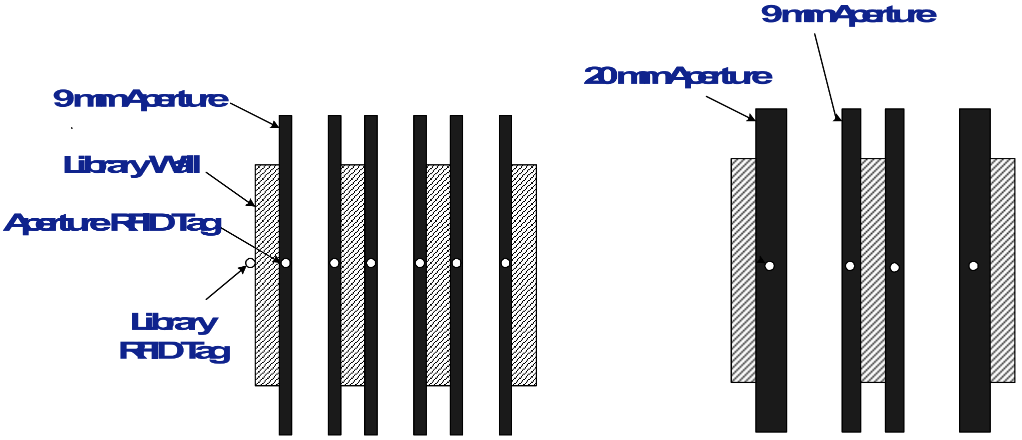


Figure 1.52 Two library configurations are available.

UNIformity COrrection Module (UNICOM).

To further improve the uniformity, or in some cases to correct for uniformity changes as the illumination setting changes, the condenser lens output will have either a gradient filter or a UNIformity COrrection Module (UNICOM).

The UNICOM is standard on 193 nm systems, and optional on 248 nm systems. The UNICOM uses two plates that can be specifically designed for a particular system. The plates are designed to overlap each other, with position for each one determined by a calibration. The positions vary to correct for changes in uniformity caused by changes in illumination settings (annular, conventional, large sigma, small sigma, etc.). The bottom of the UNICOM is covered by a fixed purge plate to provide a continuous flow of clean filtered air between the UNICOM and the reticle.

A Gradient Filter is standard on 248 nm systems to correct for uniformity issues. It consists of a quartz plate that is designed to attenuate the light in places where intensity is high within the field, giving a uniform intensity profile. The gradient filter is designed to be used with a specific machine, based on the results of the gradient filter determination test.

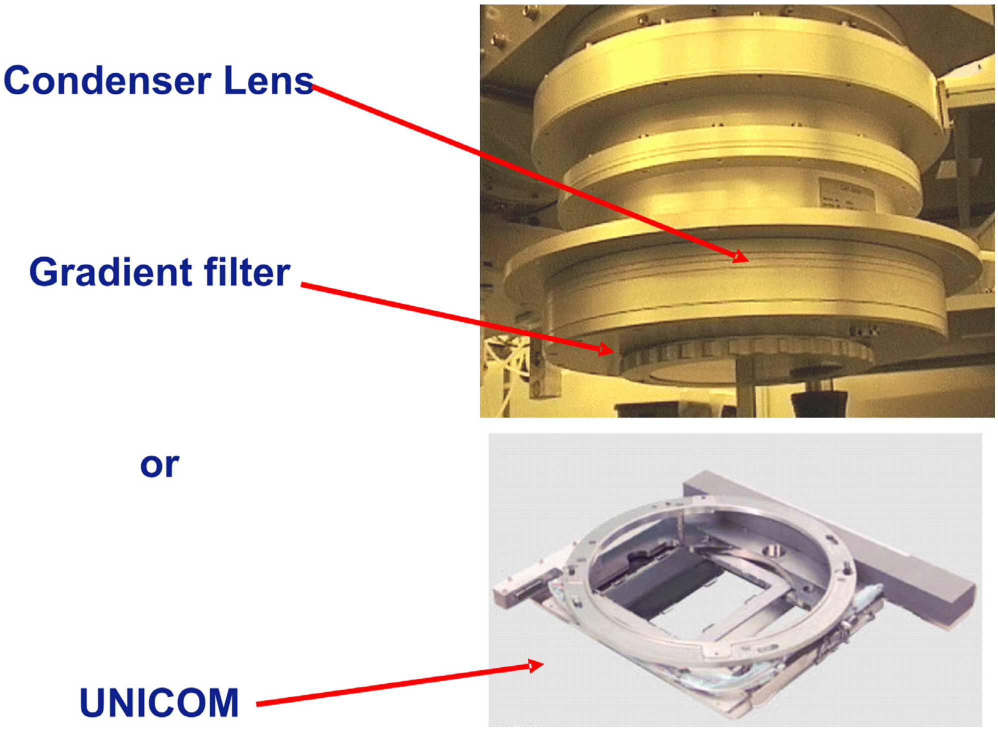


Figure 1.53 Condenser Lens, gradient filter, and UNICOM

BASIC PRINCIPLE OF DOSE CONTROL

Each square centimeter of illuminated wafer surface will receive an amount of energy during its passage under the slit.

The amount of energy is built up in time, pulse by pulse.

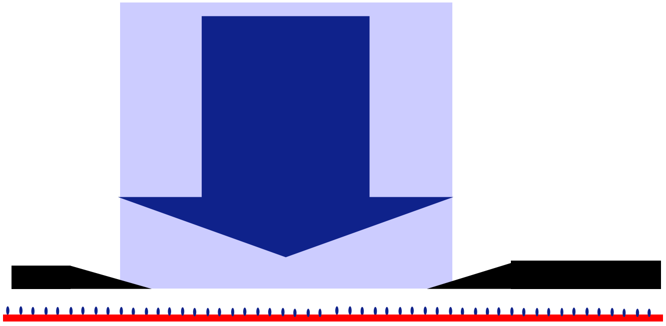


Figure 1: The amount of energy is built up, pulse by pulse

Each laser pulse delivers an amount of energy per square centimeter. If we average this out over a number of pulses, we call this the energy density. Stated differently, the energy density is the average dose given by one laser pulse (J/m2/pulse).

The energy density is calibrated on specific moments and is used by the Energy Control Algorithm during the scan.

The Dose (J/m2)is the energy density times the number of laser pulses delivered to a pixel during the scan.

The real situation is slightly more complicated because the energy of the pulses that go to the wafer is not constant during a scan. See the paragraph on the Dose Control algorithm.

Resist & dose

The photo resist on a wafer is chemically changed if enough light energy with the correct wavelength (property of the resist) is absorbed. The energy needed to expose a wafer is expressed as:

Light intensity x exposure time = dose

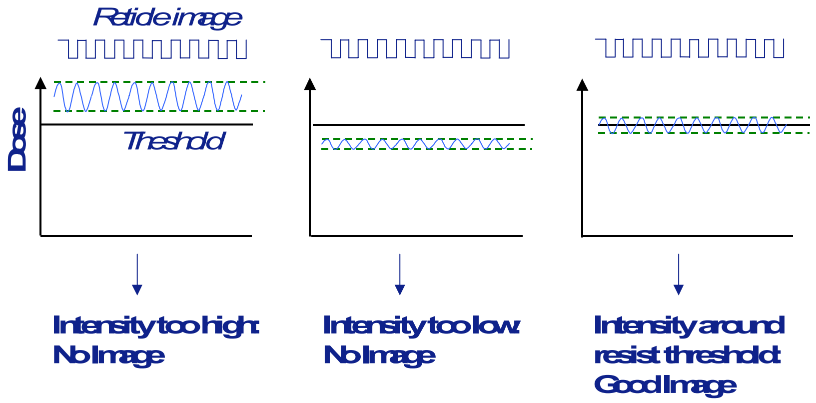


Figure 2: Photo resist threshold & dose

The figure above provides a graphical representation of how the dose and the photo resist determine if an image will be formed during resist development or not. There is a small margin around the threshold value which allows some tolerance for dose inaccuracy. However, depending on the line width and the illumination settings, this tolerance can be rather small.

If the correct dose is not reached, or if it is exceeded, the resist will not develop completely or it will develop too much. In both of these cases, the result will be bad imaging. Dose control is very important; many internal and external conditions significantly influence how well the dose is controlled.

Dose control decision process

Before the exposure starts, the software will calculate the settings for dose control. This is done in two steps.

Scan time calculation

This is done by the SN (Scan Negotiation) driver. See the figure below.

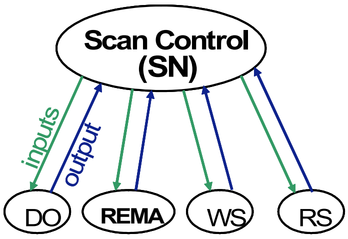


Figure 1.54 The SN driver communication with th other driver involved about the miniumum scan time.

SN asks each driver to calculate the minimum and maximum scan times. Each driver then delivers its scantime range to SN. SN then determines the shortest possible scan time. See the figure below.

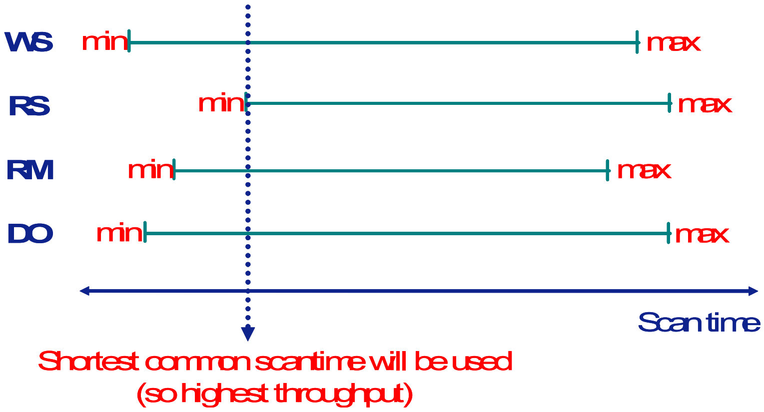


Figure 1.55 The SN driver determines the shortest scan time..

Now, SN will deliver the scan to all drivers including Dose Control. This is visualiuzed below.

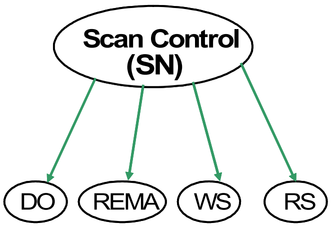


Figure 1.56 The SN driver delivers the scan time to all drivers involved..

Dose control calculations

Then the Dose Control driver will calculate the required setting for

- The number of pulses
- The laser frequency
- The VA setting

The choise of setting depends on the usage of Cost of Ownership reduction (CoO).

With CoO switched on, Dose control tries to minimize laser and VA usage by choosing the lowest possible pulse number. Dose accuracy will suffer from this.

With CoO switched off, Dose control use a higher laser frquency with a lower VA tranmission. Dose accuracy will improve by this.

Dose control calculation are easy to understand:

VA transmission is calculated using

Dose = VA transmission*Energy density * #pulses

so

VA transmission = Dose/(Energy density * #pulses)

Laser frequency is calculated using:

#pulses = laser frequency * scantime * (effective slit width / total slit length)

so

Laser frequency = #pulses / (scantime * effective slit width / total slit length)

Energy Control

The High Voltage discharge in the laser and the gas composition in the laser determine the pulse energy. But unfortunately, the process in a DUV laser is such that, even if we apply a constant High Voltage, there is a pulse to pulse energy variation present. This visualize in the figure below.

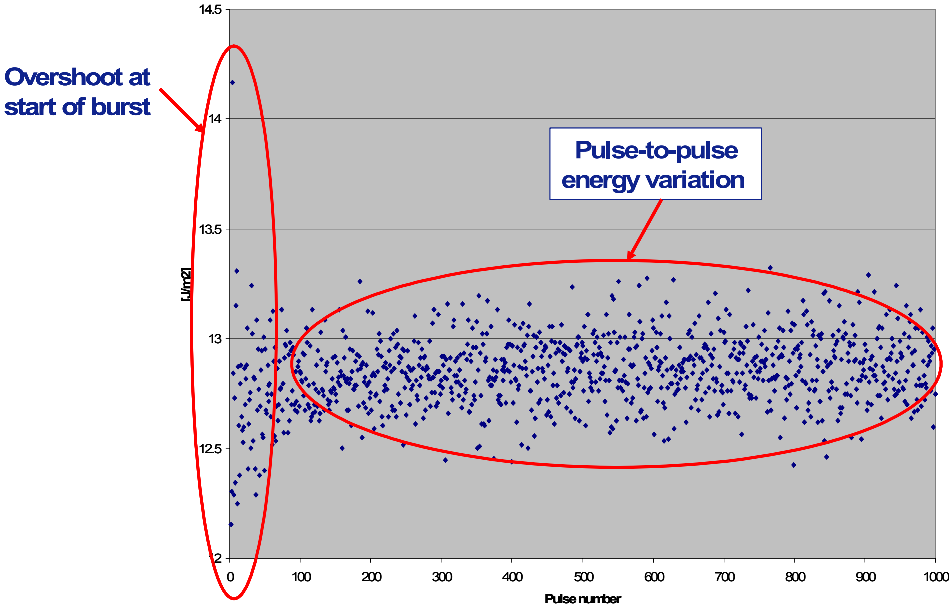


Figure 1.57 Lasers have a pulse to pulse energy variation.

The Energy Control algorithm will adjust the High Voltage on the fly in order to keep the average pulse energy close to the nominal value. The High Voltage setpoint is generated before each new pulse by looking at the energy of the preceding pulses.

Energy Control Algorithms

The TWINSCAN system can operate in two energy control modes. The Laser Energy Control algorithm (LEC), previously called Low Performance Dose Control (LPDC) is often used during tests and calibrations. Scanner Energy Control (SEC), previously called High Performance Dose Control (HPDC) is normally used in lot production. Which mode is used, is determined by the Machine Constant `Laser Pulse Energy Control Mode` or by the settings in a test.

- Laser Energy Control algorithm

In Laser Energy Control (LEC) mode, the laser itself controls the light pulse energy. The algorithm keeps the average pulse energy as close as possible to the nominal energy. The energy of the light pulse is measured with an energy sensor in the laser which is called the P-cell. The algorithm then determines the High Voltage for the next pulse.

- Scanner Energy Control algorithm

This algorithm is similar to the LEC but the Energy Sensor is used instead of the P-cell. used to stabilize the laser pulse energy. It runs in the ISB firmware.

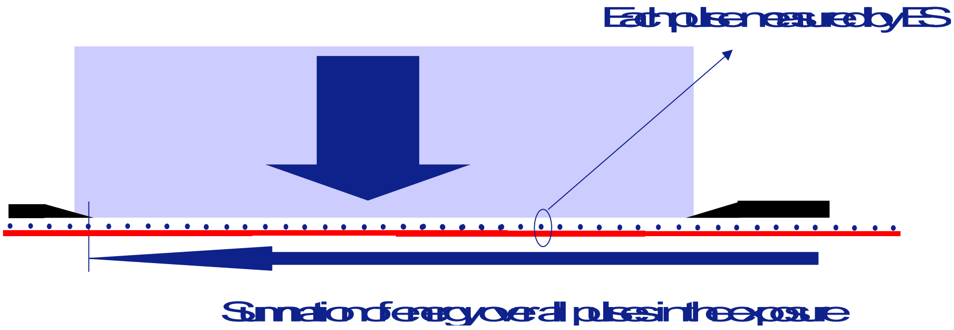


Figure 3: In SEC mode the pulse energy is measured by the ES

The control algorithm uses laser High Voltage setpoint values to influence the exposure energy. The correct HV is calculated using information that was determined in the HV-Ep calibration.

An example of the way the SEC algorithm controls the laser output is shown in the figure below.

Pulse No	Pulse energy (setHV)	Measured ES	SUM Dose	SUM Dose Predict	Energy Error &	Cal. HV
1	10	12	12	10	+2	(8mj)
2	8	9	21	20	+1	(9mj)
3	9	10	31	30	+1	(9mj)
4	9	11	42	40	+2	(8mj)
5	.	.	.	.	.	.
6	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	(9mj)
31	9	10	309	310	+1	(9mj)
32	9	11	322	320	X	X
TOT	320		322	320	2	

Figure 4: Scanner Energy Control example

Suppose that the wanted average energy value is 10 mJ. The SEC algorithm thus will send a HV value to the laser that on average will give 10 mJ energy. The energy sensor however sees an energy of 12 mJ (see figure, column of measured energy). In order to maintain an average energy level of 10 mJ, the next laser pulse should have an energy of 8 mJ. The scanner will calculate which HV value corresponds to this energy. Subsequently this setpoint will be transmitted to the laser. The laser will then start to build up the HV for the next laser pulse.

In the figure below, the sequence of events is shown.

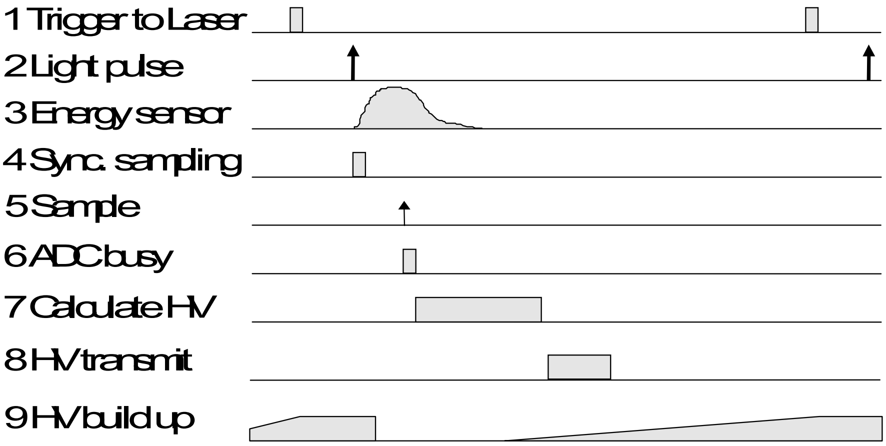


Figure 5: Scanner Energy Control algorithm

1. The sequence starts with a request of the scanner for a light pulse from the laser. The request is transmitted via a parallel IO line. IIt is called laser trigger.
2. The laser will then fire a light pulse.
3. The light will arrive at the Energy Sensor where the light energy will be converted into an electrical signal.
4. At the moment that the laser fires a light pulse, it also sends a synchronization pulse via a parallel IO line to the scanner. The scanner will start a timer that expires after a well defined time (for 750: 35 microseconds). This forms the delay between firing the pulse and the sampling time of the Energy Sensor signal. It is called the laser trigger to light delay and is found in the DO machine constants.
5. After a certain delay, the signal will be at its maximum and it is then sampled.
6. The AD converter changes the electrical signal into a digital number that can be used by the software
7. With this pulse energy data the scanner will calculate the next High Voltage (HV) setpoint.
8. This HV setpoint is sent to the laser.
9. As the setpoint arrives at the laser, it is used to set the HV value, that was already being built up by the laser.

2

PROJECTION SYSTEMS

INTRODUCTION

The projection system captures the diffracted image and projects it onto the wafer. This system includes the projection lens, moveable elements within the lens, an adjustable aperture, a purging system and suppoting electronics.

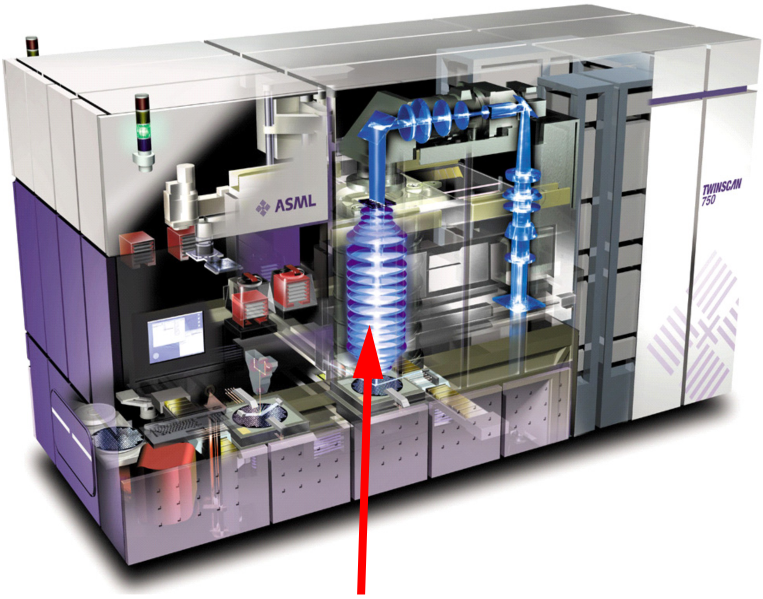


Figure 2.1 Projection lens location

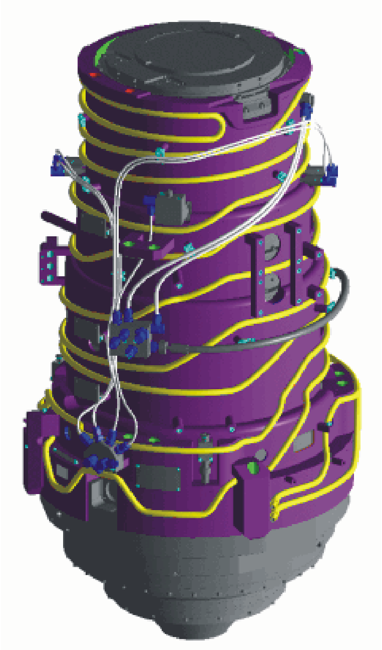


Figure 2.2 Example of a projection lens in the lens jacket

The TWINSCAN projection lens is wrapped in a housing that controls the temperature and supports a temperature and a pressure sensor, interface components and a number of electrical, pneumatic and mechanical devices.

LENS BASICS

Dual telecentric lens

The projection is dual telecentric, which means that the center of the rays pass through the optical center of the lens. See the figure below.

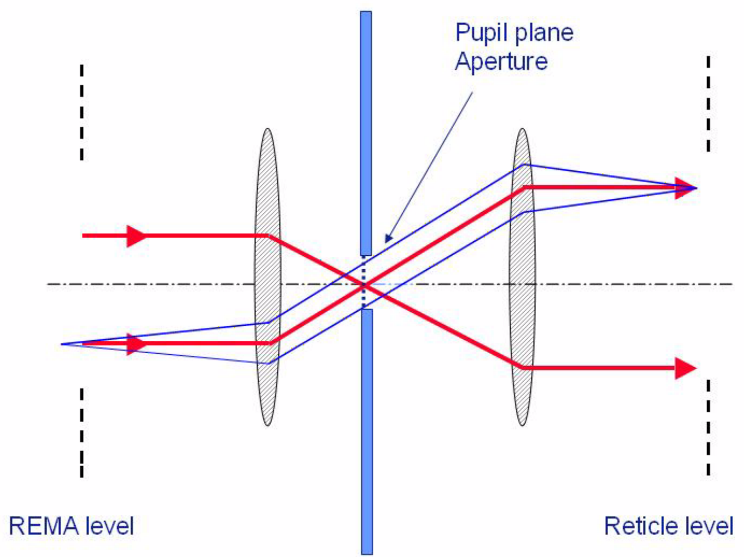


Figure 2.3 Dual telecentric lens concept.

This means that a change in reticle or wafer position in the Z axis will not cause a change in the size of the projected image.

Numerical Aperture

As already explained in the L1 computer based training, a larger depth of focus means that the image will be sharp enough over a larger range.

Note:

This would compare to the f-stop on a camera lens while the camera tries to take a picture of objects at different distances. With a large f-stop, the camera lens can gather more light, but fewer of the objects in the frame will be in focus. If the f-stop is smaller, the lens will gather less light, but more of the objects in the frame will be in focus.

Numeric Aperture (NA) is defined as the sine of the angle between the outermost rays of light and the optical axis, multiplied by the refractive index of the medium where the beams pass through (water for an immersion system).

A smaller NA means the angle is smaller, a large NA means the angle is larger.

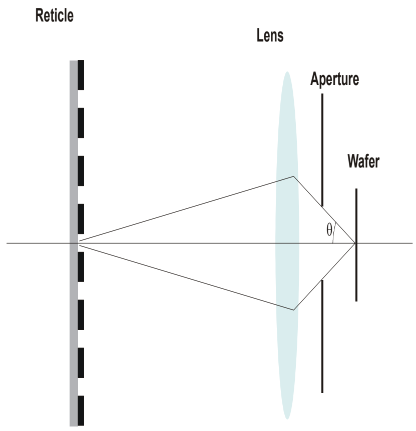


Figure 2.4 Numeric aperture

This angle changes as the aperture opening inside the projection lens is increased or decreased to allow more or less of the orders of light to expose the wafer.

The NA principle is always the same. However, three different generations of NA mechanics are used in Twinscan machines.

Lens abberations

Light is separated into orders of diffraction as it passes the chrome pattern on the bottom of the reticle. As the features of the mask get smaller, the angle of the diffracted orders increase.

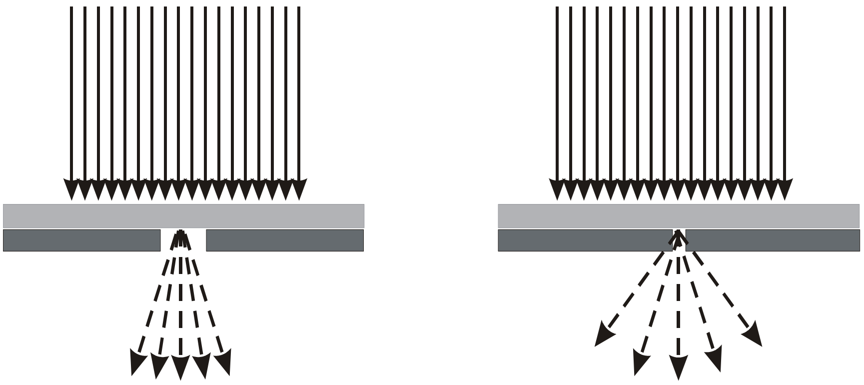


Figure 2.5 Effect of Line Size on Diffraction

The orders of light travel into the projection lens as “rays” that are then “bent” or refracted by lens elements. The zero order of light is the light that follows the direction of the incident light (light approaching the reticle grating) after passing the grating. Each order of light from the 1st, 2nd, 3rd, etc., will be diffracted at a greater angle from the zero order.

Each point on the reticle will have its own orders of light. These orders of light will each travel through a different portion of the lens and be recombined at the wafer.

A cross section of the diffracted light leaving the mask at a particular time spreads out into a perfect sphere. This sphere is called a wave front. Different portions of the wave front are slowed more than others by the lens elements, so when the cross section leaves the lens, it is no longer a perfect sphere. The deviation from a perfect wave front is called an “optical path difference” or aberration.

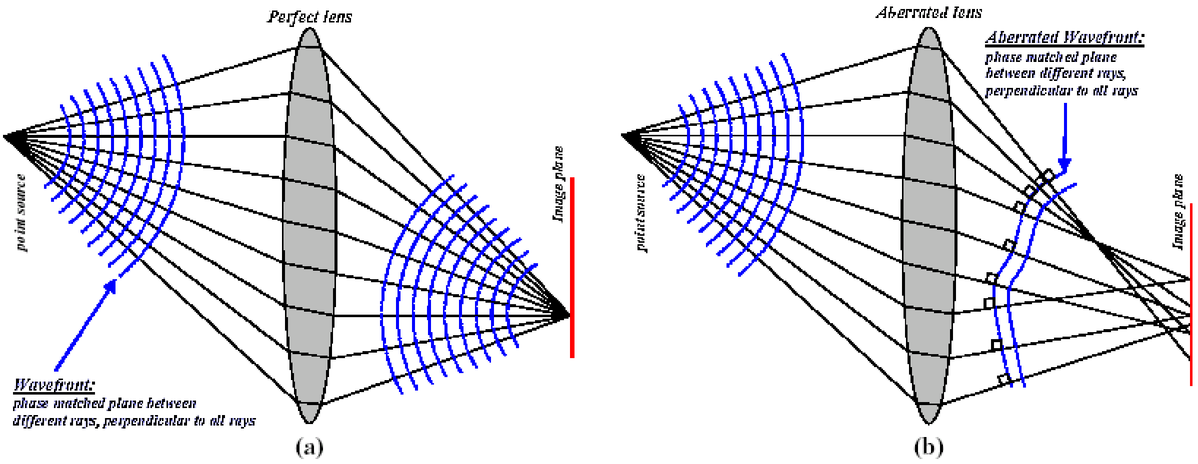


Figure 2.6 A point source reconstructs through a perfect lens to a point on the Image Plane. A point source with aberrations reconstructs into a blur.

The deviations from the perfect sphere can be looked at as a landscape with mountains and valeys. This landscape can be considered a summation of basic landscapes. These are called Zernikes. Zernikes can be measured by the Ilias sensor.

Lens models

The lens aberrations can be minimized using moveable lens elements. The relationship between the Zernikes and the positions of the moveable lens element is known. The Twinscan uses a calibration lens model and a driver lens model to optimize the settings to always obtain the best possible image.

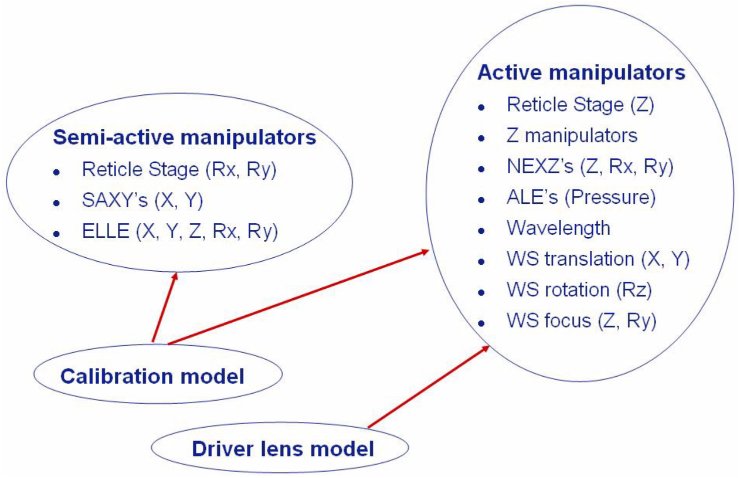


Figure 2.7 What actuators are driven by wht lens model

The calibration model sets up all actuators. The Driver lens model only applies to changes to the active manipulators just before using the lens to produces images. Some manipulators are outside the lens.

Actuators in the lens are described in the paragraphs below.

LENS ELEMENTS

The projection lenses contain many adjustable and/or replaceable elements. All of them have to do with the optimization of the projection lens. The element concepts are descibed in the paragraphs that follow.

Z elements (up till 11x0)

Inside the exposure lens are elements that can move in the vertical direction. You could also say that the elements can be manipulated in the Z-direction. Therefore, they are called Z-manipulator elements. See figure 2.8.

Inside the lens, for each element, we find the element support mechanisms and the position sensors.

The way the Z-manipulator elements work is shown in figure 2.8.

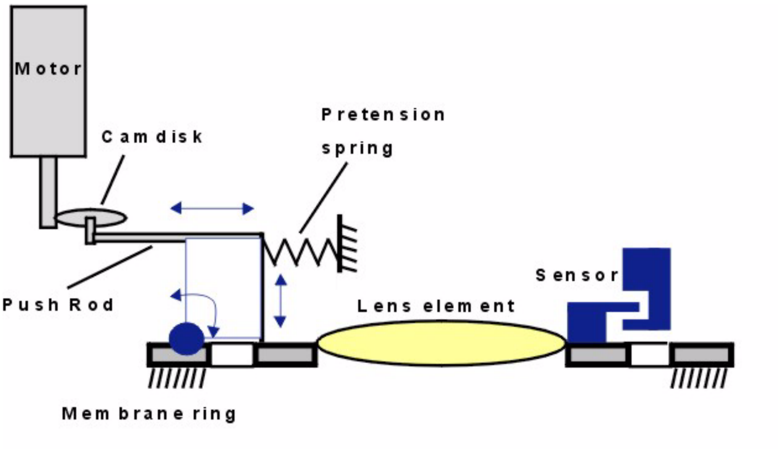


Figure 2.8 Each element has a motor actuator and a sensor

Each movable element has a motor actuator and two sensors. One or two of these sensors are connected to a pre-amplifier. The pre-amplifiers and motor actuators are mounted to the outside of the lens and are replaceable if required.

Next generation Z-manipulator (1200 and up)

The Next generation Z manipulator (NEXZ) is a lens element manipulator that makes use of piezo elements and optical sensors. The basic principle is shown below.

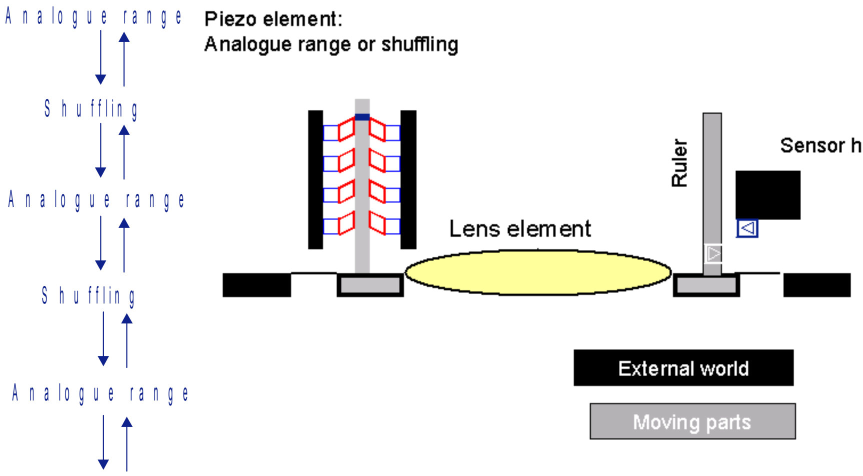


Figure 2.9 NEXZ manipulator basic principle

A piezo element contains feet. The feet are able to clamp and make vertical movements. An optical sensor measures the element position. A movement of the element can be a combination of a shuffle action and a movement in analogue range.

Analogue range A clamped piezo can be accurately set to a required position. We then say the piezo is in analogue range. The distance that can be reached in analogue range is small, the accuracy is high. See the figure below.

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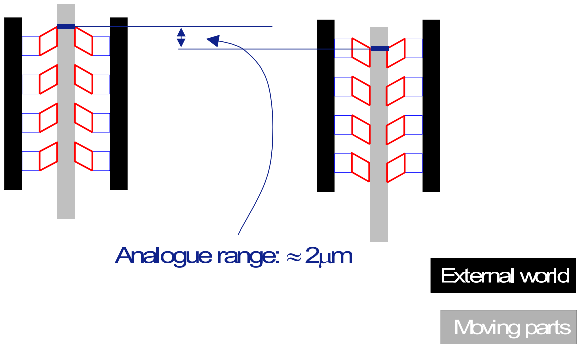

Figure 2.10 Piezo in analogue range.

Shuffling The piezo can move the lens element over longer distances by an alternating action of clamping/unclampin and moving in analogue range. This is called shuffling. A shuffle to zero action is shown below.

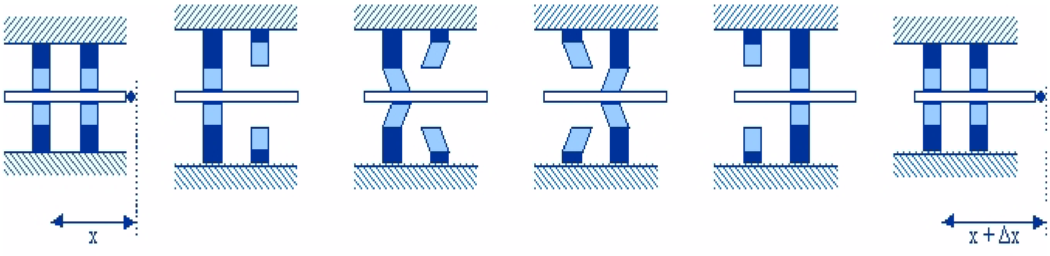

Figure 2.11 Piezo shuffling action.

The remaining voltage on the piezo's after a shuffle to zero action should be close to zero.

Physical design

A lens element contains three actuators and three sensors. The three actuators allow the element to be adjustable for height and tilt. The physical design is shown below.

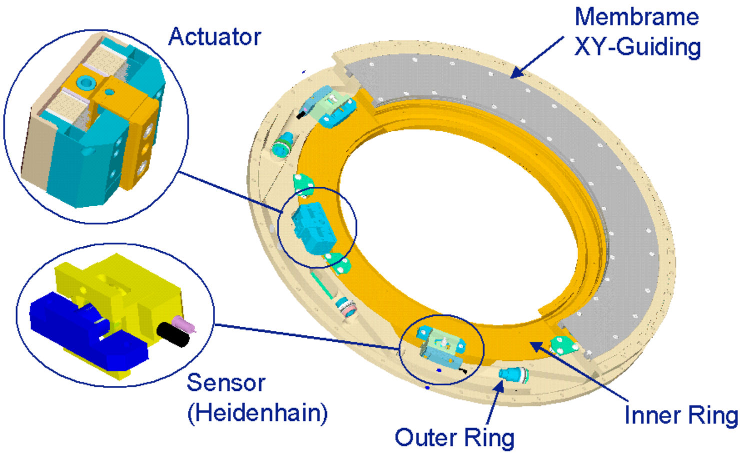

Figure 2.12 NEXZ manipulator physical design

All the items that are shown are located inside the projection lens and cannot be serviced. Failure may lead to a lens swap. However, failure is not expected.

NEXZ manipulator adjustment takes place during set-up and during production (during Lot Correction).

XY manipulator (750-11x0)

The XY manipulator is a lens element in the projection lens. It is adjustable by moving 2 motors or by manually turning screws.

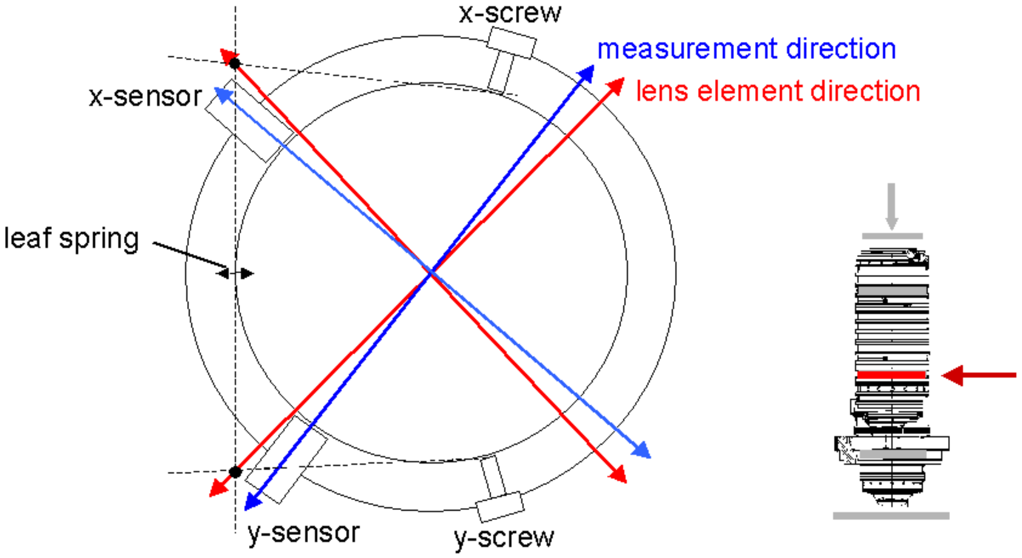

Figure 2.13 The XY manipulator contains two adjustment screws and two sensors

Adjustment is only done off-line.

The element function is to optimize the projection lens for Z7 and Z8 coma offsets.

The 850D has three XY manipulators. It has an extended lifetime compared to previous 850 lenses by adding the functionality to correct for some lower order field effects by use of two additional XY manipulators.

Corrections that XY manipulator Lens Element3 on 750/850/1100 can make are (TAMIS based)

- Z7 offset
- Z8 offset

Corrections that XY manipulators LE1/2/3 on 850D can make based on TAMIS/ FOCAL/DISTO

- Z7 offset
- Z8 offset
- Z2_2
- Z3_2
- Z5_1
- Z9_1 (Only XY manipulator adjustment induced Z9_1 can be corrected for, original lens Z9_1 is conserved)

For one Lens Element, the actuator and the sensor are shown below.

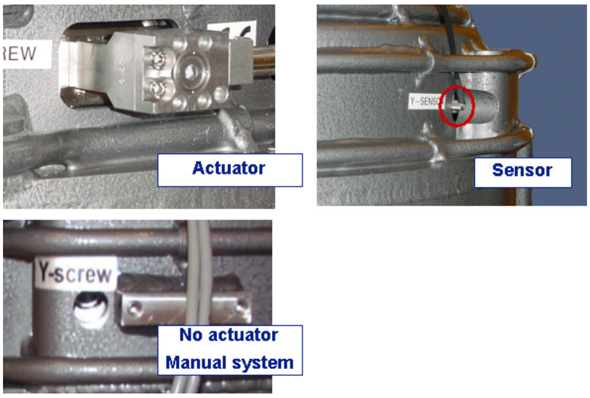

Figure 2.14 XY manipulator parts that are visible on the lens outside.

In the field, there are a few blenses that have no motor driven actuator. They have to be adjusted manually.

If needed, even the motor driven system can be adjusted by hand.

SAXY-manipulator (1200 and up)

The Semi Active XY manipulator allows a lens element to make movements in the horizontal plane. The manipulator makes use of piezo elements and capacitive sensors. The basic principle is shown below.

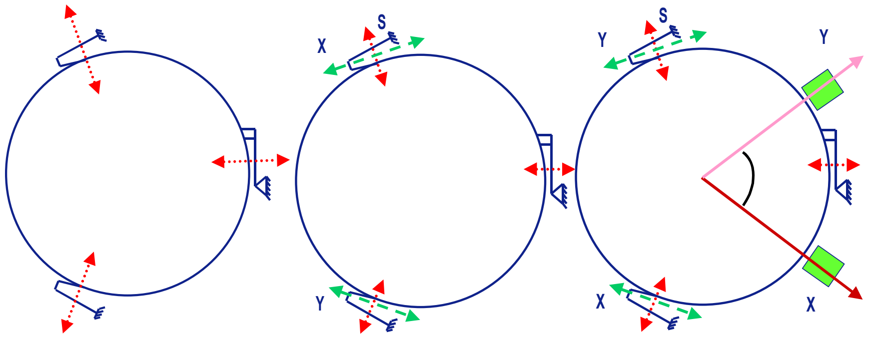

Figure 2.15 SAXY manipiulator basic principle

Three springs that hold the element have permitted movements (leftmost part).

Actuators can apply forced movements (middle part)

Forced movement result in movement in X and Y direction in a non rectangular coordinate system. Sensors are placed here (rightmost part).

Physical design A lens element contains two actuators and two sensors.The physical design is shown below.

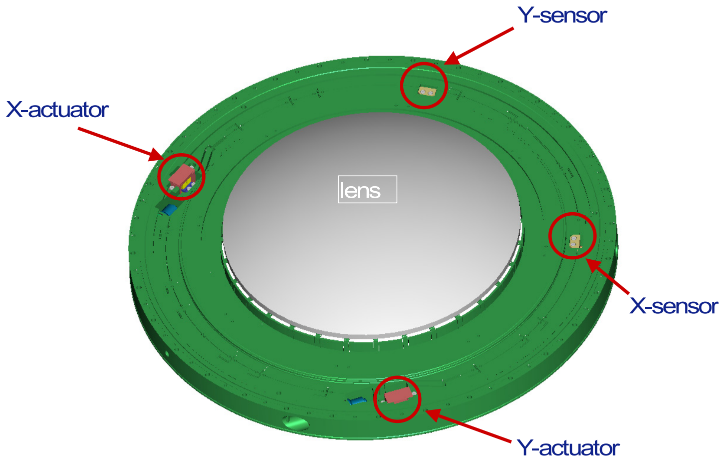

Figure 2.16 SAXY manipulator physical design

Active Lens Element (11x0-14x0)

ALE is an Active Lens Element that deforms under gas pressure. The lens element can be pressed from four directions.

When pressed, the lens element will take the shape of a saddle. This saddle is not rotational symmetric. The result is similar: non-rotational symmetric abberations can be reduced.

The ALE is brought into range during set-up. It is automatically set during production as Lot Correction or Lens Heating Correction is performed, based on a mathematical model for the lens.

The construction of the ALE element is shown in figure 2.17.

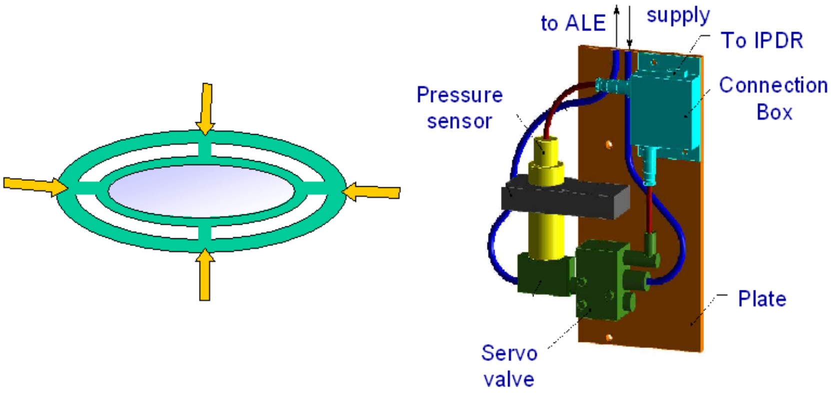

Figure 2.17 Gas pressure can change the ALE lens from normal into a saddle shape

Cables to dither valve and from ressure sensor are connected via the connection box to the electronics rack. The pressure sensor generates the feedback signal for the control loop that activates the dither valve.

ALE hose connections are shown below.

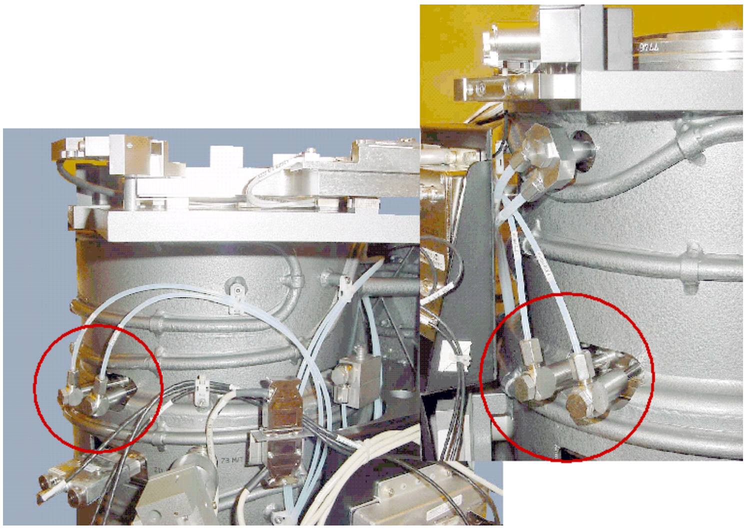

Figure 2.18 Four gas hoses connect the ALE lens interior parts to the pressure unit.

Exchangeable Pupil-near Lens Element (EPLE, 14x0)

When the projection lens is new, the Exchangeable Pupil-near Lens Element is a perfectly flat plate, mounted in the light path of the projection lens.

As the projection lens is getting older and aberrations get worse, a new EPLE can be ordered, based on a lens aberration determination. It will replace the old element. The replacement action can be performed by Zeiss engineers only. A part of the EPLE replacement action is shown below.

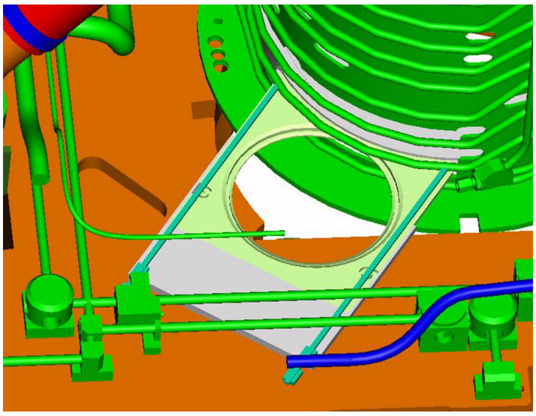

Figure 2.19 EPLE replacement action is done by Zeiss

The newly ordered element is flat on one side, and an asphere on the other side.

As EPLE can reduce the aberrations of projection lenses. An EPLE swap can extend the lifetime of the lens and therefore prevent a lens swap. An EPLE swap is simpler, cheaper and takes less time than a lens swap.

The EPLE cannot be serviced by ASML.

ELLE

ELLE stands for Exchangeable Last Lens Element. It is the last element of the lens, mounted at the lens bottom. It is shown below.

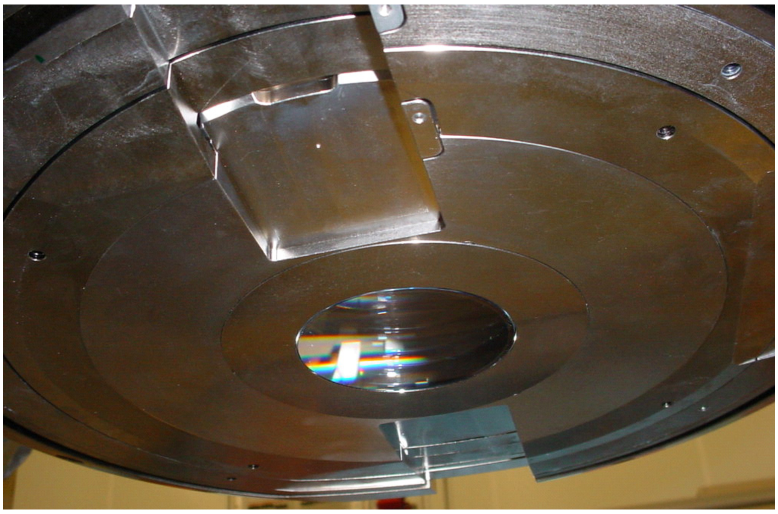

Figure 2.20 ELLE is visible at the lens bottom

It can be exchanged if non-removable contamination has built up on its surface.This can prevent a lens swap.

ELLE is mounted at the bottom of a separate semi compartment of the projection lens to swap it with minimal risk of contamination for other projection lens components. This is shown below.

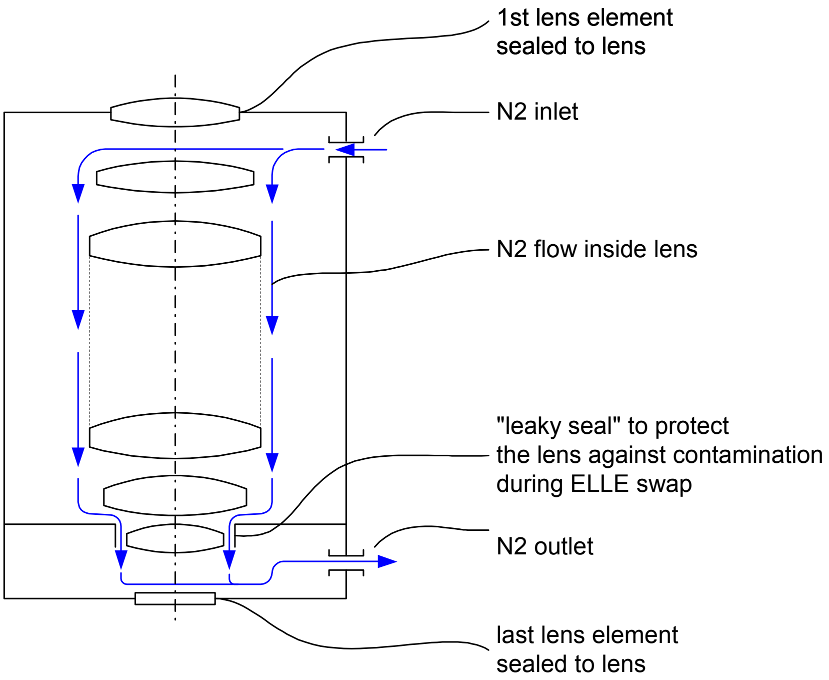

Figure 2.21 A semi-compartment at the projection lens bottom minimizes contamination during the ELLE swap.

The ELLE cannot be serviced by ASML.

NA 1/2/3

Three NA versions are used at the moment.

Basically, they consist of a motor that drives blades that can create an aperture in the pupil plane of the projection lens.

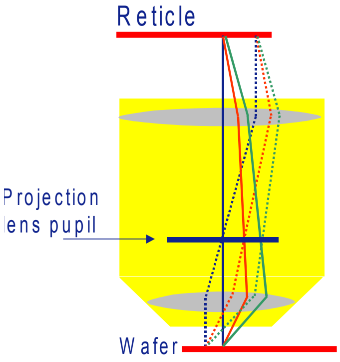

Figure 2.22 The NA is located near the bottom of the projection lens

The NA is located inside the projection lens, near the bottom.

NA1 is driven by a motor with a potentiometer for feedback.

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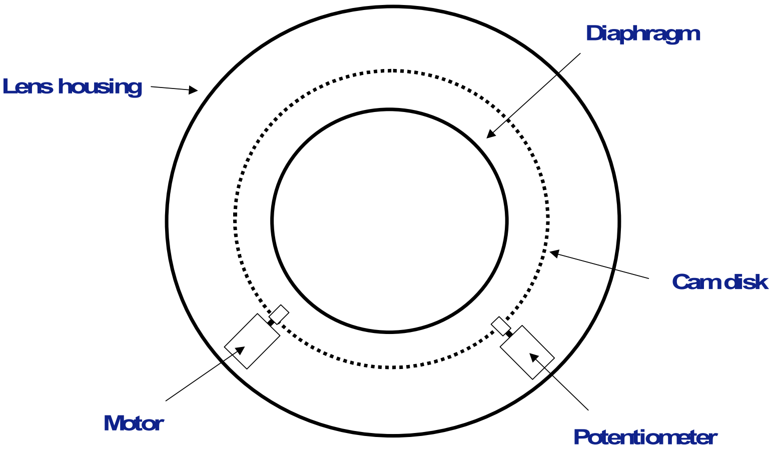

Figure 2.23 The NA1 has a motor and a potentiometer for feedback

The NA2 has a motor encoder that provides position feedback information. There is a home sensor which is calibrated by Zeiss. The NA2 is shown in figure 2.24.

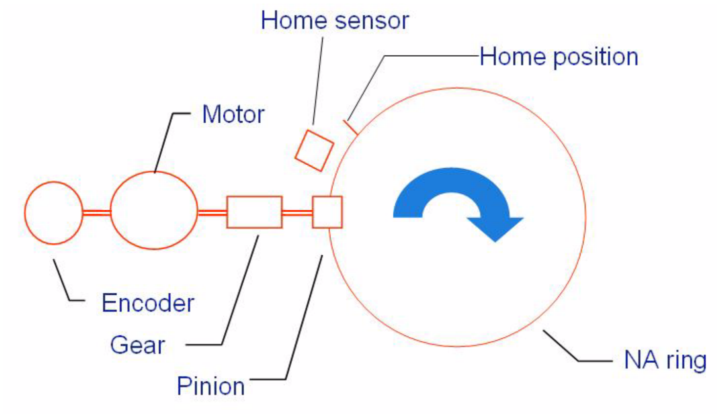

Figure 2.24 The NA2 has a motor encoder.

The ring can only move clockwise. Per turn, the aperture diameter will vary from its minimum to its maximum value 9 times. During initialisation, the home sensor is searched and found. NA2 blades are designed to follow a curved pupil.

The NA3 has a full leaf spring design inside the lens housing, so that the blades do not touch.

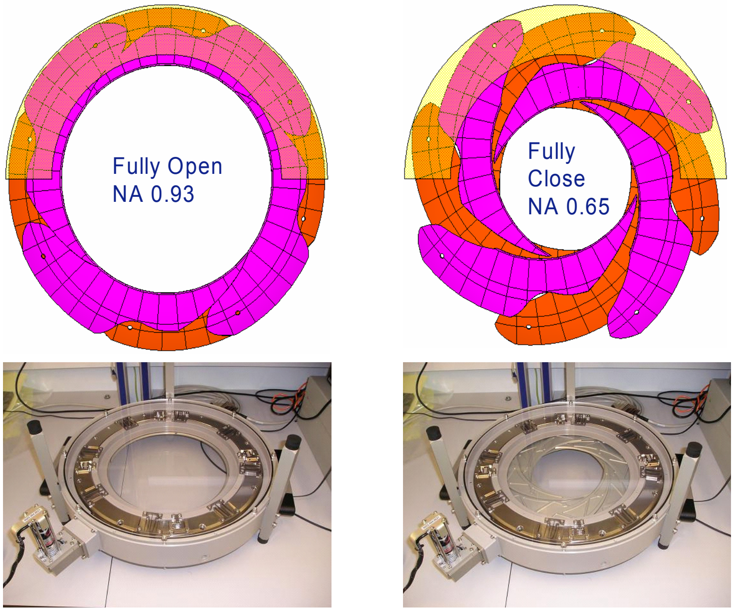

Figure 2.25 The NA3 range is larger than the NA2 range

3

DUV PROCEDURES

INTRODUCTION

This chapter will discuss the procedures to be performed as part of the level 2 qualification process for **DUV Illumination**.

We will first discuss some basic concepts to support your understanding of the procedures:

- Illuminator purge concept
- Lens purge concept
- Stray Light concept
- Pupil measurement concept
- Dose accuracy and repeatability concept
- Uniformity concept

After that, the discussion of the procedures will amplify information concerning the coach procedure.

Always refer to the coach procedure for specific prerequisites, actions, and specifications.

ILLUMINATOR PURGE CONCEPT

The purging of a compartment is done by letting the nitrogen escape via a restrictor, while monitoring the compartment pressure at the same time. This is shown in the figure below.

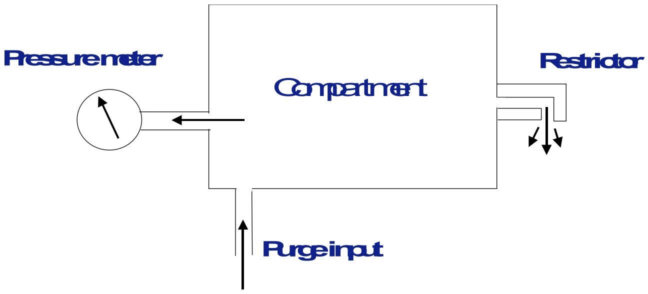

Figure 3.1 Nitrogen purge principle

The pressure meter measures overpressure. Its value is sent to the Pressure Temperature & Interlock board.

The illumination path is separated into seven different segments for nitrogen purge. Each segment is an individual sealed area. External covers on the bottom module and connections of the purged beam path have mechanical interlocks.

On 193nm systems, once an interlock of the purged area has been opened and is closed again, software prevents the safety shutter from opening for 15 minutes. This ensures that all oxygen is purged from the system prior to allowing exposure light to enter.

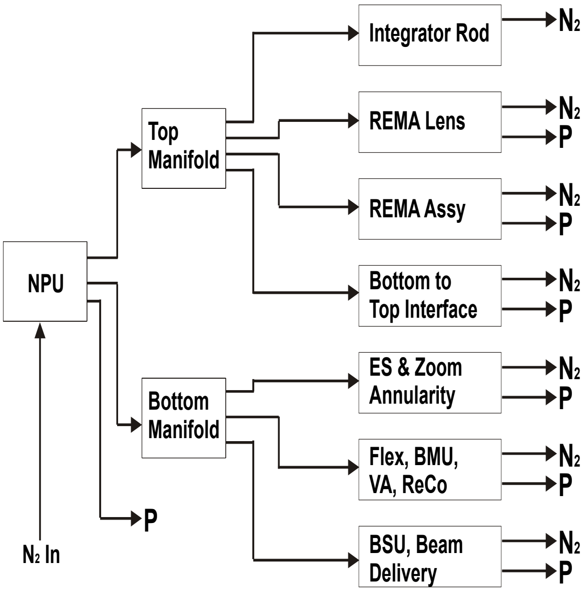

Figure 3.2 Nitrogen Purge Overview (N2 = Nitrogen P = Pressure Sensor)

The seven segments serviced by the nitrogen purge unit are as follows:

1. Integrator rod (pressure not monitored),
2. ReMa Objective (lens),
3. Reticle Masking assembly (ReMa),
4. Bottom to Top Interface,
5. Energy Sensor and Zoom Annularity Optics,
6. Flexible Coupling, Beam Measurement Unit, Variable Attenuator and Removeable Coupling,
7. Beam Steering Units, Beam Expander Unit and Beam Delivery.

The way the different compartments get their purge flow is shown below:

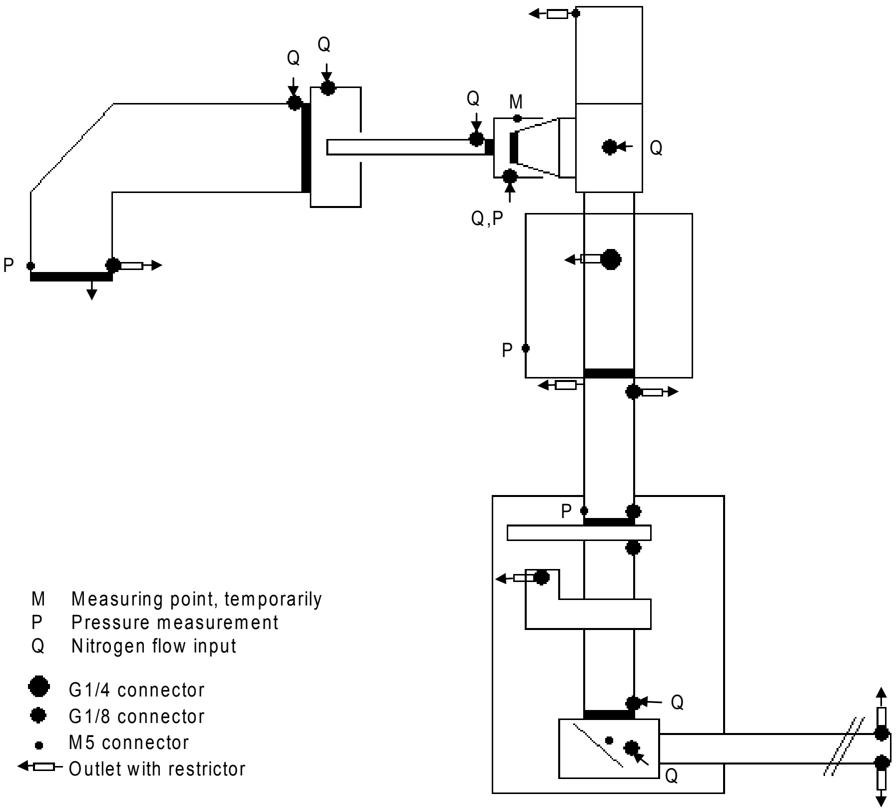

Figure 3.3 Nitrogen Purging compartments overview

The REMA compartment is open, such as the REMA unit and the Bottom to Top interface. Here, the Nitrogen flow is detected by measuring the pressure difference over a restrictor in the purging hose. This is shown in the figure below.

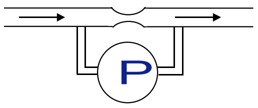

Figure 3.4 Pressure measurement over a restrictor.

The Integrator Rod does not need a pressure check because it is only purged on the non critical outside.

Except for the Integrator Rod, sensors monitor the purging pressure. The REMA, because it is an open space, monitors nitrogen flow over an inlet restrictor.

Nitrogen Purge Unit (NPU)

Nitrogen is supplied via the Nitrogen Purge Unit (NPU). The NPU contains a solenoid valve, to cut off flow if pressure is too high, a regulator valve, a carbon filter, and a particle filter. The filters are replaced as part of Periodic Maintenance.

The filters are designed for flow in only one direction. It is important when replacing the filters to ensure that they are installed in the correct direction. The filters are connected to the tubing using VCR type connections. A VCR type connection has a small, soft metal gasket. The gasket MUST be replaced each time, and the connection should not be over tightened. The correct method for tightening a VCR type connection is to tighten finger tight, and then turn 1/8th turn with a wrench.

All of the measured pressures, including the NPU supply pressure (adjusted with the regulator) may be monitored from the Machine Based Diagnostic System (MBDS).

High Purity NPU

In case a REMA C is used, high purity nitrogen is needed. Gas flows are shown below.

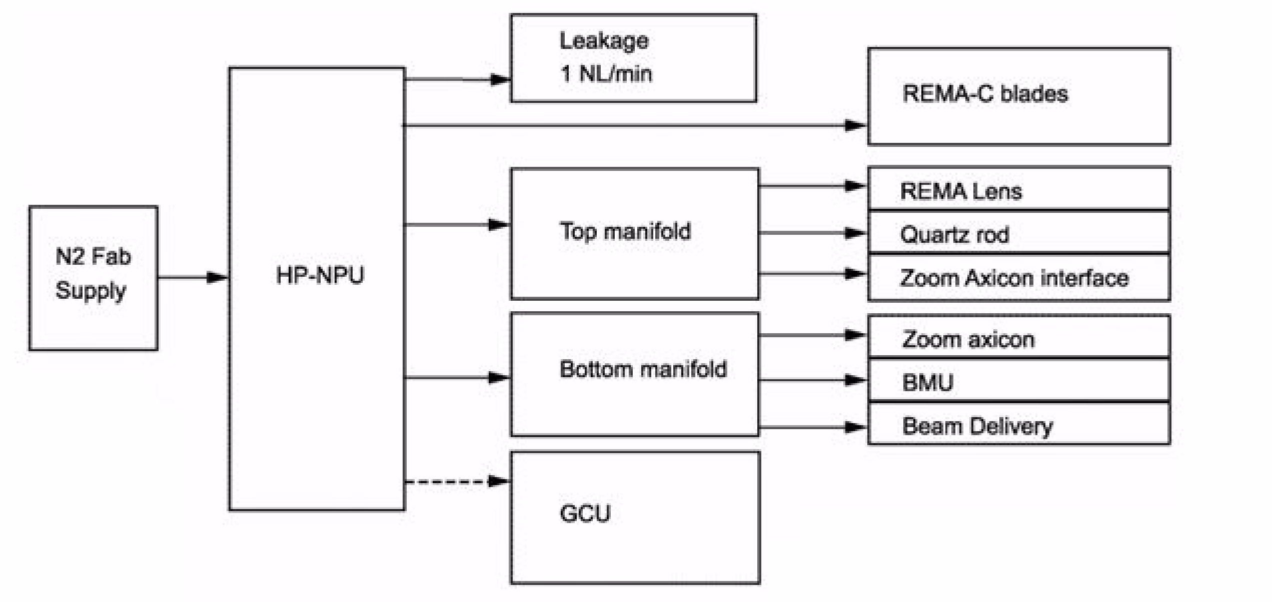

Figure 3.5 The High Purity NPU has a seperate supply branch for REMA C

The High purity NPU has two main outputs:

- The illumination optics purge output, one pressure adjustment valve and one pressure test point on the NPU
- The REMA C purge output, one pressure adjustment valve and one pressure test point on the NPU.

LENS PURGE CONCEPT

To prevent internal reflections caused by moisture, contamination or internal reactions of the DUV light with oxygen (creating ozone), the lens is purged with filtered gas. In addition to adding filters (both for system air and lens purging gas), we must also monitor the lens for development of stray light. This is done using a stray light test.

A “non-purged” lens will “breath” because of expansion and contraction of the internal gases. Moisture and airborne contaminants enter the lens as gases flow in and out as a result of this natural breathing, even when filtered.

This effect can be eliminated by sealing the lens, but in a large sealed lens, expansion and contraction will vary internal pressure. Pressure changes effect focal length by changing the density of the internal gases which, in turn, changes the index of refraction.

The best way to minimize contamination is by purging of the lens. A regulated clean, dry gas is delivered to the lens at a fixed overpressure and a constant flow. The overpressure assures that contaminants cannot enter the lens and the flow of dry gas prevents a build-up of particles that can cause stray light by scattering.

Gas Control Unit

The Gas Control Unit (GCU) controls and monitors the lens gas. See the figure below.

Figure 3.6

The lens gas is connected to the input of the GCU. A portion of this lens gas is used to control the ALE (discussed later in this module). The lens gas passes through a regulator valve, which is manually adjusted to control the overpressure in the lens. The input line also contains a barometer for measuring the supply, a capillary which bleeds a small amount of lens gas into the GCU, and an over/under pressure relief valve. If lens pressure gets too high, this valve will vent the lens to the GCU. If lens pressure drops too low, the valve will allow the lens gas inside the GCU to bleed to the lens to prevent the lens from drawing fab air into it if the pressure falls too low.

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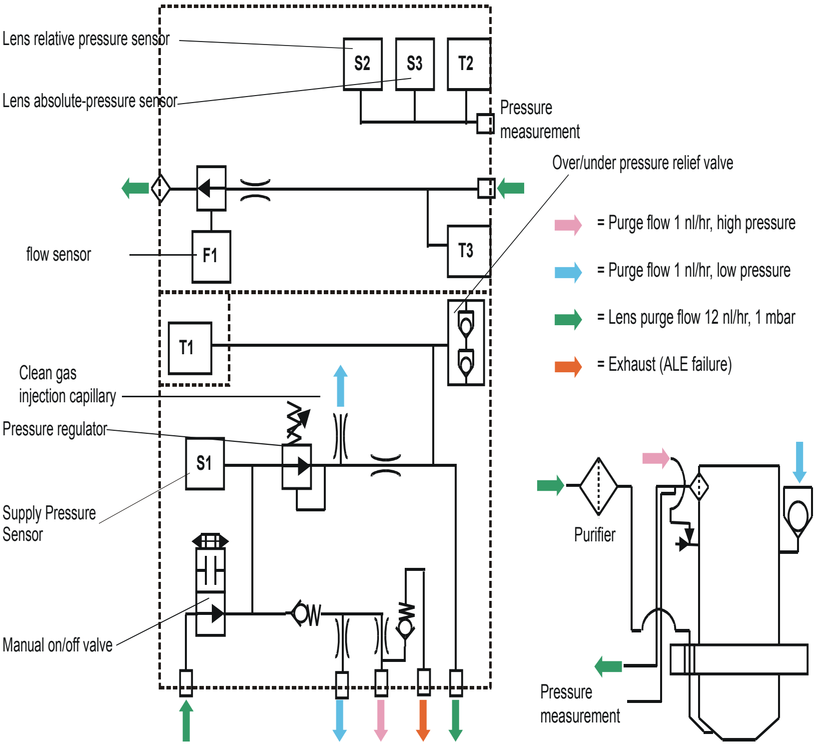


Figure 3.7 GCU layout

The regulated gas then flows from the GCU through a purifier. The purifier, as the name implies, further purifies the gas, to 100 times the purity of the supply gas. This ultra pure gas then goes to the lens. Coming out of the lens are a sensing line and a vent line. The sensing line goes to the lens absolute and relative pressure sensors in the GCU. The vent line goes to the flow meter in the GCU. On the front of the GCU is a digital display showing the relative lens overpressure. The sensors in the GCU can be displayed by on the Operator Interface Unit.

Stray Light concept

Stray light refers to rays of light rays within the lens that are not associated with an image on the reticle. Stray light is light that arrives at wafer level at positions where it should not be.

It can be caused by contamination, internal reflections, coating errors and material imperfections. See the figure below.

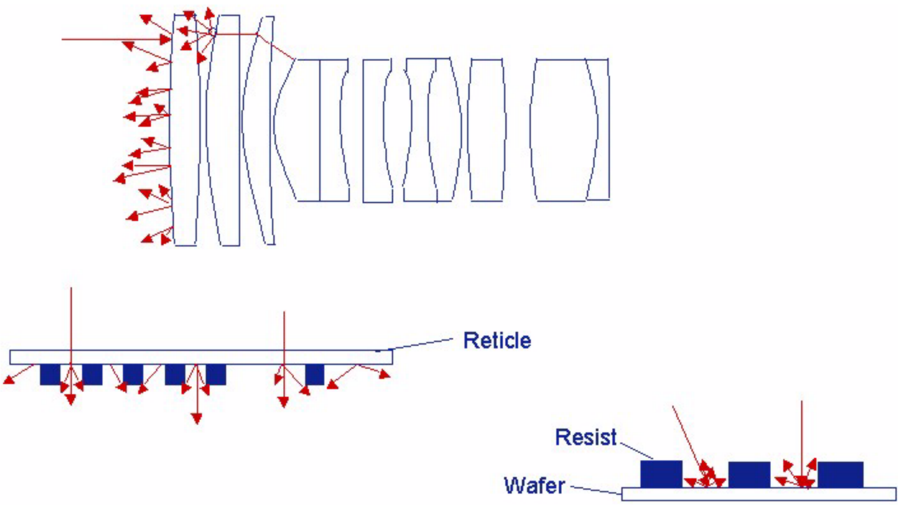


Figure 3.8 Stray light is caused by unwanted reflections

Stray light can be divided in long- (>100um), mid- and short range (<5um); boundaries depend on taste. These are the distances on reticle level over which the influence of the stray light is present. See the figure below.

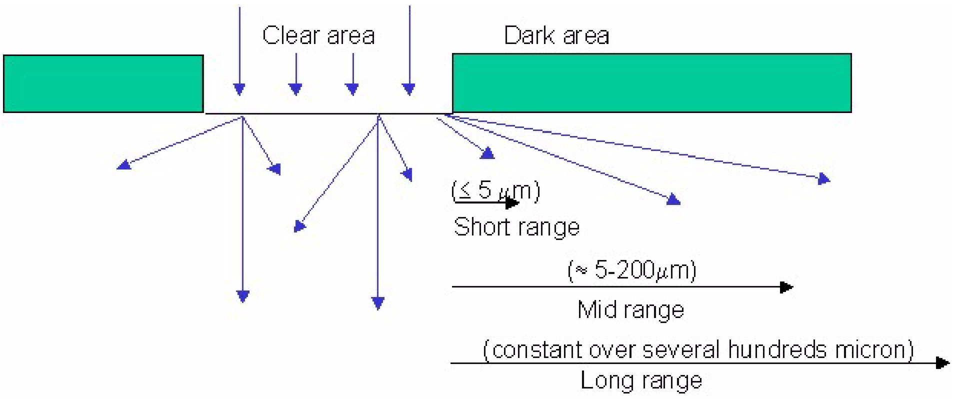


Figure 3.9 Different ranges of stray light.

Stray light reduces the intensity differences between light and dark parts of an image. In other words: stray light gives a loss of contrast and a loss of imaging performance. The loss of contrast causes CD variations.

Straylight has to be controlled and therefore measured.

If the level of stray light is too high, actions have to be taken (clean or swap lens).

Stray light measuring basics

In a stray light test, you measure light where there should be none. See the figure below.

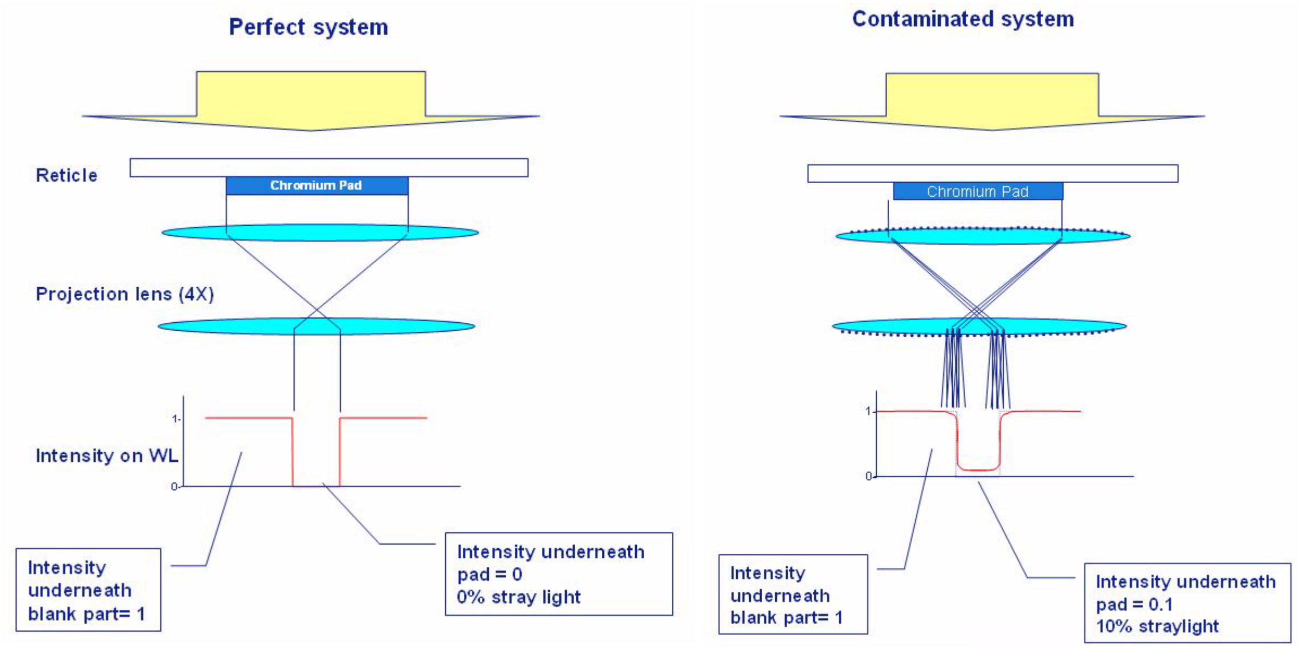


Figure 3.10 Stray light is light on a spot where it should not be.

The left picture shows a zero stray light situation, while the right picture shows a 10% stray light situation.

Components that may cause straylight

There are three main sources of stray light. They are shown in the figure below.

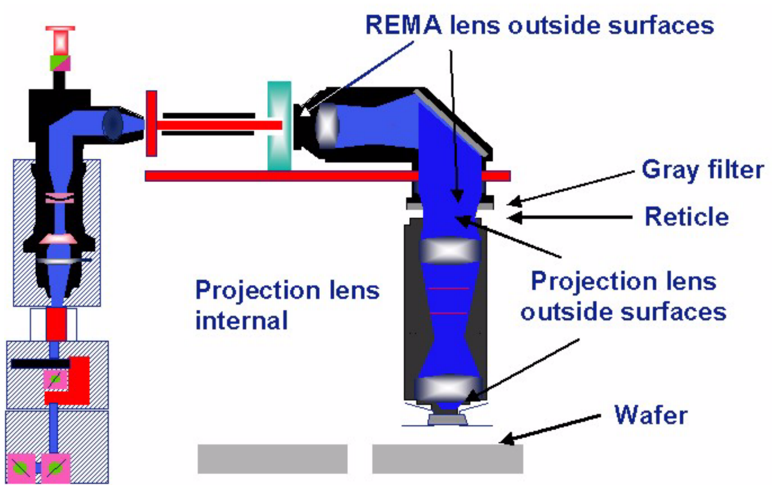


Figure 3.11 Components that may cause stray light

The projection lens

Internally, the projection lens could produce stray light caused by salt formation by photochemical reaction if the lens is not properly purges with high purity gas (low contamination content), good purging conditions (direction and amount of flow).

Outside surfaces of REMA and projection lens

These surfaces can have external contamination or damage. This stray light can be reduced by cleaning, controlling the environment, and periodic replacement of the charcoal filter. Cleaning should only be done by specially trained engineers. Never clean before consulting 3rd line Equipment Engineering.

Gradient filter or Unicom

Stray light produced by the Gray filter or Unicom blades is caused by external contamination. Dummy filters and some types of Gray filters can be cleaned. Other types should be replaced. Cleaning should only be done by specially trained engineers. Never clean before consulting 3rd line Equipment Engineering.

Pupil measurement concept

The pupil is the collection of light angles that illuminates a pixel on a reticle or a wafer. The pupil could be seen as a light source if we would be able to look into the pupil plane of the REMA lens or the projection lens. This is shown below.

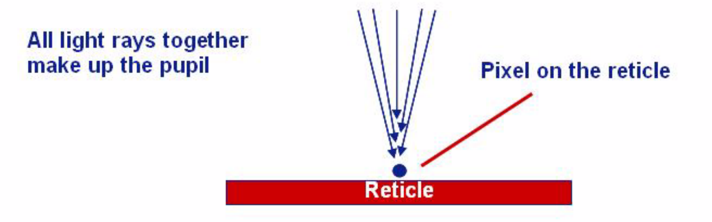


Figure 3.12 The pupil is the collection of light angles that illuminates a pixel on a reticle or a wafer.

There are 3 ways to measure a pupil

- Using the TIS sensor
- Using the ILIAS sensor
- Using exposure in resist (process related, only on special occasions, not discussed in this module)

The concept of these measurements is all the same. See the figure below.

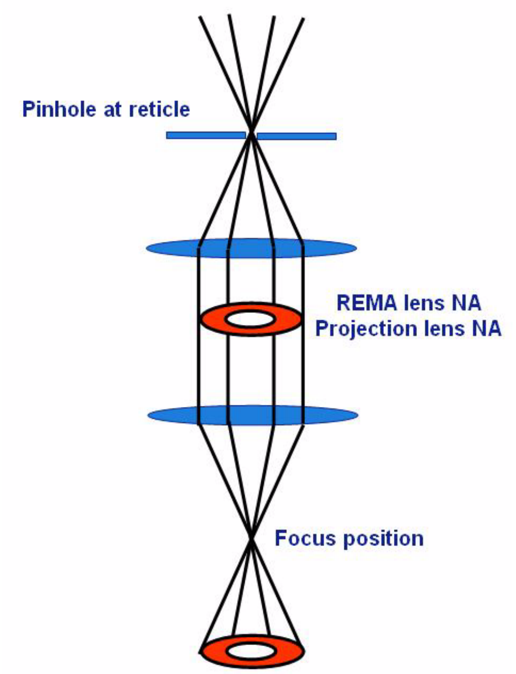


Figure 3.13 Reticle level pinhole that causes the pupil to reveal itself below or above focus level.

A pinhole at reticle level reveals the pupil if we go out of focus on wafer level. The TIS sensor or the ILIAS sensor can be used to measure this pupil. See the figure below.

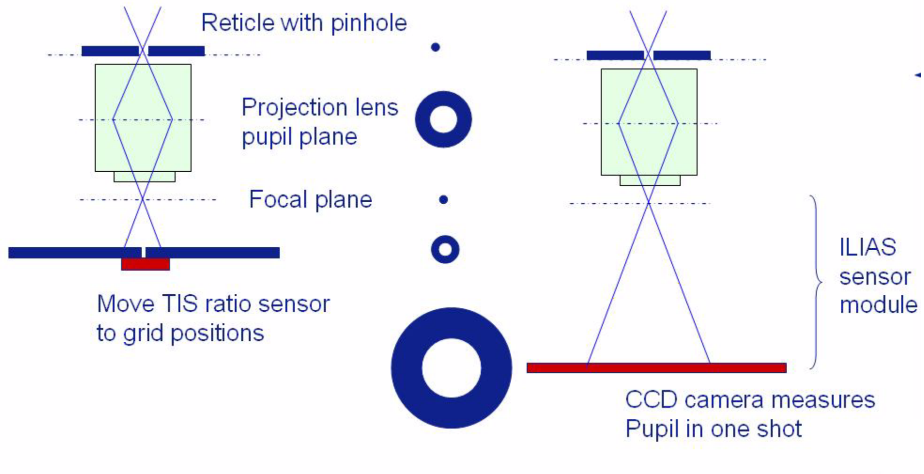


Figure 3.14 The TIS sensor and the ILIAS CCD camera are capable of capturing the pupil.

This pupil can be measured by the TIS sensor that builds up the pupil by a stepping measurement, or by the ILAS CCD camera that is able to measure the pupil in one shot.

Uniformity concept

The best reticle illumination is visualized in the figure below:

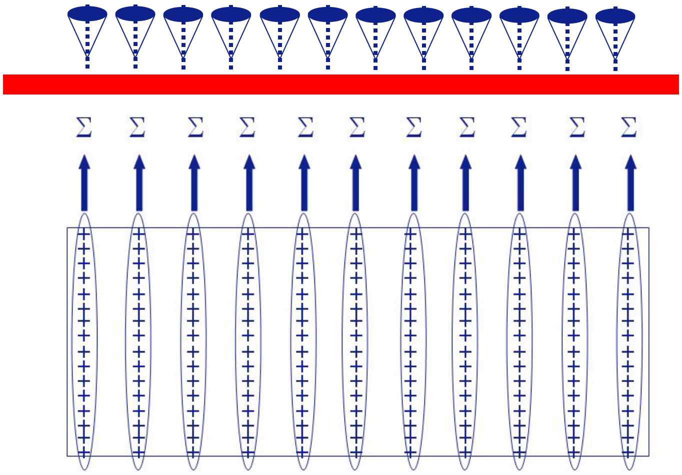


Figure 3.15 Best illumination means uniform intensity and perfect telecentricity for all pixels on the reticle

All pixels on the reticle should receive identical intensity. During the scan, the intensity is averaged out over the scanning direction.

In the non scanning directions, the intensity should be uniformly distributed over the slit. This is measured in the *Slit Uniformity Test*.

The average intensity should also be high enough. This is also measured in the *Slit Unifomity Test*.

The test concept is discussed in the section that descibes the Uniformity test.

Dose accuracy and repeatability concepts

In the figure below, the concepts of accuracy and repeatablity are explained. Accuracy increases if the average value is closer to the target value. Repeatability increases if the individual measurement data are closer to each other.

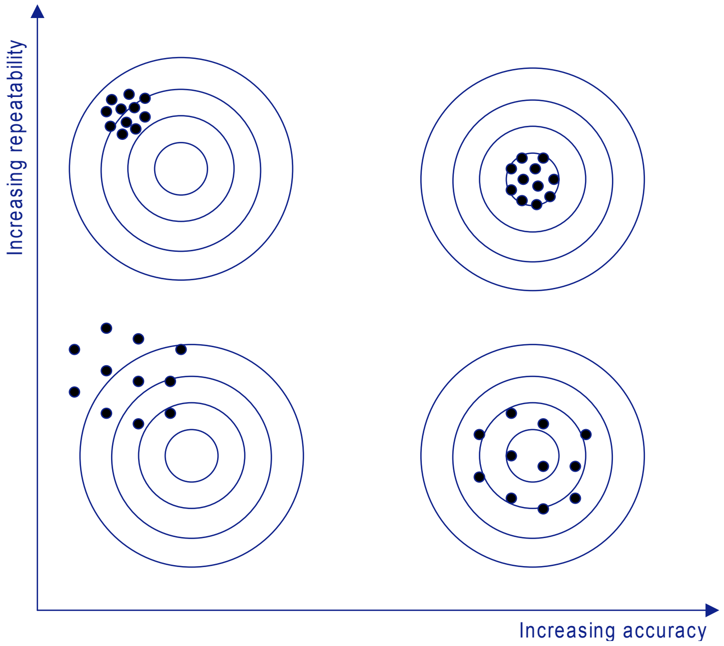


Figure 1: Dose accuracy & repeatability example

Refer to the ATP procedure for the specified limits of the scanning dose accuracy and repeatability

THE PM ACTIONS

The procedures listed below will be treated in this course.

For Illumination DUV

- Adjust the nitrogen purge unit pressure
- Adjust the high purity nitrogen purge unit pressure
- Adjust lens gas pressure and flow and flush the lens
- Remove and install the NPU filters
- Measure the dose system performance
- Measure the pupil with the tis sensor
- Measure the pupil with the ILIAS sensor

For Projection

- Check the lens manipulator actuator performance (PIPD)
- Check the NEXZ sensor performance (PINS)
- Measure the performance of the shuffle-to-zero (PINZ)
- Measure the stray light with samos
- Measure the short-range stray-light with kirk's method

Adjust Nitrogen Purge Unit (NPU) Pressure

Procedure Name	Adjust nitrogen purge unit pressure
Coach Number	csct045.adj
Function	To adjust the Nitrogen Purge Unit (NPU) pressure
Preconditions	System powered on and stable NPU overpressure control not tripped
Points of attention	Verify that N2 supply from Fab is adequate and stable
Sequence of Events	Method Gain Access to the NPU Read the pressure at the pressure test point with a pressure meter Adjust pressure by turning the adjustment knob
Procedure Results	The purge pressure and flow will be within specifications

On Screen Result

Value can be monitored on the MBDS display

Required Actions

Check results using MBDS before and after

	Check interlocks after closing system
Failure Response	Failure Mode/Actions required Verify incoming pressure is within specifications Check for leaks if NPU input is okay but purged area(s) are out of spec. If the overpressure valve is tripped, push the *Illumination Start* button on the SHB-ECAB.

Adjust High Purity Nitrogen Purge Unit(ReMa C)

Procedure Name	Adjust High Purity Nitrogen Purge Unit
Coach Number	csct104.adj
Function	To adjust the High Purity Nitrogen Purge Unit (HPNPU) pressure
Preconditions	Make sure that the fab nitrogen supply is open, and in specification with the Installation Requirements Manual (IRM).
Points of attention	Do not open the filter assembly unless the filter element is going to be replaced. Opening the assembly can contaminate the filter and require replacement. Measure the pressure before making an adjustment (adjusting may not be required)
Sequence of Events	Method Gain access to NPU assembly Measure the pressure using a pressure meter. Adjust if out of specification

Procedure Results

NPU manifold and ReMa pressures are verified in specification

On Screen Result

OK/NOK result

Required Actions	Check result and if OK save MCs
Failure Response	Failure Mode/Actions required In case the red NPU LED is on, refer to procedure csct018.dia.

Adjust Lens Gas Pressure & Flow and Flush the Lens

Procedure Name	Adjust Lens Gas Pressure & Flow and Flush the Lens
Coach Number	csct040.adj
Function	To check the lens gas pressure and flow.
Preconditions	System powered on and stable

Make sure that the lens gas supply valve is open

Make sure that the GAS SUPPLY valve on the GCU is set to ON.

If the supply has been off, allow time for the lens pressure to stabilize

Points of attention

This procedure is for Check and Adjust! The PM actions required is to ONLY check. If an adjustment is required, there are additional actions required as a result of the adjustment.

Do not adjust lens pressure unless it is out of specifications

The flow is the result of the pressure. You can not adjust the flow separate from the pressure.

If lens pressure is adjusted, it may cause a change in focus. Be sure to schedule any change in lens pressure to allow for metrology procedures that will be required to correct for focus changes.

The unit of flow in the user interface differs from the unit in the specifications.

Sequence of Events

Testing Method

Gain access to the GCU

To check the lens gas flow, · Monitor All Sensor Values

Check the LCD readout on the GCU pressure gauge

Examine the lens gas flow under CT Flows in the C&T Sensor Values screen.

Lens gas flow

Procedure Results

Lens pressure and flow are verified to be in specifications

On Screen Result

Flow value

Required Actions

If out of specifications, schedule adjustment

Failure Response

Failure Mode/Actions required

If the flow does not meet the specification, check the hoses for obstructions or leaks.

If the flow is higher than 0.33 L/min., the flow meter is out of range and an error will show.

Request support

Remove and install the NPU filters

Procedure Name Remove and install the NPU filters

Coach Number csct182.rep

Function To replace the NPU filters

Preconditions None

Points of attention Do not let large quantities of Nitrogen blow into the environment.

Sequence of Events	Get access to NPU Replace filters
Procedure Results	Filters are replaced
Failure Response	NA

Measure Dose System Performance

Procedure Name	Measure Dose System Performance
Coach Number	csil110b.per
Function	To qualify the dose control system by making sure that the: dose repeatability, dose accuracy, scanning uniformity, slit uniformity, and illumination intensity components are in the specified limits. A more realistic number for dose variations is produced than for the OSAR test. A judgement is possible about the combined effect of all encountered dose variations during one single lot
Preconditions	Measure slit uniformity to verify functionality and system performance before starting.
Sequence of Events	We will discus the test principle and the test input screen.

Test principle

The test consists of two modules that can be activated in the input screen. General test flow is shown below.

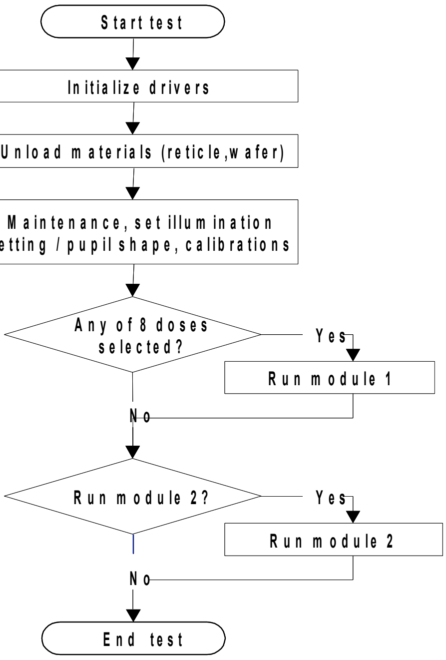


Figure 3.16 The DSP test general flow

Module 1 measures the dose dependent dose variations for different user-selectable doses (maximum 8).

Module 2 is used to determine dose variations over a user selectable die-size.

Module 1 explained

The module 1 flow is given below.

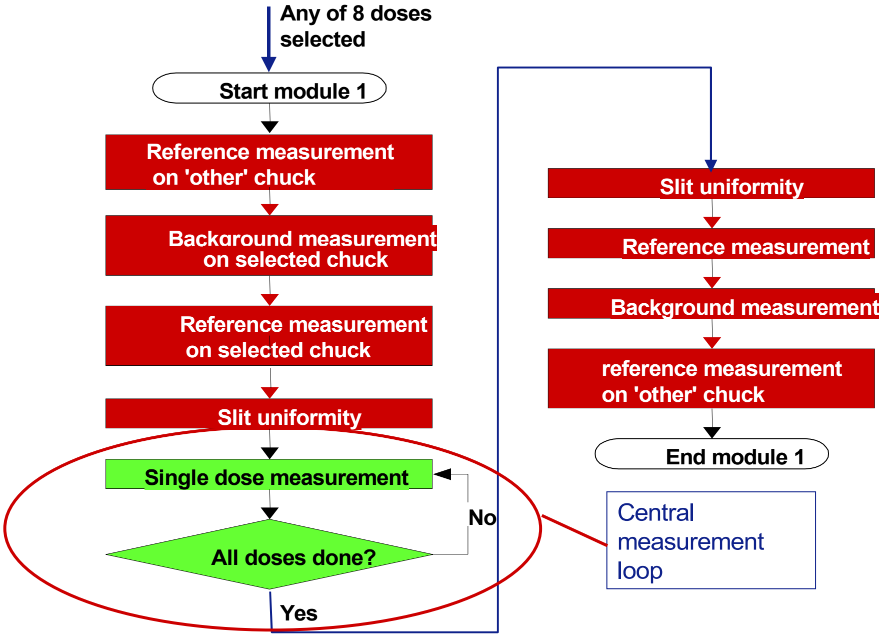


Figure 3.17 Module 1 flow

The central action for this module is called *single dose measurement*.

Single dose measurements

The single dose measurement sequence measures dose control variations that are expected to occur with changing requested dose.

The measurement uses a die size and shift to allow the customer to imitate any partial usage of the exposure field.

The scanning dose profile is determined, and it is checked whether this profile drifts. The drift is estimated worse case by jumping from low to high doses and visa versa.

Also, dose accuracy and repeatability are determined, as well as dose differences between scanning forwards and backwards.

Also, ATP dose accuracy measurements are done to be able to estimate the difference between the original and the new type of dose accuracy measurements.

Other blocks in module 1

The other blocks in the module 1 flow include:

- Reference measurements. They are performed to investigate optical transmission drift in Integrator Rod, REMA lens and Projection lens. 5 scanning doses are done with the SS in the middle of the field. REMA at small-x at x=0.
- Background measurement are done to measure the drift in the Spot Sensor. 5 scanning dose measurements are performed with the SS in the dark. REMA at small-x at x=0. Note that background measurement results are not yet taken into the calculations.
- Slit Uniformity focusses on the slit tilt drift. It uses a grid as determined in the GUI.

Module 2 explained

The module 2 flow is shown below.

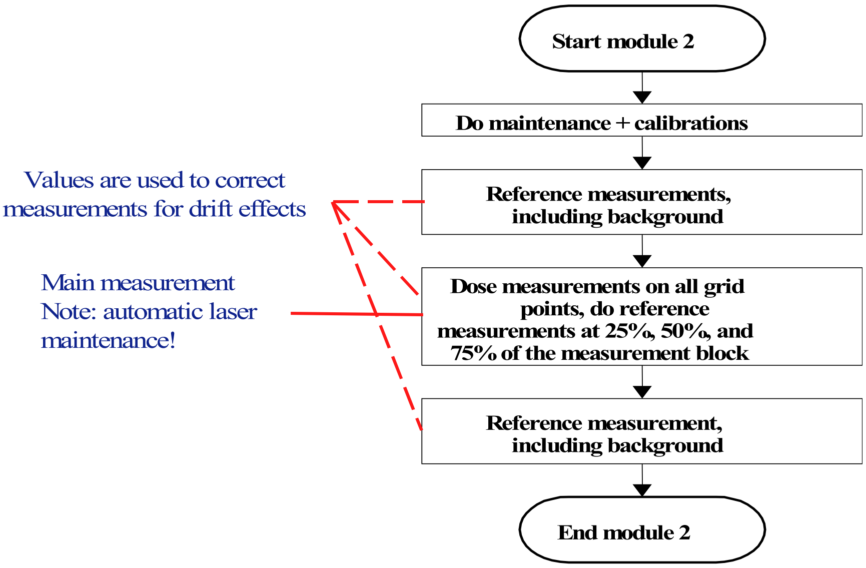


Figure 3.18 Module 2 flow

The central action for this module is a set of dose measurements on all grid points. The grid that is used is given by the GUI. It is shown below.

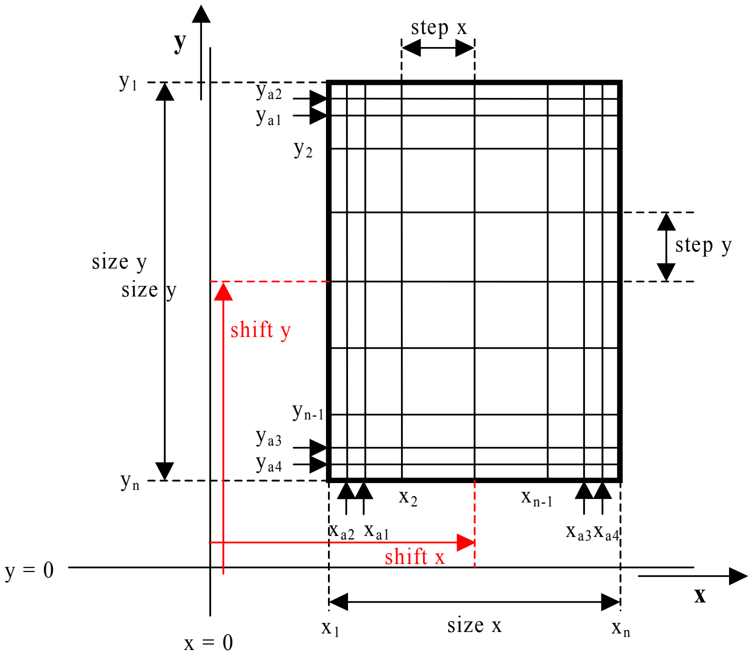
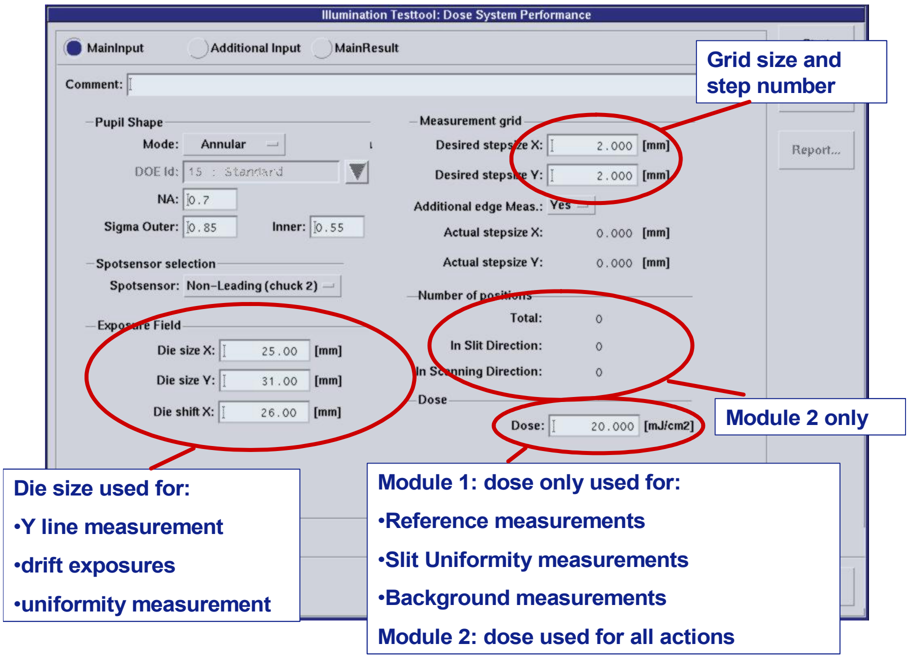


Figure 3.19 Measurement grid used in module 2

- Because most dose variations are expected close to the edges of the die, it is possible to add extra edge measurements.
- During the measurement of the grid, laser maintenance actions are done at least every 8 minutes.
- Reference measurements are done as 25%, 50% and 75% of the measurements of the grid have been done to monitor optical transmission drifts.

Input screen

The input screen is shown below.



Illumination Testtool: Dose System Performance

● MainInput ○ Additional Input ○ MainResult

Comment:

Pupil Shape
Mode: Annular
DOE Id: 15 : Standard
NA: 0.7
Sigma Outer: 0.85 Inner: 0.55

Spotsensor selection
Spotsensor: Non-Leading (chuck 2)

Exposure Field
Die size X: 25.00 [mm]
Die size Y: 31.00 [mm]
Die shift X: 26.00 [mm]

Measurement grid
Desired stepsize X: 2.000 [mm]
Desired stepsize Y: 2.000 [mm]
Additional edge Meas.: Yes
Actual stepsize X: 0.000 [mm]
Actual stepsize Y: 0.000 [mm]

Number of positions
Total: 0
In Slit Direction: 0
In Scanning Direction: 0

Dose
Dose: 20.000 [mJ/cm2]

Grid size and step number

Module 2 only

Die size used for:

•Y line measurement

•drift exposures

•uniformity measurement

Module 1: dose only used for:

•Reference measurements

•Slit Uniformity measurements

•Background measurements

Module 2: dose used for all actions

Figure 3.20 Module 3 flow

- The location of the measurement grid can be choosen in *Exposure Field.*
- *Grid size* and *Step number* can be given and the SW will calculate *Actual step size* and *Number of positions*
- *Dose* is the dose used in all measurements except the *Single Dose Measurement.*

Values are prescribed by the procedure, but can be changed on purpose. Reducing drift exposures and number of doses decreases test duration.

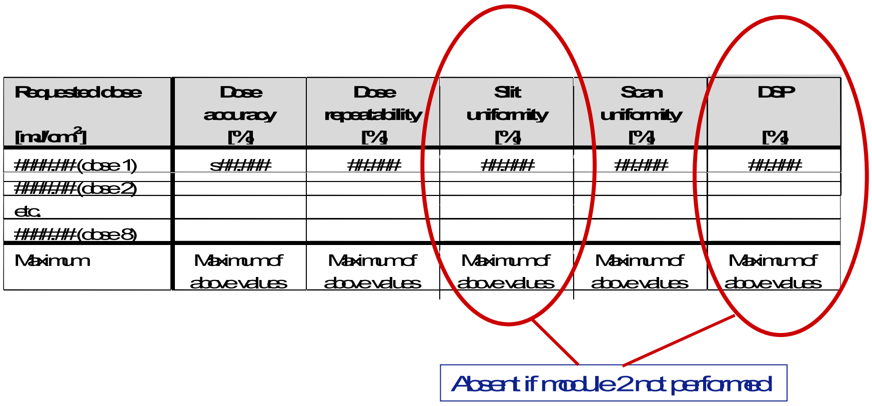
Results interpretation

Module 1 generates results for dose accuracy and repeatability as well as scan uniformity.

Module 2 generates slit uniformity.

After both module 1 and module 2 measurements have been performed, the system is able to calculate the DSP number.

A results summary is shown below.



Requested dose [mJ/cm²]	Dose accuracy [%]	Dose repeatability [%]	Slit uniformity [%]	Scan uniformity [%]	DSP [%]
#####.##(dose 1)	s##.####	##.####	##.####	##.####	##.####
#####.##(dose 2)					
etc.					
#####.##(dose 8)					
Maximum	Maximum of above values	Maximum of above values	Maximum of above values	Maximum of above values	Maximum of above values

Absent if module 2 not performed

Figure 3.21 Results summary

Results module 2

The module 2 results show the dose for different positions in an imaginary die. See the figure below.

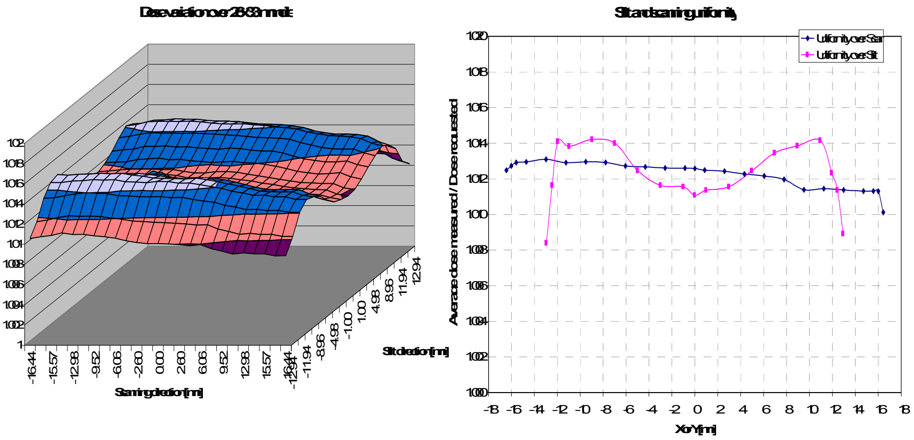


Figure 3.22 Module 2 results show the dose distribution over an imaginairy die.

In the leftmost graph, the dose variation is shown over the die surface. In the rightmost graph, the doses are shown integrated over the x and y direction.

In the scanning direction, the dose decreases. In resist, this would give a CD variation in scanning direction.

In the non-scanning direction, also CD variations will be present.

Failure Response Consult third line support.

Measure Pupil Using TIS Sensor

Procedure Name PM Procedure to measure the pupil using the TIS sensor

Coach Number csil121.per

Function To measure the distribution of the pupil for periodic maintenance using the TIS sensor

Preconditions Measure slit uniformity to verify functionality and system performance before starting.

BA-MOSAIC 4022.455.6315* or BA-LIPM 4022.455.6218* reticle required

System must be able to load and align a reticle.

System must be able to perform a TIS measurement

Points of attention If this is the first time you are using this reticle on this system, then go to the BA-LIPM or BA-MOSAIC FIRST USE section of the procedure to add the reticle to the data base.

Sequence of Events We will discuss the test principle and the input screen.

Test principle

How the TIS test works The pinhole on the reticle is imaged on wafer level. Below wafer level, the light beam will expand again. There, it can be scanned by the TIS sensor. See figure 3.23.

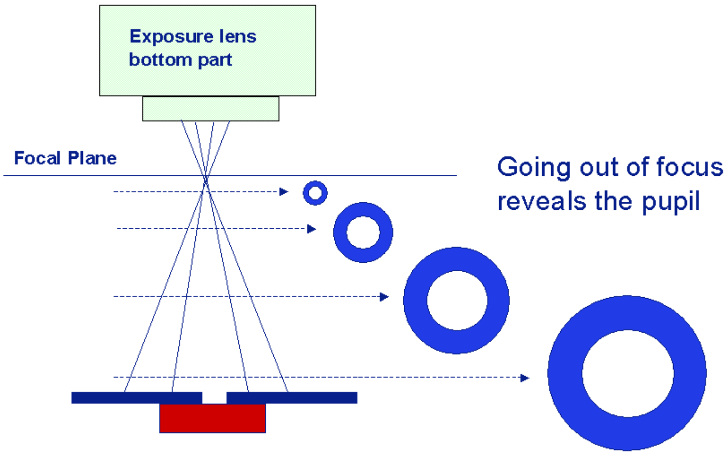


Figure 3.23 Going out of focus reveals the pupil

At the focal plane of the exposure lens, all rays come together in one point. Below wafer level, the beam expands and the image of the light source is enlarged. Here, the TIS sensor can measure the pupil. Using a measurement position grid, the image can be stored in the software.

The grid is shown below.

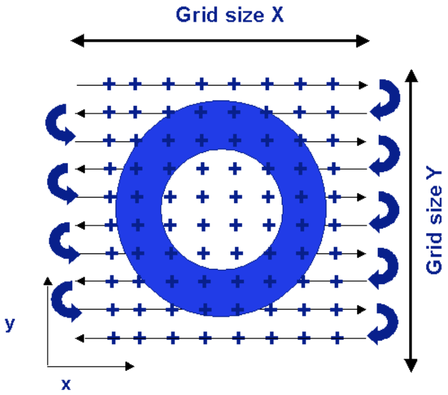
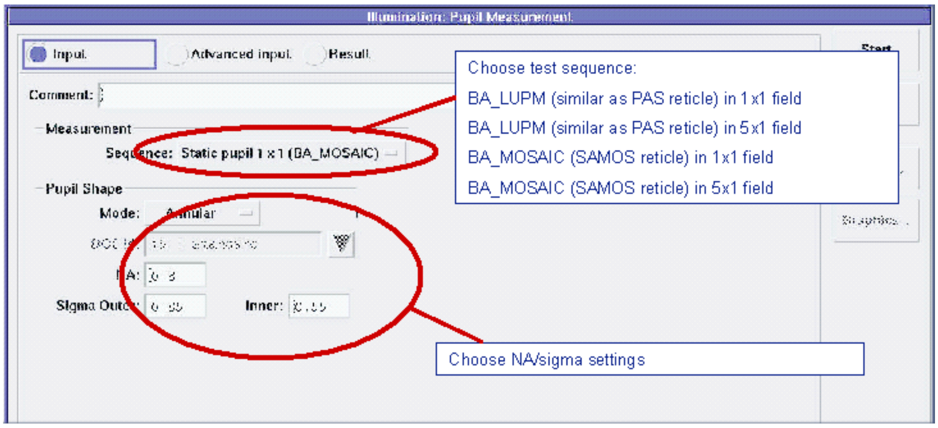


Figure 3.24 The TIS sensor measures intensities at a square grid of positions.

The measurement is done during a continuous movement of the wafer stage in the non scanning direction and by making steps in the scanning direction. During this movement, the laser is firing continuously at a fixed frequency. A selection of all the pulses that are measured by the TIS and ES are stored in a raw data file.

Input screens

The input screen is shown below.



Comment:

Measurement

Sequence: Static pupil 1 x 1 (BA_MOSAIC)

Pupil Shape

Mode: Annular

NA:

Sigma Outer: Inner:

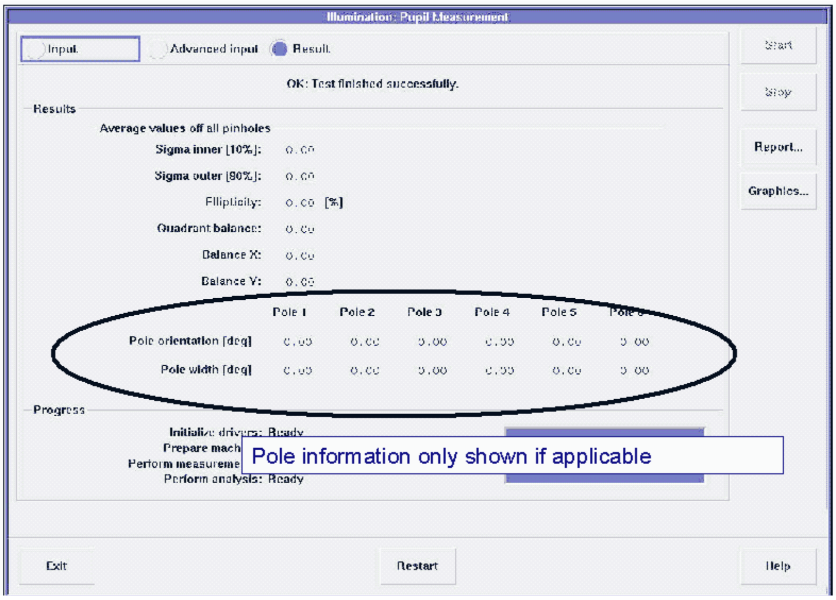
Choose test sequence:
BA_LUPM (similar as PAS reticle) in 1x1 field
BA_LUPM (similar as PAS reticle) in 5x1 field
BA_MOSAIC (SAMOS reticle) in 1x1 field
BA_MOSAIC (SAMOS reticle) in 5x1 field

Choose NA/sigma settings

Figure 3.25 In the input screen you may select reticle and illumination setting.

The measurement sequences that can be choosen depend on the reticle and may concern one central measurement or measurements on five locations in the field.

Procedure Results The results screen is shown below.



Illumination: Pupil Measurement

○ Input ○ Advanced input ● Result

OK: Test finished successfully.

Results

Average values off all pinholes

Sigma inner [10%]: 0.00

Sigma outer [90%]: 0.00

Ellipticity: 0.00 [%]

Quadrant balance: 0.00

Balance X: 0.00

Balance Y: 0.00

	Pole 1	Pole 2	Pole 3	Pole 4	Pole 5	Pole
Pole orientation [deg]	0.00	0.00	0.00	0.00	0.00	0.00
Pole width [deg]	0.00	0.00	0.00	0.00	0.00	0.00

Progress

Initialize drivers: Ready
Prepare mach
Perform measureme
Perform analysis: Ready

Pole information only shown if applicable

Figure 3.26 Test results screen.

Make sure that the Average Sigma Inner from the TIS Pupil Measurement test report is between the Periodic Maintenance target values: Sigma Inner Lower limit and the Periodic Maintenance target values: Sigma Inner Upper limit for DOE ID 15 in the DOE info pages.

Make sure that the Average Sigma Outer from the TIS Pupil Measurement test report is between the Periodic Maintenance target values: Sigma Outer Lower limit and the Periodic Maintenance target values: Sigma Outer Upper limit for DOE ID 15 in the DOE info pages.

What do sigma values mean?

Sigma values tell what area of the NA opening is filled with light. This is visualized in the figure below.

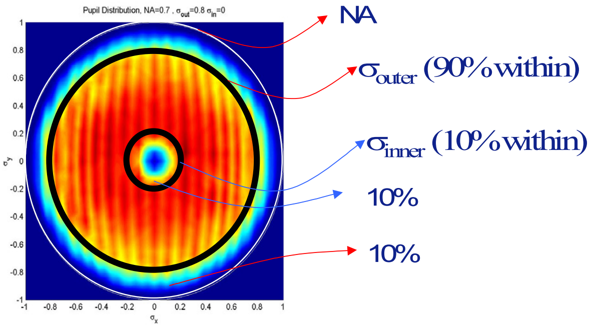


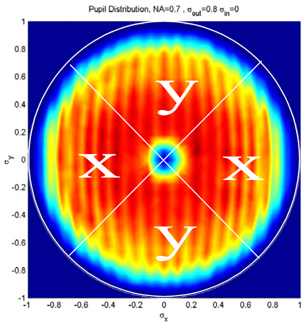
Figure 3.27 Sigma definitions.

The figure shows a realistic pupil. Colors are produced by computer processing, based on intensities measured by the TIS sensor.

The NA opening is defined as the 100% area. Sigma outer is the radius within which 90% of the light intensity is measured. Sigma inner is the radius within which 10% of the light intensity is measured. Note that even if the center of the field is not totally dark, still a sigma inner can be defined.

How is ellipticity defined?

Ellipticity is determined by deviding the TIS sensor measurement values into two areas. See also the figure below.



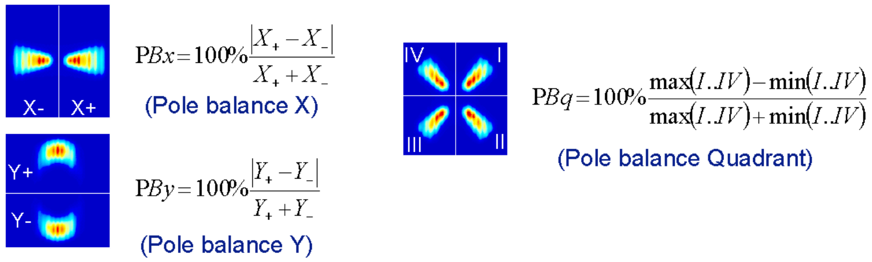
$$\text{Ellipticity} = \left(\frac{\sum Y}{\sum X} - 1\right) * 100\%$$

Figure 3.28 Ellipticity definition.

The ratio between the average intensities in the Y area and in the X area define the ellipticity.

How is pole balance defined?

Pole balances are defined as shown below.



$$PBx = 100\% \frac{|X_+ - X_-|}{X_+ + X_-}$$

(Pole balance X)

$$PBy = 100\% \frac{|Y_+ - Y_-|}{Y_+ + Y_-}$$

(Pole balance Y)

$$PBq = 100\% \frac{\max(I..IV) - \min(I..IV)}{\max(I..IV) + \min(I..IV)}$$

(Pole balance Quadrant)

Figure 3.29 Pole balance definitions.

For dipole blades, average values of the poles are used. For the quadrupole calculation, pole maximum and minimum average values are used.

How is pole orientation and width defined?

Pole orientation and width are defined as shown below.

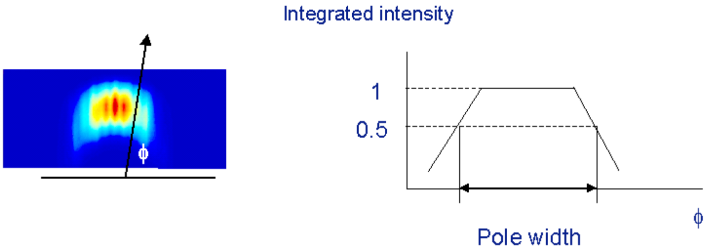


Figure 3.30 Pole orientation and width definitions.

The width is the angle difference between the two 50% points. The pole orientation is the angle of the middle between the two 50% points.

Orientation and width are measured for each individual pole.

Required Actions

Note: To find the `Best Sensor', check if there is a 'non-conformance' containing this information. If it is not known what the `Best Sensor' is, the default should be taken.

Failure Response Failure Mode/Actions required

If the Average Sigma Inner or Average Sigma Outer values are not within the target values, refer to the Improved Proximity Matching Pupil OCAP

Measure Pupil Using the ILIAS Sensor

Procedure Name PM Procedure to measure the pupil using the ILAS sensor

Coach Number csil153.per

Function To measure the distribution of the pupil for periodic maintenance using the ILIAS sensor

Preconditions Measure slit uniformity to verify functionality and system performance before starting.

BA-MOSAIC 4022.455.6315* or BA-LIPM 4022.455.6218* reticle required

System must be able to load and align a reticle.

System must be able to perform a TIS measurement

Points of attention If this is the first time you are using this reticle on this system, then go to the BA-LIPM or BA-MOSAIC FIRST USE section of the procedure to add the reticle to the data base.

Sequence of Events We will discuss the test principle and the input screen.

Test principle

The pinhole on the reticle is imaged on wafer level. Below wafer level, the light beam will expand again. There, the pupil can be scanned by the ILIAS CCD camera. See the figure below.

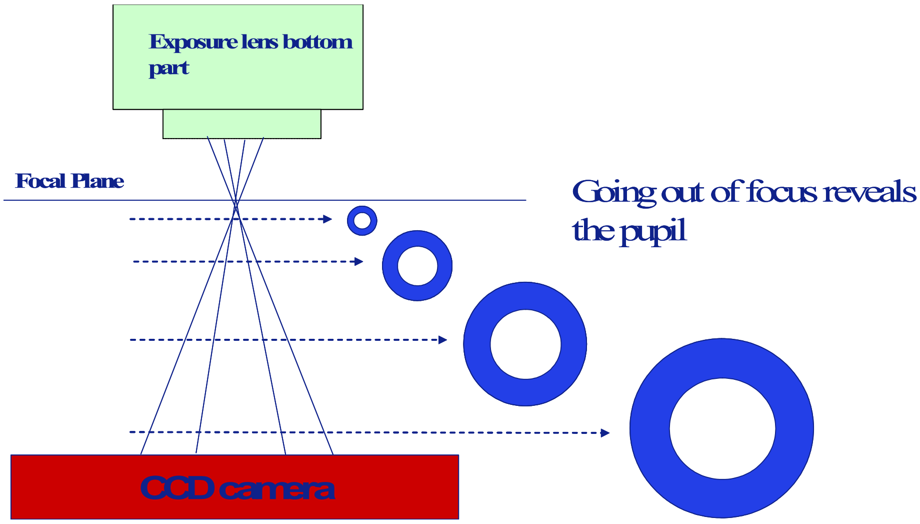


Figure 3.31 The ILIAS CCD camera makes in image of the pupil.

The measurement is done during a scanning movement of the wafer stage.

The input screen is like the one for the TIS pupil test.

Procedure Results The results screen looks the same as that for the TIS pupil test.

Failure Response Failure Mode/Actions required

If the Average Sigma Inner or Average Sigma Outer values are not within the target values, refer to the Improved Proximity Matching Pupil OCAP

Check the lens manipulator actuator perfromance (PIPD)

Procedure Name Check the lens manipulator actuator performance

Coach Number cspr101.per

Function The purpose of the actuator performance test is to qualify the NEXZ actuators.

Preconditions All cable connections are checked, see procedure: ctpr097.per or cspr091.per

All reference Piezo capacities of the PIPA's have been calibrated, see procedure: ctpr025.adj

Sequence of Events

Test principle

The test consists of three parts.

- Part that measures the position range of the lens in Z that an actuator can reach without shuffling (analogue range). See figure below.

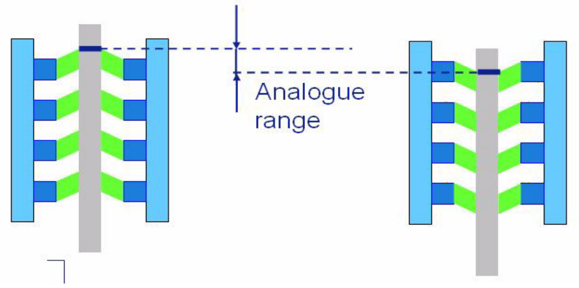


Figure 3.32 The analogue range test measures maximum range without shuffling.

- Part that measures the displacement of the lens element in Z when a non-clamped piezo-group is *sheared* (actuator wave). See figure below.

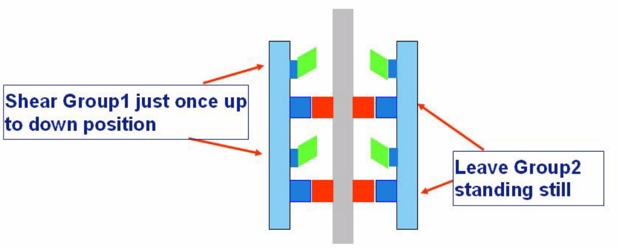


Figure 3.33 The actuator wave test measures displacement of the lens in Z when a non-clamped piezo group is sheared.

- Part that measures the displacement of the lens element in Z when a piezo-group is *clamped* (actuator cross-talk). See figure below.

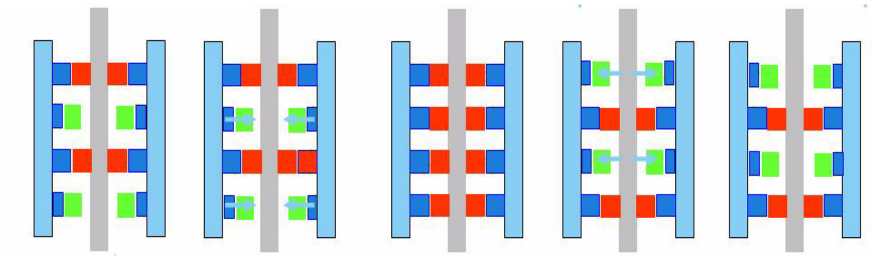
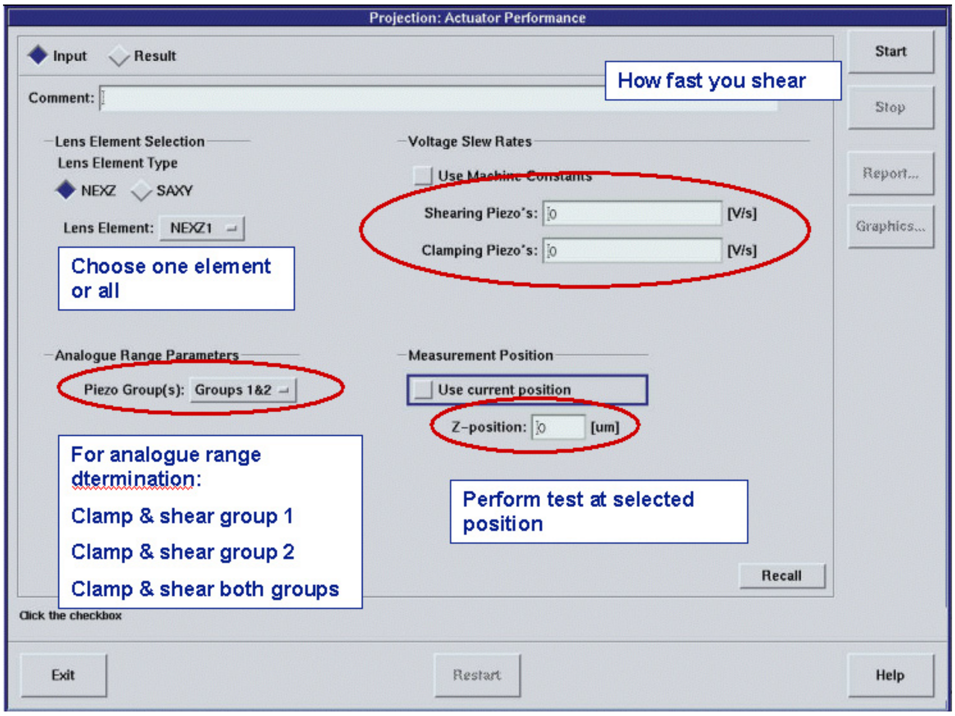


Figure 3.34 The actuator cross talk test the displacement of the lens in Z when a piezo group is clamped

Input screen

The input screen is shown below.



● Input ○ Result

Comment:

NEXZ ● ○ SAXY

Lens Element: NEXZ1

☐ Use Machine Constants

Shearing Piezo's: 0 [V/s]

Clamping Piezo's: 0 [V/s]

Piezo Group(s): Groups 1&2

☐ Use current position

Z-position: 0 [um]

Click the checkbox

How fast you shear

Choose one element or all

For analogue range dtermination:

Clamp & shear group 1

Clamp & shear group 2

Clamp & shear both groups

Perform test at selected position

Figure 3.35 Actuator performance test input screen

Procedure Results

All NEXZ actuators are qualified for

- Analog Range typical values
- Actuator Wave typical values
- Cross-talk typical values

On Screen Result

When the test has finished successfully, the Result screen will appear automatically with the message “Test is finished.”

The performance report can be found in the next directory: /TM/Projection/LensElementManipulators/ManipulatorPerformance/PIPD.log/

Required Actions

Select: Report and check if the measured parameters for all NEXZ actuators are within the following typical values.

Failure Response

Failure Mode/Actions required

If the test failed, the Result screen will appear automatically with the message Test failed. Rerun the test.

For troubleshooting reasons it's sometimes useful to check the actuator functionality of one element separately. Be sure that when every sensor has been checked in this way, the test is repeated for all NEXZ elements simultaneously at the end, or you will have problems uploading test data into the database.

If the test continues to fail, contact support.

Measure Performance of Shuffle-to-Zero (PINZ)

Procedure Name Check the NEXZ shuffle to zero performance

Coach Number cspr116.per

Function High voltages at the trans piezos of the NEXZ elements lower the life time of the piezos. To make the time period at which the voltage at the piezos is high as short as possible after each static move and at the end of each die, a so-called shuffle-to-zero is performed. The shuffle-to-zero sets the piezo voltage to (nearly) zero volt at the desired position of the lens element. This test checks that after a shuffle-to-zero at any Z-position, the rest voltage at the piezos is close to zero. At each selected Z-position, two rest voltages are measured. One rest voltage after a shuffle-to-zero starting when the voltage at the trans piezos is largely positive. And the other rest voltage after a shuffle-to-zero starting when the voltage at the trans piezos is largely negative.

Preconditions If a lens is replaced, do procedure cspr017.adj to load the NEXZ, SAXY, and ALE settings into the machine constants.

Calibrate piezo capacity of NEXZ and SAXY lens-element amplifiers (cspr022.adj).

Calibrate the index-pulse amplitude of the NEXZ lens-elements (cspr023.adj).

Points of attention Select the test in test software and enter the test parameters:

Set the Manipulator can be used by test software to True for the five NEXZ lens elements

Sequence of Events

- Measure the remaining voltage after a shuffle to zero at different Z positions. The test checks the remaining voltage at a range of z-positions.
- Each position is tested at two conditions. One test part starts with the trans piezos in upmost position, one in the lowest position. See the figure below.

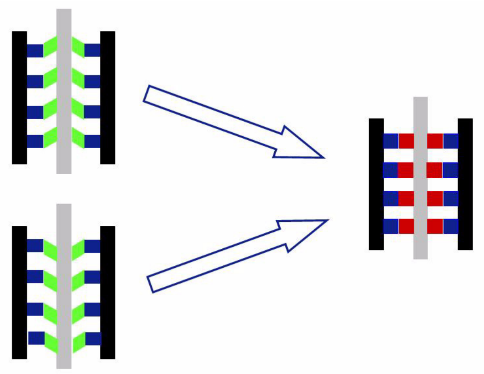
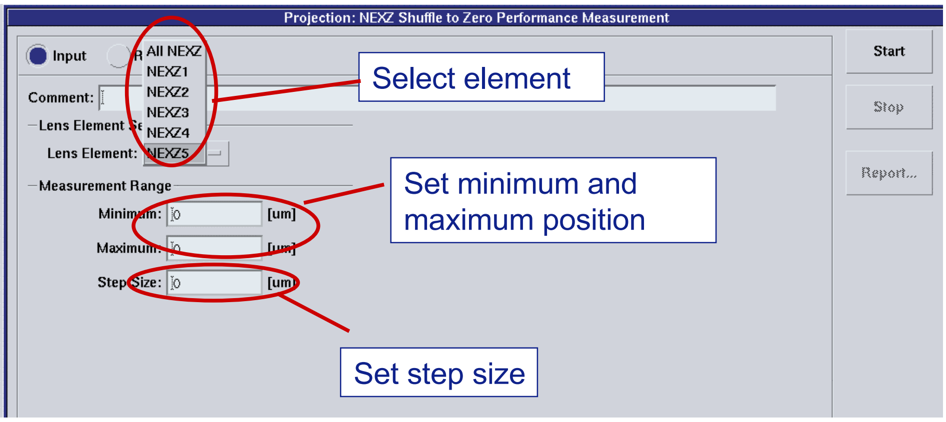


Figure 3.36 Shuffle te zero performance test input screen.

Input screen The input screen is shown below.



Comment:

Lens Element Se

Lens Element: NEXZ5

Measurement Range

Minimum: 0 [um]

Maximum: 0 [um]

Step Size: 0 [um]

Select element

Set minimum and maximum position

Set step size

Figure 3.37 Shuffle te zero performance test input screen.

If the All function is selected in the Lens Element button, the NEXZ lens-elements are measured simultaneously.

Procedure Results

On Screen Result

Check in the Main Result window that the message OK: Test finished successfully is shown.

Graph

The graph shows the remaining voltage after shuffling.

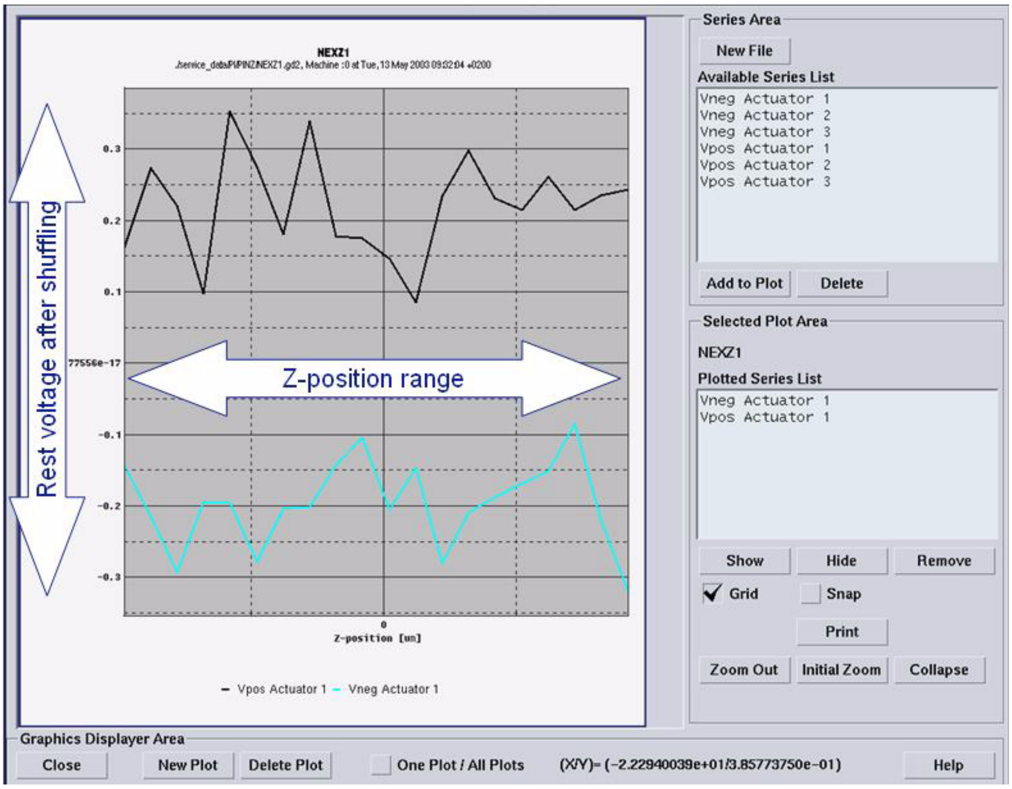


Figure 3.38 Remaining voltages are shown for shuffling starting in upmost and downmost feet positions.

Required Actions

The calibration report is found in the directory that follows: /TM/Projection/LensElementManipulators/ManipulatorPerformance/PINZ.log

Verify maximum absolute rest-voltage of each of the piezos is not greater than 2.0 V

Failure Response Failure Mode/Actions required

Check the cable connections of the NEXZ and SAXY actuators and sensors. (cspr091.per)

Check the NEXZ sensor performance (PINS)

Procedure Name Check the NEXZ sensor performance (PINS)

Coach Number Cspr175.per

Function The NEXZ (Next Generation Z-manipulators) manipulators contain Heidenhain sensors. Within the HIB (Heidenhain Interpolation Board), raw sensor signals are transferred to positions. Internally, the HIB checks the quality of these raw signals against the end-of-life specification. So, once these signals are out of spec, the sensor cannot be used anymore. The Heidenhain Sensor test qualifies the raw sensor signals. The quality will be checked against the zero-hour specification, which is tighter, The test can also be used to diagnose the origin of possible problems with the sensor.

Preconditions

IIn closed loop mode:

- Cables must be connected.
- Piezo Capacity Calibration (PIPC) must be performed.
- IP can fully initialize

In open loop shuffle mode or open loop analog mode:

- Cables connected.
- IP can stepwise initialize to level: Servo Configured

Points of attention

Select the test in test software and enter the test parameters:

Sequence of Events

See the figure below.

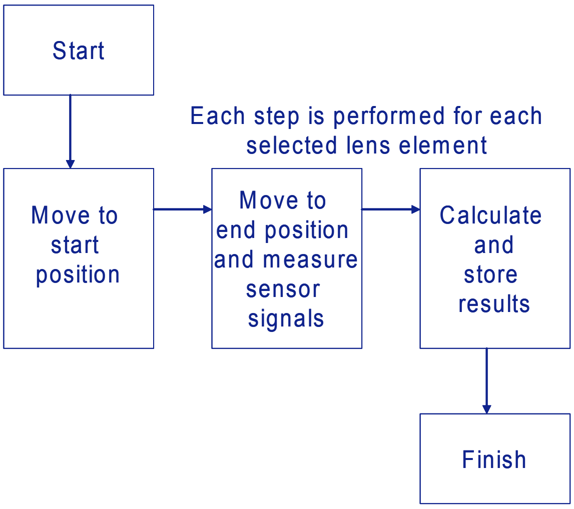
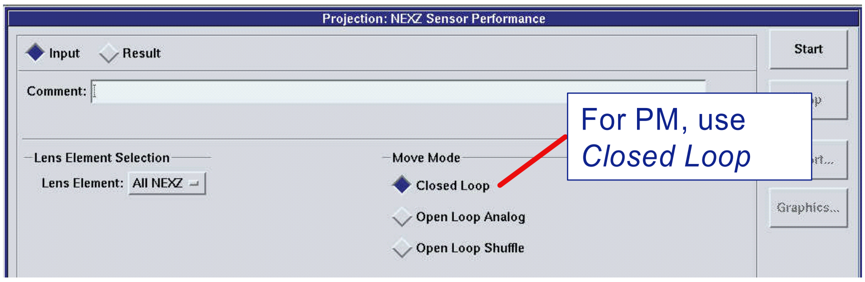


Figure 3.39 Shuffle te zero performance test input screen.

Input screen

The input screen is shown below.



Projection: NEXZ Sensor Performance

● Input ○ Result

Comment:

Lens Element Selection

Lens Element: All NEXZ

Move Mode

● Closed Loop
○ Open Loop Analog
○ Open Loop Shuffle

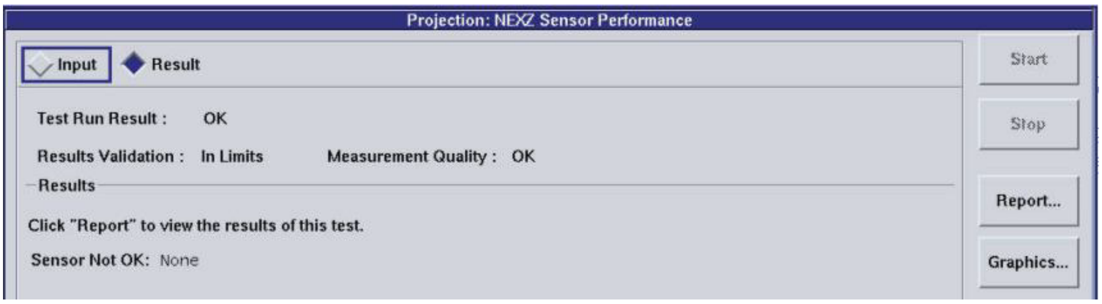
For PM, use *Closed Loop*

Figure 3.40 Check the NEXZ sensor performance input screen.

Procedure Results

On Screen Result

Check in the Main Result window that the message OK: Test finished successfully is shown.



Test Run Result : OK

Results Validation : In Limits

Measurement Quality : OK

Results

Click "Report" to view the results of this test.

Sensor Not OK: None

Figure 3.41 Results screen..

Required Actions

Results are expected to be OK, if NOK, contact third line support.

Failure Response Consult third line support.

Measure Short Range Stray Light (Kirk’s Method)

Procedure Name Measure Short Range Stray Light

Coach Number cspr073a.per

Function To measure the short-range stray-light with Kirk's method. This procedure determines the system setup, system monitoring, and system diagnostic stray-light values.

Preconditions Measure slit uniformity to verify functionality and system performance before starting.

Make sure that the setup of the system is correct.

Two lens qualification 300 mm wafers with a die flatness of < 0.18 µm/die.

Points of attention

1. BA_STRAYLIGHT RETICLE SERV.455.6291* required
2. Access to a microscope for reading of the wafer is required
3. If the customer uses their own process, make sure that a resist with a BARC is used
4. Kirk's method Microsoft TM Excel tool. You will find the tool on the 3rd line Illumination & Projection home page in the ASML Intranet.
5. Refer to the Intranet address that follows for the Kirk recipes: http://www4nl.asml.nl/nonconf/dept/TEC/html/illumination_projection/Lens_Monitor/KIRK/index.html

If a BARC is used, a block that is fully cleared of resist can look like it is not cleared. This is because an image is formed in the BARC. By looking at other field positions (especially modules 1 to 5 and 31 to 35) where the stray-light is lower, it is possible to see the difference between the blocks that contain images in the BARC and normal resist-imaged blocks.

Sequence of Events

Test principle

As discussed in the generic section, stray light means that there still is light where there should be none.

The test detemines the energy to clear and exposes the reticle part shown below at different energies. (eg 20*E0, 30*E0 … 100*E0)

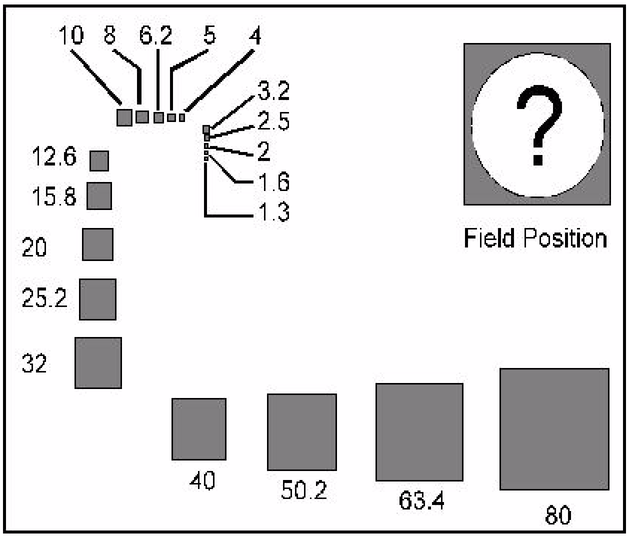
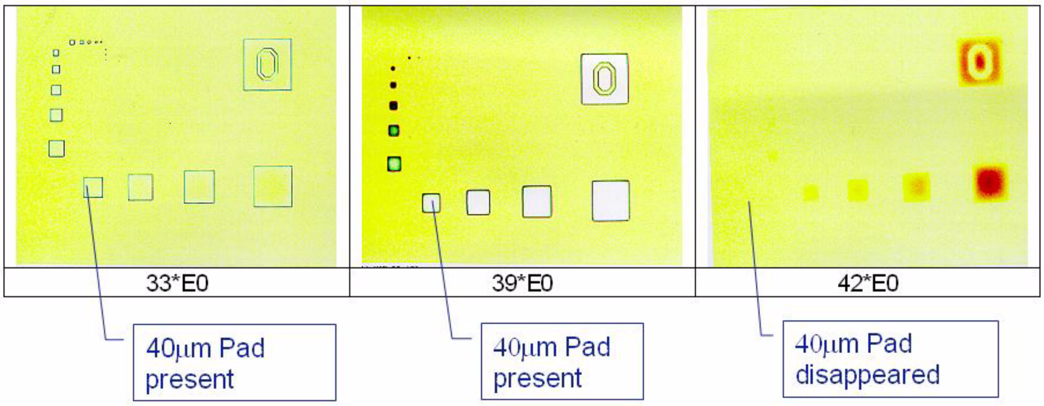


Figure 3.42 The stray light reticle has square chrome pads of different size.

Under the squares, there should be no light, so all the resist should remain. However, due to stray light, parts of the resist will be removed. For a specific square size, the energy at which all resist was removed due to stray light is determined using an optical microscope. See also the next figure.



$$SL_{40\,\mu m pad} = \frac{E0}{energy\_to\_clear\_pad} = \frac{1*E0}{42*E0} = 2.4\%$$

Figure 3.43 The energy needed to remove the resist even under the 40 micrometer pad determined the stray light over the 40 micrometer range.

Stray light values are calculated for the 5 micrometer boxes.

The exposures are done on two wafers. Wafer one contains Kirk dies that will receive the highest energies, and the Energy To Clear (ETC) dies. Wafer two contains the Kirk dies that will receive the lower energies. Because the ETC is different in different resists, and changes as time passes, make sure that the ETC that was last used is entered in the recipe before the wafers are exposed.

Main steps

Load wafers and stray light reticle.

Enter required values in the test set-up screen.

Expose layer with highest energies.

Expose the ETC (energy to clear) layer

Expose the layer with the lowest energies.

PEB and develop the wafers

Read out the ETC values

Read out the Kirk modules

Identify the blocks that contain resist, and type the block sizes in the Kirk's method Microsoft TM Excel tool.

Procedure Results A wafer is exposed that can be interpreted, using a microscope, to determine the amount of stray light reaching the wafer. The results are entered into an Excel worksheet on a laptop PC. The Excel tool can be used to calculate the amount of stray light.

On Screen Result

Indication of successful completion of wafer exposure

Required Actions

Make sure that you enter the results of this test in the Kirk's method Microsoft TM Excel tool.

Select the calculate button in the Microsoft TM Excel tool to calculate the quantity of stray-light.

If necessary, use the minimum and the maximum stray-light values from modules 16 through 20 to calculate a range or TIR number.

Check that the result of the calculation of the tool is in the specified limit that is shown in the table below. W.r.t. system type determine cleaning trigger max stray-light at reference block size as a percentage.

Failure Response Failure Mode/Actions required

Only use the specified limit as a guideline to trigger cleaning actions. The specified limit can NOT be used as lens replacement criteria.

Cleaning is only performed by specially trained personel. Never start cleaning without consulting third line support.

Measure Stray Light With SAMOS Method

Procedure Name Measure Stray Light with SAMOS

Coach Number cspr093a.per

Function To measure the stray light with the Stray light At Multiple Opaque-Squares (SAMOS) monitoring test.

Preconditions Measure slit uniformity to verify functionality and system performance before starting.

BA-MOSAIC reticle 4022.455.63154.P00X required

Make sure illumination integrated slit-uniformity is in the specification. (csil006.per)

Make sure scanning dose accuracy and repeatability is in specification. (csil008.per)

Make sure that the reticle masking accuracy is in the specification. (csil009.per).

Points of attention

Enter the test reticle in the reticle data base if it is not already there.

If this test is used for monitoring purposes, run the test with the default settings.

If you want to change the default settings for troubleshooting purposes, then change the settings in the Advanced Input button.

Sequence of Events

Test principle

The test measures the light intensities with the Transmission Image Sensor (TIS) ratio sensor, below the chrome pads on the BA-MOSAIC reticle. The long range (> 50 um) and short range (> 2 um) stray-light is measured below chrome pads of different sizes.

Like Kirk, SAMOS measures the amount of remaining light under a chrome pad. In SAMOS, this is done using the TIS sensor. SAMOS is process independent, takes a comparatively short time and is therefore preferred over Kirk.

The example of a SAMOS test part is shown below.

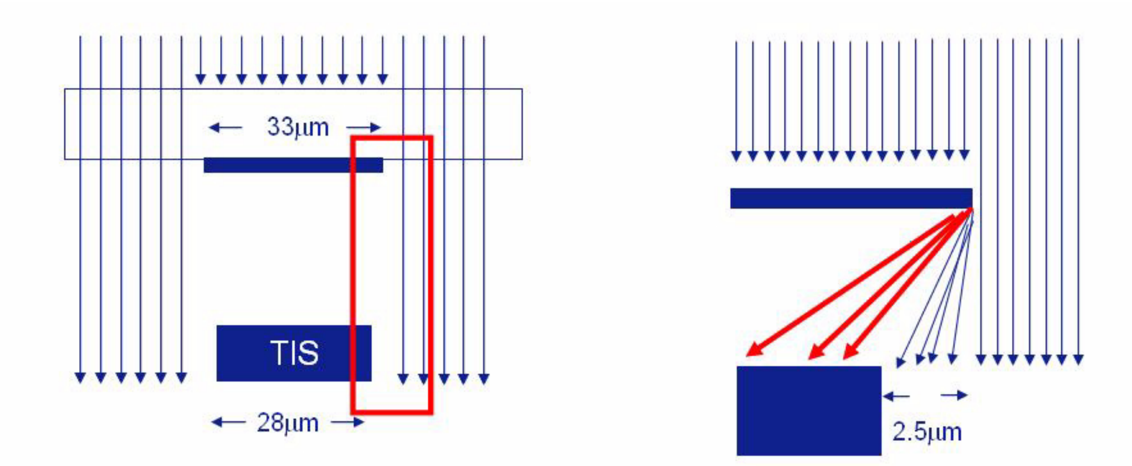


Figure 3.44 Intensity underneath a 33*33mm (@ wafer level) Chromium pad is measured with TIS ratio sensor

As can be seen in the figure, only straylight that has a range of >2.5mm reaches the sensor.

That mean that with a pad of X*X mm2, you measure straylight of ranges 0.5*(X-28)mm and more.

The reticle used is shown below.

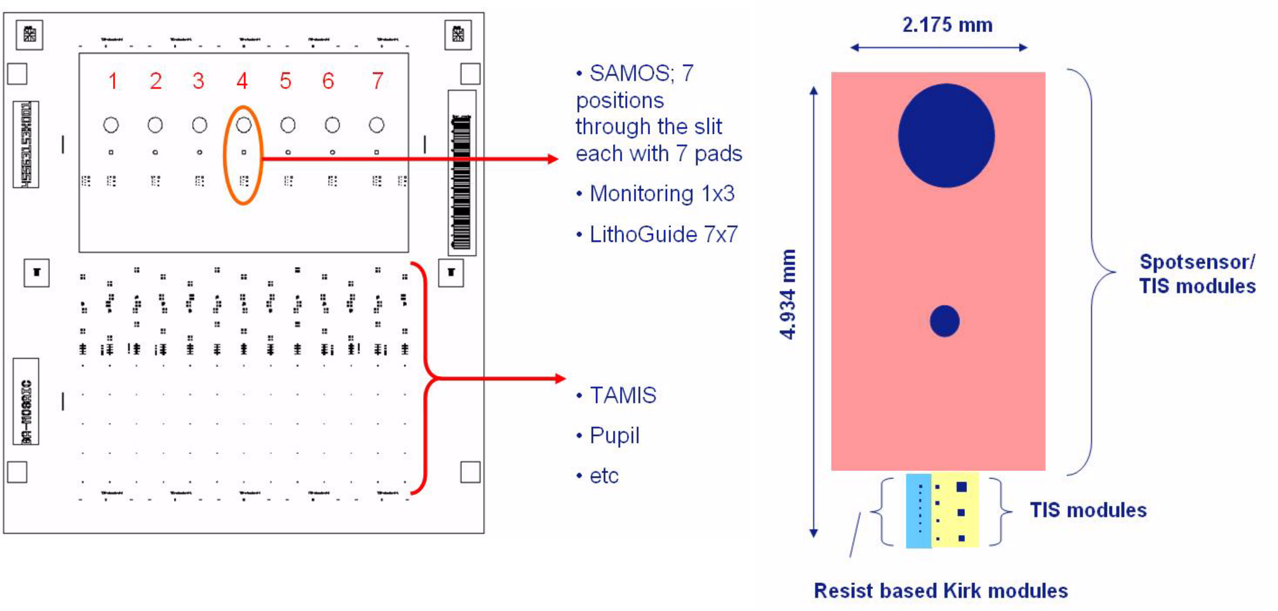


Figure 3.45 Intensity underneath a 33*33mm (@ wafer level) Chromium pad is measured with TIS ratio sensor

The TIS sensor data are bits, and the sensor is not calibrated for intensity. One of the circular pads is used to calibrate the TIS sensor with reference to the Spot Sensor. Both sensors are put below the circle and then exposed.

Square pads are used for the TIS stray light measurement. Sizes are 108, 88, 68, 48, 36, 33, 30 um.

Square pads are used for for Kirk based resist measurements. They are 25,16,10,6.3,4,2.5,1.6,1.3 um.

Wafers are not used in the SAMOS test. The test only gives stray-light data from the top lens-element, bottom lens-element, and the inner side of the lens.

Main steps

Perform the test using COACH.

Procedure Results

This qualification test does not change the state of the system. The amount of stray light is known. This information can be used to determine the status of the machine or as a base-line reference for future evaluation of system status.

On Screen Result

Successful completion of test - data supplied for evaluation of stray light

The test report is stored in the folder TM/Projection/Straylightmonitoring/EMCA.log

Required Actions

Make sure that the stray-light number in the block size 33 um field of the report, meets the applicable specified limit

The data given by this test is for the calculation of stray light. Do this test at set intervals to monitor the performance of the lens. Also do this test before the lens is cleaned, after the lens is cleaned, and after the TIS ratio sensor is replaced.

Failure Response

Failure Mode/Actions required

Performance w.r.t. stray light only. Not a pass or fail test.

Cleaning is only performed by specially trained personel. Never start cleaning without consulting third line support.

IMPORTANT TESTS OUTSIDE THE PM LIST

There are two tests that er done automatically in MX actions. They are very important and used many times as stand alone tests. Therefore, they have to be discussed in the L2 course.These tests are:

Measure Integrated Slit Unifomity and Intensity

Measure Scanning dose Accuray and Repeatability

Measure Integrated Slit Uniformity & Intensity

Procedure Name	Measure Integrated Slit Uniformity & Intensity
Coach Number	csil006c.per
Function	To measure the integrated slit uniformity and intensity.
Preconditions	If necessary, for AT:11x0, AT:12x0, XT:12x0, and XT:1250i systems, do procedure csil003.cle to eliminate reversible uniformity drift effects with stabilization exposures
Points of attention	The parameters of the test vary depending on system model and configuration. Be sure to enter the correct parameters as defined by the procedure.
Sequence of event	We will discus the test principle and the test input screen.

Test principle

Choose a grid and let the Spot Sensor step through the grid, step by step. See the figure below. Expose a number of pulses on each grid point and measure using ES and SS.

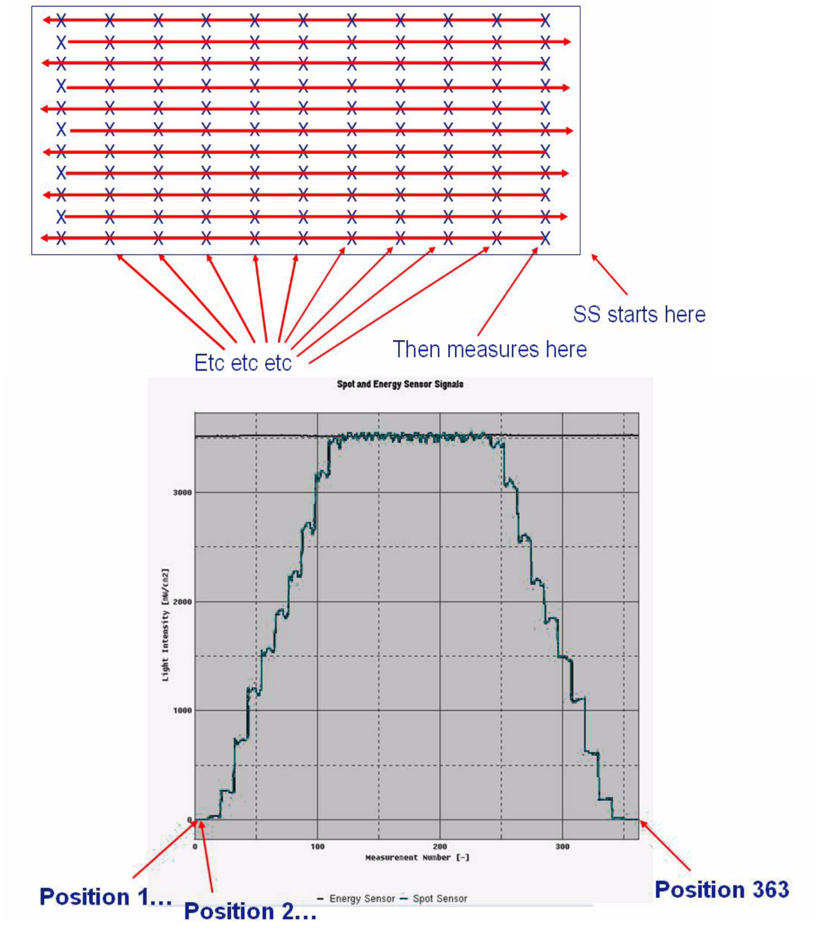


Figure 3.46 The steps that the SS makes can be recognized in the intensity plot.

In ATP setting, the grid is larger than the slit size, but the test can be done for any field size, containing any number of measuring points.

All test data, including ES and SS values, are stored in the log file.

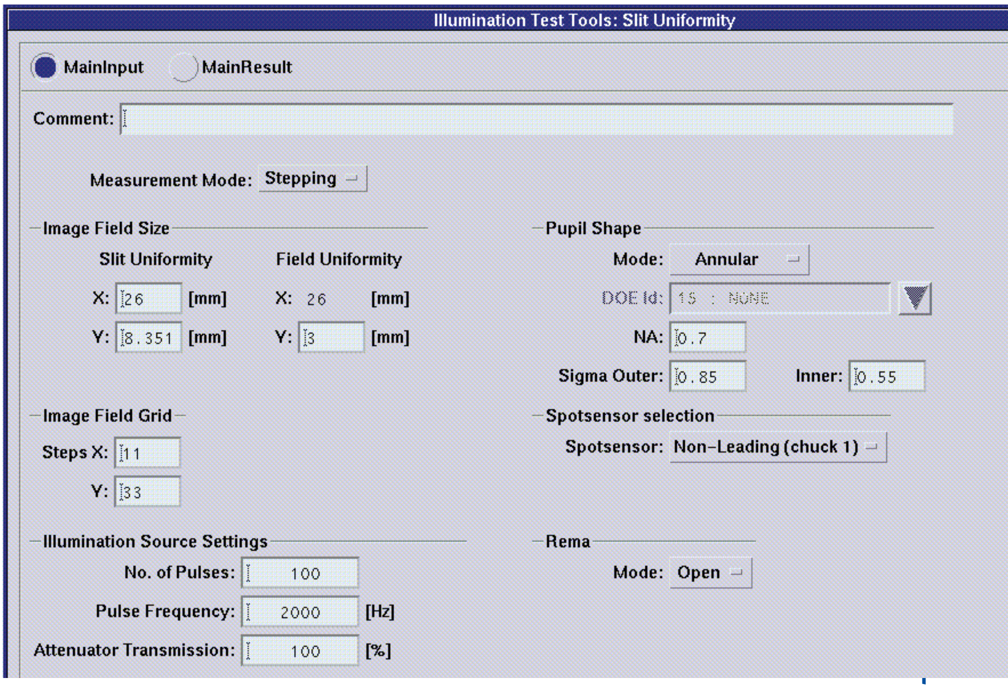
After the test:

- Data at each X position are summed (see figure) to simulate the actual dose a pixel would get during its travel under the slit. Results show an intensity pattern in the non scanning direction (X),
- Data on a smaller field in the slit are processed one by one to generate the intensity and the Field Uniformity.

Note: the Ratio R between SS & ES is measured, to average out fluctuations in the laser pulse intensity.

Input screen

See figure below.



Comment:

Measurement Mode: Stepping

Slit Uniformity X: 26 [mm]
Slit Uniformity Y: 8.351 [mm]
Field Uniformity X: 26 [mm]
Field Uniformity Y: 3 [mm]

Mode: Annular
DOE Id: 15 : NONE
NA: 0.7
Sigma Outer: 0.85
Inner: 0.55

Steps X: 11
Y: 33

Spotsensor: Non-Leading (chuck 1)

No. of Pulses: 100
Pulse Frequency: 2000 [Hz]
Attenuator Transmission: 100 [%]

Mode: Open

Figure 2: Example of Integrated slit uniformity dialogue window

`Measurement mode`

In this test we are interested in the performance of the optical column and to exclude other influences. The measurement is therefore performed in stepping mode (= non-scanning)

`Image Field Size`

Slit Uniformity gives the grid size where the measurements will take place. *Field Uniformity* sets the range of the selection of measuring data for the calculation of the field uniformity and intensity.

`Image Field Grid`

Define steps in x and y. These will be distributed equally over the entered *Image Field Size*.

`REMA`

Set REMA around SS to prevent stray light influence on the measurement, set REMA to *open* to do the opposite. In case of *Spot,* the size of the REMA window is ten times the Spot Sensor pinhole dimension, so 1.2 x 1.2 mm. In case of *Image,* you may select any REMA window.

`Illumination Mode`

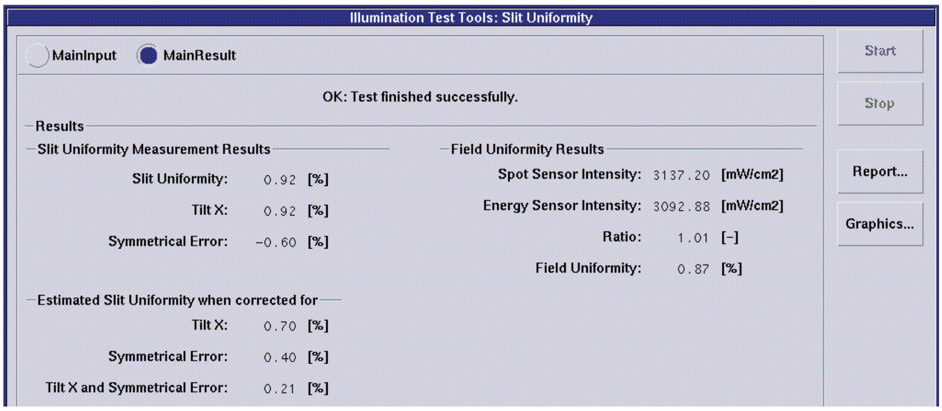
The uniformity in the illuminated field and also the intensity depend on the pupil shape, because different pupil shapes use different paths in the optical column. For this reason you will find different uniformity values for different pupil shapes.

If the test failed for some reason and the problem was fixed so that the test can be run again, the `Recall` button will restore all the input data.

Procedure Results

Uniformity of illumination across the slit is known

See figure below.



OK: Test finished successfully.

Results

Slit Uniformity Measurement Results

Slit Uniformity: 0.92 [%]

Tilt X: 0.92 [%]

Symmetrical Error: -0.60 [%]

Field Uniformity Results

Spot Sensor Intensity: 3137.20 [mW/cm2]

Energy Sensor Intensity: 3092.88 [mW/cm2]

Ratio: 1.01 [-]

Field Uniformity: 0.87 [%]

Estimated Slit Uniformity when corrected for

Tilt X: 0.70 [%]

Symmetrical Error: 0.40 [%]

Tilt X and Symmetrical Error: 0.21 [%]

Figure 3: Slit uniformity results screen.

The Slit Uniformity is the uniformity we may see if we move in the non scanning direction. The scanning direction is averaged out.

To understand the other values, we must consider the way of calculation. It is shown in the figure below.

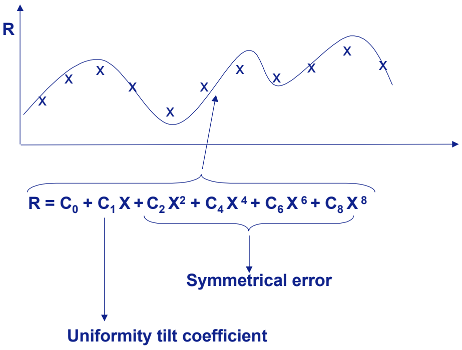


Figure 4: Polynomial fit in the slit uniformity data plot

As a function of X (non scanning direction), you see the average ratio (SS/ES).

The polynomial shown below is fitted and coefficients are determined.

$R = C_0 + C_1 X + C_2 X^2 + C_4 X^4 + C_6 X^6 + C_8 X^8$

The $\mathbf{C_1}$ coefficient leads to the Tilt X calculation over the field by finding maximum and minimum R value for $\mathbf{R = C_1 X}$.

The $\mathbf{C_2}$, $\mathbf{C_4}$, $\mathbf{C_6}$ and $\mathbf{C_8}$ values lead to the Symmetrical error estimation by finding the maximum and minimum R value for $\mathbf{R = C_2 X^2 + C_4 X^4 + C_6 X^6 + C_8 X^8}$.

Note: polynomial parts can be negative, as can be seen in the results for Symmetrical Error.

If the Tilt line is substracted from the measurement data, the remaining data lead to the estimated Slit Uniformity when corrected for Tilt X.

If the Symmetrical Error polynomial is substracted from the measurement data, the remaining data lead to the estimated Slit Uniformity when corrected for Symmetrical Error.

By substracting both polynomial parts, we get the estimated Slit Uniformity when corrected for Tilt X and Symmetrical Error.

Note:

In the Unicom and in the Gray Filter determinations tests, a Slit Uniformity is done in the 100% intensity area (11mmx3mm). The polynomial used is more complex, and it is used in a two dimensional fit.

Graphics

A typical graph is shown below.

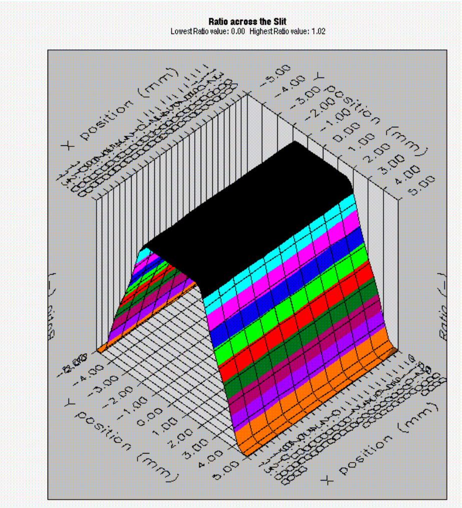


Figure 5: Results graph Slit Uniformity

The ratio all over the slit is visible.

Failure Response Failure Mode/Actions required

Request 2nd Line Support

Measure Scanning dose Accuracy & Repeatability

Procedure Name Measure Scanning Dose Accuracy & Repeatability

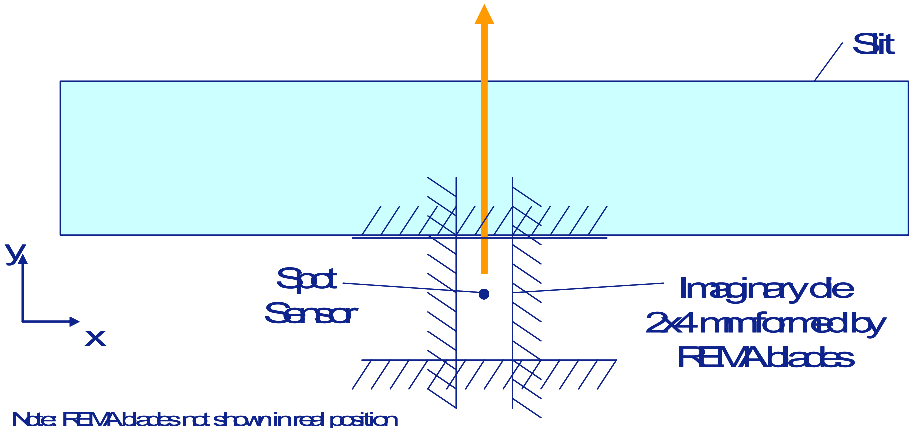
Coach Number csil008f.per

Function	The objective of this test (ODAR) is to measure the repeatability and accuracy of the dose control algorithm (and hardware). The dose control hardware consists of the laser, attenuator, IIB/SC and various sensors. The test will perform regular exposures, like they would be performed during normal use of the system.
Preconditions	Measure slit uniformity to verify functionality and system performance before starting. The illumination system has to be fully adjusted and calibrated to obtain reliable information from these tests.
Points of attention	Setup of test values is required before running test.
Sequence of events	We will discus the test principle and how the test input screen.

Test principle

- Create an imaginary die using the REMA blades.
- Place the spot sensor in the middle of the imaginary die
- Move the spot sensor through the slit while dose control tries to.
- Expose at a selected dose.
- Repeat the exposure 100 times

The concept is shown in the figure below.

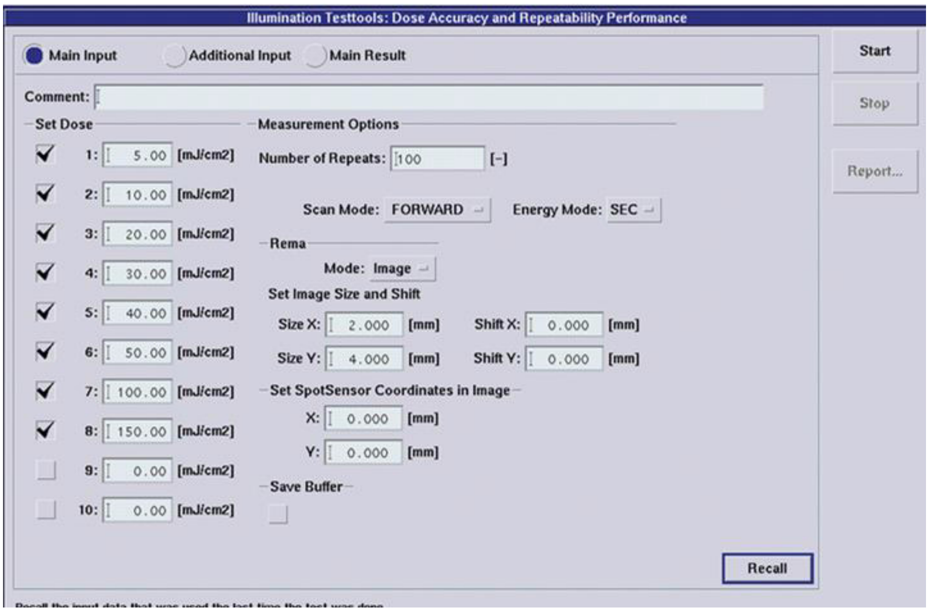


Note: REMA blades not shown in real position

Figure 3.47 The ODAR test imitates a real die.

Test input screen:

The input screen is shown in the figure below.



● Main Input ○ Additional Input ○ Main Result

Comment:

Set Dose

☑	1:	5.00	[mJ/cm2]
☑	2:	10.00	[mJ/cm2]
☑	3:	20.00	[mJ/cm2]
☑	4:	30.00	[mJ/cm2]
☑	5:	40.00	[mJ/cm2]
☑	6:	50.00	[mJ/cm2]
☑	7:	100.00	[mJ/cm2]
☑	8:	150.00	[mJ/cm2]
☐	9:	0.00	[mJ/cm2]
☐	10:	0.00	[mJ/cm2]

Measurement Options

Number of Repeats: 100 [-]

Scan Mode: FORWARD Energy Mode: SEC

Rema

Mode: Image

Set Image Size and Shift

Size X: 2.000 [mm] Shift X: 0.000 [mm]

Size Y: 4.000 [mm] Shift Y: 0.000 [mm]

Set SpotSensor Coordinates in Image

X: 0.000 [mm]

Y: 0.000 [mm]

Save Buffer

☐

Figure 3.48 Scanning dose accuracy & repeatability dialogue window

The measurements should be setup such, that they approach the normal use of the system as good as possible, which implies that Scanner Energy Control should be enabled etc.

`Measurement Mode`

Scans might be either forwards or backwards only, or even concatenated as in jobs/ batches. The die size speaks for itself, the spot sensor position will define the position where the spot sensor will be positioned within the die. The internal REMA can be switched to either `Die` or `Spot` mode.

`Measurement Settings`

In this field the energies that should be exposed are defined. The default values can be switched off, by selecting `No` in the `Apply` field. The default values can also be edited, in order to investigate the system performance in a specific range of doses.

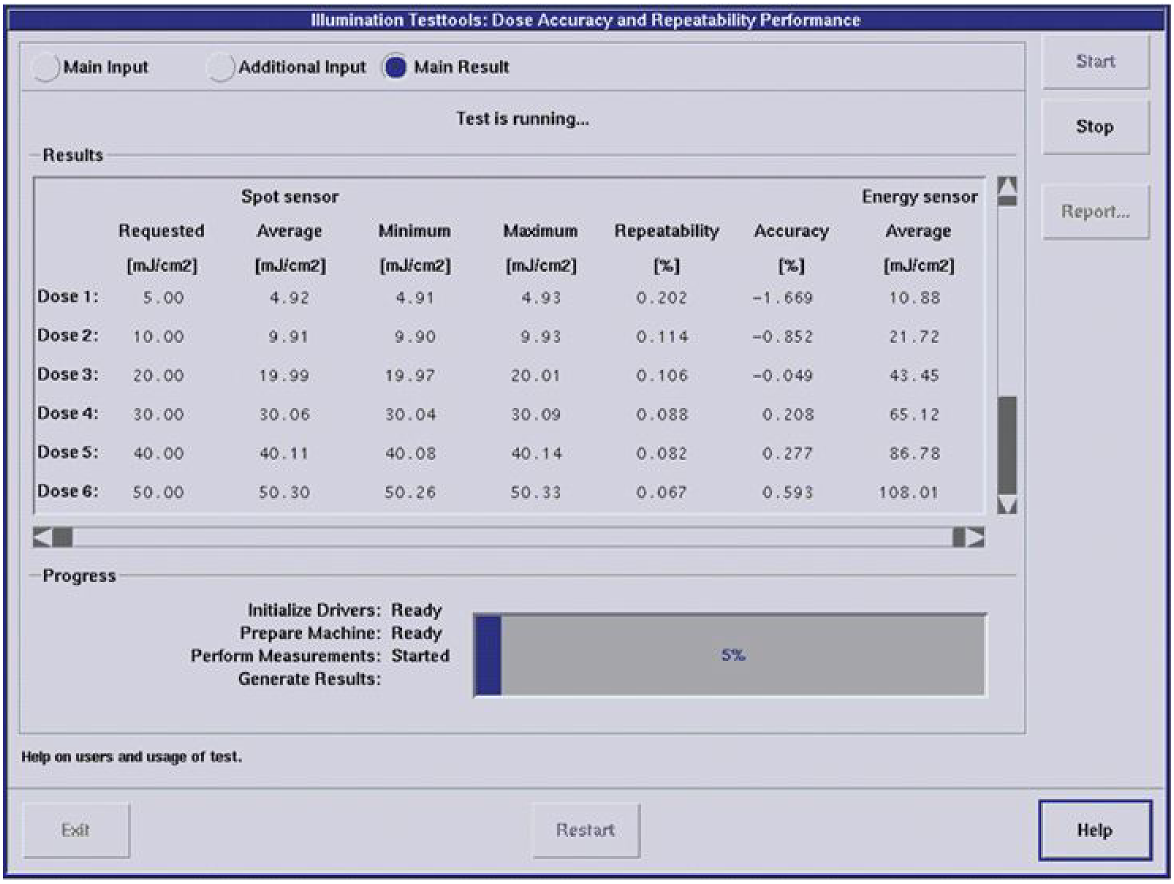
`Number of Repeats / Number of Doses`

The value in this field will define how many times an exposure at any requested energy will be repeated.

`Illumination Mode`

After this button is selected, a standard input form for NA/σ settings will be visible. In this dialog box any allowed setting can be chosen in either conventional, annular or quadrupole illumination mode.

Results interpretation The result screen is shown below.



Test is running...

	Requested [mJ/cm2]	Spot sensor Average [mJ/cm2]	Minimum [mJ/cm2]	Maximum [mJ/cm2]	Repeatability [%]	Accuracy [%]	Energy sensor Average [mJ/cm2]
Dose 1:	5.00	4.92	4.91	4.93	0.202	-1.669	10.88
Dose 2:	10.00	9.91	9.90	9.93	0.114	-0.852	21.72
Dose 3:	20.00	19.99	19.97	20.01	0.106	-0.049	43.45
Dose 4:	30.00	30.06	30.04	30.09	0.088	0.208	65.12
Dose 5:	40.00	40.11	40.08	40.14	0.082	0.277	86.78
Dose 6:	50.00	50.30	50.26	50.33	0.067	0.593	108.01

Initialize Drivers: Ready
Prepare Machine: Ready
Perform Measurements: Started
Generate Results:

5%

Help on users and usage of test.

Figure 3.49 ODAR results screen.

The dose repeatability is defined as:

Repeatabilty = $((E_{MAX} - E_{MIN}) / (E_{MAX} + E_{MIN})) \cdot 100\%$

The dose accuracy is defined as:

Accuracy = $((E_{SET} - E_{MEAN})/ E_{SET}) \cdot 100\%$

Failure Response Failure Mode/Actions required

If the test is not in specifications, first look at the report and use common sense.

Try repeating with the other spotsensor.

Check the stability of the ES and SS. See applicable procedure.

+

4

UV ILLUMINATION SYSTEM (I-LINE)

INTRODUCTION

Critical Dimensions continue to get smaller, making it necessary to use shorter wavelengths of light to produce these very small features. However, even on devices with the smallest features, most of the layers in a process are what are known as “non-critical” layers. These are layers that normally have features sizes of .4 microns or larger and do not require shorter wavelengths of light. By using an I-Line, or UV system, the cost of ownership of the machine is much lower. For this reason, even though the latest devices have critical dimensions of less than 100 nanometers, there is still a demand for the lower priced I-Line systems. In this module we will discuss the features of the AERIAL 1 I-Line illumination system.

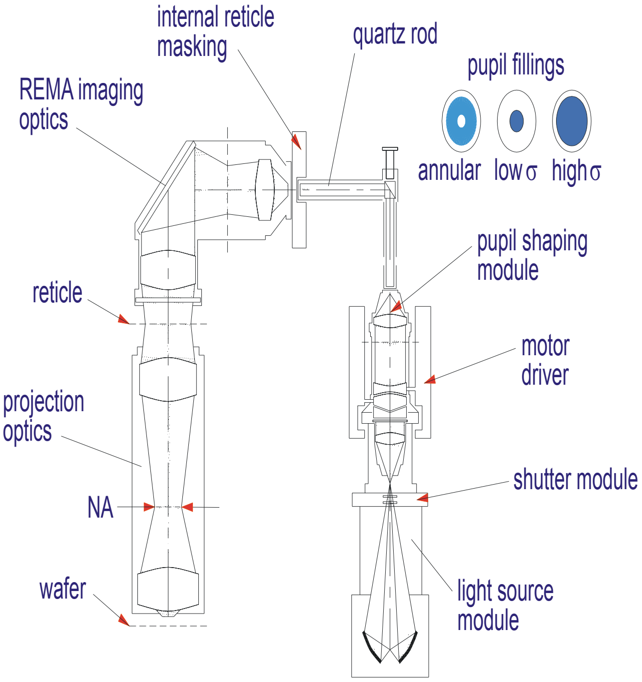


Figure 4.1 Aerial 1 UV overview

The illumination system has specific functions that must be performed for the die on the wafer to be successfully imaged. The components of the AERIAL I illumination system are designed to fulfill these functions efficiently. These functions and the responsible components include, but are not limited to:

- Supply exposure light - Mercury arc lamp
- Provide adequate intensity - powerful lamp
- Control intensity - mechanical attenuation
- Deliver the light - mirrors and lenses
- Shape the light - pupil shaping optics
- Make the light uniform - integrator rod
- Filter as needed - optical filters
- Control the dose (Quantity) - lamp current and stage speed
- Mask the Reticle - Reticle masking system
- Illuminate the Reticle - optics and light

BOTTOM MODULE

Light Source including low pressure mercury arc lamp

UV illumination systems utilize a mercury (Hg) arc lamp light source and an AERIAL-1 illumination subsystem

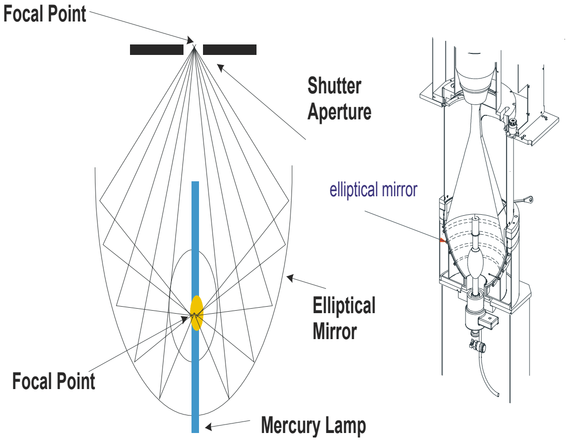


Figure 4.2 Ellipsoidal Mirror

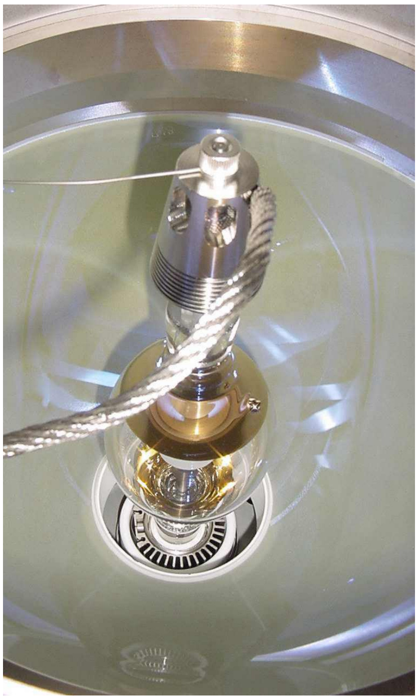
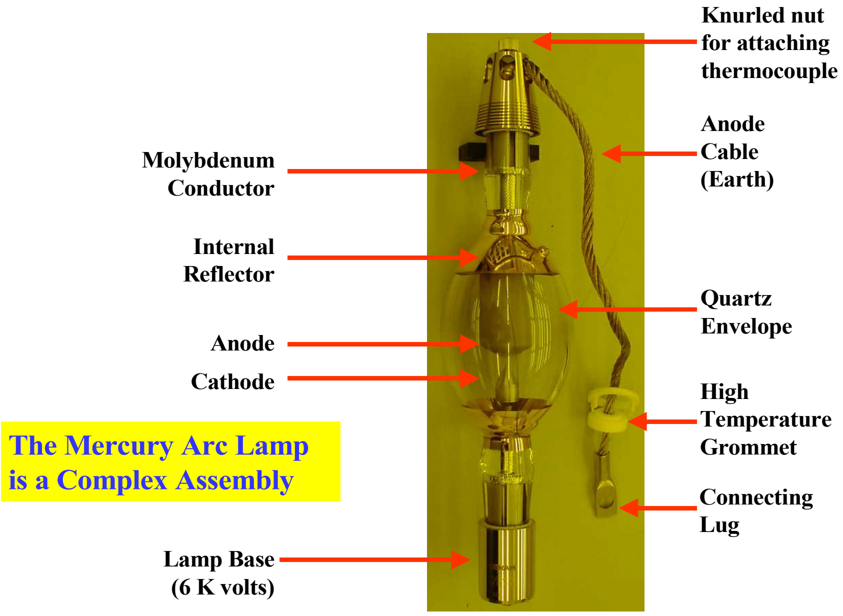


Figure 4.3 Lamp Mounted in Socket with thermocouple



The Mercury Arc Lamp is a Complex Assembly

Figure 4.4 The Mercury Arc Lamp is a Complex Device

The Hg lamp is a complex device. The quartz envelope provides an environment that allows the internal pressure to increase to several atmospheres when at operating temperature.

The base of the lamp is a pressure fit in the lamp socket. The socket is mounted on a X,Y,Z manipulator that can move the lamp within the elliptical mirror to position and focus the reflected cone of light for best position. The best position and focus will provide the highest intensity.

A high voltage cable is attached to the bottom of the lamp. This connection provides up to six kV to the lamp, to create the initial arc, when it is being ignited. Once the lamp is at operating temperature, the voltage drops and lamp current is maintained by the lamp controller.

An internal reflector in the lamp directs light that would not be focussed or directed back toward the elliptical mirror. Each electrode is connected through the ends of the quartz envelope by molybdenum ribbons which are excellent conductors of electricity but poor conductors of heat.

The anode cable is a permanent part of the lamp assembly, A lug on the end of the braided cable connects it to the earth return on the starter power supply in the bottom module. A high temperature grommet supports the anode cable where it exits the lamp housing.

A threaded stud is connected to the anode end (top) so a thermocouple can be attached for monitoring of lamp temperature.

5500W high pressure mercury arc lamp

The new 5500W high pressure lamp contains a high pressure nobel gas. It is mounted on all 4x0E/F XT machines. It is shown below.

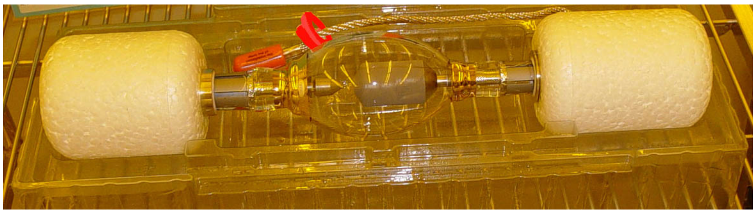


Figure 4.5 The 5500W high pressure lamp.

The lamp has the same size as the low pressure lamp. Only the golden reflectors are smaller than in the low pressure types.The lamp mounting is similar, but the High Pressure lamp bottom (the cathode) has a longer pin. See the figure below.

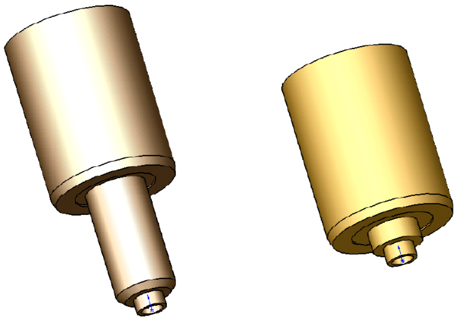


Figure 4.6 The high pressure lamp (left) has a longer pin than the low pressure lamp (right)

The figure below shows a the lamp in position.

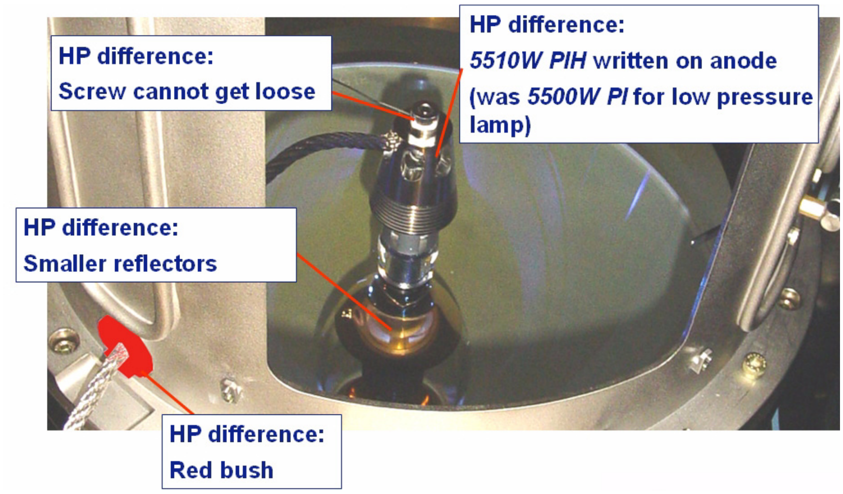


Figure 4.7 The 5500W high pressure lamps in position.

On top, the thermocouple connection is visible. The bold that holds the thermocouple cannot be removed. The bush that leads the lamp power cable through the wall of the lamp compartment is colored red.

For the high pressure lamp, the gold reflector surface is smaller.

Optical Filtering

Optical filtering is employed to isolate the preferred wavelength of 365 nm from the broad-spectrum of the mercury arc lamp light source. Filtering starts with the elliptical mirror, located in the lamp housing. The elliptical mirror reflects light with a wavelength shorter than 400 nm (UV) toward the exposure shutter, allowing longer wavelengths to pass. The longer wavelength light transmitted through the elliptical mirror is absorbed by a water-cooled jacket (heat sink) where accumulated heat is removed by facilities supplied cooling water.

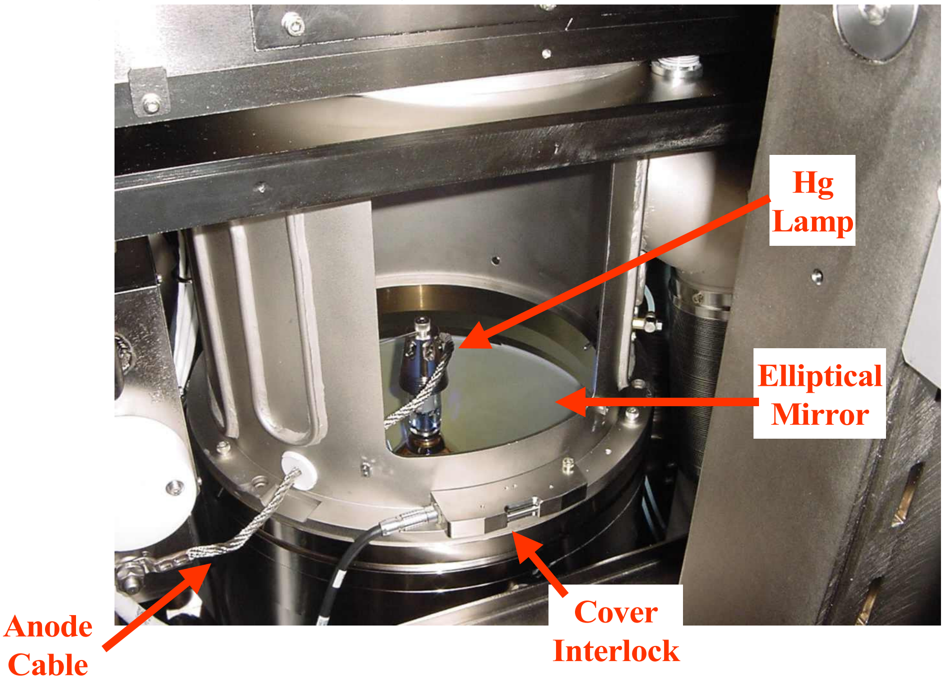


Figure 4.8 Hg Lamp and Lamp Housing

The reflected light then passes through an optical filter block that removes most of the shorter wavelengths and an additional filter that removes a remaining peak at 305 nm, but allowing the 365 nm light to pass. By the time the light has passed the 305-nm filter, intensity remaining at wavelengths other than 365 nm is very low.

Figure 4.9 WG Block Filter

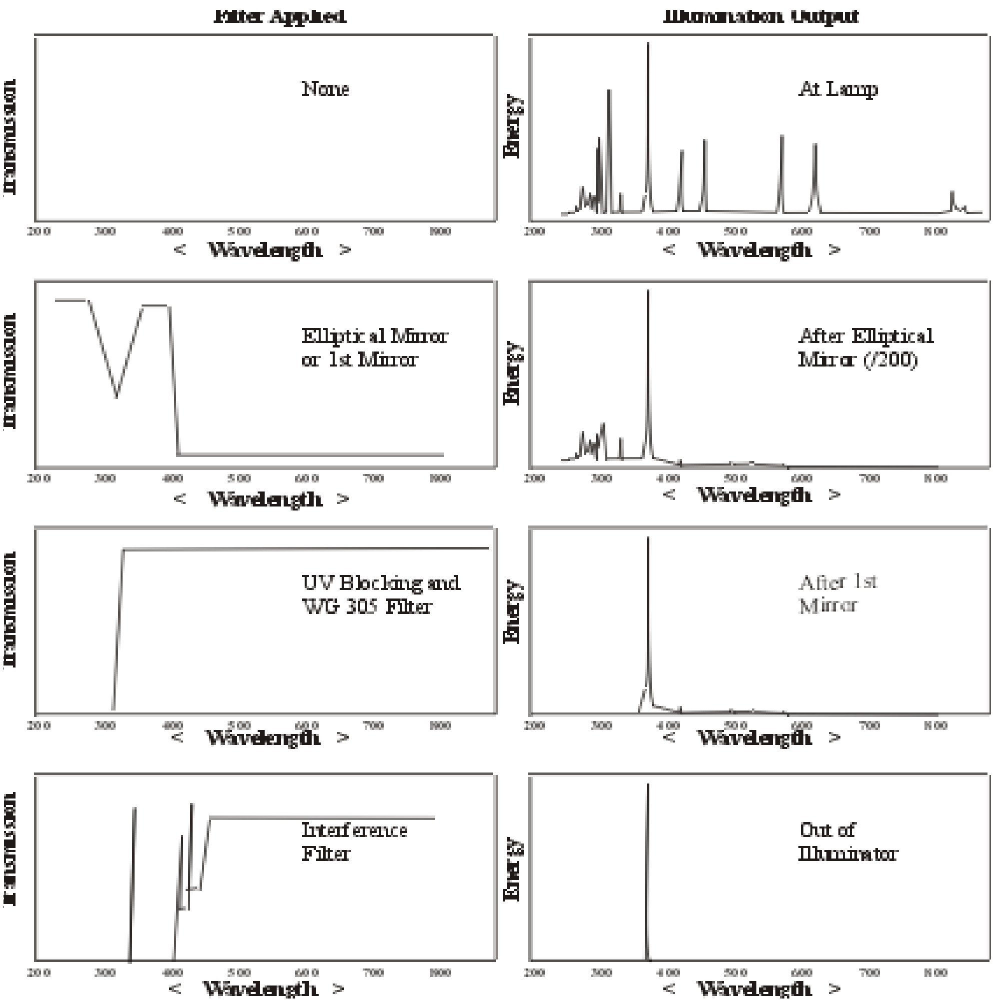


Figure 4.10 Filtering 365 nm light

The output characteristics of the illumination lamp are unique to the mercury arc lamp. Because the energy of a Hg lamp has peaks of radiation energy at known wavelengths, lithographic processes have been developed to exploit those peaks. The “G” line, which uses the 635 nm peak was widely used in the past, and because of the shorter wavelength, the 365 nm peak is used in the “I” line UV systems.

The diagram above shows the effects of optical filtering. The objective of the filtering is to remove as much light as possible that is not of the desired wavelength.

The left column shows the characteristics of the applied filters. The right column shows the light from the Hg lamp after passing the filtering shown on the left. The top row shows no filtering on the left, therefore all of the energy peaks are shown at the right.

The second row shows that the elliptical mirror, which is a reflective device, reflects most of the energy that is shorter than about 400 nm and passes the longer waves throught the mirror (where it is absorbed by the heat sink). The light that is directed toward the exposure shutter includes the desired peak of 365 nm along with other short wavelength light.

The third row shows the application of the UV and WG305 filters. This filter block tends to filter out all of the light above about 300 nm. The light that travels through this filter set includes the 365 nm and some lower level noise at various wavelengths that has survived the filtering.

Finally an interference filter is applied that blocks all of the remaining light except for 365 nm. This peak of light is the "I" line light for which many processes have been developed.

Shutter Block

Because the Hg lamp is a continuous light source, an exposure shutter is used to block the light between exposures. A motor driven shutter blade opens before exposure of a die and closes after completion, traveling 360º.

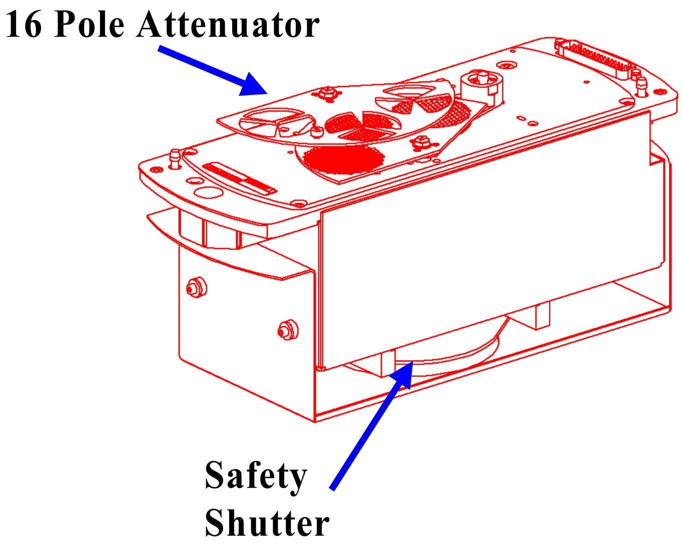


Figure 4.11 Shutter Assembly

The shutter assembly includes the exposure shutter, a sixteen pole attenuator and a safety shutter. The exposure energy (dose) is primarily a function of stage speed and exposure intensity. It is possible with a lower dose that the stage would be unable to move fast enough to avoid over exposure. In this case an attenuator blade (resembling a shutter blade with many small holes) partially blocks the light, lowering the intensity so that the required dose can be achieved. The attenuator has two blades that work together to provide a selection of intensities. Software automatically selects the appropriate combination, based on the user's job. A Safety Shutter is located at the entry to the shutter assembly. If a condition occurs that could allow exposure to UV radiation, the safety shutter will close and cannot be opened again until the system is made safe.

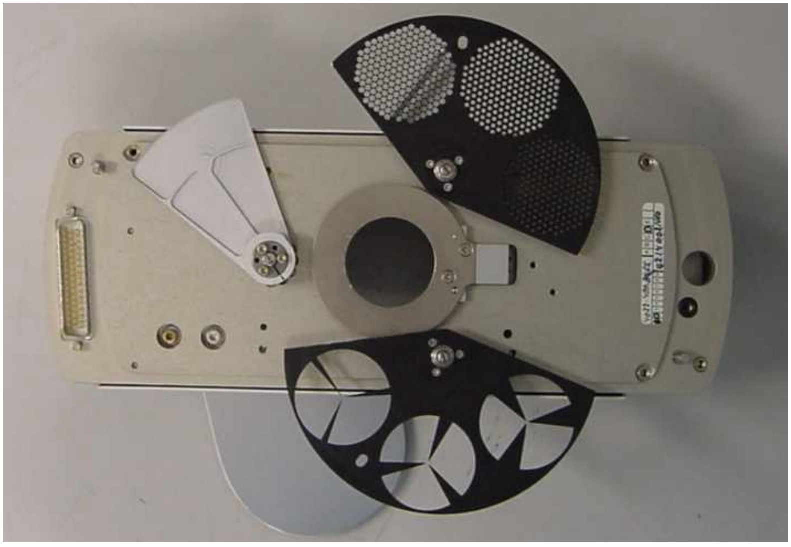


Figure 4.12 Shutter Assembly showing Safety Shutter (at the bottom), Exposure Shutter and Attenuator Blades (at the top)

UV systems dose control

For UV systems, discrete attenuation steps are used. For A architecture, a 4 step attenuator is used. For B architecture, a 16 step attenuator is used.

The way dose control works is shown in the figure below.

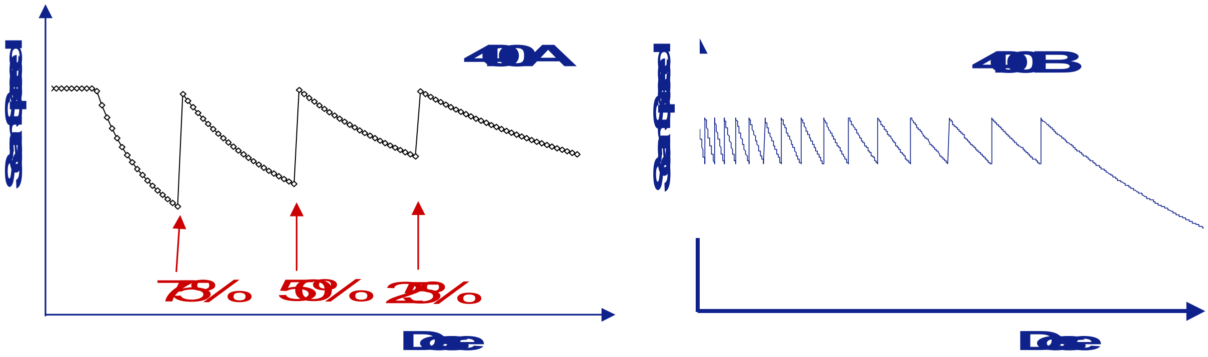


Figure 4.13 Dose versus scan speed for different attenuator settings.

For the description of the shutter/attenuator block, see the chapter on components and connections.

Going from high to low doses, the scan speed is increased. As the maximum speed is reached, lower doses can be achieved by inserting an attenuator blade in the beam. When the maximum scan speed is reached again, the next attenuator blade with less transmission is inserted.

Pupil Shaping Optics

The light then passes through an interference filter (sometimes called a coherence filter) and then enters the light shaping optics. The interference filter is responsible for limiting light that reaches the wafer to the narrow 365-nm "I-line" part of the spectrum.

An optical pupil shaping device has two elements. One is stationary (fixed) and the other moves. When the two elements are close together (almost touching), light passes through as a single "conventional mode" spot. When the moveable element moves away from the fixed, the light forms a halo or "annular" mode. As the element moves farther from the fixed, the dimensions of the center or inner dark area increase, as does the outside diameter of the ring, or halo, of light.

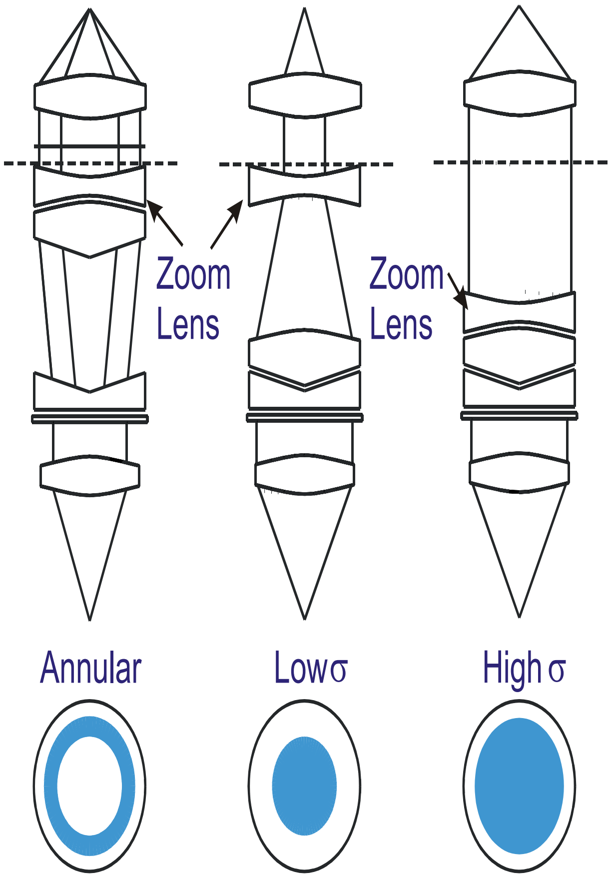


Figure 4.14 Function of Zoom and Axicon Lenses (UV)

The pupil shaping optics and zoom lens work together to establish sigma settings and the illumination mode. As the light travels through a zoom lens it has additional influence on the size of the beam. The combination of pupil shaping optics and zoom lens position determines the size of the beam and the ratio of the inner diameter and outer diameter to the diameter of the projection lens numeric aperture setting. These values are called the inner sigma and outer sigma values. Light is then directed to the out-coupling optics, which direct the beam toward the integrator rod assembly.

TOP MODULE

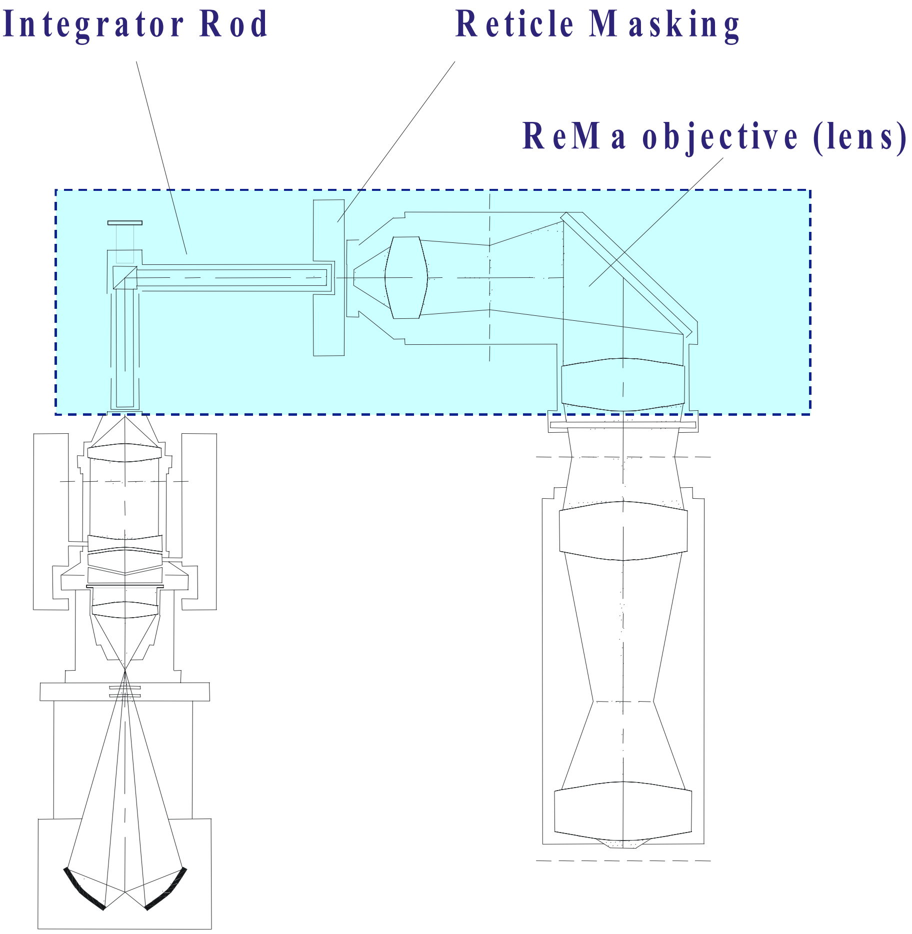


Figure 4.15 Main Top Module Components

Integrator Rod

The AERIAL 1 integrator rod is a two piece unit made out of quartz.

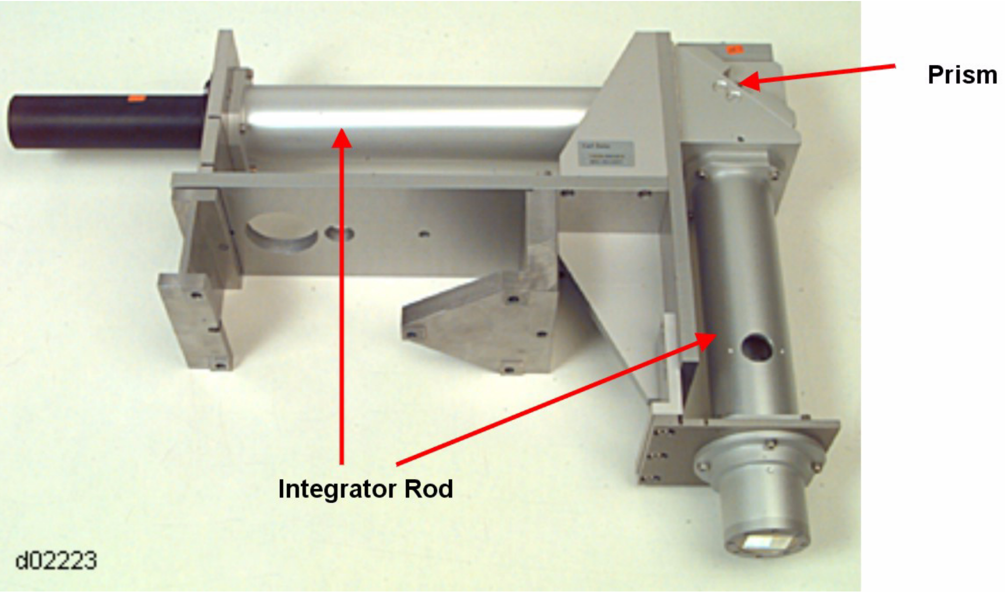


Figure 4.16 Integrator Rod

Light is directed into the entrance of the integrator rod and travels to the rod exit while preserving the angles of entry. In this way, the pupil shaping and modes of light are still present at the reticle. The rod has a vertical and then a horizontal section. At the 90º bend, a prism reflects most of the light into the horizontal part, but allows about 1% to pass to an energy sensor. This energy sensor samples the light, which represents the energy delivered at the wafer. The other 99% of the light exits the integrator rod and is delivered to the REMA lens.

Internal REMA and REMA Objective

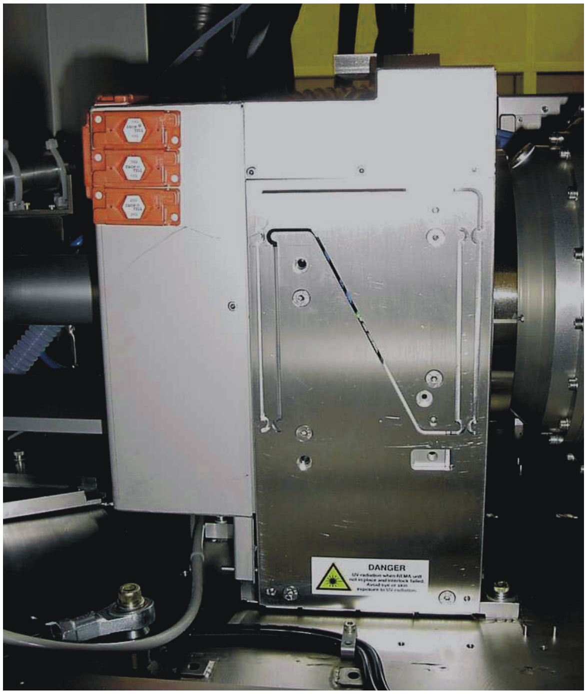


Figure 4.17 Internal REMA

At the exit of the integrator rod four blades are positioned to block light that would illuminate parts of the reticle outside of the area used to form the desired image. These blades are part of the Reticle Masking Assembly (REMA). The light that is allowed to pass is magnified by the REMA lens (objective) and directed down onto the reticle through a condenser lens. The condenser lens projects the image of the illuminated reticle into the pupil of the projection lens.

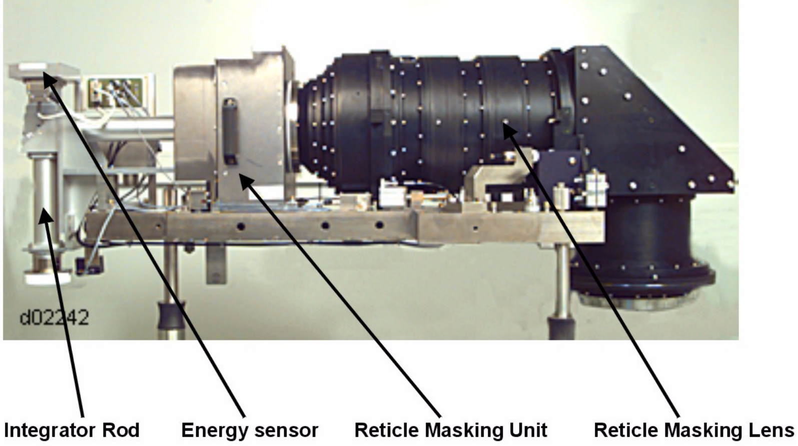


Figure 4.18 Top Module

The AERIAL 1 top module includes several assemblies. Not labeled is the condenser lens at the lower right corner.

WHAT MACHINE HAS WHAT?

Refer to ASML product page:
http://www4nl.asml.nl/nonconf/product/AT/index.html

5

UV PROCEDURES

INTRODUCTION

This chapter will discuss the procedures to be performed as part of the level 2 qualification process for **UV Illumination**. The discussion of the procedures will amplify information concerning the coach procedure.

Always refer to the Coach procedure for specific prerequisites, actions, and specifications.

UV PROCEDURES

UV PM procedures treated in this course are:

1. Remove and install the aerial illuminator lamp
2. Remove and install the high pressure aerial illuminator lamp
3. Calibrate and adjust temperature, pressure & flows
4. Adjust mercury arc lamp temperature
5. Adjust lamp position and intensity
6. Measure Integrated Slit Uniformity and Intensity
7. Monitor the i-line lens

UV PM action that were done in the DUV PM course:

8. Adjust lens gas pressure and flow and flush the lens.

Remove & Install the AERIAL Illuminator Lamp

Procedure Name	Remove & Install the AERIAL Illuminator Lamp
Coach Number	csil027b.rep
Function	Remove and install the AERIAL illuminator lamp when required as a result of meeting or exceeding the lifetime hours of usage limitation.
Preconditions	Measure slit uniformity to verify functionality and system performance before starting.
Points of attention	Be sure lamp is off and has had time to cool. Lamp may explode if cold air is allowed into lamp compartment when lamp is hot Verify Power at the IPDR is off and locked out Do not touch elliptical mirror MAKE SURE THAT THE OLD LAMP IS HANDLED/DISPOSED OF IN ACCORDANCE WITH LOCAL REGULATIONS AND THE APPROPRIATE MATERIAL SAFETY DATA SHEET IS COMPLETED Allow 30 minutes of lamp on time, after replacement, before follow up procedures
Sequence of Events	Method Measure slit uniformity (make fingerprint) Power lamp off IPDR OFF & Lock Disabled with Maintenance key Allow 15 minutes minimum cooling time Gain access to lamp in bottom module Remove the mercury lamp Install the new mercury lamp Set the MAIN switch on the IPDR to ON and set Maintenance key to enable Press the START button in the SHB to open the safety shutter.

Procedure Results Lamp intensity will be optimum

Uniformity will be as good or better than before lamp replacement

Lamp lit time will be reset

Required Actions

Perform a fast start-up

Select Start up/shut down

Set lamp lit time = 0

Do procedure csil037.adj to adjust the lamp position and intensity.

Do procedure csil038.adj to adjust the lamp temperature.

Do procedure csil039.adj to check the cooling air and water.

Do procedure csil068.per to measure the slit and intensity.

Failure Response Failure Mode/Actions required

Lamp will not start - recheck connections & interlocks

verify IDPR power on & key enabled

Remove and install the high-pressure aerial illuminator lamp

Procedure Name Remove and install the high-pressure aerial illuminator lamp

Coach Number csil027c.rep

Function Remove and install the AERIAL illuminator lamp when required as a result of meeting or exceeding the lifetime hours of usage limitation.

Preconditions Measure slit uniformity to verify functionality and system performance before starting.

Points of attention See points of attention of the low pressure lamp.

Except for the engineer involved, no more people are allowed to be present near the High Pressure lamp after taking it out of the package.

The special suit and the screen are available as a tool.

The suit is available in the sizes S/M/L/EL/EEL. It can be bought by the customer.

Sequence of events Switch off the lamp, open the machine and open the Bottom Module compartment.

Remove the lamp power cable.

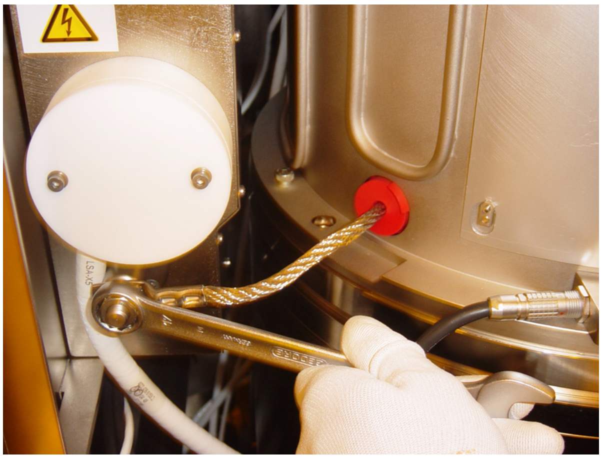


Figure 5.1 The power cable can be removed and installed without using the protection suit..

Put a screen around open Bottom Module. For an exemple of the screens that can be purchased, see the figure below.

Figure 5.2 An example of the screens that can be put around the Bottom Module.

Dress with a special protection suit. See the figure below.

Figure 5.3 Wear a special suit to protect yourself against an exploding lamp.

Prepare the empty lamp package. Keep in mind the differences between a low pressure and a high pressure lamp.

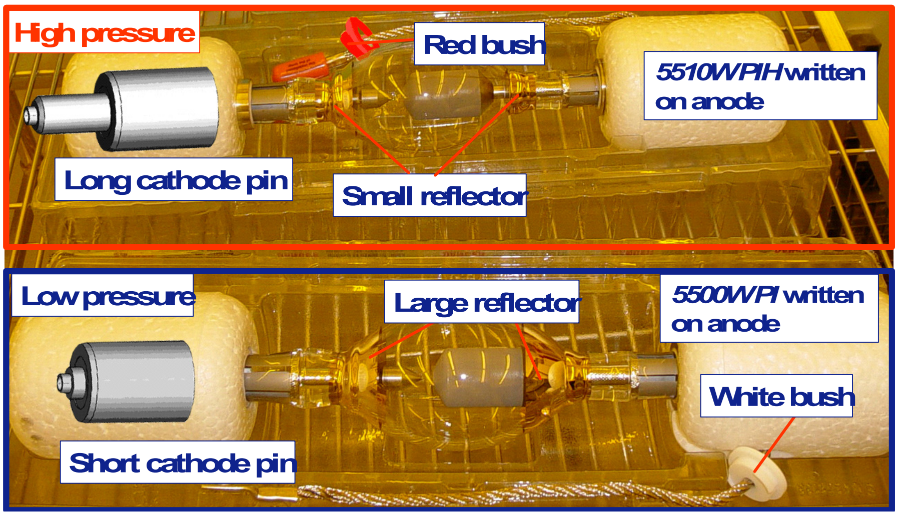


Figure 5.4 The four difference between a high pressure and a low pressure lamp

Replace lamp as with previous lamp types. Hold the lamp on both sides if possible.

Figure 5.5 Reduce the risk of dropping the lamp by using two hands to hold it.

Note that the lamp replacement itself is similar to low pressure lamp replacements.

Figure 5.6 The replacement itself.

As you can see, the protection suit makes it difficult to work with the lamp.
To mount the bush, start with the part inside the lamp compartment.

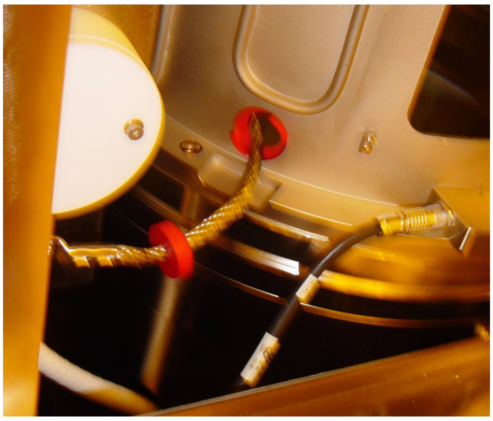


Figure 5.7 First mount the bush part inside the lamp compartment.

For ASML engineers, the suit and the screen are supplied by ASML.

Procedure Results

Lamp intensity will be optimum

Uniformity will be as good or better than before lamp replacement

Lamp lit time will be reset

Required Actions

Perform a fast start-up

Select Start up/shut down

Set lamp lit time = 0

Do procedure csil037.adj to adjust the lamp position and intensity.

Do procedure csil038.adj to adjust the lamp temperature.

Do procedure csil039.adj to check the cooling air and water.

Do procedure csil068.per to measure the slit and intensity.

Failure Response

Failure Mode/Actions required

Lamp will not start - recheck connections & interlocks

verify IDPR power on & key enabled

Adjust Lamp Position and Intensity

Procedure Name Adjust Lamp Position and Intensity

Coach Number csil037.adj

Function To find the lamp position for maximum intensity

Preconditions

Lamp illuminated for at least 30 minutes before adjustment

If test is being run during a set-up the lens top tool may be mounted. If so there is a place in the test to note that the LLT is in place.

Points of attention You may want to run the uniformity check to verify performance before you begin

Sequence of Events

Testing Method

User input values selected from table in procedure.

While measuring intensity using spotsensor;

Move lamp through +/- range in Z and calculate curve fit to determine peak intensity

Move lamp to this Z position.

Move lamp through +/- range in X and calculate curve fit to determine peak intensity

Move lamp to this X position. Save this position value.

Move lamp through +/- range in Y and calculate curve fit to determine peak intensity

Move lamp to this Y position. Save this position value.

Move lamp through +/- range in Z with a high resolution (very small steps) and calculate curve fit to determine peak intensity

Move lamp to this Z position. Save this position value.

The position values are saved as MCs upon completion of the test.

Procedure Results

The best X, Y, Z position for lamp position are calculated and may be saved by the user if desired.

On Screen Result

A graphic of the progress is displayed during testing

Test results are displayed in report

Required Actions

Save MCs

Re-initialize DO to make new MCs active

Failure Response

Failure Mode/Actions required

Check spot sensor position

Verify free cable length at lamp manipulator bracket

Check lamp functionality

Adjust AERIAL Mercury Lamp Temperature

Procedure Name

Adjust AERIAL Mercury Lamp Temperature

Coach Number

csil038.adj

Function

To control the mercury lamp temperature on the AT 400 by adjusting its anode cooling air flow

Preconditions

csil037.adj has been done to adjust the lamp to the best position.

Points of attention

Make sure the lamp has been on for at least 30 minutes

If the safety shutter was found closed let the lamp temperature stabilize for additional 10 minutes with the safety shutter opened.

Note:

The adjustment valve is a soft metal “needle” valve that reduces flow by insertion of a tapered pin into a conical opening. If the valve is forced completely closed, the opening can be damaged, and the adjustability of the valve will be compromised.

Sequence of Events

Method

Calculate required themocouple temperature

Check thermocouple temperature

Adjust lamp anode temperature by adjusting CDA flow of cooling jet

Wait for temperature to stabilize.

Procedure Results

The lamp temperature is adjusted to the most efficient operating temperature.

Required Actions

Recalculate to verify correct temperature value

Failure Response

Failure Mode/Actions required

Check lamp position

Check lamp uniformity

Check CDA flow

Check adjustment valve functionality

Calibrate and Adjust The Temperature, Pressure and Flow of The Cooling Water & Air

Procedure Name Calibrate and Adjust the Temperature, Pressure and Flow of the Cooling Water & Air

Coach Number csil039.adj

Function To calibrate and adjust the temperature, pressure and flow of the cooling water and air so the stability and efficiency of the illumination lamp can be maintained.

Preconditions

Make sure the PTI board has the number 4022.471.65543

Check and adjust the pressure of the clean air supply

Points of attention

Make sure the lamp has been off for at least 30 minutes because the first adjustments require a cold lamp.

The Pressure Lamp Compartment must always be less than -0.5 Pa. If it is not, the Illumination Power Supply (IPS) will be set to OFF

Due to temperature changes caused by the lamp, the flow can deviate within 10 m3/h

If the lamp is OFF, the cooler ellipse temperature should be the same as the temperature of the fab water supply. If the lamp is on, the temperature should be approximately 5 °C higher than that of the fab water supply.Table 9

Sequence of Events

Method

Connect laptop to PTI board and start Hyperterminal

Monitor sensor values:

Temperature energy sensor C

Temperature lampC

Temperature Ellips-cooler C

Pressure Cooling Air Input Pa

Pressure Fab Exhaust Pa

Flow Fab Exhaustm3/hr.

Pressure Lamp Compartment Pa

Position Exhaust Valve %

Check cooling water flow

If any values are out of spec, follow the procedure to adjust.

Procedure Results

The lamp temperature is adjusted to the most efficient operating temperature.

Required Actions

Turn lamp on and allow to stabilize for 30 minutes:
Do procedure csil038.adj to adjust the Aerial mercury lamp temperature.

Failure Response Failure Mode/Actions required
Check facilities supplies

Measure Integrated Slit Uniformity & Intensity

Procedure Name	Measure Integrated Slit Uniformity & Intensity
Coach Number	csil068b.per
Function	To measure the integrated slit uniformity and intensity.
Preconditions	Lamp and C&T must be stable.
Points of attention	The parameters of the test vary depending on system model and configuration. Be sure to enter the correct parameters as defined by the procedure.
Sequence of event	We will discus the test principle and the test input screen.

Test principle

Choose a grid and let the Spot Sensor step through the grid, step by step. See the figure below. Expose on each grid point and measure using ES and SS.

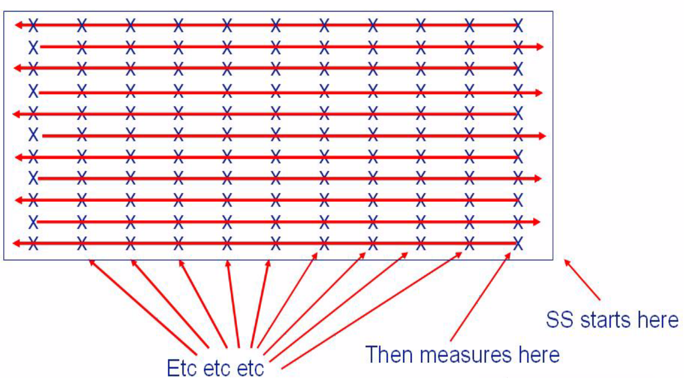


Figure 5.8 The steps that the SS make during the test.

In ATP setting, the grid is larger than the slit size, but the test can be done for any field size, containing any number of measuring points.

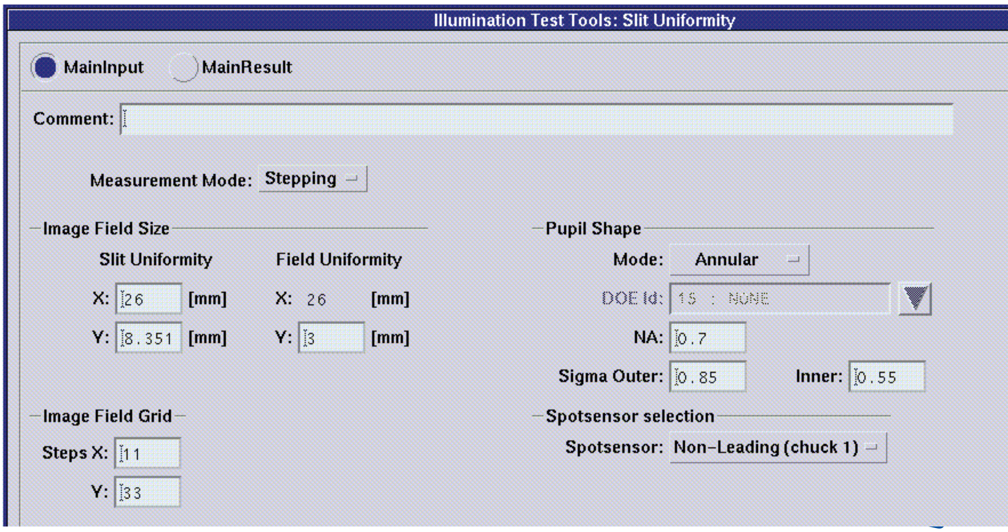
All test data, including ES and SS values, are stored in the log file.

After the test:

- Data at each X position are summed (see figure) to simulate the actual dose a pixel would get during its travel under the slit. Results show an intensity pattern in the non scanning direction (X),
- Data on a smaller field in the slit are processed one by one to generate the intensity and the Field Uniformity.

Input screen

See figure below.



Comment:

Measurement Mode: Stepping

Image Field Size

Slit Uniformity X: 26 [mm] Y: 8.351 [mm]

Field Uniformity X: 26 [mm] Y: 3 [mm]

Pupil Shape

Mode: Annular

DOE Id: 15 : NONE

NA: 0.7

Sigma Outer: 0.85 Inner: 0.55

Image Field Grid

Steps X: 11

Y: 33

Spotsensor selection

Spotsensor: Non-Leading (chuck 1)

Figure 1: Example of Integrated slit uniformity dialogue window

`Measurement mode`

In this test we are interested in the performance of the optical column and to exclude other influences. The measurement is therefore performed in stepping mode (= non-scanning)

`Image Field Size`

Slit Uniformity gives the grid size where the measurements will take place. *Field Uniformity* sets the range of the selection of measuring data for the calculation of the field uniformity and intensity.

`Image Field Grid`

Define steps in x and y. These will be distributed equally over the entered *Image Field Size*.

`REMA`

Set REMA around SS to prevent stray light influence on the measurement, set REMA to *open* to do the opposite. In case of *Spot,* the size of the REMA window is ten times the Spot Sensor pinhole dimension, so 1.2 x 1.2 mm. In case of *Image,* you may select any REMA window.

`Illumination Mode`

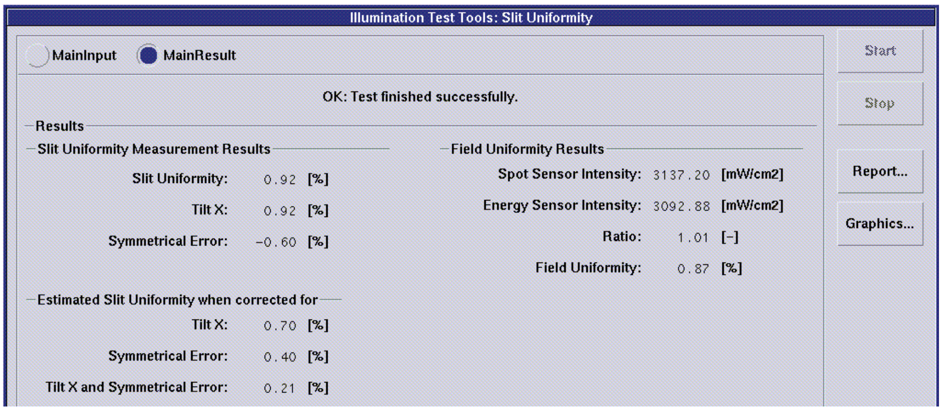
The uniformity in the illuminated field and also the intensity depend on the pupil shape, because different pupil shapes use different paths in the optical column. For this reason you will find different uniformity values for different pupil shapes.

If the test failed for some reason and the problem was fixed so that the test can be run again, the `Recall` button will restore all the input data.

Procedure Results

Uniformity of illumination across the slit is known

See figure below.



Illumination Test Tools: Slit Uniformity

○ MainInput ● MainResult

OK: Test finished successfully.

Results

Slit Uniformity Measurement Results

Slit Uniformity: 0.92 [%]

Tilt X: 0.92 [%]

Symmetrical Error: -0.60 [%]

Field Uniformity Results

Spot Sensor Intensity: 3137.20 [mW/cm2]

Energy Sensor Intensity: 3092.88 [mW/cm2]

Ratio: 1.01 [-]

Field Uniformity: 0.87 [%]

Estimated Slit Uniformity when corrected for

Tilt X: 0.70 [%]

Symmetrical Error: 0.40 [%]

Tilt X and Symmetrical Error: 0.21 [%]

Figure 2: Slit uniformity results screen.

The Slit Uniformity is the uniformity we may see if we move in the non scanning direction. The scanning direction is averaged out.

To understand the other values, we must consider the way of calculation. It is shown in the figure below.

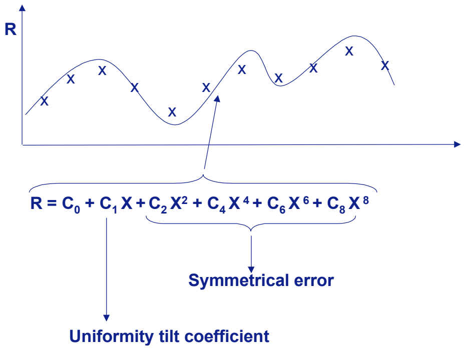


Figure 3: Polynomial fit in the slit uniformity data plot

As a function of X (non scanning direction), you see the average ratio (SS/ES).

The polynomial shown below is fitted and coefficients are determined.

$R = C_0 + C_1 X + C_2 X^2 + C_4 X^4 + C_6 X^6 + C_8 X^8$

The $\mathbf{C_1}$ coefficient leads to the Tilt X calculation over the field by finding maximum and minimum R value for $\mathbf{R = C_1 X}$.

The $\mathbf{C_2}$, $\mathbf{C_4}$, $\mathbf{C_6}$ and $\mathbf{C_8}$ values lead to the Symmetrical error estimation by finding the maximum and minimum R value for $\mathbf{R = C_2 X^2 + C_4 X^4 + C_6 X^6 + C_8 X^8}$.

Note: polynomial parts can be negative, as can be seen in the results for Symmetrical Error.

If the Tilt line is substracted from the measurement data, the remaining data lead to the estimated Slit Uniformity when corrected for Tilt X.

If the Symmetrical Error polynomial is substracted from the measurement data, the remaining data lead to the estimated Slit Uniformity when corrected for Symmetrical Error.

By substracting both polynomial parts, we get the estimated Slit Uniformity when corrected for Tilt X and Symmetrical Error.

Note:

In the Unicom and in the Gray Filter determinations tests, a Slit Uniformity is done in the 100% intensity area (11mmx3mm). The polynomial used is more complex, and it is used in a two dimensional fit.

The ratio all over the slit is visible.

Failure Response Failure Mode/Actions required

Request 2nd Line Support

Monitor the I-line lens

Procedure Name Monitor the I-line lens

Coach Number csil044a.per

Function This procedure describes the test procedures that monitor the I-line lenses. The data from the system is collected by the ADC (Automatic Data Collection) system, and is processed in Veldhoven for more analysis.

Preconditions Lamp illuminated for at least 30 minutes before adjustment

If test is being run during a set-up the lens top tool may be mounted. If so there is a place in the test to note that the LLT is in place.

Points of attention You may want to run the uniformity check to verify performance before you begin

Sequence of Events The normal FOCAL test that is done as a Metrology PM action.

In the test input screen make shure the extended test report is made.

Data will then be collected and send to Veldhoven using an automatic Data Collection System.

Procedure Results Data are collected and automatically send to Veldhoven.

Required Actions

None.

Failure Response Not aplicable.

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APPENDIX: GLOSSARY OF TERMS AND ACRONYMS

Term	Definition
Aberration	Deviation of the wavefront of an image from an ideal wavefront
ALE	**A**ctive **L**ens **E**lement - an element in the projection lens that is pneumatically actuated to control asymmetric lens heating effects, such as astigmatism
annular mode	The mode of illumination created by the pupil shaping optics that forms a ring or halo of light.
attenuation	Reduction in intensity by blockage, absorption, reflection or interference.
beam shaping	The function of distributing the light in a desired pattern.
broad-spectrum light	Light with a wide range of wavelengths. The Hg lamp is a broad-spectrum light source emitting light from IR (long wave light) through UV (short wave light) so filters are used to isolate the preferred wavelength.
CD	**C**ritical **D**imension - The smallest (therefore the most difficult to resolve) features in an image to be exposed.
conventional mode	The mode of illumination created by the pupil shaping optics that forms a single spot of light.
diffraction	Bending of light as it passes or moves around an object. As the wavefronts of the “bent” light encounter other parts of a wavefront, they interfere and form patterns or “orders” of light which correspond to the shape of the object. The orders of light contain the required “information” to reconstruct the image at the wafer.
DOE	**D**iffractive **O**ptical **E**lement – a multi-faceted quartz plate that separates the laser beam into sub-components and distributes them to create an angular distribution.
DoF	**D**epth of **F**ocus – the range, usually expressed as +/- above and below best focus within which the image will be acceptably resolved
Dose	The amount of energy required per unit of area for exposing an image. The amount of energy delivered per unit of area in an exposure.
DUV	**D**eep **U**ltra**v**iolet – a light source of 248-nm or 193-nm wavelength.

ELLE	**E**xchangeable **L**ast **L**ens **E**lement - An external lens element that can be replaced when contaminated.
EPLE	**E**xchangeable **P**upil-Near **L**ens **E**lement - An internal lens element that can be replaced by Zeiss engineers to correct lens abberation changes as lens ages
E0	"E sub zero" A reference value indicating the amount of energy required to clear resist as defined by a test of variable exposures, often with an open frame (no chrome) reticle.
ETC	**E**nergy **t**o **C**lear. The amount of energy required to completely expose resist on a wafer. A common starting value used is E0 + 10% to compensate for features or process variations.
excimer	The common name for the type of laser used as a lithography light source – Excimer = excited dimer. It relates to a diatomic molecule usually of an inert gas atom and a halide atom, which are bound when in excited states. They have short lifetimes and release UV photons when they dissociate.
FC	Field Curvature. This lens aberration creates a non flat image plane. Instead, it is convex or concave. The lens model is used to minimize this aberration.
GCU	**G**as **C**ontrol **U**nit - The component that controls the pressure and flow of gas to the projection lens.
Hg	Mercury, in chemistry
I-line	An intensity peak in the electromagnetic spectrum that occurs at 365 nm wavelength. Used by /400 systems – See UV.
ILIAS	**I**ntegrated **L**ens **I**nterferometer **A**t **S**canner - A sensor used to measure the pupil and lens aberrations
image	The pattern of light formed at the *object plane* (reticle) and exposed at the *image plane* (wafer).
image plane	A plane (about 12 mm below the bottom of the lens) where the image is in focus.
interference	The interaction of phases of E-M energy, such as light, that results in an additive or subtractive effect. For example, if two light waves, that are 180° out of phase, combine (by converging at the same point on a wafer), they will destructively interfere and the sum of the energy exposing the resist will be zero.
IR	**I**nfra**r**ed – lower frequencies of energy in the light spectrum. The UV systems filter IR light out of the optical path. (3.10^{11} - 4.10^{14} Hz)
Lens Mag	The ratio of the size of the image on the wafer compared to the size of the image at the reticle formed by the projection lens. Lens magnification is adjustable to compensate for variables between systems and process changes.
mask	The reticle; the chrome on the bottom of the reticle that creates an image by diffracting light into a pattern to be exposed onto a wafer.

NA	Numeric Aperture - a measurement that represents the size of the projection lens opening at the pupil, defined as the sine of the angle between the outermost rays of light and the optical axis. A software controlled, electrically powered, mechanically operated aperture controls this value in the TWINSCAN.
NEXZ	**NEX**t Generation **Z** element - An internal, software controlled, adjustable lens element that uses piezo crystals to move the lens element in the Z axis.
object plane	The point in the optical path where the reticle mask is placed.
optical device	A lens, mirror or other device that is used to change the characteristics or direction of the illumination light or an image.
orders of light	A component of light that has been diffracted by an obstacle. See diffraction.
pulse	A single emission of light from the excimer laser. The laser emits a series of pulses of light during exposure of a die, with each pulse requested by the exposure unit.
QUASAR	**QUA**drupole **S**egmented **A**nnula**R** Software controlled automatic DOE exchanging system that can place an element in the light path, using a carousel-like mechanism, to form angular distributions of the light. (see DOE)
REMA	The **Re**ticle **Ma**sking Unit. It blocks light from illuminating areas on the reticle that are not to be exposed.
ROE	**R**efractive **O**ptical **E**lement – an optical device that fills the integrator rod and reduce localized intensity.
SAXY	**S**emi **A**ctive **XY** element - An internal, software controlled, adjustable lens element that uses piezo crystals to move the element in the XY axis.
shutter	A mechanical device that blocks light by moving a metal blade into the light path.
Sigma Sigma outer Sigma inner	The ratio of the diameter of the illumination “spot” to the diameter of the current setting of the projection lens aperture. Sigma Inner is the circular area in the lens aperture that contains 10% of the total energy in the aperture. Sigma Outer is the circular area in the lens aperture that contains 90% of the total energy in the aperture.
Slit	The field of light at the reticle (and 4X smaller at the wafer) It varies, depending on model but may be from about 7 to 12 mm in Y and is 26 mm in X at the wafer. It is formed by the projection of the defocused integrator rod on the reticle bottom.
Sph	Spherical Aberration – a radial distortion of the image. A lens model adjusts to minimize this aberration.
UV	**U**ltra**v**iolet – For our purposes refers to “I-Line’ systems which use a mercury arc lamp as a light source and filter the output to 365 nm wavelength – See I-line.
Wavefront	In an ideal case, the surface in an electromagnetic field which connects points of equal phase equidistant from the source. Deviation from an ideal wavefront is used to describe the lens aberrations

Zernike Polynomial	A set of mathematical polynomials and their coefficients that are used to describe the deviation of a real wavefront with respect to the ideal wavefront.
zero order	Light that travels in the direction of the incident light after passing through the reticle grating. It carries energy to expose resist but no information to define the shape or edges. (see diffraction)
Zoom	Magnification or demagnification as the result of the positioning of a lens A lens that changes magnification as a result of movement along an axis. The pupil shaping optics in a UV system have one zoom lens, in a DUV system there are two zoom lenses.